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Program Operating Plan
FY2015 - FY2016

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Program Operating Plan

FY2015 – FY2016

February 20, 2015

The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

1.2 Financial and Budget Overview

This POP is written to a balanced budget, based on NSF-AST FY2015 and 2016 projections for NRAO and the following NSF Scientific Program Orders (SPOs), Cooperative Support Agreements (CSAs) and other funding elements:

- NSF CSA-1 Management and Operations of the NRAO
- NSF CSA-2 Operations and Maintenance of the ALMA
- Non-programmatic activities associated with NSF, (i.e., collaborations with other NSF Divisions, other educational institutions funded by NSF, etc.)
- Programmatic elements funded by non-NSF sources (e.g. program income, external contracts and proceeds)

ALMA North American Operations funding is expected to move to steady state operations in FY2015 and FY2016 though NRAO North American (non-ALMA) operations funding is expected to decline. A small amount of financial carryover is typically maintained as reserve to address expected deficits in future years, unexpected U.S. dollar to Chilean Peso exchange rate fluctuations, variations in assumed inflation or benefit rates, or sudden cash needs for unpredictable events such as infrastructure or other emergencies.

The FY2015 Work Breakdown Structure (WBS) enables visibility and clarity across all business units and sites. All financial tables in this POP reflect this WBS structure. Details of the preliminary funding profile – new funds, carryover, total available, the financial plan including budget narrative, and the WBS Dictionary are provided in Appendix A and F.

NRAO Operations Funding History FY2010-FY2016, $K

	Actual Funding					Projected Funding	
	FY10	FY11	FY12	FY13	FY14	FY15	FY16
NRAO	43,144	43,134	43,115	41,000	43,140	40,000	42,230
ALMA*	17,592	23,500	31,027	34,307	35,571	40,171	40,350

* Does not include Canadian contribution

Issues Arising

Small but steady inflation in the overall market continues to erode the purchasing power of NRAO's funding. This has given rise to a number of issues, noted below.

Infrastructure – NRAO has been unable to undertake major infrastructure maintenance and renewal projects, which compromises the long-term reliability of services, both from a staffing and funding perspective. To cite just two examples, maintenance of the VLA track and VLBA active maintenance has fallen behind. Two years ago $200K in continuing funding was diverted to allow the purchase of ballast and rail ties. This year, an additional $185K has been moved to increase the track crew and purchase more ties. This funding, carved out of a declining funding profile, is still inadequate to meet externally recommended maintenance goals. At the VLBA, there is a dire need to replace the masers and failing wheel assemblies. There is no funding available to make these key maintenance investments, and future decreases in telescope availability can be anticipated.

Development – Funding for key research and instrumentation projects has been moved off of NRAO core funding and now depends at the level of $500K-$1M on proceeds from external activities. NRAO's commitment to ALMA development dictates maintaining specialized staffing in the Central Development Laboratory (CDL) and other areas. Delays in the approval of ALMA development projects result in funding gaps for those staff members as well as unexpected fluctuation in the ALMA budget.

Staffing levels – Certain core services, especially telescope maintenance and track crews, which were impacted by the early retirement programs of the last five years have had to be replenished, rolling back the savings achieved in those areas and creating a rolling deficit within the Observatory. Stretched crews and resources have increased demands on the safety program and additional investments have been made here as well. The increased demands on the safety program and safety personnel are a result of the rolling deficit in the staffing levels described above and the lag in infrastructure maintenance and infrastructure investments. As an example, the declining condition of the VLA track has resulted in an increased reliance on inspections and monitoring to ensure safe operation, further stretching the availability of both maintenance crews and safety staff.

Compensation and Retention – As the economy recovers, NRAO, with its recent history of job cuts and lack of compensation adjustments, is seeing the impact. The observatory has made a number of pre-emptive wage level adjustments for certain key job classes, but targeted adjustments do not take the place of a consistently administered and competitive compensation program. There is no planned raise pool in the 2015 or 2016 budget. In the period 2009-2014, NRAO's salary actions have lagged the market by a cumulative amount of 15.5%. (Market increases – 21.7% vs. NRAO – 6.2%) Attrition rates, adjusted for planned staff roll-offs, have increased in the last year.

Uncertainty for GBT and VLBA – NSF funding for these instruments and operations has been cut to the bare minimum in an effort to maintain the support of VLA and core CDL operations. External and non-cooperative agreement funding has increasingly paid for these operations. External funding for these instruments has risen from $0.5M in FY12 to $2.7M in FY2015.

Major Budgetary Actions in FY2015

NRAO has an iterative and inclusive budget process which begins in the spring with initial guidance from NSF. The budget process evaluates expense trends for key inputs such as rents, power, benefits, and compensation, and solicits input from the assistant directors about significant needs and revenue opportunities. This information is collated to produce a preliminary budget. This budget is discussed with the ADs at an annual budget summit where tradeoffs are made in order to produce a balanced budget. To get to the current state of the budget, NRAO reduced continuing expenses by $800K primarily impacting central and computing services, user and visitor support, and the Jansky post doctoral program.

In the face of critical support needs and external cost increases, NRAO has opted to support the instruments and mission while sacrificing inflationary and merit compensation increases. Hence there are no compensation increases scheduled for FY2015 or FY2016.

Aggressive management of salary breakage (salary funds available from vacant positions) to meet funding levels leaves little contingency space. In prior years, breakage from interim vacancies has created the management and operational leeway necessary to address some maintenance and contingency issues. NRAO has been fortunate not to face a significantly expensive equipment failure over the last 2-4 years. There is no formal budgeted contingency.

Fully leverage shared services model with ALMA and other operations – The cost allocation process has created an opportunity to share core administrative and support expenses among the various NRAO funding sources. The end of the EVLA and ALMA construction projects significantly reduces the base over which those costs can be allocated with only minimal reductions to the costs themselves. In addition, the Education and Public Outreach (EPO) and Data Management and Software (DMS) departments are spread directly across the two major CSA's with support provided for program specific activities as well as core competencies. With the FY2015 budget, these approaches are now fully integrated and matured.

1.3 Structure of Plan

The FY2015-2016 program plans for each NRAO organizational unit are described in Sections 2 through 17. Each of these 16 sections concludes with the major milestones and financial charts associated with the planned activities.

Sections 2 through 4 describe the plans for the telescope systems and research facilities operated by NRAO for the astronomy community: ALMA (Section 2), the Karl G. Jansky Very Large Array (Section 3.1), the Very Long Baseline Array (Section 3.2), and the Robert C. Byrd Green Bank Telescope (Section 4.1).

Section 2 describes the FY2015-2016 plans for North American (NA) ALMA Operations, the department that provides NA's scientific and technical partnership support to the international ALMA Observatory and supports the NA community in their use of ALMA. NA ALMA Ops now incorporates four divisions: the North American ALMA Science Center (NAASC), Offsite Technical Maintenance and Support, the NA ALMA Development Program, and the NRAO-Chile Office. Subsections describe the science, operations, development, and the maintenance and renewal plans for NA ALMA; the plans for the NRAO Chile Office follow.

The FY2015-2016 plans for the New Mexico Operations department are given in Section 3, including the Observatory's plans for the VLA (3.1) and the VLBA (3.2). Subsections for each of the VLA and VLBA highlight their science, operations, development, maintenance and renewal, and site operations plans.

Section 4 provides the FY2015-2016 plans for West Virginia Operations, including the GBT (4.1) and Other Telescopes located at the NRAO – Green Bank facility (4.2). Each of these telescope sections further describes the relevant science, operations, development, maintenance and renewal plans, and site operations plans.

Section 5 details the FY2015-2016 CDL plans to support the evolution of NRAO's existing facilities and develop the technology and expertise to build the next generation of radio astronomy instruments. Subsections describe plans for CDL repair, maintenance, production and support activities, development, and long-term research and development programs.

Section 6 describes the FY2015-2016 plans for the Science Support and Research (SSR) department that coordinates, aligns, and manages the Observatory-wide efforts to support science users of NRAO facilities, broaden NRAO's impact, and oversee the research and performance of the scientific staff. Subsections describe plans for telescope time allocation, science user support, and science support and research activities.

2 NORTH AMERICAN ALMA OPERATIONS

2.1 Science

ALMA, an interferometer consisting of 66 total array elements and located at 5000 meters altitude in the high Atacama Desert of northern Chile, was inaugurated in March 2013. Construction of the science instrument will be completed in 2014. Early Science observing is already yielding spectacular results and is changing our understanding of planet and galaxy formation and stellar evolution, among other areas. This global project has been a remarkable example of scientific cooperation and promises to be a world-leading discovery instrument for years to come.

FY2015

Cycle 2 of ALMA Early Science began 1 June 2014 and will extend to 30 Sept 2015, thus falling within FY2015. The 1381 proposals received for Cycle 2 was the highest number ever submitted for any telescope, prompted by the availability of a number of newly commissioned capabilities. Forty-five antennas are nominally available for science observing, operating in six wavelength windows four of which are ideally suited for ALMA's high dry site. ALMA's ability to carry out polarization observations was first offered for Cycle 2, initiating ALMA's capacity for imaging the magnetic universe. With the availability of baselines of up to 1.5 km in length, ALMA imaging reaches a new sharpness, with an angular resolution as fine as 0.1 arcsec, matching that of the Hubble Space Telescope (HST). After review, ALMA accepted 117 North American science programs at its highest priority, along with 50 lower priority "Filler" programs. From the published abstracts of these programs we can glean a summary of the exciting science ALMA may provide its North American users.

A key ALMA property for study of cosmology and the high redshift universe is its great sensitivity. ALMA's sensitivity speeds measurement of the long wavelength optically thin emission from dust, making possible an efficient survey of dust in ~180 distant galaxies (z=1~5) to determine the mass of the interstellar medium contained within them. From this, the gas mass fraction as a function of redshift and stellar mass may be determined and correlated with elevated star formation activity to determine if the activity arises from a larger interstellar medium mass or from an enhanced efficiency for conversion from gas to stars. Neutral hydrogen-rich galaxies are identified in absorption against background quasars and called damped Lyman alpha absorption systems. Two candidate galaxies at redshifts of about two show strong [C II] absorption and substantial star-forming activity. ALMA's great sensitivity will allow the [C II] 158 micron line to be measured in these galaxies to assess the mass, kinematic structure and morphology of these enigmatic systems. From sensitive ALMA observations of strongly lensed dusty star-forming galaxies, dark matter sub-halos will be measured in five lens galaxies. The abundances of the sub-halos will be contrasted to Λ Cold Dark Matter (CDM) predictions. This pilot study will lead to the detection of further dark matter sub-halos, providing unprecedentedly accurate measurement of their mass function, resolving one of the more important puzzles in modern cosmology.

A key ALMA advantage for the study of galaxies and galactic nuclei is its exquisite resolution. The resolution is further amplified by strong lensing. In one spectacular system, a galaxy at z=1.5, ALMA will provide 500 pc resolution in each of four distinct images, allowing the gathering of a census of molecular gas and cold dust content for a galaxy like our own Milky Way when the Universe was only a third its present age. Combination of high resolution ALMA data with VLA and HST data will provide star formation rates and molecular hydrogen masses for about twenty individual complexes in this system. A key Cycle 0 discovery was the measurement of substantial starburst-driven outflow in the nearby galaxy NGC253. New observations will sharpen our view of that outflow, determining its extent further from

reduction workshops in Charlottesville per year, and data reduction training events at American Astronomical Society (AAS) and other large community meetings.

NA ALMA Student and Visitor Programs

NA ALMA Ops will support several programs for students and scientific professionals in FY2014:

- Student Observing Support (SOS) Program. The SSR department will administer the SOS program for eligible NA graduate and undergraduate students with successful ALMA Cycle 2 Early Science (high priority) observing proposals. The program is described on the *science.nrao.edu* website. Stipends of up to $35,000 per investigator per year are possible.
- Data Reduction Visitor Support. The NAASC encourages data reduction visits and can support up to two, two-person teams per week. The NAASC will reimburse the travel and lodging for one person from each team, and a second person if he/she is a student.
- Sabbatical visitors. The NAASC has budgeted partial support for several sabbatical visitors. The NAASC is particularly interested in scientific or technical visitors willing to contribute to ALMA optimization and development, or development of training materials that especially target the non-traditional radio millimeter/submillimeter (RMS) community.

Value-Added Tools, Materials, and Programs

A primary strategic goal of NA ALMA is to ensure that ALMA is an Observatory for *all astronomers,* regardless of principal focus or background. To achieve this, the Observatory works to make tools, processes, and documentation as intuitive and easy-to-use as possible. This requires continuous refinement and evolution of existing systems and facilities based on experience of use. NA ALMA depends on the involvement of its user community in this refinement process and has created several programs to broaden the user base and enable science, which are described below and in the SUS section.

Operations Milestones by Year

FY2015

ALMA Cycle 3 will be the first that puts the observatory on a yearly cycle, with a Call for Proposals in March, a proposal deadline one month later, panel reviews in the (northern) summer, and the start of science observing in October. The current plan is that a similar number of hours will be offered in Cycle 3 as was offered for Cycle 2, so the expected workload will be similar to the previous year. During this time, we expect to train Data Analysts to take over more standard support tasks so that the scientific staff has more time for developing pipeline heuristics, data reduction path for non-standard modes, EOC support and (if possible) improved analysis tools for users.

Support of ALMA Cycle 3 observations begins in Q1 FY2015 with four NAASC or NAASC-supported science experts participating in the EOC "long baseline campaign" (goal to commission observations on baselines out to 5-10 km). NAASC experts will also participate in the Cycle 3 Obsmode "go/no-go" meeting in the same time period, during which the capabilities to be offered for Cycle 3 are defined.

Support of the ALMA Cycle 3 proposal process will continue in Q2 FY2015 with testing of all proposal-related software subsystems (Observing Tool, Phase 1 Manager, Project Tracker, ALMA Science Archive, Science Portal) and preparation and review of all call-related documentation, especially the Technical Handbook, Proposers Guide, Capabilities, proposal "roadmap" and the NRC-led "ALMA

FY2016, NAASC staff will prepare the SBs for all successful NA-supported proposals. CS staff will review the SBs with their assigned PI projects throughout this period.

Visits by Cycle 1-3 PI teams may occur throughout the year and will be supported by the CS staff. Visits and remote support for scientists using non-proprietary archival ALMA data will require CS support throughout the year.

In summer of FY2016, Q4, NAASC will host a new summer school for interferometry, a summer school 'lite'. The intent is to recast the bi-yearly Socorro intensive summer school into an alternating year shorter school with a lighter approach to the material, held in Charlottesville. The Socorro intensive school is ideal for students and postdocs who wish to make a career focus of radio and submm/mm interferometry and who are able to invest the time and effort involved. Now that both ALMA and EVLA are offering pipelined data products, which do not require intensive data processing expertise to image and analyze, there is a pressing need for scientists to learn the basics of interferometry and of CASA with a lesser time investment. This is especially true given that both ALMA and EVLA are much more accessible to the entire community than has been traditionally the case for radio interferometry.

For FY2016, the pipeline heuristics group will concentrate on providing input to help increase the number of observing use-cases that the pipeline can handle for Cycle 4, as well as providing imaging heuristics to move the pipeline beyond basic reference imaging for at least some standard observing modes, as a step towards the ultimate goal of "science ready" pipeline imaging.

2.3 Development

Upgrades typically progress through three successive phases of development, and correspond to an increasing level of technology readiness. The principal phases are:

- Conceptual study (including scientific justification, specification, and outline costing),
- Prototype/pre-production, and
- Rate production and implementation.

The North American ALMA partnership typically funds conceptual studies in the community (hereafter referred to as "studies") on a yearly basis. Prototype/pre-production and rate production initiatives (hereafter referred to as "projects") are typically funded every two (2) years. Calls, proposal evaluation, and award of studies and projects are governed by different (albeit similar) processes. The following text describes the processes governing studies and projects, anticipated FY2016 Studies, and ongoing projects.

Development Studies

The ALMA Operations Plan provides funding for targeted exploratory research and feasibility studies aimed at facilitating or assessing the viability of possible development projects, including assessments of opportunities for collaboration. This Hardware Small Projects and Upgrades (OFF-002) budget line is equivalent to approximately twenty percent (20%) of the funds available for the FY2016 NA ALMA Development Program.

The North American ALMA Development Program Manager, in coordination with the ALMA Development Steering Committee (ADSC), issues a Call for Study Proposals on a yearly basis as funding becomes available. An independent review panel evaluates and ranks the proposals. The results are reviewed and approved by the NAASC and the NRAO Director, with final consent by the NSF. The

ADSC is informed of the selections for coordination. The NA ALMA Executive has responsibility for executing the NA ALMA Development Studies plan.

Development Projects

The ALMA Operations Plan provides funding for final development and implementation of advanced techniques, hardware, and software. The North American ALMA Development Projects budget is equivalent to approximately 80% of the funds available for the FY2016 NA ALMA Development Program.

NA ALMA Development Projects are organized according to the following. The JAO periodically hosts an ALMA Development Coordination Workshop. The timing of the Workshop is synchronized with a series of Regional ALMA Development Workshops (hosted by the respective Executives) that address regional scientific and technical interests. The JAO thereafter initiates a synchronized "Call for Development Project Proposals" on a cycle that is expected to repeat every two to three years. The NRAO conducts an internal review of its proposal(s) in preparation for the JAO Call. The sponsoring Executive presents its project proposals to the ADSC. The ADSC (considering the needs of the JAO, advice from the ALMA Science Advisory Committee (ASAC), scientific benefit, cost, schedule, safety, product/quality assurance, software, integration, operations, maintenance, and any associated risks) develops an integrated and balanced program of proposed projects. The ALMA Director submits this Integrated Development Plan proposal, along with suggested prioritization, to the Directors Council for concurrence and then to the ALMA Board for approval.

Development Milestones

FY2015

Ongoing Studies

Advanced Solar Observing Techniques (Lead Institution: NRAO): This study will coordinate effort by the members of the international solar physics community to develop recommendations and requirements for enabling an initial suite of solar observing modes for use on ALMA in Cycle 3. Study completion is scheduled Q2 FY2015.

Concept Study of a Millimeter Camera for ALMA (Lead Institution: NRC – Herzberg): A study of heterodyne focal-plane receiver array technology that will allow mapping speeds of at least an order of magnitude faster than present if placed on the Total Power Array (TPA) antennas. Such instrumentation will allow large-scale emission to be recovered much more easily, increasing dramatically the efficiency of the TPA, and ALMA as a whole. Study completion is scheduled Q2 FY2015.

A 2nd Generation Receiver for ALMA Band 10 (Lead Institution: NRAO): To study the design of new, more sensitive, wide-band, sideband-separating, highly reproducible and reliable Superconductor–Insulator–Superconductor (SIS) receivers to be built for ALMA Band 10 (787-950 GHz). Study completion is scheduled Q2 FY2015.

A 2nd Generation Receiver for ALMA Band 6 (Lead Institution: NRAO): To study the design of a second-generation Band 6 receiver with improved sensitivity and bandwidth. Study completion is scheduled Q2 FY2015.

- Commissioning of a Front End test cryostat by the FE group in Charlottesville, which will greatly enhance maintenance and optimization of the two on-site FE test systems, as well as allow for complete qualification of repaired and newly constructed assemblies. This activity was planned for FY2014, but could not be completed due to delay in the delivery of the cryostat from Europe.
- Transition of Front End Test and Measurement System (FETMS) computers to Windows 7 and LabView 2013.
- Support of the Band 5 integration activities.
- Support of the early Band 1 integration testing.
- Support of the evaluation of Front End Monitor and Control (FEMC) firmware upgrades related to the Front End operation (firmware previously delivered in FY2014).
- Support of the FE Thermal Interlock Module (FETIM) rollout to all antenna receiver cabins.
- For the next ALMA Development Proposals cycle, we intend to submit a Study proposal to enable automated FEMC firmware and configuration settings deployment to the array.
- Support the OSF retrofit of AIPC1 (Antenna Inspection Point Chile of antenna number 1) rack deliverable in order to create an additional BE Antenna Article Test Stand, thereby increasing throughput of repairs executed by the AMG staff. The AIPC1 racks were form and fit-only prototype deliverables for use by antenna vendors.
- Execute on-site (re) training activity for various AMG groups, at least once in the year.

FY2016

In addition to the regular maintenance and technical support for various pieces of telescope hardware (based on the tiered approach described earlier in section 2.4), the following activities are planned for FY2016. The activities listed are heavily dependent on external partners who typically dictate the scheduling; hence, specific quarter milestones are not listed. We anticipate activity during the fiscal year period, however.

- Support of the early Band 2 integration testing at the conclusion of the Band 2 pre-production cartridge development project.
- Support of the Band 1 and Band 5 integration activities.
- Execute on-site (re) training activity for various AMG groups, at least once in the year.

2.5 NRAO Chile Office

The NRAO Chile Office in Santiago supports the legal and business affairs of AUI/NRAO in Chile for ALMA operations activities. The office will continue its administrative services at the ALMA site. The office specifically provides the services that require a local presence in Chile and cannot be effectively discharged from North America. The Chile Office will also continue its oversight of ALMA human resources activities, including contracts, payroll, travel support, and interactions with the labor union of local Associated Universities, Incorporated (AUI) staff. The office is also responsible for local property management and NRAO import/export activities for ALMA. The office will also monitor NRAO safety in Chile with the supervision of NA Site Safety Officers. A more detailed description of these functions follows.

Legal Representation: This function links NRAO, AUI and the ALMA project with the Chilean government and institutions as well as with the JAO. It is the exclusive role of the Executive. The legal representation staff includes the Representative/NRAO Chile Associate Director, the Chief of Staff (as of September 2014), the Chile Business Manager and secretarial support: the latter includes the support activities of expats and all travel arrangements for NRAO as well as for the U.S. AUI and NRAO staff

Table 2.6.2: ALMA FY2016 Major Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Operations	Cycle 3 Observing and Operations	1	1	1	1
	Cycle 3 JAO Support: 14 AoD Shifts (3-4/quarter)	2	2	2	2
	Support EOC	3	3	3	3
	Cycle 4 Obsmode go/no-go meeting	4			
	Cycle 4 s/w tests, doc prep, CfP		5		
	Offer Data Reduction Workshop in Charlottesville		6		
	Cycle 4 CDEs, User Support for Proposal Deadline			7	
	Cycle 4 Tech Assessment, Tech Secretary Supp.			8	
	Cycle 5 Capabilities Planning			9	
	Cycle 4 P2G and CS Assignments				10
	Cycle 4 SBs (first batch) validated				11
Development	Hold NAASC Interferometry Basics Summer Sch.				12
	FY2014/2015 Project Completion		13		
	FY17 Project CfP			14	

Milestones:

1. Cycle 3 observing & operations begin Q1, ongoing through Q4
2. Cycle 3 JAO Support: AoD support shifts at the OSF
3. Support Extension of Capability efforts at the JAO
4. Cycle 4: Participate in the Obsmode go / no-go meeting
5. Cycle 4: s/w tests, documentation, CfP
6. Offer data reduction workshop in Charlottesville
7. Cycle 4: CDEs, User Support, Proposal Deadline Supp.
8. Cycle 4: Tech Assessment, Tech Sec Supp.
9. Cycle 5: Capabilities Planning
10. Cycle 4: P2G and CS Assignments
11. Cycle 4: SBs validated
12. NAASC Interferometry Summer School
13. NA ALMA Development Projects for FY2014/2015 will be completed
14. NA ALMA Development Projects – Next Call for Proposals

Deliverables:

[1] Support Cycle 3 – Scheduling Block Prep, Contact Scientist, Data Reduction, Helpdesk & Visitor Support
[2] 3-4 AoD shifts per quarter
[3] Provide domain experts to JAO
[4] Decisions will be made on the readiness of the Cycle 4 S/W for Cycle 4 observations
[5] Documents. S/W test reports
[6] Two day workshop: staffing, presentations and tutorials
[7] Event presentations and tutorials; helpdesk responses
[8] Written proposal assessments; review meeting staffing
[9] Meetings and analysis leading to a decision on the planned capabilities for Cycle 5
[10] Staffing assignments
[11] Scheduling blocks (scripts) for Cycle 4 telescope operation
[12] Week long summer school: staffing, presentations and tutorials
[13] Five Development Projects initiated in FY2014 will be completed. They are: "Prototype Band 2 Cartridge," Band 3 Cold Cartridge Assembly Magnet and Heater," ALMA Data Mining Toolkit," "Next Generation ALMA Image Viewer," and "Expansion of the ALMA Central LO Article to 5 Subarrays."
[14] The next Call for Proposals for NA ALMA Development Projects will be issued (subject to continued availability of funds).

2.7 ALMA Financial Charts

Table 2.7.1: FY2015 by Location (ALL CSA-2 expenditures)

Work Breakdown Structure	Charlottesville TOTAL	Charlottesville FTE's	Chile TOTAL	Chile FTE's	Green Bank TOTAL	Green Bank FTE's	Socorro TOTAL	Socorro FTE's	GRAND TOTAL TOTAL	GRAND TOTAL FTE's
⊟1000 Telescope Operations										
⊟1100 Maintenance										
⊟1110 Corrective										
1113 Hardware (Config)	1,740,462	9.9					601,934	4.3	2,342,396	14.1
⊟1200 Operations										
⊟1230 Support & Testing										
1236 Scientific Support	216,846	1.3	605,334	2.2					822,180	3.5
⊞1240 M&C Software	530,076	4.5					630,572	6.0	1,160,648	10.5
⊟1400 Infrastructure Mods & Upgrades										
⊞1420 Modifications	2,400,000	0.0							2,400,000	0.0
⊟1500 Management										
⊞1510 Telescope operations Mgmt			16,792,018	0.0					16,792,018	0.0
⊞1550 Software Mgmt	89,795	0.5							89,795	0.5
1000 Telescope Operations Total	4,977,179	16.1	17,397,352	2.2			1,232,506	10.3	23,607,037	28.6
⊟2000 Development Programs										
⊟2200 Technology Development										
⊟2210 Enabling Technologies										
2218 Unallocated Projects	5,359,202	0.0							5,359,202	0.0
⊞2500 Management	266,799	1.0							266,799	1.0
2000 Development Programs Total	5,626,001	1.0							5,626,001	1.0
⊟3000 Science Operations										
⊟3200 Reference										
⊞3210 Library	97,500	0.0							97,500	0.0
⊟3300 Broader Impacts										
⊟3310 Student Programs										
3312 Graduate	152,000	0.0							152,000	0.0
3313 Student Observing Support	280,000	0.0							280,000	0.0
⊞3320 Visitor Support	214,794	0.3							214,794	0.3
⊟3400 Scientific Staff										
⊟3410 Staff Research										
3411 NRAO Staff	120,000	0.0							120,000	0.0
3412 Jansky Fellows	98,486	1.0					295,458	3.0	393,944	4.0
3413 NRAO Postdocs	196,822	2.5							196,822	2.5
⊞3500 Management	558,364	2.7							558,364	2.7
⊟3600 Scientific User Services										
⊟3610 Community Support										
3611 User Assistance	745,455	8.5			20,318	0.3	29,268	0.5	795,041	9.2
3612 Education & Training	366,796	2.1							366,796	2.1
3613 Workshops & Conferences	12,000	0.0							12,000	0.0
⊟3620 Science Data Processing										
3621 Data Processing Operations	1,420,318	9.3					100,095	0.7	1,520,413	10.0
3622 Data Analysis Tools	131,358	0.8							131,358	0.8
⊟3630 Science Software										
3631 Post-Processing Software	201,640	1.5					851,570	7.0	1,053,210	8.5
3634 Application Software	260,277	2.0					99,090	1.0	359,367	3.0
3635 Software Testing	338,687	3.1					36,624	0.3	375,311	3.4
3000 Science Operations Total	5,194,497	33.7			20,318	0.3	1,412,105	12.5	6,626,920	46.5
⊟4000 Administrative Services										
⊟4100 Business Services										
⊞4110 Business Office	46,185	0.7	1,017,000	8.4					1,063,185	9.1
⊞4800 NRAO Internal Common Costs	3,397,083	0.0							3,397,083	0.0
4000 Administrative Services Total	3,443,268	0.7	1,017,000	8.4					4,460,268	9.1
⊟5000 Director's Office										
⊞5200 Public Outreach	647,338	4.9	59,284	0.1					706,622	5.0
⊞5300 Communications	223,296	0.9							223,296	0.9
⊞5800 AUI Fee and IDC	2,018,690	0.0							2,018,690	0.0
5000 Director's Office Total	2,889,324	5.8	59,284	0.1					2,948,608	5.9
Grand Total	22,130,269	57.3	18,473,636	10.7	20,318	0.3	2,644,611	22.8	43,268,834	91.0

* Note that this is a complete picture of CSA-2 expenditures. Some of these expenditures are also shown in their respective departments.

ALMA Financial Charts (cont.)

Table 2.7.3: FY2016 by Location (ALL CSA-2 expenditures)

Work Breakdown Structure	Charlottesville		Chile		Green Bank		Socorro		GRAND TOTAL	
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟1000 Telescope Operations										
⊟1100 Maintenance										
⊟1110 Corrective										
1113 Hardware (Config)	1,601,877	9.9					601,934	4.3	2,203,811	14.1
⊟1200 Operations										
⊟1230 Support & Testing										
1236 Scientific Support	111,464	0.8	354,630	1.7					466,094	2.5
⊞1240 M&C Software	553,615	4.5					658,495	6.0	1,212,110	10.5
⊟1400 Infrastructure Mods & Upgrades										
⊞1420 Modifications	1,000,000	0.0							1,000,000	0.0
⊟1500 Management										
⊞1510 Telescope operations Mgmt			17,127,858	0.0					17,127,858	0.0
⊞1550 Software Mgmt	93,593	0.5							93,593	0.5
1000 Telescope Operations Total	3,360,549	15.6	17,482,488	1.7			1,260,429	10.3	22,103,466	27.6
⊟2000 Development Programs										
⊟2200 Technology Development										
⊟2210 Enabling Technologies										
2218 Unallocated Projects	5,084,812	0.0							5,084,812	0.0
⊞2500 Management	278,190	1.0							278,190	1.0
2000 Development Programs Total	5,363,002	1.0							5,363,002	1.0
⊟3000 Science Operations										
⊟3200 Reference										
⊞3210 Library	63,000	0.0							63,000	0.0
⊟3300 Broader Impacts										
⊟3310 Student Programs										
3312 Graduate	117,000	0.0							117,000	0.0
3313 Student Observing Support	350,000	0.0							350,000	0.0
⊞3320 Visitor Support	165,687	0.3							165,687	0.3
⊟3400 Scientific Staff										
⊟3410 Staff Research										
3411 NRAO Staff	80,000	0.0							80,000	0.0
3412 Jansky Fellows	102,508	1.0					307,523	3.0	410,031	4.0
3413 NRAO Postdocs	163,830	2.0							163,830	2.0
⊞3500 Management	577,313	2.7							577,313	2.7
⊟3600 Scientific User Services										
⊟3610 Community Support										
3611 User Assistance	770,615	8.3			21,202	0.3	30,520	0.5	822,337	9.1
3612 Education & Training	357,572	2.4							357,572	2.4
3613 Workshops & Conferences	30,000	0.0							30,000	0.0
⊟3620 Science Data Processing										
3621 Data Processing Operations	1,285,089	8.9					104,532	0.7	1,389,621	9.6
3622 Data Analysis Tools	135,012	0.8							135,012	0.8
⊟3630 Science Software										
3631 Post-Processing Software	210,621	1.5					889,415	7.0	1,100,036	8.5
3634 Application Software	271,043	2.0					103,471	1.0	374,514	3.0
3635 Software Testing	353,411	3.1					38,214	0.3	391,625	3.4
3000 Science Operations Total	5,032,701	32.9			21,202	0.3	1,473,675	12.5	6,527,578	45.7
⊟4000 Administrative Services										
⊟4100 Business Services										
⊞4110 Business Office	48,270	0.7	1,017,000	8.4					1,065,270	9.1
⊞4800 NRAO Internal Common Costs	3,559,293	0.0							3,559,293	0.0
4000 Administrative Services Total	3,607,563	0.7	1,017,000	8.4					4,624,563	9.1
⊟5000 Director's Office										
⊞5200 Public Outreach	603,259	4.9	59,698	0.1					662,957	5.0
⊞5300 Communications	173,595	0.9							173,595	0.9
⊞5800 AUI Fee and IDC	2,082,411	0.0							2,082,411	0.0
5000 Director's Office Total	2,859,265	5.8	59,698	0.1					2,918,963	5.9
Grand Total	20,223,080	56.0	18,559,186	10.2	21,202	0.3	2,734,104	22.8	41,537,572	89.2

* Note that this is a complete picture of CSA-2 expenditures. Some of these expenditures are also shown in their respective departments.

Capability	Description
	• Single, dual, and full polarization products • Number of channels summed over all polarization products up to 16,384 (no recirculation) or 65,536 (with recirculation x4)
Mixed 3- and 8-bit samplers	• Allows more flexibility for simultaneous continuum and high-resolution spectral line observing
Subarrays	• Up to three independent subarrays using standard 8-bit continuum setups
Phased-array for VLBI	• All antennas phased to simulate a single antenna with larger collecting area ("Y27")

Shared Risk capabilities being offered for FY2015 include On-The-Fly-Mosaicing (OTFM), 32 subbands per baseband with 8-bit samplers, and recirculation up to a factor of 64.

Scientific Support of Receiver, Antenna, and Array Performance: In addition to the standard support tasks described above the following items will take scientific support to make operational during FY2015:

- Automation of Multiple Subarray Observations: Observations using multiple subarrays were stabilized during FY2014, but must still be scheduled by hand. During FY2015 this mode will be automated and incorporated into the dynamic scheduler for testing (Q3).
- Incorporation of the New Atmospheric Phase Interferometer (API) into Regular Operations: The API is used to continuously measure the atmospheric stability, and is primarily used to guide the dynamic scheduler as to when the weather conditions are appropriate for high frequency observations. The old API has been replaced with a more robust, four-element API, which must be incorporated fully into regular operations during FY2015 (Q3).
- Integration of VLITE Operations: As VLITE completes its construction phase, it will pass into an operational mode that must be supported. Additional tests that require the extended B-configuration must be carried out during FY2015 (Q2).
- Evaluation of new 3-bit Samplers: New 3-bit sampler modules will be built and installed (224 new boards), replacing the poorest performing current samplers. These must be tested as they are installed (Q4).
- Test and Make Operational Frequency Averaging in Correlator Back-End (CBE): Continuum observations must currently use a maximum channel width of 2 MHz, which is not necessary for most experiments. Making averaging available will not only reduce the amount of data that our users must deal with, but will also mean less required disk storage space (Q2).

Array Operations

Array Configurations: Table 3.1.2 shows the antenna move schedule for FY2015.

Table 3.1.2: VLA Array Reconfiguration Schedule for FY2015

To Array	C	CnB	B	BnA	A	D
Start	10/06/2014	01/05/2015	01/26/2015	05/11/2015	06/01/2015	09/21/2015
Complete	10/17/2014	01/09/2015	02/06/2015	05/15/2015	06/12/2015	10/13/2015

Operating Model: VLA Operations continues to explore the possibility of moving operator control to Socorro for the evening and night shifts in order to achieve savings in vehicle use and to reduce the number of operators needed to maintain full operational coverage. The staff that provides custodial and security services will continue to work at the site. In FY2015 a control room for VLA Operations will be

established in the Domenici Science Operations Center (DSOC) (Q2), with the goal of commencing DSOC VLA Operations in Q3. Maintenance of appropriate levels of safety for site personnel and equipment will be carefully monitored during and after this transition.

FY2016

Science Operations

Observing Programs: An overview of the capabilities expected to be offered for GO for 2016 is given in Table 3.1.3 below.

Table 3.1.3: VLA Capabilities in FY2016

Capability	Description
8-bit samplers	• Standard default setups for: o 2 GHz bandwidth continuum observations at S/C/X/Ku/K/Ka/Q-Bands o 1 GHz bandwidth continuum observations at L-Band o 256 MHz bandwidth continuum observations at P-Band • Flexible setups for spectroscopy, using two independently tunable 1 GHz basebands, each of which can be split into up to 16 flexibly tunable subbands • Single, dual, and full polarization products • Number of channels summed over all polarization products up to 16,384 (no recirculation) or 65,536 (with recirculation X 4)
3-bit samplers	• Standard default setups for: o 8 GHz bandwidth continuum observations at K/Ka/Q-Bands o 6 GHz bandwidth continuum observations at Ku-Band o 4 GHz bandwidth continuum observations at C/X-Bands • Flexible setups for spectroscopy, using four independently tunable 2 GHz basebands, each of which can be split into up to 16 flexibly tunable subbands • Single, dual, and full polarization products • Number of channels summed over all polarization products up to 16,384 (no recirculation) or 65,536 (with recirculation X 4)
Mixed 3- and 8-bit samplers	• Allows more flexibility for simultaneous continuum and high-resolution spectral line observing
Subarrays	• Up to three independent subarrays using standard 8-bit continuum setups
OTFM	• Simple OTFM mosaics to cover large regions of the sky
Phased-array for VLBI	• All antennas phased to simulate a single antenna with larger collecting area ("Y27")

Shared Risk capabilities offered for FY2016 may include pulsar observing, fast dumps (integration times <50 msec), and triggered observing.

Scientific Support of Receiver, Antenna, and Array Performance: No additional scientific support for array operations is expected to be needed in FY2016 above and beyond the standard support tasks described above.

Array Operations

Array Configurations: Table 3.1.4 shows the antenna move schedule for FY2016. Note that in addition to the possibility of modifications to the hybrid configurations noted above, should the VLA Sky Survey be approved to start in FY2016, it is highly likely that it will also have a major impact on the array configuration schedule. It is therefore possible that the antenna move schedule for FY2016 could be substantially different from that given in Table 3.1.4.

Table 3.1.4: VLA Array Reconfiguration Schedule for FY2016

To Array	DnC	C	CnB	B	BnA	A
Start	01/04/2016	01/25/2016	04/25/2016	05/16/2016	08/29/2016	09/19/2016
Complete	01/08/2016	02/05/2016	04/29/2016	05/27/2016	09/02/2016	09/30/2016

Operating Model: By FY2016, we anticipate the evening and night shifts of the VLA operators will be staffed from the DSOC, in the VLBA Control Room. Day shifts will be staffed at the VLA site. Other VLA array operations personnel include the supervisor, who along with the established supervisory duties, also acts as the scheduler for major maintenance and overhauls for the VLA and the VLBA. Additionally, custodians and security guards are present for all evening and night shifts as well as weekend day shifts. The staff that provides custodial and security services will continue to work at the site. Provided DSOC VLA Operations is shown to be reliable, it is expected that it will be possible to reduce the leased General Services Administration (GSA) vehicle fleet for Operations by at least one vehicle in FY2016 (Q1). Maintenance of appropriate levels of safety for site personnel and equipment will be carefully monitored.

3.1.3. Development

At the time of writing no new development projects have been approved for the VLA in FY2015 within the current funding profile. However, NM Operations has several development projects ready to be undertaken, should funding become available. NRAO will assess the development project prioritization for FY2016 as per the standard schedule mid-spring. The following projects will be assessed for potential funding at that time.

All potential new development projects are reviewed by local scientific and engineering staff and evaluated based on science impact, technical readiness, and cost. The engineering cost of NM Operations development projects includes personnel costs, to enable the backfilling of technical support to minimize the impact on maintenance, operations, and technical upgrades. In contrast, it is very difficult to hire temporary scientific staff to backfill the functionality of scientific staff engaged in development projects, so new development effort is balanced against other upgrade and enhancement work. Key elements considered in evaluating the impact of transferring scientific staff from other activities to new development work are: safety; operational efficiency; impact on data quality and delivery of science; and impact on overall NRAO strategic goals.

Water Vapor Radiometry: The successful design and implementation of Water Vapor Radiometry (WVR) on the VLA and VLBA would increase the fraction of time available for high frequency observations, and increase observing efficiency by reducing the need for fast calibrator-target-calibrator cycle times in the extended VLA configurations and on the VLBA. It would also improve the resolution and accuracy of both imaging and astrometry at high frequencies, by minimizing the radio "seeing." This development project would investigate various WVR designs with the goal of determining which would be suitable for eventual implementation on the VLA and VLBA.

Commensal Fast Transient System: The field of fast transient detection has experienced an explosion of interest in recent years. Re-analyses of large, single-dish pulsar survey data have discovered new classes of transients, of both galactic and extragalactic origin. These discoveries show that these transients exist, but are difficult to interpret given the poor localization of single-dish telescopes, highlighting the potential for interferometers to revolutionize this field of study. The goal of this development project would be to design a prototype commensal fast transient system for the VLA, and

to investigate various options available for searching for these events: number of antennas, bandwidth, processing needed, algorithms to be used, etc.

VLA-Pie Town Link: One of the key technical challenges that will need to be met for any next generation cm array is the transmission of data, local oscillator distribution, and timing synchronization over large distances. This development project would digitally connect the VLBA Pie Town antenna to the VLA Wideband Interferometric Digital Architecture (WIDAR) correlator via a dark fiber, to be a low-cost demonstration for linking stations over 100 km and longer, and to provide a test bed for further technical development.

4-Band Feed Development: To date, 4-Band observations on the VLA have required special dipoles that cross under the subreflector and attach to the quadrupod legs. Although these dipoles are adequate for observing at 4-Band, their presence reduced the sensitivity at L and S-Bands, and the dipoles must be mounted temporarily for observing "campaigns," requiring staff both to mount and remove the dipoles. New designs have been developed that "strut straddle" the quadrupod legs in a square shape with minimal blockage of the subreflector, and so could be left up permanently. Six of the new 4-Band Modified J-Pole (MJP) feeds were installed in FY2014. These units will undergo testing and scientific verification by scientific staff in FY2015, when the VLA is in the B configuration. However, further development and testing may be required prior to considering outfitting the entire array with 4-Band feeds.

3.1.4. Maintenance and Renewal

New Mexico Operations supports over 3,300 modules, power supplies, and receivers for the VLA, VLBA, and the ALMA BE, as well as all mechanical parts in the antennas, such as motors, gears, and structural elements. Support work includes addressing the over 3,000 maintenance forms generated yearly and requires engineers and technicians to investigate, diagnose, trouble shoot and ultimately resolve these reports. To this end, there is a daily maintenance meeting attended by the group leads of all Electronics and Engineering Services personnel to review all new problem reports to assure all problems are assigned to the proper group. Older forms are reviewed to avoid stagnation of those issues and to identify recurring issues that may require an improvement or redesign of a module or procedure. Technicians are also available for after-hours callouts to address problems that seriously impact the safety of the array, such power failures, electrical problems, antennas stuck in unsafe positions. Callouts also occur if there are more than three antennas unusable for astronomy due to problems that may not be safety related, such as warmed receivers following a power outage. Specific maintenance activities are described further below.

Electronics Maintenance and Renewal

The New Mexico Electronics Division is responsible for maintaining all VLA electronic components and the WIDAR Correlator. Routine work for FY2015 and FY2016 will consist of the following:

- Overhaul approximately 30 receiver cold heads per quarter to keep VLA receivers operating.
- Recondition and replace receiver desiccant in each of 240 units twice per year.
- Perform preventive maintenance on 25 VLA compressor lines twice per year.
- Overhaul two VLA compressors due to normal wear-and-tear.
- Perform preventive maintenance on four helium circuits to maintain cryogenic performance.
- Repair and/or replace 24 FE receivers per year.
- Perform checks on the Correlator boards, replace or repair as needed.
- Perform checks of the fiber optics system to ensure proper operations, reset as needed.

maintenance presently perform by NRAO. Among these recommendations include an increase of 2500 cross-tie replacements to 5000 cross-tie replacements per year. To accomplish this, the NM Operations budget was increased to allow for an additional four FTE for the track crew beginning in FY2015.

Seventy-three intersections to antenna pads are included in the VLA Wye. As with the track cross-ties, the ties which make up these intersections must be replaced on a regular basis. Due to the complexity of rebuilding an intersection, the decision was made to replace failing intersections with fabricated concrete ties rather than wooden ones. This method requires more time to accomplish than working with wooden ties, but the payoff is extended life, greater safety during moves, and less maintenance. To date, approximately 13 of the 73 intersections have been replaced. Five intersections will be fabricated and replaced in each of FY2015 and FY2016.

Site Infrastructure: The VLA site buildings, utility systems, and grounds will continue to undergo routine annual inspection and preventive maintenance in FY2015 and FY2016. The site electrical system hatch gear and all site transformers undergo yearly preventive maintenance procedures. Other regular activities include: annual road grading; roof repairs; heating and cooling systems maintenance; pest and weed control along the railways and central site; fire brigade and emergency medical response team training; and the routine servicing of gas pumps, sewer and water supply systems, backup generator power, and other related systems.

Technical Upgrades and Enhancements

Several technical upgrades and enhancements are planned for FY2015 and FY2016, some of these being multi-year projects. Technical upgrades are chosen based on whether they improve array performance, increase observing efficiency, or retire some form of technical or operational risk. Details of what each entails are given below by year. In addition, there are several upgrades for which funding has not yet been identified, also summarized in the FY2015 section below. The decision of which potential upgrades are carried out within the existing operations budget of a given year is based on consideration of safety, operational efficiency, ease of maintenance, impact on data quality and delivery of science, cost, and impact on overall NRAO strategic goals.

FY2015

- Solar Capable Receiver Installation: The process of installing solar-capable receivers in the array will continue in FY2015. The process of modifying a receiver requires the receiver be removed from the array. At the DSOC, the components are replaced in the dewar, and the receiver is tested before being reinstalled in the array. Solar-capable receivers at L, X, Ku, and S-Band will be installed in FY2015, as specified in Section 3.4.
- Card Cage Upgrades: A revised Front End (FE) card cage design was completed in FY2014 to address reliability issues and over 48 units were installed in 2014. An additional 35 units will be installed in FY2015.
- C and L-Band Thermal Gap Retrofits: A new thermal gap design has been shown to decrease the noise temperature of both the C and L-Band receivers and significantly improve performance. At the end of FY2014 a total of six C-Band and seven L-Band receivers had been retrofitted. Four additional C-Band and six L-Band receivers will be modified in FY2015.
- Front End Cal Board: Each VLA receiver incorporates a warm electronics enclosure that houses the noise calibration monitor and control card. A new revision of the printed circuit board is now available that enhances the drive pulse used to switch the noise diode on/off for solar

observing. Eighteen boards of the new revision were built, tested and installed in 2014. We anticipate that 20 boards will be installed in FY2015.

- Temperature Stabilization of the VLA receiver noise diodes: The noise diodes used in every VLA receiver are located in the warm electronics enclosure. This enclosure is not temperature controlled and as the temperature changes the noise calibration diode output changes. This is a small effect but does affect the calibration of the receivers. In FY2015 a prototype temperature stabilized noise diode assembly will be developed and tested (Q3).
- Replace Legacy Q-Band Receiver Interface Hardware: Presently there are eight Q-Band receivers with legacy interface hardware. This hardware will be replaced in FY2015, making all thirty Q-Band receivers similar, allowing one software package to communicate with all of the Q-Band receivers.
- VLA ACU Replacement: The electronics parts to repair the existing ACUs are no longer available. Without replacement parts, antennas with failed ACUs would no longer be able to participate in observations, posing a serious operational risk. All of the legacy VLA antenna control units must be replaced with newer technology units, which enables a more supportable VLA, as well as eliminating some inherent problems with the legacy design and greatly improving the pointing and tracking capabilities of the antennas. The first new VLA ACU was installed in antenna 21 during the last quarter of FY2013. The second ACU replacement occurred in Q2 FY2014. The third ACU is scheduled to be installed in Q3 FY2015. Once an antenna has been outfitted with a new ACU, scientific staff will evaluate its performance. The short-term operations risk has been retired by building the three prototype ACUs. The existing set of spares is adequate for 1 to 2 years. A long-term risk still exists unless we continue to replace ACUs at about three per year.
- VLA 3-bit Sampler Upgrade: There are 224 3-bit sampler boards installed in the VLA, which provide the widest bandwidths. Some of the boards do not perform as well as others, and installation of all the best performers in the array has reduced the number of good spare sampler boards below a comfortable level. The current 3-bit sampler chip is obsolete, so a board was developed and tested that uses a commercially available chip. Six Data Transmission System (DTS) transmitter modules incorporating Hittite 3-bit sampler boards were installed in FY2014. An analysis and presentation on performance was given to the senior staff in Q4 FY2014. Thirteen additional Data Transmission System (DTS) transmitter modules incorporating Hittite 3-bit sampler boards will be installed by end of Q3 FY2015, to enable scientific evaluation in Q4.
- F318 Installation: The F318 is a control module for the Low Band Receiver (LBR) with an option for incorporating other hardware in a more modern, maintainable design. It replaces the F320, which controls only the LBR. This retrofit uses some of the F320 hardware and is therefore tied to eliminating the older card cage designs, which are driven by the F320. The replacement of the card cages has a separate milestone. Ten F318s will be deployed in FY2015.

Unfunded Upgrades

- Front End Receiver Test Rack Upgrade: The test racks used to verify the performance of the VLA and VLBA receivers in the laboratory are becoming unreliable. Two of these test racks need to be upgraded by replacing the obsolete signal generators and by writing a new LAB-View interface program ($92k per rack).
- VLA ACU Replacement: Additional ACUs could be replaced if funding were available ($35k per unit).

Operational Enhancements

In addition to the new capabilities that NRAO plans to offer its users, there are several planned enhancements to the technical or scientific operation of the VLA that will result in improvements in overall data quality, or enhanced data products. In FY2015 and FY2016 these focus on improved calibration procedures, including heuristics for the VLA calibration pipeline, and on supporting the VLA Sky Survey, if the latter is approved by the Director following its Community Review.

FY2015

- Improvements to Referenced Pointing: Referenced pointing has been implemented using a relatively narrow bandwidth associated with a single subband, with that subband being at a fixed relative position in the baseband. In FY2015, we will investigate improving the robustness of the reference pointing solutions with respect to bad antennas, RFI, etc. (Q4).
- Implement Tipping Scans for Opacity Correction: When it is not possible to observe an absolute flux density calibrator within the same elevation range as that spanned by the science target, it is necessary at high frequencies to estimate the difference in atmospheric opacity between the calibrator and the science target. A tipping scan can be used to derive the zenith opacity during an observation to characterize elevation-dependent gain terms, improving the accuracy of the absolute flux density scale. Although this was possible with the old VLA system, it has not yet been implemented with the EVLA, and is currently potentially limiting the absolute flux density calibration accuracy at high frequencies. Old-style VLA TIPs will be implemented to regain that capability (Q3).
- Develop a Method to Use Switched Power Values for Improved Calibration: The switched power calibration values can be used to remove gain variations as a function of time if the measured system power is stable. Thus, it has the potential to decrease observing overhead and simplify the post-processing steps in several observing bands. Several problems remain to be solved with respect to the use of switched power calibration, and commissioning of the switched power system and documentation of the best practices for how to use the values in CASA will continue into FY2015 (Q4).
- Pipeline Heuristic Development: The VLA Calibration Pipeline currently delivers calibrated visibility data for continuum experiments. Heuristics will continue to be developed during FY2015 to extend the use of the pipeline to polarization experiments (Q3).
- Ionospheric Calibration Improvements: At low frequencies, variability in the ionosphere becomes the limiting factor determining the quality of images that can be produced. During FY2015 methods for improving the ionospheric calibration will be investigated and documented. The possibility of utilizing simultaneous VLITE ionospheric data will also be investigated (Q2).
- Support for the VLA Sky Survey (VLASS): Should the VLASS be approved for observing, several enhancements will need to be developed and tested to support it, including such items as best imaging practices for mosaics, delivery of VLASS image products through the NRAO Archive, and the ability for triggered overrides of current observing (Q4).

FY2016

- Improvements to Referenced Pointing: Combination of multiple subbands (either pre- or post-solution) to facilitate use of weaker reference pointing calibrators will be investigated (Q4).
- Implement Tipping Scans for Opacity Correction: Continuous slew TIPs will be tested, implemented, and documented (Q2).

can be used for GO depends upon what is available for each station. The Calls for Proposals identify explicitly what the available options will be for each semester.

The SRO program allows users access to capabilities that can be set up via the standard VLBA software packages and run without intervention, but are not as well tested as GO capabilities. The Shared Risk capabilities being offered for FY2015 and FY2016 are those related to the use of the DDC with Effelsberg in HSA observations, and the inclusion of the Large Millimeter Telescope (LMT) in HSA observations for 3mm VLBI, as specified in the by-year summaries below.

The RSRO program provides users with early access to new capabilities in exchange for a period of residence to help test and verify those capabilities. As an example, the phased VLA system was developed through the VLA RSRO program. For FY2015 and FY2016 NRAO is encouraging additional RSRO participation to expand the phased VLA and HSA capabilities, implement the use of a single VLA antenna in a sub-array for VLBI observing while the remaining VLA antennas perform VLA observations ("Y1"), develop a rapid response (5 to 10 minutes latency) for triggered VLBA observations, and develop a narrow bandwidth, quasi-real-time correlation capability that would be suitable for real-time fringe checks and spacecraft tracking.

Capabilities to be offered for each observing semester are defined approximately four months ahead of the associated proposal submission deadline, to allow them to be incorporated into the various software tools associated with the Call for Proposals.

Scientific Support of Receiver, Antenna, and Array Performance: Operational tasks that will be carried out by the scientific staff during FY2015 and FY2016 in support of maintaining receiver, antenna and array performance and ensuring that the user community has access to quality instrumentation and updated information to effectively use the VLBA include (but are not limited to):

- Support Calls for Proposals: Prepare user documentation for offered capabilities before the call goes out, provide scientific testing of user tools needed to prepare proposals (e.g., PST, EVN Sensitivity Calculator), provide technical reviews for proposals and evaluate proposals for RSRO contributions.
- Hardware, Software, and Operational Documentation: Write technical documentation detailing hardware and software functionality for staff and users, develop and improve operational procedures and write documentation for the operations staff. This includes updating the VLBA "Observational Status Summary" before each Call for Proposals.
- Track and Measure VLBA Sensitivity, Pointing, Focus: Characterize the sensitivity, pointing and focus of each antenna at each band. This must be done periodically as receivers and equipment are replaced or as software is upgraded.
- Clock Maintenance: Accurate time keeping is central to VLBI, and is provided by hydrogen masers and reference signals inserted into the astronomical data. Quality assurance checks are performed periodically by scientific staff and data analysts.
- RFI Characterization and Mitigation: Run RFI tests to characterize and help mitigate RFI contamination in the observing bands.
- System Health and Maintenance Feedback: Run routine health checks and critically analyze the data to determine if there are any hardware failures that must be followed up with maintenance tickets.
- Data Quality Assurance Checks: Evaluate data quality and run test observations to identify and diagnose problems that are not caught by engineering checks.
- Coordination with Other Observatories for Global mm VLBI and the HSA: The VLBA occasionally observes in parallel with other observatories, as requested by users whose scientific

- Maintain the grounds and building infrastructure.
- Other diagnostic and repair tasks as needed.

Electronics Division staff based at the DSOC will perform the following routine work in FY2015 and FY2016:

- Overhaul approximately 60 receiver cold heads per year to keep VLBA FEs operating.
- Perform preventive maintenance on four helium circuits to maintain cryogenic performance.
- Repair and/or replace eight VLBA FE receivers per year.
- Perform checks on the Correlator Computers, replace as needed.
- Investigate issues with locking, fringing, output power, and general communication dropouts.
- Retrofit upgrades or additions to enhance equipment safety.
- Perform bench work on modules for repair or assembly.
- Monitor maser performance and timing, adjusting as needed.
- Perform maintenance on ACUs and FRM controllers.
- Monitor for local RFI at the VLBA sites.
- Send calibrated site weather station hardware to each site as needed.
- Repair of 24 VLBA recording and playback modules
- Repair of 100 Mark 5 disk packs.

Masers are expected to continue to fail at a rate of 1 to 2 per year. At the beginning of FY2015 there will be two spares available, with a third one on order for lease or purchase (there is a six to nine month lead time on the acquisition of new masers). This is expected to be sufficient to cover the VLBA maser needs for the FY2015 and FY2016 period, but depending on actual failure rates, an additional maser may be ordered in FY2016.

Site Maintenance and Renewal

Antennas: Two VLBA stations per year are scheduled to receive major maintenance visits by the VLBA Tiger Team in FY2015 and FY2016, comprising eight personnel from the antenna mechanics and the Electronics Division servo groups. Note that the number of visits was reduced from three per year to two per year in FY2013, in order to reduce operations costs. NRAO will continue to monitor the impact of the reduced Tiger Team visits to VLBA stations, bearing in mind that the VLBA antennas are now 20 years old. The Tiger Team will inspect and upgrade drive wheel assemblies, inspect, repair, and upgrade mechanical and electronic components, as needed. Gears will be greased and checked for early signs of potential failure, and elevation bearings checked. Most, if not all, of the VLBA antennas will likely need both elevation bearings replaced over the next ten years. Detailed descriptions of past VLBA Tiger Team tasks are documented in the Antenna memo series available on the VLBA web site.

FY2015

In FY2015, the Owens Valley and St. Croix VLBA stations are scheduled to receive major maintenance visits by the VLBA Tiger Team.

FY2016

In FY2016, the Kitt Peak and Mauna Kea VLBA stations are scheduled to receive major maintenance visits by the VLBA Tiger Team.

New Mexico Operations Financial Chart (cont.)

Table 3.5.3: FY2016 by Fund Source and Instrument

	CSA-1 NRAO Ops								CSA-2 ALMA Ops		Internal Common Costs			
	VLA		VLBA		NON-TELESCOPE		TOTAL, CSA-1		ALMA		NON-TELESCOPE		GRAND TOTAL	
Work Breakdown Structure	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
1000 Telescope Operations														
1100 Maintenance														
1110 Corrective														
1111 Unscheduled	1,760,827	20.0	1,309,554	14.6			3,070,380	34.5					3,070,380	34.5
1112 Scheduled	1,008,508	11.1	584,251	6.6			1,592,759	17.7					1,592,759	17.7
1113 Hardware (Config)									601,934	4.3			601,934	4.3
1114 Software			200	0.0			200	0.0					200	0.0
1120 Preventive														
1121 Scheduled	1,386,412	18.5	60,873	0.3			1,447,285	18.8					1,447,285	18.8
1200 Operations														
1210 Scheduling														
1211 Telescope Status & Scheduling	55,979	0.4	67,729	0.6	3,997	0.0	127,706	1.0					127,706	1.0
1220 Operating														
1221 Observing	345,121	6.0	143,424	2.4			488,545	8.4					488,545	8.4
1222 Recording & Media Distribution	13,368	0.2	93,755	0.8			107,123	1.0					107,123	1.0
1230 Support & Testing														
1231 Calibration	2,175	0.0	61,460	1.0			63,635	1.0					63,635	1.0
1232 Antenna Moves/Repositioning	72,195	1.1					72,195	1.1					72,195	1.1
1236 Scientific Support	1,035,991	7.1	84,967	0.6			1,120,958	7.7					1,120,958	7.7
1240 M&C Software	26,752	0.3	43,610	0.4			70,362	0.6					70,362	0.6
1400 Infrastructure Mods & Upgrades														
1410 Small Scale R&D														
1411 Projects			202,829	1.5			202,829	1.5					202,829	1.5
1420 Modifications														
1421 Projects	659,656	5.6	54,104	0.5			713,760	6.1					713,760	6.1
1500 Management														
1510 Telescope operations Mgmt	79,002	0.8	124,046	0.8	84,004	0.5	287,051	2.1					287,051	2.1
1520 Science Support Mgmt	166,636	1.0	106,425	0.6			273,061	1.6					273,061	1.6
1530 Mechanical Engineering Mgmt	608,277	4.2	31,273	0.2			639,550	4.4					639,550	4.4
1540 Electronics Mgmt	307,003	2.0	175,074	1.4			482,077	3.4					482,077	3.4
1000 Telescope Operations Total	7,527,901	78.2	3,143,575	32.2	88,001	0.5	10,759,477	110.9	601,934	4.3			11,361,411	115.2
3000 Science Operations														
3300 Broader Impacts														
3320 Visitor Support					3,600	0.0	3,600	0.0					3,600	0.0
3600 Scientific User Services														
3610 Community Support														
3611 User Assistance	3,428	0.1	47,216	0.7			50,644	0.7					50,644	0.7
3000 Science Operations Total	3,428	0.1	47,216	0.7	3,600	0.0	54,244	0.7					54,244	0.7
4000 Administrative Services														
4100 Business Services														
4110 Business Office					421,492	3.0	421,492	3.0			204,118	4.5	625,610	7.5
4200 Facilities														
4210 Plant Maintenance	304,718	6.0	65,000	0.0			369,718	6.0			368,000	0.0	737,718	6.0
4220 Communication	27,000	0.0	60,500	0.0	192,000	0.0	279,500	0.0					279,500	0.0
4230 Utilities	1,211,715	0.0	446,851	0.0			1,658,566	0.0			307,000	0.0	1,965,566	0.0
4240 Leases			42,581	0.0			42,581	0.0					42,581	0.0
4260 Vehicles	377,525	3.0	43,000	0.0			420,525	3.0			93,397	1.0	513,922	4.0
4270 Central Instrument Shop	297,651	3.6	26,197	0.5			323,847	4.0					323,847	4.0
4300 Auxiliaries														
4320 Housing														
4322 Residence Hall					4,000	0.0	4,000	0.0					4,000	0.0
4500 Management					117,414	1.5	117,414	1.5			349,287	2.0	466,701	3.5
4000 Administrative Services Total	2,218,608	12.6	684,128	0.5	734,906	4.5	3,637,643	17.5			1,321,802	7.5	4,959,445	25.0
Grand Total	9,749,937	90.8	3,874,920	33.3	826,507	5.1	14,451,364	129.2	601,934	4.3	1,321,802	7.5	16,375,100	140.9

The facility's laboratories, utilities and support facilities make it an attractive location for independent research experiments and it serves as the field station for several university-based research instruments.

FY2015

In FY2015 the GBT will remain in general operation with approximately 6500 hours of time devoted to science. However, the number of hours available for open-sky science proposals will be reduced to approximately 5800 hours due to decreased funding from the NSF as a result of the divestiture recommendation provided by the 2012 Portfolio Review Committee. A number of new instruments will be available in FY2015, including a new 32–element 82-100 GHz bolometer array and a 16-element feed horn array from 75-115 GHz. VEGAS, an Field-programmable Gate Array (FPGA) + Graphics Processing Unit (GPU)-based back end for spectral line and pulsar observations, will be complete before FY2016, when it will enter into use as a general observer's instrument.

The science to be delivered by the GBT in FY2015 will remain extremely varied, from searching for nanoHertz Gravitational Waves through pulsar timing, to discovery and confirmation of new interstellar molecules, mapping the star formation regions and potential in the Milky Way and other galaxies, and studying the SZ effect in distant galaxy clusters. One new area of science which will open up for the GBT in FY2015 is the mapping of star formation rates using the CO (1-0 and 2-1) molecule in nearby ($z< 0.2$) galaxies with the new 16-element 75-115 GHz array being developed by a university consortium led by Stanford University.

FY2016

No new instruments are scheduled for deployment in FY2016. As a result the science from the GBT is expected to remain similar to that of FY2015, although the total number of hours available for open-sky proposals may continue to decline in preparation for continued divestiture of the facility from the NSF's budget portfolio. It is estimated that in FY2016 3,000-5,000 hours of science time will be open for use by the general astronomy community through NRAO's open skies policy.

4.1.2. Operations

The GBT is in operation 362 days of each year, with an average of 6500 hours of science time annually. The GBT has achieved excellent 3 mm capabilities, with 35% and 18% aperture efficiency at 90 and 115 GHz, respectively. GBT also has a dynamic scheduling system that will optimize the current weather conditions against each observing project's scientific goals.

FY2015

By the start of FY2015, the GBT instrument suite consists of single/dual-pixel receivers from 300 MHz - 96 GHz (non-contiguous), a 7-pixel heterodyne focal plane array at 18 - 26 GHz, and an improved bolometer array at 81 - 100 GHz. Industry-leading signal processing systems for the GBT are now in place, with a new high dynamic range, state of the art hardware for high time and high frequency resolution observations installed as well as ability to make very wide bandwidth (≥10 GHz) observations for spectral line and pulsar detection experiments.

In addition to the two new instruments placed on the telescope, FY2015 will see two other changes for the GBT. If resources allow there will be a change in the primary backend used for pulsar observations as pulsar modes are transferred to the VEGAS backend. Additionally, we will begin the process of

- *Ku-Band Wide* (12.0 - 19 GHz): This receiver is intended for wide bandwidth observations which do not require smooth band passes. It has two beams on the sky, each with dual circular polarization
- *K-Band Focal Plane Array* (18.0 - 27.5 GHz): The K-Band Focal Plane Array has seven beams total, each with dual circular polarization. Each beam covers the 18-27.5 GHz frequency range. The feeds have cooled polarizers producing circular polarization.
- *Ka-Band* (26.0 - 39.5 GHz): This receiver has two beams, each with a single linear polarization. The polarizations of the two beams are orthogonal and are aligned at 45° angles to the elevation (and cross-elevation) direction. The receiver is built according to a pseudo-correlation design.
- *Q-Band* (38.2 - 49.8 GHz): This receiver has two beams, each dual circular polarization.
- *W-Band 4mm* (67 - 93.3 GHz): This receiver has two feeds with native circular polarization.
- *MUSTANG-1.5* (75-105 GHz): MUSTANG-1.5 is 32 dual polarization, feed horn coupled bolometers with an instantaneous ~3′.5 field of view.
- *ARGUS* (75-115 GHz): ARGUS is a 16-pixel W-Band focal plane array for millimeter spectroscopy that will be deployed at the GBT in FY2015. The array operates in the 75-115.3 GHz range and has a 4×4 square-packed configuration.

- Backends:
  - *VEGAS*: The VErsatile GBT Astronomical Spectrometer (VEGAS) is an FPGA+GPU based backend. VEGAS is comprised of eight separate spectrometers that can be run independently of each other. Observers can use any combination of spectrometers - from a single spectrometer to all eight - at the same time. VEGAS has a larger dynamic range than the GBT spectrometer and can retain a linear response in the presence of stronger RFI than the GBT spectrometer. In comparison with the previous GBT spectrometer, VEGAS also has a wider total bandwidth, higher time resolution, and provides all four stokes parameters. VEGAS also has significantly higher time and spectral resolution than the (now retired) spectral processor as well as more bandwidth.
  - *GUPPI*: The Green Bank Ultimate Pulsar Processing Instrument (GUPPI) is a pulsar backend intended for use for both pulsar timing and searches. GUPPI has one hardware mode and many software modes. GUPPI can be used with any receiver (with the exception of MUSTANG.) Only one polarization would be available for the Ka-Band receiver. It is anticipated that during FY2015 GUPPI will be replaced by pulsar modes on the VEGAS backend.
  - *DCR*: The Digital Continuum Receiver (DCR) is the GBT's general purpose continuum backend. It is used both for utility observations such as pointing, focus, and beam-map calibrations, as well such as for continuum astronomical observations including point-source on/off, and extended source mapping.
  - *CCB*: The Caltech Continuum Backend (CCB) is a sensitive, wideband backend designed exclusively for use with the GBT Ka-Band receiver over the frequency range of 26-40 GHz. It provides carefully optimized wideband detector circuits and the capability to beam-switch the receiver rapidly to suppress instrumental gain fluctuations.
  - *Mark5*: VLBI/VLBA observing with the GBT is supported with a VLBA backend using the Mark5 recording system.

FY2015

The following development projects will continue into FY2015:

ARGUS: In FY2014 a group led by Sarah Church (Stanford University) began the construction of a 16-pixel 75-115.3 GHz traditional feed horn array, funded through the NSF-AST ATI program. The GBT is the best telescope in the world for molecular line research in the 70-100 GHz band. The proposed camera will capitalize on that fact by using the GBT's sensitivity to create an on-the-fly image of cometary molecules. When combined with the GBT's sensitivity, the camera will be the only system in the world which can provide information about the structure of comets as they move through the solar system.

Development of the instrument will complete in FY2015, with commissioning of the instrument taking place in the winter of 2014/2015. NRAO staff will be assigned to the project to aid in the adaption of the instrument to a full user instrument. Milestones for FY2015 are listed in Section 4.4 and are for the project as a whole and are monitored and controlled by the project PI.

MUSTANG: In FY2013 a group led by the University of Pennsylvania began building a new 75-105 GHz bolometer array for the GBT. This array is assembled from new frequency-domain microwave SQUID (mSQUID) multiplexers recently developed by National Institute of Standards and Technology (NIST) (using the same backend electronics as mKIDS) and contoured feed horns. Due to the small size of the array (32 pixels), it will provide only a small increase in the overall sensitivity and mapping speed of the GBT. The array will, though, provide a more stable array than exists and the infrastructure needed to install the full 200+ pixel MUSTANG2 system which will provide a greater than 100x increase in the GBT's mapping speed. The MUSTANG2 array is not yet funded.

The project was scheduled to be complete in FY2013. However, delays in getting NIST to deliver the detectors for the instrument have resulted in delays from the original schedule. Receiver commissioning will now begin in Q1, FY2015.

FY2016

Any new development projects in FY2016 will be the result of new partnerships formed and are not yet defined.

4.1.4. Maintenance and Renewal

The following maintenance and renewal activities occur annually and will continue throughout FY2015 and FY2016:

Track repair: The GBT track is now ten years old and is showing signs of wear. Beginning in FY2014 NRAO, on an annual basis, is replacing those GBT track pieces which show significant wear.

Telescope painting: Painting of the GBT is necessary to preserve the overall integrity of the structure. In FY2015 we will continue our annual painting efforts at roughly the same levels as in the past three years.

Routine maintenance: Ongoing telescope front-end and back-end maintenance will continue routinely in FY2015 and FY2016, including cold-head and compressor maintenance for the cryogenic

receivers, repair of failed parts in the front ends, servo and LO-IF systems, and the maintenance and repair of fiber optic connections. Antenna mechanics also analyze lubricants for metal and other foreign particles in the field, on the GBT and all other antennas, to be alerted to potential failure of moving parts, especially azimuth truck bearings and elevation gears and bearings.

Additional Maintenance and Renewal Milestones by Year

FY2015

Digital Servo Replacement: The original analog servo system for the GBT is outdated and difficult to maintain. It is being replaced by a digital servo system that will provide the platform for model-based servo control, allowing for significantly improved telescope pointing and motion. The servo replacement is being performed as part of operations and will continue in FY2015.

Telescope inspections: The tri-annual GBT inspections will occur in Q3 and Q4 of FY2015.

FY2016

Digital Servo Replacement: The digital servo replacement project should complete in FY2016.

4.2 Other Telescopes

4.2.1. Science

The scientific output of site instruments other than the GBT is set by the existing contracts. The science output is varied – from looking for fast radio bursts through monitoring solar outbursts, providing mapping positions, and aiding a space-based VLBI station looking to observe the edge of black holes.

FY2016

No change in the instrument usage is currently planned in FY2016, although new, as of yet undefined, contracts are possible.

4.2.2. Operations

The Green Bank facility is a large protected site with laboratories, utilities and support facilities that makes it an attractive location for staging a variety of research experiments. The site hosts eight large telescopes, ranging in diameter from 13.7m through the 100m GBT, as well as numerous other site instruments. All non-GBT instruments are funded outside AUI's cooperative agreement with the NSF for NRAO operation. Below is a listing of instruments as they are currently used on site.

RadioAstron Earth Station: In FY2013 the 43m diameter telescope was refitted for operation as a down link (Earth) station for the Lebedev Institute's RadioAstron science satellite. Operation as an Earth Station continues through FY2015, with an anticipated renewal of the current contract (slated to end Nov 25, 2014).

Precision Array to Probe the Epoch of Reionization (PAPER): The Green Bank facility is the Northern site for the PAPER telescope, the HERA prototype run by a partnership that includes UC Berkeley and the University of Virginia, which also operates a larger array in the Karoo desert of South

Africa. This project is staffed and run through the University of Virginia. It is anticipated use of this facility will be minimal in FY2015 and FY2016.

Radio SkyNet: SKYNET is a distributed network of robotic telescopes operated by students, faculty, and staff at the University of North Carolina at Chapel Hill. The network began operation in January 2006 with the opening of the six PROMPT telescopes in Chile. Since then, several more telescopes in the U.S. and Europe have been integrated into the network. The NRAO 20m telescope on the Green Bank site is the first (and presently only) radio telescope within the network. The Radio SkyNet telescope refurbishment was complete in FY2013 and the instrument is now operational and will remain so through FY2015 and FY2016.

40ft Educational Telescope: The 40ft diameter telescope is operated by the NRAO's EPO division for on-site education and outreach programs.

Low Frequency All-Sky Monitor Project: LoFASM is a University of Texas, Brownsville project which will consist of four phased dipole arrays, separated by several thousand kilometers. One of its first arrays was installed on the Green Bank site in FY2013 and the instrument is anticipated to be fully operational in FY2015, continuing through FY2016.

MEASURE: West Virginia University has installed a magnetometer on site as part of the University of California-led Magnetometers along the Eastern Atlantic Seaboard for Undergraduate Research and Education (MEASURE) project to study magnetosphere dynamics. This project is staffed and run through the West Virginia University.

West Virginia Geospatial Information Network: A reference Global Positioning System (GPS) sensor for the West Virginia Geospatial Information Network is installed on site. This project is staffed and run through the State of West Virginia.

4.2.3. Development

No development is currently planned for the other (non-GBT) site telescopes in FY2015 or FY2016.

4.2.4. Maintenance and Renewal

Telescope painting: Painting of the site telescopes is necessary to preserve the overall integrity of the structure. In FY2015 and FY2016 we will continue our annual painting efforts at roughly the same levels as in the past three years.

Routine maintenance: Ongoing telescope structural maintenance will continue routinely in FY2015 and FY2016, as will work to maintain any funded instruments on the telescopes.

Routine Inspections: Site telescopes are regularly inspected for structural issues and such issues will be handled as they arise.

4.3 Site Operations

Site Facilities: In addition to the science instruments on site, Green Bank hosts a number of other facilities. The NRAO central instrument shop provides much of the large (m – cm) work for all NRAO telescopes and projects. The onsite housing, ranging from bunkhouses and motel-like lodgings through

4.4 West Virginia Operations Major Milestones

Table4.4.1: West Virginia Operations FY2015 Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
GBT Development	Commissioning of MUSTANG 1.5 receiver	1			
	Commissioning of ARGUS receivers		2		
GBT Maintenance	Telescope Painting			3	4
	GBT Track inspection and repair				5
	GBT structure inspections			6	7
	Active surface replacement				8
Site Operations	Repair/replace culvert in interferometry area				9

Milestones:	Deliverables:
1. Commissioning of MUSTANG1.5 2. Commissioning of ARGUS receiver 3. Beginning of summer painting 4. End of summer painting 5. GBT track inspection will take place, any needed repairs completed 6. Beginning of structural inspections 7. End of structural inspections 8. Begin replacement of GBT active surface electronics 9. Repair culvert by interferometer	[1] Commissioning report for MUSTANG1.5 [2] Commissioning report for ARGUS [3] Telescope painters hired, trained [4] Telescope painting complete [5] Track inspection and repair report [6] Structural inspection contract and schedule complete [7] Structural inspections complete [8] Report and plan for replacement of active surface electronics [9] Culvert repaired

Table 4.4.2: West Virginia Operations FY2016 Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
GBT Maintenance	Telescope Painting			1	2
	GBT Track inspection and repair				3
	GBT structural inspections report			4	
	Active surface electronics replacement				5

Milestones:	Deliverables:
1. Beginning of summer painting 2. End of summer painting 3. GBT track inspection will take place, any needed repairs completed 4. 2015 structural inspections report complete 5. Begin active surface electronics replacement	[1] Telescope painters hired, trained [2] Telescope painting complete [3] Track inspection and repair report [4] Structural inspection report [5] First components installed

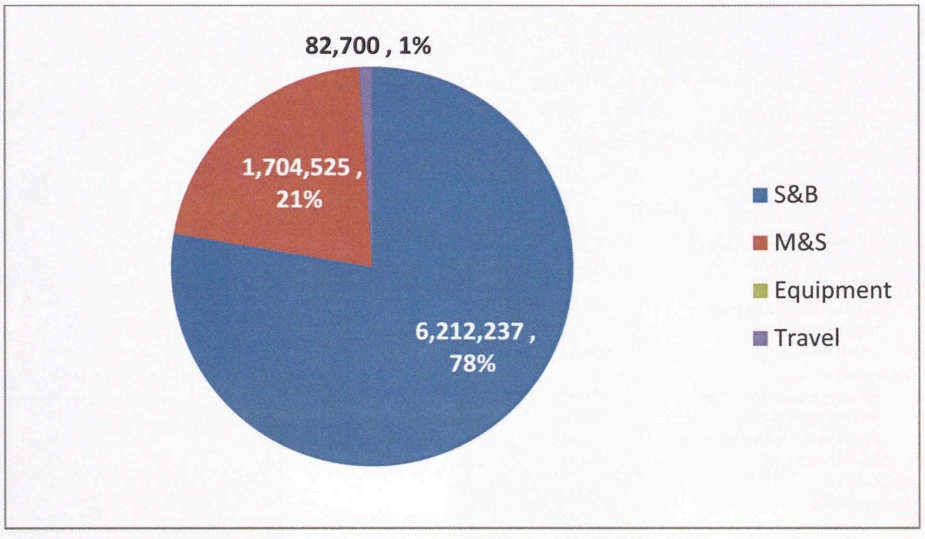
4.5 West Virginia Operations Financial Chart

Table 4.5.1: FY2015 by Fund Source

Work Breakdown Structure	C5A-1 NRAO Ops		Development		Internal Common Costs		Grand Total	
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟1000 Telescope Operations								
⊟1200 Operations								
⊟1210 Scheduling								
1211 Telescope Status & Scheduling	39,195	0.3					39,195	0.3
⊟1220 Operating								
1221 Observing	347,064	5.7					347,064	5.7
⊟1230 Support & Testing								
1231 Calibration	134,171	1.4					134,171	1.4
1235 Systems Hardware Support	1,743,657	17.7					1,743,657	17.7
1236 Scientific Support	142,600	2.3					142,600	2.3
⊞1240 M&C Software	35,217	0.3					35,217	0.3
⊟1400 Infrastructure Mods & Upgrades								
⊟1420 Modifications								
1421 Projects	650,824	4.8					650,824	4.8
⊟1500 Management								
⊞1510 Telescope operations Mgmt	251,541	2.0					251,541	2.0
⊞1520 Science Support Mgmt	189,812	1.0					189,812	1.0
⊞1530 Mechanical Engineering Mgmt	75,149	0.5					75,149	0.5
⊞1540 Electronics Mgmt	175,269	1.5					175,269	1.5
⊟1100 Maintenance								
⊟1110 Corrective								
1112 Scheduled	61,741	0.6					61,741	0.6
⊟1120 Preventive								
1121 Scheduled	255,355	3.2					255,355	3.2
1122 Painting	204,171	3.0					204,171	3.0
1123 Inspections	175,000	-					175,000	-
1125 Telescope Structure	63,968	0.8					63,968	0.8
1000 Telescope Operations Total	4,544,736	44.7					4,544,736	44.7
⊟2000 Development Programs								
⊟2200 Technology Development								
⊟2210 Enabling Technologies								
2214 Receivers			204,000	1.3			204,000	1.3
⊞2500 Management	32,882	0.3					32,882	0.3
2000 Development Programs Total	32,882	0.3	204,000	1.3			236,882	1.5
⊟3000 Science Operations								
⊟3600 Scientific User Services								
⊟3610 Community Support								
3613 Workshops & Conferences	10,000	-					10,000	-
⊟3400 Scientific Staff								
⊟3410 Staff Research								
3413 NRAO Postdocs	20,000	-					20,000	-
3000 Science Operations Total	30,000	-					30,000	-
⊟4000 Administrative Services								
⊟4100 Business Services								
⊟4110 Business Office								
4111 Business Office	252,501	2.1			306,745	3.0	559,246	5.0
4112 Visitor Support	10,500	-					10,500	-
⊟4200 Facilities								
⊞4210 Plant Maintenance	477,287	12.3			464,776	-	942,062	12.3
⊞4220 Communication	70,692	-					70,692	-
⊞4230 Utilities	253,318	-			176,031	-	429,349	-
⊞4260 Vehicles	30,466	0.4			29,681	0.6	60,147	1.0
⊞4270 Central Instrument Shop	351,503	3.9					351,503	3.9
⊟4300 Auxiliaries								
⊞4310 Visitor Centers	12,875	0.1					12,875	0.1
⊟4320 Housing								
4321 Dorms	(11,000)	-					(11,000)	-
4322 Residence Hall	(72,438)	0.5					(72,438)	0.5
4323 Houses	(79,256)	0.9					(79,256)	0.9
⊟4330 Food Handling								
4331 Cafeteria	105,101	4.6					105,101	4.6
4332 Cafe	61,239	2.6					61,239	2.6
⊞4350 Management	52,840	0.9					52,840	0.9
⊟4500 Management								
⊞4510 AD Mgmt	67,203	0.7			202,780	1.0	269,983	1.7
⊞4520 Community Relations	10,000	-					10,000	-
4000 Administrative Services Total	1,592,831	28.6			1,180,013	4.6	2,772,844	33.1
Grand Total	6,200,449	73.5	204,000	1.3	1,180,013	4.6	7,584,462	79.4

West Virginia Financial Chart (cont.)

Table 4.5.2: FY2015 Expenditures by Object (Excluding Revenue)



West Virginia Financial Chart (cont.)

Table 4.5.3: FY2016 by Fund Source

Work Breakdown Structure	CSA-1 NRAO Ops		Internal Common Costs		Grand Total	
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟1000 Telescope Operations						
⊟1100 Maintenance						
⊟1110 Corrective						
1112 Scheduled	61,741	0.6			61,741	0.6
⊟1120 Preventive						
1121 Scheduled	255,355	3.2			255,355	3.2
1122 Painting	204,171	3.0			204,171	3.0
1123 Inspections	175,000	0.0			175,000	0.0
1125 Telescope Structure	63,968	0.8			63,968	0.8
⊟1200 Operations						
⊟1210 Scheduling						
1211 Telescope Status & Scheduling	39,195	0.3			39,195	0.3
⊟1220 Operating						
1221 Observing	347,064	5.7			347,064	5.7
⊟1230 Support & Testing						
1231 Calibration	134,171	1.4			134,171	1.4
1235 Systems Hardware Support	1,948,343	19.4			1,948,343	19.4
1236 Scientific Support	157,391	2.5			157,391	2.5
⊞1240 M&C Software	30,683	0.2			30,683	0.2
⊟1400 Infrastructure Mods & Upgrades						
⊟1420 Modifications						
1421 Projects	448,875	3.1			448,875	3.1
⊟1500 Management						
⊞1510 Telescope operations Mgmt	251,541	2.0			251,541	2.0
⊞1520 Science Support Mgmt	189,812	1.0			189,812	1.0
⊞1530 Mechanical Engineering Mgmt	86,732	0.5			86,732	0.5
⊞1540 Electronics Mgmt	256,417	2.0			256,417	2.0
1000 Telescope Operations Total	4,650,460	45.6			4,650,460	45.6
⊟3000 Science Operations						
⊟3400 Scientific Staff						
⊟3410 Staff Research						
3413 NRAO Postdocs	20,000	0.0			20,000	0.0
⊟3600 Scientific User Services						
⊟3610 Community Support						
3613 Workshops & Conferences	10,000	0.0			10,000	0.0
3000 Science Operations Total	30,000	0.0			30,000	0.0
⊟4000 Administrative Services						
⊟4100 Business Services						
⊟4110 Business Office						
4111 Business Office	180,200	2.1	306,745	3.0	486,945	5.0
4112 Visitor Support	10,500	0.0			10,500	0.0
⊟4200 Facilities						
⊞4210 Plant Maintenance	466,819	12.3	455,244	0.0	922,062	12.3
⊞4220 Communication	70,692	0.0			70,692	0.0
⊞4230 Utilities	253,318	0.0	176,031	0.0	429,349	0.0
⊞4260 Vehicles	30,466	0.4	29,681	0.6	60,147	1.0
⊞4270 Central Instrument Shop	351,503	3.9			351,503	3.9
⊟4300 Auxiliaries						
⊞4310 Visitor Centers	12,875	0.1			12,875	0.1
⊟4320 Housing						
4321 Dorms	(11,000)	0.0			(11,000)	0.0
4322 Residence Hall	(82,438)	0.5			(82,438)	0.5
4323 Houses	(79,256)	0.9			(79,256)	0.9
⊟4330 Food Handling						
4331 Cafeteria	95,101	4.6			95,101	4.6
4332 Cafe	61,239	2.6			61,239	2.6
⊞4350 Management	52,840	0.9			52,840	0.9
⊟4500 Management						
⊞4510 AD Mgmt	106,662	1.0	202,780	1.0	309,442	2.0
⊞4520 Community Relations	10,000	0.0			10,000	0.0
4000 Administrative Services Total	1,529,521	28.9	1,170,481	4.6	2,700,001	33.4
Grand Total	6,209,981	74.4	1,170,481	4.6	7,380,462	79.0

5 CENTRAL DEVELOPMENT LABORATORY

In FY2015 and FY2016 the CDL will continue to carry out its mission to support the evolution of NRAO's existing facilities and to develop the technology and expertise needed to build the next generation of radio astronomy instruments. The Observatory currently operates four of the world's most powerful premier facilities: ALMA, VLA, GBT and VLBA. Although the radio astronomy community has started thinking about the so-called "Next Big Thing" (NBT) for the next generation of radio telescopes, it seems clear that a large portion of the major discoveries and research breakthroughs in radio astronomy over the next 10 years or so are likely to stem from observations carried out using these four NRAO instruments. This is due in part to projected national budget constraints during the next decade, and to the fact that it will likely take several years for the astronomy community to identify and develop new instrumentation ideas, establish strong and sound scientific justifications for them, and obtain the support of the community to have them constructed. (It took ~ 30 years to build ALMA!) Therefore, improving the performance of NRAO's existing facilities until the NBT can be brought online becomes vital. Since significantly enhancing the performance of our existing antennas is impractical due to poor benefit/cost ratio, it is crucial for the CDL to continue its support for the development of new capabilities for these instruments to maintain their current status as cutting edge instruments. These major core support, production and development activities for FY2015 and FY2016 are described in Sections 5.1 and 5.2.

In FY2015 and FY2016, the CDL also intends to continue its support for two major long-term R&D programs that are currently underway. These development activities for the Phased Array Feed and Integrated Receiver programs are described in Section 5.3.

5.1 Repair, Maintenance, Production, Support

The CDL has a long heritage as a world leader in low-noise amplifiers, millimeter and sub-millimeter detectors, optics and other electromagnetic components, digital signal processing, and in developing new receiver architectures. The CDL maintains core expertise in each of these critical areas to: (1) support and continually develop critical capabilities that could be used for upgrading all of NRAO's current facilities; (2) lay the groundwork for building the next generation of radio astronomy instruments; where such activities do not interfere with its obligations to carry out the Program Plan, (3) to help the community realize mid- and small-scale projects such as those recommended by the NWNH decadal report; and (4) to support the astronomical community at large on a work for others basis. This section describes CDL's core production and support activity for FY2015 and FY2016. Note that North American ALMA Development, Maintenance, and Renewal activities, which are carried out at the CDL but supported by ALMA operations funds, are described elsewhere in Sections 2.3 and 2.4.

FY2015

Millimeter and Submillimeter Detectors: The current generation of mm/sub-mm SIS receivers, now in use on all of the higher frequency bands of ALMA, emerged as the result of a long period of development at the CDL carried out in collaboration with the University of Virginia Microfabrication Laboratory (UVML). Progress during this period was marked with the introduction of niobium-based superconducting circuits for radio astronomy, and the development of wideband SIS mixer Monolithic Millimeter-wave Integrated Circuit (MMICs), which enabled large number of receivers to be built repeatably and reliably. The configuration and use of sideband-separating SIS mixers was also pioneered at the CDL during this period.

design and OMT will be carried out if necessary. Support will be also provided for the ALMA Band 6 and Band10 second-generation receiver development projects.

FY2016

Millimeter and Submillimeter Detectors: In FY2016, the CDL will continue to support the offsite maintenance of the ALMA Band 6 receivers and ensuring a sufficient quantity of spare mixers and preamps. As resources permit, the CDL will also support community projects on a work for others basis.

Low Noise Amplifiers: In FY2016, the production run for a quantity of about 150 of the 35-52 GHz LNAs for the ALMA Band 1 receivers is expected to continue. Depending on the success of our MMIC wafer runs in FY2015 as well as other factors, the production of amplifiers for an ALMA Band 2 receiver build-out may be initiated. Continued support will be provided for all VLA, GBT and VLBA receivers (about 1000 amplifiers in the field). As CDL personnel resources permit, the LNA group will also continue to support the general radio astronomical community on a work for others basis.

Digital Signal Processing: In FY2016, the DSP group will continue to support the ALMA Baseline Correlator. We will be available to help fix correlator problems for which ALMA might need support and also expect to provide development support for the ALMA correlator group when new capabilities are brought on line. During FY2016, scientific commissioning and observations using the ALMA phasing system will take place; our role at that time will be to support those observations by rapidly responding to any failures, bugs or requests for enhancements.

Precision Array for Probing the Epoch of Reionization (PAPER): The PAPER project is scheduled to be completed by the end of FY2015 and new activities will be merged into HERA work. The level of funding for this work has not yet been fully determined.

5.2 Research and Development

The CDL's research and development efforts are aimed at achieving the following specific Observatory Strategic Goals:

- Developing technologies necessary for the long-range objectives of the Observatory.
- Advancing the state-of-the-art in mission-related technology.

The activities of CDL's R&D programs address these goals.

FY2015

Millimeter and Submillimeter Detectors: The CDL will continue its work with UVML to develop the next generation of SIS mixers, technology that will be critical for upgrading the current high frequency ALMA receivers. In FY2015, the CDL will continue its development of: (1) an improved ALMA Band 6 mixer in a balanced sideband-separating configuration with a wider 4-12 GHz IF, and (2) SIS mixers with NbTiN electrodes for lower noise above the superconducting band gap of Nb (suitable for use above ~600 GHz).

The upgraded Band 6 mixers will utilize AlN tunnel barriers (resulting in an improved noise performance at the RF band edges), and will also have a wider 4-12 GHz IF band compared to the present Band 6 receiver design. The wider IF response will require the development of a 4-12 GHz balanced LNA with

The DSP group's expertise has already been brought to bear on the ALMA Phasing Project. The correlator hardware and firmware modifications required to phase the ALMA antennas have been under this group's purview during the past few years and are being commissioned for eventual use in the Event Horizon Telescope (EHT) project. During FY2015, equipment designed by the DSP group, along with that provided by other external groups, will undergo system tests at ALMA, and the CDL will support these commissioning efforts to the extent required. The DSP group will also continue its support of the PAPER project by helping with the testing of a data acquisition system (12 × 500 MHz analog input, 2 × 10 GbE time-tagged outputs) which it designed in FY2014. Finally, in FY2015, the DSP group will also assist in the digital and signal processing aspects of the NRAO Phased Array Feed Project.

Precision Array for Probing the Epoch of Reionization (PAPER): PAPER is an example of a road-map type investigation in radio astronomy. The project was conceived, developed, deployed, and operated with one scientific purpose in mind: to detect the signature of the Epoch of Reionization (EoR). PAPER is a team effort that was begun over six years ago by two researchers and a couple of graduate students, and has since expanded to include additional researchers, postdocs, students, engineers, and technicians, with each one applying his or her expertise where needed.

PAPER activities will continue in FY2015 and will gradually roll into HERA work. Spare components will be fabricated, evaluated, and delivered to the site in FY2015.

Integrated Receiver Development (IRD): The aim of the integrated receiver development project is to leverage modern advances in integrated electronics and digital signal processing to enable forefront instrumentation for future radio astronomy facilities. In FY2015, we will build upon the past success of this program to further optimize the performance and flexibility of the unformatted serial photonic link, to implement the established signal processing algorithms for precision sideband separation and for polarization synthesis in real-time, and to improve the scalability of IRD technologies for large-format focal plane arrays through focused miniaturization and deeper integration of critical components. Specific activities to be carried out in FY2015 are highlighted below:

- Implement a six-channel IRD Backend using a Kintex-7 FPGA processor.
- Demonstrate de-interleaving of multiple data sources on a shared fiber-optic link using a Complex Programmable Logic Device (CPLD) keyed to gain mismatch.
- Implement advanced topologies and miniaturized packaging of reflectionless filters.

HR Challenges: Many of the activities listed above have previously relied heavily on the skills of a single digital hardware and firmware design engineer, who is currently allocated to IRD for only 50% of his time. In FY2015, we are according high priority to hiring a second engineer with these skills to mitigate the risk of a single-point loss and to share the digital hardware design and firmware programming load across the CDL.

Risks Assumed Due to Budget Constraints: In order to make the best possible use of the limited personnel resources described above, we have elected to switch our backend developments over to a National Instruments platform, which is better supported than CASPER-based hardware; however, this comes at the cost of a less-advanced FPGA chip and therefore reduced computing capacity.

Phased Array Feeds (PAF): The aim of the PAF project is to develop new instrumentation, modeling capability, a real-time beamforming demonstration, and proof-of-concept scientific observations so that future NRAO radio astronomy receivers can be conceived that will employ the PAF-based approach for enhanced field-of-view and survey speed. There are several ongoing PAF projects in the international radio astronomy community, all of which utilize a common approach based on uncooled detectors and

5.4 Central Development Laboratory Financial Chart

Table 5.4.1: FY2015 by Fund Source

Work Breakdown Structure	CSA-1 NRAO Ops TOTAL	CSA-1 NRAO Ops FTE's	CSA-2 ALMA Ops TOTAL	CSA-2 ALMA Ops FTE's	Development TOTAL	Development FTE's	Internal Common Costs TOTAL	Internal Common Costs FTE's	Grand Total TOTAL	Grand Total FTE's
⊟1000 Telescope Operations										
⊟1100 Maintenance										
⊞1110 Corrective			1,545,493	8.9					1,545,493	8.9
1000 Telescope Operations Total			1,545,493	8.9					1,545,493	8.9
⊟2000 Development Programs										
⊟2200 Technology Development										
⊞2210 Enabling Technologies	768,660	7.1			2,364,000	3.8			3,132,659	10.9
⊞2220 Production	876,439	6.7			1,056,063				1,932,502	6.7
⊞2230 Next Generation Facilities	194,572	1.4							194,572	1.4
⊟2300 R&D Support										
⊞2310 Machining	314,175	3.7							314,175	3.7
⊞2320 Chemistry Lab	112,244	0.8							112,244	0.8
⊞2500 Management	187,800	-					230,369	1.0	418,169	1.0
2000 Development Programs Total	2,453,889	19.7			3,420,063	3.8	230,369	1.0	6,104,321	24.4
Grand Total	2,453,889	19.7	1,545,493	8.9	3,420,063	3.8	230,369	1.0	7,649,814	33.3

Table 5.4.2: FY2015 Expenditures by Object

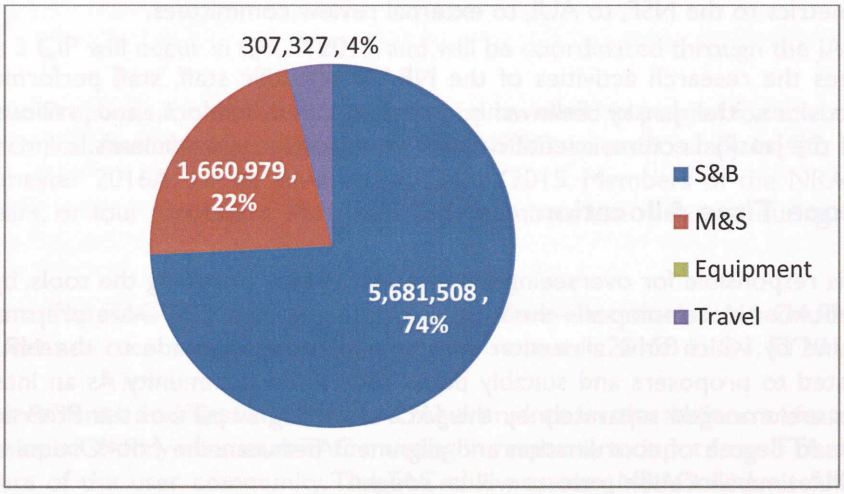


Table 5.4.3: FY2016 by Fund Source

Work Breakdown Structure	CSA-1 NRAO Ops TOTAL	CSA-1 NRAO Ops FTE's	CSA-2 ALMA Ops TOTAL	CSA-2 ALMA Ops FTE's	Development TOTAL	Development FTE's	Internal Common Costs TOTAL	Internal Common Costs FTE's	Grand Total TOTAL	Grand Total FTE's
⊟1000 Telescope Operations										
⊟1100 Maintenance										
⊟1110 Corrective			1,398,584	8.9					1,398,584	8.9
1113 Hardware (Config)			1,398,584	8.9					1,398,584	8.9
1000 Telescope Operations Total			1,398,584	8.9					1,398,584	8.9
⊟2000 Development Programs										
⊟2200 Technology Development										
⊞2210 Enabling Technologies	768,660	7.1			-				768,660	7.1
⊞2220 Production	876,439	6.7			2,891,207				3,767,646	6.7
⊞2230 Next Generation Facilities	194,572	1.4							194,572	1.4
⊟2300 R&D Support										
⊞2310 Machining	314,175	3.7							314,175	3.7
⊞2320 Chemistry Lab	112,244	0.8							112,244	0.8
⊟2500 Management										
⊞2510 R&D Management	187,800	0.0					230,369	1.0	418,169	1.0
2000 Development Programs Total	2,453,889	19.7			2,891,207		230,369	1.0	5,575,465	20.7
Grand Total	2,453,889	19.7	1,398,584	8.9	2,891,207		230,369	1.0	6,974,049	29.6

other tools: sensitivity calculators, the General Observing Setup Tool (GOST), and the Proposal Finder Tool (PFT). Finally, TTA is responsible for ensuring that the necessary documentation in support of all TTA activities and tools is available and up to date. Documentation supporting ALMA Calls for Proposals (CfPs) and is currently handled through Science User Support (see 6.2) in coordination with the NAASC.

Telescope Time Allocation Milestones by Year

FY2015

Calls for Proposals: The CfP for semester 2015A occurred in Q4 of FY2014. The proposal review and time allocation process will continue in Q1 of FY2015 with the TAC meeting and the Director's Review. It will conclude with the posting of the approved science program in Q1, FY2015.

The NRAO will issue the CfP for semester 2015B in early Q2, FY2015, with a proposal submission deadline of Feb 2. The CfP for semester 2016A will be early in Q4, FY2015, with a proposal submission deadline of Aug 3. Documentation will be updated to alert users to new observing modes supported by telescope operations, new PST features, and news regarding changes to policies or procedures.

The ALMA Cycle 3 CfP will occur in Q3, FY2015, and will be coordinated through the JAO and the ARCs.

Proposal Review: Proposals for semester 2015B will be reviewed in parallel for scientific merit (by the SRPs) and for technical feasibility (by members of the NRAO scientific staff) in Q2, FY2015. Similarly, proposals for semester 2016A will be reviewed in Q4, FY2015. Members of the NRAO SRPs typically serve for two years, or four semesters. Most new SRP members are recruited during Q1 of each fiscal year.

Time Allocation: The TAC will meet to recommend time allocations for semester 2015A in Q1, FY2015, and will meet to recommend time allocations for semester 2015B in Q3, FY2015.

Software Requirements and Testing: Software requirements for the addition of features to TTA tools are normally developed shortly after each TAC meeting in response to input from TTA staff, the SRPs, the TAC, and members of the user community. The TAC also provides NRAO with useful feedback on the PHT and the GBSE, used to support TAC function. Priority is given to the PST initially as it must be ready for use when the CfPs are made. Hence, the implementation and testing of PST features will occur in Q1 and Q3 of FY2015, whereas the implementation and testing of PHT/GBSE features will occur in Q2 and Q4 of FY2015.

TTA Tool Redesign: In parallel to the above routine development activities, the TTA tool suite will undergo a redesign in response to two factors: i) the need to improve the performance, robustness, ease of development, and maintainability of the PST; ii) the need to implement key recommendations made by an external review of the TTA in Q2, FY2014, intended to improve the community access and use of the PST for the preparation, submission, and review of proposals. The first phase of this development, a refactor of the PST, will be delivered at the end of Q2, FY2015. The detailed requirements for the second phase of this process will be developed in FY2015 and conveyed to DMS in Q2, FY2015.

FY2016

Calls for Proposals: The CfP for semester 2016A will occur in Q4, FY2015. The proposal review and time allocation process and will continue in Q1 of FY2016 with the TAC meeting and the Directors Review. It will conclude with the posting of the approved science program.

The NRAO will issue a CfP for semester 2016B in early Q2, FY2016, with a proposal submission deadline of Feb 1. The CfP for semester 2017A will be early in Q4, FY2016, with a proposal submission deadline of Aug 1. Documentation will be updated to alert users to new observing modes supported by telescope operations, new PST features, and news regarding changes to policies or procedures.

The ALMA Cycle 4 CfP will occur in Q2, FY2016, and will be coordinated through the JAO and the regional centers.

Proposal Review: Proposals for semester 2016B will be reviewed in parallel for scientific merit (by the SRPs) and for technical feasibility (by members of the NRAO scientific staff) in Q2 FY2016. Similarly, proposals for semester 2017A will be reviewed in Q4 FY2016. Members of the NRAO SRPs typically serve for two years, or four semesters. Most new SRP members are recruited during Q1 of each fiscal year.

Time Allocation: The TAC will meet to recommend time allocations for semester 2016A in Q1 FY2016 and will meet to recommend time allocations for semester 2016B in Q3 FY2016.

Software Requirements and Testing: Development of software requirements for TTA tools begins shortly after each TAC meeting. PST requirements are gathered from TTA staff with input from users, the SRPs, and the TAC. The TAC also provides NRAO with useful feedback on the PHT and the GBSE, used to support TAC function. Priority is given to the PST initially as it must be ready for use when the CfPs are made. Hence, the implementation and testing of PST features will occur in Q1 and Q3 of FY2016, whereas the implementation and testing of PHT/GBSE features will occur in Q2 and Q4 of FY2016.

TTA Tools Redesign: The requirements for the TTA tool suite based on community recommendations will be implemented beginning in Q3, FY2015; the first phase of the redesign will be completed by Q1, FY2016; i.e., in time for the semester 2016B CfP.

6.2 Science User Support

Science User Support (SUS) is responsible for providing the scientific community with the support necessary to execute successful scientific programs with NRAO facilities: the GBT, VLA, VLBA and ALMA. The mission of the SUS group is to increase the scientific user base of NRAO facilities beyond traditional radio astronomers and working with DMS, to provide the scientific support necessary for users to access, reduce, calibrate and analyze their data as well as to help the community generate new and innovative ideas for science by fostering cross-disciplinary and cross-field ideas and techniques.

To this end, the SUS group includes Community Education and Outreach services, which comprise face-to-face visitor support/data reduction visits, Helpdesk support, Knowledgebase articles, Science Forums, Astronomy Community Days; Science meetings and conferences, Science Web content and the NRAO user portal interface, User Documentation, Workshops and Tutorials, Online training and educational material. In addition, as part of its education services, SUS oversees the NRAO student programs,

including the REU and NRAO summer student programs, co-op students, undergraduate and graduate student interns, and Reber pre-doctoral fellows, and Student Observing Support.

SUS also supports certain user data and scientific software services, including assistance with manual data reduction, pipeline testing, and requirements definition for a number of projects, recently including the Archive Access Tool/ALMA Science Archive (AAT/ASA) user interface, the integrated science portal, and the integrated helpdesk. Other data services – notably, scheduling block validation, pipeline data processing, pipeline heuristics development, and the associated QA – are coordinated with the sites.

Science User Support Milestones by Year

FY2015

Community Education and Outreach Services

Helpdesk Services: In FY2014 preliminary requirements were developed for a fully integrated Helpdesk for NRAO users seeking support related to ALMA, VLA, GBT, and the VLBA. These requirements will be finalized in FY2015 Q1 and conveyed to DMS for implementation in Q2.

Community Days, Tutorials, Schools and Training Workshops: Community Day Events (CDEs) were originally developed by the NAASC in advance of the ALMA Cycle 0 CfP. Hosted by user institutions, these events introduce the astronomical community to ALMA's observing capabilities, to proposal and observing preparation tools, and to CASA. The CDEs were subsequently broadened to include the GBT, VLA, and VLBA. CDEs will be organized in Q2 in advance of the ALMA Cycle 3 CfP and proposal submission deadline, and the NRAO NA semester 2016A CfP and proposal submission deadline. The number of CDEs will be determined by demand, but is expected to be 3-6 annually.

In FY2015 Q1, the 4th VLA Data Reduction Workshop will be held in Socorro. SUS also plans to lead one or two data reduction workshops in Charlottesville, supported by NAASC staff, again depending on demand associated with Cycle 3.

Face-to-face Visitor Support, Contact Scientists, Data Delivery: The SUS will continue to provide expert, "hands on" support that has historically always been associated with NRAO face-to-face visits. Green Bank will continue to host single dish users for "on site" training on the GBT. Such training is a prerequisite for remote observing. In Socorro, staff continue to support users in need of data reduction assistance, especially with large datasets that need access to high performance computing capabilities. Finally, in Charlottesville, staff will assist visitors needing assistance with proposal preparation with the ALMA Observing Tool (OT) along with visitors throughout FY2015 who want assistance re-reducing/further reducing, and analyzing, their Cycle 1, Cycle 2, or archival data products. On the GBT and ALMA, each successful PI of an accepted project will be assigned a "contact scientist" or "project friend" that will work with the PI in reviewing the scheduling blocks and observing scripts for that project. For the VLA, PIs will continue to have all scheduling blocks reviewed by expert data analysts before being approved for observing.

User Documentation, Web Material, and Online Training Material: For ALMA, by international agreement, the end user documentation including the ALMA Proposers Guide and Technical Handbook are prepared by the JAO as stand-alone documents available off the ALMA Science Portal. Given the anticipated Cycle 3 CfP in March, a review and final edits of all user documentation will be completed before being deployed off the ALMA Science Portal in Q2. As with previous Cycles a User

Survey will occur in Q3 soon after the proposal deadline to assess the ease of use of the tools, the proposal preparation process, and interactions with ARC staff.

In anticipation of the next CASA releases in FY2015, all CASAGUIDES will be reviewed, edited and deployed after being fully tested on the new versions of CASA. The deployment of the new CASAGUIDES will take place in Q1 and Q3 FY2015.

Scientific workshops and conferences: In Q1, NRAO will host "Filamentary Structure in Molecular Clouds" in Charlottesville. The NAASC will be a co-sponsor of the "Revolution in Astronomy with ALMA – the Third Year", to be held in Tokyo, Japan. A splinter session on New Capabilities in Radio Astronomy will be organized at the AAS in Q2. A session on galaxy assembly at the AAAS will occur in Q2. The NRAO will also sponsor "SPF 1: Star and Planet Formation in the Southwest" meeting and a CDE in Q2 at the Biosphere 2 Center in Arizona. An ALMA science workshop is under consideration for Q4.

User Data and Scientific Software Services

ALMA Pipeline Support: SUS will support the ALMA pipeline-assisted data reduction effort, largely through its data analysts. In particular, they will continue to support the manual reduction of non-compliant Cycle 0, 1, and 2 as well as the manual imaging component of pipeline-processed data.

VLA Pipeline Processing: All observed VLA data are passed through a calibration pipeline based on the CASA data reduction package. It is currently optimized for the reduction of Stokes I continuum data. At the start of FY2015 the pipeline will continue to be based on python scripts that use CASA tools and tasks (the "scripted pipeline"). In parallel, the Stokes I continuum reduction heuristics have been implemented in CASA within a framework that also incorporates the ALMA pipeline (the "CASA pipeline"). In FY2015 Q1 the CASA pipeline will be validated against the scripted pipeline output. Any final modifications to the CASA pipeline will be incorporated and tested in Q2, with a goal of implementing the CASA pipeline as the production VLA calibration pipeline in Q3.

Pipeline Reprocessing Interface (RPI): The RPI is a web-based application that will allow our users to access the NRAO computing clusters in Charlottesville and Socorro to re-run pipeline reductions on their data. SUS coordinated a RPI Working Group to developed science requirements for the RPI, now being developed by DMS. A working prototype of the RPI will be delivered by DMS in FY2015 Q2. SUS will coordinate user testing and feedback.

New NRAO Archive: A large part of the RPI is user access to all data products held either in the ALMA Science Archive or the NRAO Data Archive. The initial science requirements were developed in FY2014 and conveyed to DMS. The new NRAO archive will be operationalized in Q2 FY2015 and SUS will coordinate user testing and feedback.

Integrated NRAO/ALMA Science Portal: The NRAO User Portal and ALMA Science Portal are currently built and deployed on very different platforms. In FY2014, SUS considered the feasibility of refactoring the NRAO User Portal and drafted preliminary science requirements for a redesign of the portal. These will be finalized by Q3 FY2015 and conveyed to DMS for prioritization.

NRAO Student Programs

Undergraduate Programs: The long-running (since 1959) NRAO summer student program continues to be very successful. This 10–12 week program allows approximately 25 students to work

under the supervision of NRAO staff members at sites in New Mexico, West Virginia, and Virginia, to carry out original research in astronomy, computing, and engineering. Most of these students are funded through the NSF REU program. Outstanding students that are otherwise ineligible for support by the REU program (graduating seniors, foreign students, and early-career graduate students) are supported by NRAO operating funds or by external grants to NRAO staff members. In addition, as a means of diversity outreach, we have significantly increased recruiting from under-represented demographics (HBCUs, HSIs, Community Colleges, etc) to provide research experience to students who might otherwise have no such opportunities.

The REU and summer student programs are competed programs with an application deadline on Feb 1 (Q2). Offers are made on Mar 1 and students typically arrive at each site in May (Q3) and depart in August (Q4).

The NRAO supports a co-op program that enables undergraduate engineering students to gain practical, career-based experience as part of their formal academic education. Students from participating institutions work at NRAO sites for two semesters. Under the supervision of NRAO technical staff, co-op students are engaged in R&D on the technological frontier.

A modest amount of funds are available for undergraduate internships, where promising undergraduate students participated in scientific or engineering activities, supervised by NRAO staff, over a period of weeks to a semester.

Graduate Programs: The NRAO is committed to training the next generation of scientists in radio astronomical science, techniques, and technology. Several NRAO programs exist for this purpose. Graduating seniors and first- and second-year graduate students are able to participate in the NRAO summer student program described above. This gives students experience in radio astronomy research early in their graduate careers, allowing them to incorporate these skills into their thesis research. The NRAO also awards Reber Pre-Doctoral Fellowships to students who have completed institutional requirements for doctoral candidacy so that only their thesis research remains for them to complete their PhDs. Such fellows take up residence at one of the NRAO sites, typically for two years, while they complete their research and thesis under the supervision of an NRAO staff member. The NRAO currently supports 6 Reber Pre-doctoral Fellows, a level of support that will continue through FY2015.

The NRAO also supports many of the 100+ PhD students making use of NRAO telescopes each year. Travel reimbursement, low-cost accommodations, and computing facilities are provided on-site to assist these students. The Observatory also supports stays lasting several weeks to several months by students who wish to collaborate with NRAO staff scientists as part of their PhD research. These student internships help forge valuable long-term links between the NRAO and the university community.

Student Observing Support (SOS): Financial support will be available on a competitive basis for students performing observations with ALMA in FY2015 and FY2016. Students at U.S. universities are eligible for the SOS program, which is designed to cover stipend and miscellaneous expenses such as computers and travel to conferences to a maximum of $35,000. Unfortunately, due to the extreme budget pressure, the SOS program associated with the GBT, VLA, and VLBA was suspended in FY2014. Funds are not available to resume this component of the SOS program.

The ALMA Cycle 3 SOS selections will not be made until completion of the Cycle 3 proposal evaluation and time allocation process in Q4. Hence, the selection process will be initiated in Q4 but will not be completed until Q1 of the FY2016.

NRAO Student Programs

Undergraduate Programs: The REU and summer student programs are competed programs with an application deadline on Feb 1 (Q2). Offers are made on Mar 1 at the beginning of Q3; students typically arrive at each site in May (Q3) and depart in August (Q4).

NRAO co-op students will continue as funds allow. A modest amount of funds are available for undergraduate internships, where promising undergraduate students participated in scientific or engineering activities, supervised by NRAO staff, over a period of weeks to a semester.

Graduate Programs: We will strive to continue support of Reber Predoc Fellows at FY2015 levels. Similarly, we will strive to continue support of PhD students using NRAO facilities as described previously.

Student Observing Support: As part of the FY2016 budget development process, the question of whether or not the SOS program can be partially or fully restored for one of more of the VLA, GBT, and the VLBA will be considered. If funding is restored, SOS selections will be made for semester 2016A in Q1, FY16, and selections for semester 2016B will be made in Q3, FY2016.

The ALMA Cycle 3 SOS selections will not be made until completion of the Cycle 3 proposal evaluation and time allocation process in Q4. Hence, the selection process will be initiated in Q4 but will not be completed until Q1 of the FY2016.

The ALMA Cycle 4 SOS selections will be made at the completion of the Cycle 4 proposal evaluation and time allocation process in Q4 of FY2016 but not completed until Q1 FY2017.

6.3 Science Support and Research Services

The NRAO Library and Historical Archives

The NRAO Library has been proactive in migrating to online, distributed access to research and reference materials for NRAO staff and the wider community. This has resulted in an increase in usage coincident with increased efficiency of internal staff operations. To ensure continuing and expanding access for users of Library resources it is important that the NRAO Library continue print-to-electronic conversions without violating copyright while expanding coverage and use. In the coming years the NRAO Library will also continue to expand eBook titles.

The Library staff also continues to support NRAO internal and external reporting functions by collecting a variety of data and metrics in coordination with Statistics and Metrics services (see below). This effort now includes ongoing development of ALMA user and publications metrics. These efforts will be supplemented by populating NRAOPapers (the NRAO publications bibliography) with the associated metadata to enable the publication to be linked to the archival data. This requires updating legacy proposal identification codes to ensure they map appropriately to modern proposal IDs. This process will occur on a quarterly basis.

Finally, the Library will continue to assist the Technology Transfer Office with searches for patent disclosure applications and provide information and suggestions concerning patents for those submitting such disclosure applications.

a required element in the full realization of the scientific potential of the NRAO facilities by the astronomical community.

SSR has primary responsibility for oversight of the scientific productivity and research environment at the NRAO, overseeing the research aspects of all astronomers, computer scientists, and research engineers at all sites. Specifically, SSR responsibilities include: oversight of scientific staff research travel budget, annual scientific performance appraisals, scientific staff hiring and academic promotions. SSR supports selected scientific meetings, the colloquium series at each site, the Jansky Fellowship program, and the Jansky Lecture. Unfortunately, several of the activities critical to the scientific environment at the observatory have been adversely affected by budget pressures, and have been curtailed, suspended, or eliminated. In addition to successive rounds of cuts to the student programs – most recently the suspension of key elements of Student Observing Support (section 6.2) – we have suspended support for visiting scientists and have curtailed support for our flagship Jansky Fellowship program.

The Jansky Fellowship program is NRAO's long-standing prize research fellowship program. It is a highly competitive program that attracts some of the best young scientists in the field. Jansky Fellows can be in residence at an NRAO site, or be located at external institutions in the U.S. (non-resident Fellow). The program currently assigns no formal functional responsibilities, although Janskys are highly encouraged to participate in activities at the sites, including telescope commissioning and technology development. The Jansky selection process occurs in Q1 of each fiscal year. NRAO also hosts postdoctoral fellows funded by other institutions, such as Hubble, Einstein, and NSF fellows. For FY2015, we have cut back the Jansky Fellowship program by two positions as a means of addressing budget shortfalls.

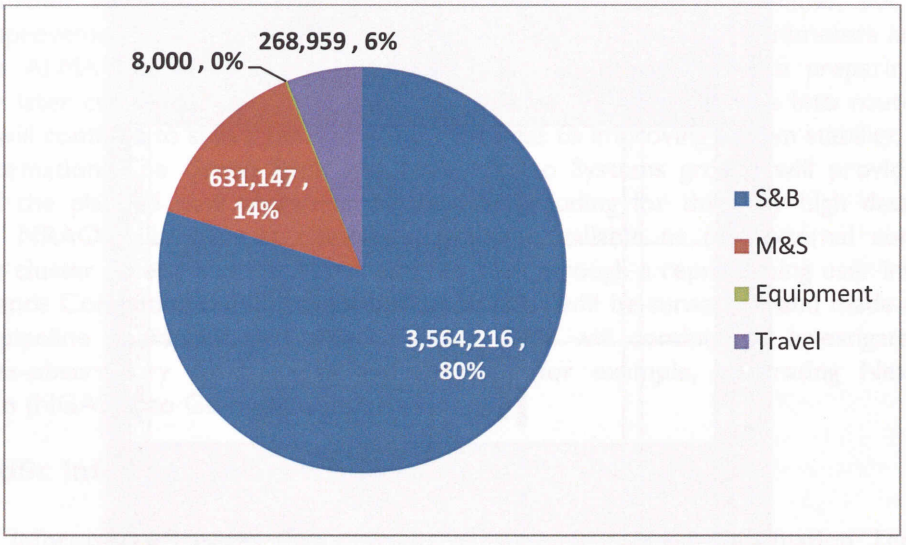
The NRAO strives to foster the professional development of postdocs at the observatory, highlighted by the annual NRAO Postdoc Symposium: an excellent forum for all postdocs at NRAO (including non-resident Jansky fellows) to present their latest work, and to establish collaborations with their colleagues. The symposium rotates between NRAO sites and takes place in Q3, annually. Each site has an informal postdoc lunch once per week. Lectures have been presented on career development, and professional development is a key aspect of the mentoring duties of the NRAO staff primarily responsible for the postdoc programs. Each site has various lectures and formal instruction on key skill areas, such as python programming or training in the use of astronomical tools. NRAO provides substantial research support, including travel, page charge support, and computing resources.

Some of the mechanisms that are being implemented for postdoc monitoring include the biannual submittal of progress reports and annual interviews for Jansky Fellows. For non-resident Fellows, NRAO requires an annual progress report from the host institution. Project postdocs are required to participate in the annual NRAO Performance Evaluation Process as per standard scientific staff policy. This includes a functional review by the immediate supervisor, and a scientific review by SSR.

In addition to its commitment to educating and training future generations of undergraduate, graduate, and post-graduate students, the NRAO is working to assist and support an active U.S. radio astronomy community. This is accomplished in a variety of ways including staff community service, a visitor program, organizing and hosting scientific meetings, and providing funding assistance to university-led hardware and software projects. These interactions enable NRAO scientists and engineers to engage with the wider astronomical community, and they serve as important links through which the community can maintain a fruitful relationship with the Observatory. A key benefit of these programs is that they allow for community-wide input into Observatory priorities for science, instrumentation, and software development.

Scientific Support and Research Financial Chart (cont.)

Table 6.6.2: FY2015 Expenditures by Object



Scientific Support and Research Financial Chart (cont.)

Table 6.6.3: FY2016 by Fund Source and Location

	CSA-1 NRAO Ops										CSA-2 ALMA Ops		Internal Common Costs							
	Charlottesville		Green Bank		Socorro		Observatory Wide		TOTAL, CSA-1		Charlottesville		Charlottesville		Socorro		TOTAL, ICC		GRAND TOTAL	
Work Breakdown Structure	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
2000 Development Programs																				
2400 Software Development																				
2410 Software Development																				
2412 Pipeline Processing	163,683	1.1			136,100	1.2			299,784	2.3									299,784	2.3
2000 Development Programs Total	163,683	1.1			136,100	1.2			299,784	2.3									299,784	2.3
3000 Science Operations																				
3100 Observatory Time Allocation																				
3110 Tools & Documentation	65,052	0.5							65,052	0.5									65,052	0.5
3120 Proposal Review & Time Allocat			51,386	0.4	39,636	0.3			91,022	0.7									91,022	0.7
3200 Reference																				
3210 Library	65,000	0.0							65,000	0.0	63,000	0.0	370,668	2.0			370,668	2.0	498,668	2.0
3220 Historical Archives													38,560	0.3			38,560	0.3	38,560	0.3
3230 Metrics / Statistics													86,923	0.5			86,923	0.5	86,923	0.5
3300 Broader Impacts																				
3310 Student Programs																				
3311 Undergraduate					95,714	1.0			95,714	1.0									95,714	1.0
3312 Graduate	100,088	1.0	28,642	0.0	57,051	0.0			185,781	1.0									185,781	1.0
3320 Visitor Support	278,549	2.6	8,526	0.0	25,849	0.0			312,924	2.6									312,924	2.6
3400 Scientific Staff																				
3410 Staff Research																				
3411 NRAO Staff	59,205	0.0	31,505	0.0	117,225	0.0			207,935	0.0									207,935	0.0
3412 Jansky Fellows	98,751	1.0			226,445	3.2			325,196	4.2									325,196	4.2
3413 NRAO Postdocs					145,962	2.0			145,962	2.0									145,962	2.0
3500 Management	55,666	1.0			83,969	0.6			139,635	1.6			296,833	1.7	216,878	1.0	513,710	2.7	653,346	4.3
3600 Scientific User Services																				
3610 Community Support																				
3611 User Assistance	660,309	3.4	87,936	0.7	258,418	1.9			1,006,662	5.9									1,006,662	5.9
3613 Workshops & Conferences	15,000	0.0			16,500	0.0	20,000	0.0	51,500	0.0									51,500	0.0
3620 Science Data Processing	7,000	0.0	17,763	0.2	28,229	0.5			52,992	0.7									52,992	0.7
3630 Science Software																				
3631 Post-Processing Software	128,054	1.3	35,527	0.3	156,219	1.2			319,800	2.8									319,800	2.8
3000 Science Operations Total	1,532,674	10.7	261,285	1.5	1,251,217	10.7	20,000	0.0	3,065,176	22.9	63,000	0.0	792,984	4.5	216,878	1.0	1,009,861	5.5	4,138,038	28.4
Grand Total	1,696,357	11.8	261,285	1.5	1,387,317	11.9	20,000	0.0	3,364,960	25.1	63,000	0.0	792,984	4.5	216,878	1.0	1,009,861	5.5	4,437,821	30.6

***Science Portal Service*:** Responsible for the installation and management of the Observer facing services obtained from external entities (e.g. Kayako Helpdesk, ALMA Science Portal, NRAO User Forum). It is also responsible for the Observer identity/permission Database and the close integration of the service access they enable.

***Wide-Area Networking*:** Science data capacity driven group responsible for provisioning the long-haul, high bandwidth, connectivity to deliver reliable throughput in support of observation data delivery. Operational support for commodity circuits will be handed off to Communication Services (CIS) once a network service has been accepted into production.

The following sections outline the activities and milestones coordinated by SIS, to ensure an optimum computing, storage, and communications environment for staff and users of NRAO telescopes as well as providing agile service support for an active research and development program.

FY2015

Helpdesk Integration: For expedience during the go-live for the VLA and the multi-ARC implementation of ALMA Observer support, two separate instances of the same Kayako commercial helpdesk software were delivered. During FY2014, the key components for Observer account association and Single Sign-On (SSO) were delivered in ALMA, with support ESO. In FY2015 the implementation of an integrated observer helpdesk supporting all NRAO instruments and the three regions of ALMA (North American, East Asia, and Europe) will be implemented, ensuring appropriate Knowledgebase (KB) views, depending on observer affiliation.

NAASC Observer post-processing access: Following the success of the VLA cluster access initiative in FY2014, the NAASC cluster will be expanded (from 40 to 64 nodes) in order to support PI data reduction workload for both interactive and pipeline tasks.

Network enhancement: In FY2015 a campaign of bandwidth enhancement will be undertaken with two objectives: to increase the major site bandwidth (Charlottesville (CV), New Mexico (NM)) to 10 Gb/s to align with Green Bank, and to provision fiber access to at least three additional VLBA sites, to >200Mbps; conditional on external funding for near real-time VLBI.

Externally hosted resource access evaluation: Due to the projected rise in demand for PI data processing resources, NRAO will evaluate options to mitigate contention for internal computational resources: e.g. XSEDE, Pittsburgh Supercomputing Center Blacklight/Storage SuperCell, and Amazon Elastic Compute Cloud for CASA. A key component of this work will be the evaluation of federated identity solutions to allow for transparent access between Service Providers e.g. XSEDE/Globus.

Multi-core evaluation: In support of parallel algorithmic development, SIS purchased a multi-core evaluation system hosting both an Nvidia GPU and Intel microwave integrated circuit (MIC) co-processor architectures. These will be delivered in early FY2015 to inform future strategic shift to support this processor rich environment, in an input/output intensive regime that typifies observational radio astronomy data analysis.

Disaster Recovery measures for Lustre: As the reliance of NRAO on massive storage arrays increases, the potential for catastrophic data loss must me managed. In Q3 FY2015, SIS will evaluate options for low cost backup solutions.

FY2016

External Cyber resource utilization: Science Computing Infrastructure will initiate a pilot program for automated processing on XSEDE, or other external resources, in preparation for normal pipeline reprocessing operations (e.g. Fast Radio Burst [FRB] detection, CHILES). Also investigated will be the feasibility of a Radio Astronomy centric XSEDE Science Gateway to facilitate data processing access, without the overhead to the Observer of XSEDE resource allocation requests. Finally, the Science Computing Infrastructure group will investigate secondary cloud Virtual Machines to allow for rapid provisioning of computational capacity on demand.

NGAS and Green Bank Archive integration: Due to the nature of the Green Bank telescope, and the legacy of historical observation from the other instruments at the site, the Green Bank archive has been file system based. DMS expects to upgrade the version of NGAS in FY2016 and then transitioning the Green Bank archive data into the NGAS architecture already leveraged for the other NRAO instruments, including ALMA.

Multi-core Co-processor implementation: It is clear that the gradual expansion of SMP/multi-core is now complemented by co-processor technology (both Nvidia GPU and Intel MIC). Informed by the evaluation of these architectures for data processing algorithms in FY2015, it is expected that targeted adoption strategy will be formulated in FY2016.

Redesigned NRAO User Portal: Based on the finalized requirements from SUS in FY2015, the NRAO User Portal will be redesigned to reflect a more cohesive approach both with ALMA and across the NRAO toolset. The first version of this portal (V1) will be delivered in Q3.

7.2 System Software

FY2015

ALMA System Software

NRAO is responsible for delivering software to the JAO as part of the ICT. The ICT is staffed by personnel in all three ALMA Executives and the JAO. In North America, some work is provided by the National Research Council of Canada for the ALMA Archive Subsystem. This contribution is technically managed by ESO and is not described here.

The bulk of the work done at NRAO by the ALMA System Software group consists of Offsite Maintenance and Repair, which in the ALMA Operations Plan version D is described by the OFF-004 budget line. In addition, the ALMA System Software group is responsible for the NRAO software (not firmware) contribution to the ALMA Phasing Project.

The NRAO ALMA System Software group contributes to the following ALMA ICT work areas:

- Control/Correlator Software. This is the software that controls and monitors all the ALMA equipment excluding the ALMA Atacama Compact Array correlator, interprets the scheduling blocks, and forms the bulk data and auxiliary data for the post-observing and Archive systems. It includes many online GUIs, including the quick-look display screens. It also includes the NRAO contributions to the ALMA Phasing Project. This software is almost entirely the responsibility of the NRAO (< 0.5 FTE at ESO).

- Scheduling. The NRAO is responsible for the dynamic scheduling ranking software (the dynamic scheduling parameters and weights are the responsibility of Division of Science Operations (DSO)), manual and queued observing modes, scheduling GUIs, and an offline planning mode. This functionality is entirely the responsibility of the NRAO.
- Other. NRAO makes other software contributions to the JAO, including a contribution to overall ICT management, software testing, and modest (0.5 FTE) contributions to various operations GUIs (primary responsibility ESO).

It should be understood that the planning priorities for this group are the responsibility of the JAO; in particular the Science Operations IPT, led by the DSO, defines the priorities. The below items represent only the highest priority items or summarize items which in details are split into several sub-items.

Because ALMA is moving into full science operations, the focus during this planning cycle will be on improving operational stability. The FY2015 planning items for the ALMA System group are as follows:

Fall 2014 Release: Improve Operations support, fast scanning, implement focus Z axis correction use temperatures from antenna metrology sensors, add sequencing to the total power processor, and a new QuickLook graphical user interface.

Spring 2015 Release: Improve Operations support, add baseline correlator sub-array capability, 90-degrees Walsh functions sideband separation, add flags into the ALMA Science Data Model (ASDM) Flag table in QuickLook, improve control error handling and reporting, flag by antenna shadowing, add WVR parameters and SchedBlock into the ASDM, and complete the ALMA Phasing Project.

VLA/VLBA System Software

VLA/VLBA system software functional priorities are defined by New Mexico Operations within resource limits provided by DMS. DMS is responsible for non-functional prioritization, e.g. software maintenance items, technology choices, and similar.

VLA/VLBA Support for Commissioning and Observing in semesters 2014B, 2015A, and 2015B: The new capabilities described in sections 3.1.2 and 3.2.2 above will be supported in the system software for the two telescopes. This includes completing the VLA Atmospheric Phase Interferometer and weather station operators' screens, implementing VLA frequency averaging in the correlator back-end, and software support for new VLA HSA observing modes as required.

VLA: Integrate VLITE into Operations: Software development and maintenance support will be provided for the integration of VLITE operation into normal VLA operations. Much or most of the software required will already be in place by the end of the VLITE construction project; however, integration into VLA operations might require some software modifications or changes to databases used in VLA operations. NRAO has no commitment to store VLITE data. At present we are storing the primary VLITE data on NRAO storage systems (40 TB/year) to enable independent science verification of any important science results. As there is no continuing commitment, we will recycle it for normal use if/when we can no longer prudently maintain it.

VLA: Make frequency averaging operational: Frequency averaging in the VLA correlator will become an operational capability. This capability will enable the reduction in visibility data rates from the correlator for continuum observing.

VLA: Write pointing table: The Science Data Model pointing table will be written by the VLA MCAF sub-system when required. The pointing table will be needed in support of the VLASS program, during solar and planetary observing, and for the implementation of more capable tipping scans.

VLBA: Deploy new operator Graphical User Interface (GUI): A new operator GUI for the VLBA will be completed and deployed. The new GUI will be based on updated Java technology, and will incorporate improved operator access to site data at each VLBA station, and improved browsing and graphing of real-time monitor data.

VLBA: VME Replacement: As part of the effort to replace the VME control computer functionality, software support for on-site testing of VLBA M450 interface box will be provided. In addition we will complete the initial design and development of the VME monitor data stream replication software through control computer to VLBA monitor data archive.

GBT System Software

GBT system software functional priorities are defined by West Virginia Operations within resource limits provided by DMS. DMS is responsible for non-functional prioritization, e.g. software maintenance items, technology choices, and similar.

Modify Astrid To Use Streaming: The Astronomer's Integrated Desktop (Astrid) is a single, unified workspace that incorporates the suite of applications that can be used with the GBT and is the primary observer's interface. As a continuation of the streaming work to support VEGAS from FY2014, Astrid will be modified to use streaming.

Operations Software: The Green Bank Operations Division uses a web application to log and report on detailed GBT usage. The application uses obsolete technology, is undocumented and is currently unsupported by any GBT employee. In FY2014 Q3 we assigned a resource to begin gathering requirements in preparation for re-writing the application. The new system will utilize the same technology used by all GB web applications as well as provide the same features and appearance. Due to limited resources, this effort will continue through FY2015 with final delivery in FY2016.

VEGAS Pulsar Modes: The project will implement pulsar modes in the VEGAS spectrometer. Due to resource limitations, we expect this effort to begin in FY2015 and end in early FY2016. Note that as GUPPI is still available for pulsar observations but with fewer capabilities than will come with VEGAS, we consider this item to have high ultimate science priority, but is not currently urgent.

National Radio Quiet Zone Software: This projected 1.5 year project will replace and optimize the existing system used for propagation path analysis within the National Radio Quiet Zone and West Virginia Radio Astronomy Zone (WVRAZ), allowing for more accurate and rapid response to all NRQZ applicants. The project will begin in FY2015. Green Bank personnel will pursue this work following the priorities that come from operations.

Monitor and Control System Release: The annual GBT monitor and control system software release will occur in FY2015 Q4. This release consolidates "patches" made to the system throughout the course of the year, validates our revision control system, and provides an opportunity to prune obsolete subsystems.

CLEO Port: To exploit the full powers of the GBT system, observers and staff members require intuitive user interfaces. CLEO, a set of applications providing one of the two main graphical user interfaces that have been built for the telescope, is designed for very detailed monitoring and debugging of telescope components. CLEO is implemented in Tcl/Tk, and is now approximately 20 years old. This effort will port CLEO to C++/Python, languages used by all current GBT monitor and control system software, using Qt as the widget toolkit. A project proposal for this work was been submitted to the WVU Engineering division for consideration as a Senior Capstone project. If selected, WVU students under the guidance of GBT Software Development group will implement the project. The goal for FY2015 is to update the system design and implement a replacement for one CLEO application (Device Manager).

GBT Pipeline: In FY2015, DMS will complete the pipeline work to support the highest non-pulsar VEGAS data rates necessary for mapping. This will use of the GBT streaming infrastructure and is expected to involve parallelization of the data stream.

The capabilities and use-cases of the GBT Pipeline will be improved in FY2015. Working with the GBT Scientific Staff, we will develop a prioritized list of improvements needed for expanding the role of the GBT Pipeline. These improvements are likely to include calibration of high-frequency data, software Doppler tracking, data-flagging and additional mapping use cases.

We will also evaluate the environment and resources available at the Pittsburgh Supercomputing Center (PSC) for potential use by the GBT Pipeline. GBT projects that would be most likely to benefit from such an HPC environment will be identified and tests will be conducted to determine whether additional software development of the GBT Pipeline at the PSC would be useful for GBT observers.

FY2016

ALMA System Software

In this planning cycle the focus is likely to continue to be on operational stability. The planning items for the ALMA System group are as follows:

Fall 2015 Release: Improve Operations support, provide control enhancements, including improvements to monitoring and alarms, and additional hardware tests during control startup; provide correlator enhancements, including 3-bit quantization correction and flagging high edge channels; enhance scheduling.

Spring 2016 Release: Improve Operations support, port to 64 bits, additional control and correlator enhancements to be determined by the JAO.

VLA/VLBA System Software

VLA/VLBA Support for Commissioning and Observing in semesters 2015B, 2016A, and 2016B: The new capabilities described in sections 3.1.2 and 3.2.2 above will be supported in the system software for the two telescopes. This includes support for VLA pulsar observing commissioning, VLA fast data dumps, VLA triggered observations, the VLBA Ka-Band receiver, and the VLBA Ka/X dichroic.

VLBA: VME Replacement: In FY2016 we will complete the development and deployment of the VLBA monitor data stream replication software.

GBT System Software

Operations Software: This will be the continuation and final deployment of the development effort started in FY2015.

VEGAS Pulsar Modes: The project will implement pulsar modes in the VEGAS spectrometer. Due to resource limitations, we expect this effort to begin in FY2015 and end in early FY2016.

NRQZ Software: This projected 1.5 year project will replace and optimize the existing system used for propagation path analysis within the NRQZ and WVRAZ, allowing for more accurate and rapid response to all RQZ applicants. The project will begin in FY2015.

Monitor and Control System Release: The annual GBT monitor and control system software release will occur in FY2016 Q4. This release consolidates "patches" made to the system throughout the course of the year, validates our revision control system, and provides an opportunity to prune obsolete subsystems.

CLEO Port: Additional CLEO applications will be ported to C++/Python throughout FY2016.

Astrid Refactor: The Astronomer's Integrated Desktop (Astrid) is a single, unified workspace that incorporates the suite of applications that can be used with the GBT and is the primary observer's interface. The applications need to be re-factored to accommodate other recent changes to the system (viz., data streaming), provide a real-time interface for the VEGAS back end and resolve on-going operational issues. Due to limited resources, the project probably won't begin until FY2016.

GBT Pipeline: The capabilities and use-cases of the GBT Pipeline will be improved in FY2016. Working with the GBT Scientific Staff, we will develop a prioritized list of improvements needed for expand the role of the GBT Pipeline.

In FY2016, testing with PSC will continue with one or more suitable pipeline projects. A summary of test results and lessons learned will be produced in Q3.

7.3 Software Development

This section contains user-facing software developed at the NRAO, with the exception of GBT post-processing software which is described in GB System, above.

FY2015

New NRAO Archive: The prototype software for the new NRAO archive will be migrated into production, replacing the current archive. Development activities are anticipated to make it operational and to improve its long-term supportability. In addition, work to improve capability will be in progress during FY2015 and delivered in FY2016. Examples of these include image data retrieval and overall integration between NRAO and ALMA data.

CASA: Development of CASA, the NRAO post-processing software, continues to emphasize support for the VLA and ALMA, unlocking the scientific potential of these world-leading telescopes. During FY2015, NRAO will continue to add capabilities and support our evolving understanding of the requirements of these forefront telescopes.

CASA version 4.3 will be released to the public in Q1 FY2015. This release will expand the capabilities of the CASA-based pipeline, deploy a refactored imaging suite, and improve the handling of weights throughout the package. CASA 4.4 will introduce the Calibration Library, cutting disk space requirements by approximately one third, and will support data reduction and the pipeline for the VLA 2015B semester.

We anticipate input from the newly-formed external CASA Users Committee to help guide further CASA development choices. The internal CASA Science Steering Committee (CSSC) will continue to provide feedback on primary requirements from NRAO telescopes. This feedback will be incorporated in our development plans as time and resources allow.

The international CASA development team, led by NRAO, continues to increase support for single dish data reduction and high performance computing capabilities working on the integration of HPC capabilities with the standard reduction pipelines. The team will continue to support and develop new imaging and calibration algorithms through a close connection to the NRAO algorithm research and development group (ARDG). CASA's connection to the wider radio community continues to grow with collaborations such as the CARTA and ADMIT teams.

CASA Pipeline: The CASA pipeline will be used throughout ALMA Cycle 2 data reduction for calibration of standard modes of observing, while undergoing continued development and commissioning. Pipeline reduction will be primarily executed at the JAO although all three regional science centers have parallel capabilities and are expected to use the pipeline for reprocessing and commissioning. Both interferometric and single dish observations are currently supported by the ALMA pipeline, although only the interferometric calibrations have been accepted by the ALMA project. Single dish capabilities, primarily the responsibility of our National Astronomical Observatory of Japan (NAOJ) partners, are expected to undergo acceptance testing in Q2 FY2015.

The VLA continuum Stokes I calibration heuristics in the CASA pipeline will undergo validation during the first half of FY2015, with the goal of implementing the CASA pipeline as the production VLA calibration pipeline in Q3 to replace the current scripted pipeline. This will result in both ALMA and the VLA using the CASA pipeline for calibration in production.

The pipeline will continue to evolve throughout the FY2015 time period as more observing modes are commissioned and additional experience is gained by the community in using ALMA and the VLA. Most importantly, the focus will switch from calibration and flagging to evaluating and improving the pipeline imaging stages. Additionally, ALMA Cycle 2 experience in Single Dish and ALMA Compact Array observations are expected to drive additional heuristic development in preparation for ALMA Cycles 3 and 4.

Proposal Submission Tool: The PST will be updated to support required functionality for the 2015B and 2016A calls for proposals. New functionality that is needed for those calls is described in sections 3.1.2 and 3.2.2.

Proposal Handling Tool: The PHT will be updated to support required functionality for the TAC meetings for the 2015B and 2016A observing semesters.

Observation Preparation Tool: The OPT for the VLA will be updated to support new instrumental capabilities during each observing semester. This includes support for commissioning (including RSRO) observations, and once commissioned for general observing. Updates for commissioning occur in the semester prior to when they are needed for general observing. New capabilities for the VLA, along with their status for the 2014B, 2015A, and 2015B observing semesters are listed in section 3.1.2.

Reprocessing: Along with the New NRAO Archive, the RPI will be migrated into production. This initial delivery of reprocessing capability will provide the ability to reprocess data via CASA from the NRAO and ALMA archives via separate methods. During FY2015 work will be done to combine these into a single interface. This work will be completed in FY2016, with timing depending in part on the delivery of suitable data retrieval capabilities from the ESO ALMA partners.

Tool Redesign: This project will review the current design of user facing tools, in particular the PST, PHT, and OPT. Recent user and time allocation review committee feedback has provided usability and performance improvement suggestions for the tools. It is believed that an approach which identifies and combines common functions between the tools may be a productive way to make the toolset both more functional and easier to use. The tools will be reviewed in FY2015 and the first phase of improvements delivered in FY2016.

Mobile: In collaboration with the EPO team we will develop a NRAO mobile app. The primary purpose of the app is to educate the public about NRAO using videos, animations, illustrations, panoramas, audio, and behind the scenes shots. During FY2015 the DMS software team will begin to build an NRAO informational iOS mobile app, with the EPO team focusing on Android.

Testing: The scope of CASA automated testing will be expanded to include most supported platforms and multiple code branches. Testing for ALMA control and correlator software will be migrated to the ALMA ICT (Chile) as agreed in FY2015, with provisions to keep NRAO code development and unit testing coordinated with the ICT.

FY2016

New NRAO Archive: DMS Software will deliver improvements to the Archive, including the ability to retrieve image data and overall integration between NRAO and ALMA data. Timing may be dependent on the delivery of suitable data retrieval capabilities from the ESO ALMA partners.

CASA: CASA versions 4.5 and 4.6 will be released in this period. Both CASA releases will support Pipeline improvements for the VLA, with the 4.5 release additionally focusing on ALMA priorities for Cycle 3. The development plan will be informed by our ongoing experience with the VLA and ALMA, the CASA Users Committee and the CASA Science Steering Committee.

CASA Pipeline: The CASA Pipeline will continue to evolve as ALMA reaches full science operations, with patches developed and released throughout the period. A major release will be scheduled Q1 FY2016 to coincide with ALMA Cycle 3. Reference images will be released to ALMA users in FY2016.

Proposal Submission Tool: The PST will be updated to support required functionality for the 2016B and 2017A calls for proposals. New functionality that is needed for those calls is described in sections 3.1.2 and 3.2.2.

7.4 Data Management & Software Major Milestones

Table 7.4.1: DMS F2015 Major Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Scientific Information Services					
SIS	Unification of the ALMA and NRAO helpdesk	1	2		
	NAASC Cluster access			3	
	Increase bandwidth to sites	4	5	6	7
	Externally hosted resource access		8,9	10	11
	Multi-core co-processor development testbed	12			
	Lustre backup options			13	
ALMA System Software					
ALMA	Fall 2014 Release	14			
	Spring 2015 Release			15	
VLBI Modifications	ALMA Phasing Project			16	
VLA/VLBA System Software					
VLA/VLBA	Support 2014B Observing		17		
	Support 2015A Commissioning		18		
	Support 2015A Observing				19
	Support 2015B Commissioning				20
	VLA – Integrate VLITE Operations		21		
	VLA – Frequency Averaging	22			
	VLA – Write Pointing Table		23		
	VLBA – VME Replacement				24
GBT System Software					
Green Bank	Modify Astrid to Use Streaming	25			
	Operations Software Update	26			
	Vegas Pulsar Modes	27			
	NRQZ Software		28		
	M&C Release				29
	CLEO Port			30	
GBTPP - Pipeline	Parallelize Pipeline	31			
	Pipeline Improvements				32
	Test with PSC		33		
Software Development					
New NRAO Archive and RPI	Operationalize		34		
CASA Pipeline	VLA Integration			35	
CASA	4.3 Release	36			
	4.4. Release			37	
PST	Updated for 2015B Call for Proposals	38			
	Updated for 2016A Call for Proposals			39	
PHT	Updated for 2015B TAC Meeting		40		
	Updated for 2016A TAC Meeting				41
OPT	2015A VLA Observing Updates	42			
	2015B VLA Observing Updates			43	
Tool Redesign	Create Architecture		44		
Testing	Expand CASA Test Scope			45	
	ALMA Testing Handover				46

Milestones:	Deliverables:
1. SSO aligned for MyNRAO and ALMA accounts	1. Transparent access from single login
2. Merger of helpdesk	2. All tickets, departments and KB articles migrated
3. PI Access to NAASC cluster	3. Access to NAASC cluster aligned with VLA
4. Increase bandwidth to sites	4. VLBA site bandwidth enhancement (e.g. Brewster)

15. NRQZ Software 16. M&C Release 17. CLEO Port 18. GBT Pipeline Improvements 19. Test with PSC 20. New NRAO Archive 21. ALMA Cycle 3 Pipeline Release 22. Pipeline Reference Imaging 23. Release CASA version 4.5 24. Release CASA version 4.6 25. Implement PST updates for Semester 2016B Call for Proposals 26. Implement PST updates for Semester 2017A Call for Proposals 27. Implement PHT updates for Semester 2016B TAC Meeting 28. Implement PHT updates for Semester 2017A TAC Meeting 29. Implement OPT updates for Semester 2016A VLA Observing 30. Implement OPT updates for Semester 2016B VLA Observing 31. Integrate ALMA and NRAO RPI 32. Deliver Phase1of the Observatory Tools Update 33. Deliver iOS App for Public Outreach 34. Expand CASA Test Scope	13. Software update 14. Software and documentation 15. Software and documentation 16. Software 17. Software and documentation 18. Software and documentation 19. Test report 20. New Archive Tool in production 21. Software and heuristics update 22. Software and heuristics update 23. CASA Package 4.5 24. CASA Package 4.6 25. PST software updates for Semester 2016B Call for Proposals 26. PST software updates for Semester 2017A Call for Proposals 27. PHT software updates for Semester 2016B TAC Meeting 28. PHT software updates for Semester 2017A TAC Meeting 29. OPT software updates for Semester 2016A VLA Observing 30. OPT software updates for Semester 2016B VLA Observing 31. Software updates 32. Observatory Tools software updates 33. Software and documentation delivered and deployed 34. Include C++ and GUIs in automated testing

7.5 Data Management & Software Financial Chart

Table 7.5.1: FY2015 by Fund Source and Location

FY15

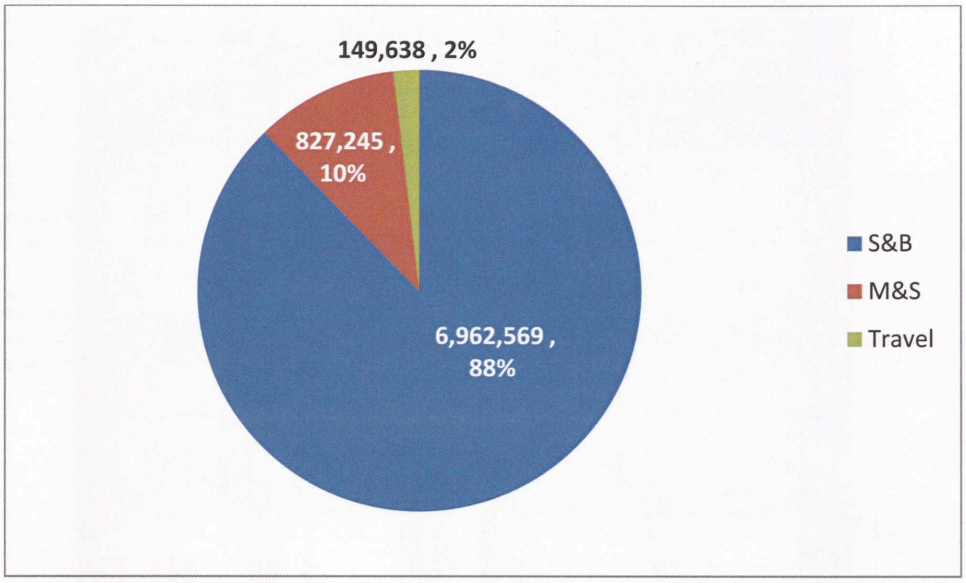
Work Breakdown Structure	CSA-1 NRAO Ops: Charlottesville TOTAL	FTE's	Green Bank TOTAL	FTE's	Socorro TOTAL	FTE's	TOTAL, CSA-1 TOTAL	FTE's	CSA-2 ALMA Ops: Charlottesville TOTAL	FTE's	Socorro TOTAL	FTE's	TOTAL, CSA-2 TOTAL	FTE's	Internal Common Costs: Charlottesville TOTAL	FTE's	Green Bank TOTAL	FTE's	Socorro TOTAL	FTE's	TOTAL, ICC TOTAL	FTE's	GRAND TOTAL TOTAL	FTE's
1000 Telescope Operations																								
1200 Operations																								
1230 Support & Testing																								
1235 Systems Hardware Support			106,989	0.7			106,989	0.7															106,989	0.7
1236 Scientific Support			18,248	0.2			18,248	0.2															18,248	0.2
1240 M&C Software			277,478	2.7			277,478	2.7	530,076	4.5	630,572	6.0	1,160,648	10.5									1,438,126	13.2
1500 Management																								
1550 Software Mgmt			97,078	0.8	1,206,912	9.8	1,303,990	10.5	89,795	0.5			89,795	0.5									1,393,785	11.0
1000 Telescope Operations Total			499,794	4.3	1,206,912	9.8	1,706,706	14.1	619,871	5.0	630,572	6.0	1,250,443	11.0									2,957,149	25.1
3000 Science Operations																								
3500 Management															201,182	1.2	12,000	-	255,441	1.0	468,623	2.2	468,623	2.2
3600 Scientific User Services																								
3620 Science Data Processing	28,959	0.3	445,648	2.1	333,652	1.2	808,258	3.6	712,400	3.0	63,006	0.5	775,406	3.4									1,583,664	7.0
3630 Science Software																								
3631 Post-Processing Software	102,282	0.7	222,395	1.9	379,121	3.0	703,798	5.6	201,640	1.5	851,570	7.0	1,053,210	8.5									1,757,008	14.1
3633 Data Access Software			28,069	0.3	599,823	5.9	627,892	6.1															627,892	6.1
3634 Application Software	185,749	1.5					185,749	1.5	260,277	2.0	99,090	1.0	359,367	3.0									545,116	4.5
3000 Science Operations Total	316,990	2.5	696,112	4.2	1,312,596	10.0	2,325,698	16.7	1,174,317	6.5	1,013,666	8.5	2,187,983	14.9	201,182	1.2	12,000	-	255,441	1.0	468,623	2.2	4,982,303	33.8
Grand Total	316,990	2.5	1,195,906	8.5	2,519,508	19.8	4,032,403	30.8	1,794,188	11.5	1,644,238	14.5	3,438,426	25.9	201,182	1.2	12,000	-	255,441	1.0	468,623	2.2	7,939,452	58.9

FY16

Work Breakdown Structure	CSA-1 NRAO Ops: Green Bank TOTAL	FTE's	Green Bank TOTAL	FTE's	Socorro TOTAL	FTE's	TOTAL, CSA-1 TOTAL	FTE's	CSA-2 ALMA Ops: Charlottesville TOTAL	FTE's	Socorro TOTAL	FTE's	TOTAL, CSA-2 TOTAL	FTE's	Internal Common Costs: Charlottesville TOTAL	FTE's	Green Bank TOTAL	FTE's	Socorro TOTAL	FTE's	TOTAL, ICC TOTAL	FTE's	GRAND TOTAL TOTAL	FTE's
1000 Telescope Operations																								
1200 Operations																								
1230 Support & Testing			125,237	0.9			125,237	0.9															125,237	0.9
1235 Systems Hardware Support			106,989	0.7			106,989	0.7															106,989	0.7
1236 Scientific Support			18,248	0.2			18,248	0.2															18,248	0.2
1240 M&C Software			277,478	2.7			277,478	2.7	553,615	4.5	658,495	6.0	1,212,110	10.5									1,489,588	13.2
1500 Management																								
1550 Software Mgmt			97,078	0.8	1,206,912	9.8	1,303,990	10.5	93,593	0.5			93,593	0.5									1,397,583	11.0
1000 Telescope Operations Total			499,794	4.3	1,206,912	9.8	1,706,706	14.1	647,208	5.0	658,495	6.0	1,305,703	11.0									3,012,409	25.1
3000 Science Operations																								
3500 Management															201,182	1.2	12,000	0.0	255,441	1.0	468,623	2.2	468,623	2.2
3600 Scientific User Services																								
3620 Science Data Processing	28,959	0.3	445,648	2.1	333,652	1.2	808,258	3.6	575,852	3.0	65,814	0.5	641,666	3.4									1,449,924	7.0
3630 Science Software	279,031	2.2	250,464	2.1	978,944	8.9	1,508,440	13.2	481,664	3.5	992,886	8.0	1,474,550	11.5									2,982,990	24.7
3631 Post-Processing Software	93,282	0.7	222,395	1.9	379,121	3.0	694,798	5.6	210,621	1.5	889,415	7.0	1,100,036	8.5									1,794,834	14.1
3633 Data Access Software			28,069	0.3	599,823	5.9	627,892	6.1															627,892	6.1
3634 Application Software	185,749	1.5					185,749	1.5	271,043	2.0	103,471	1.0	374,514	3.0									560,263	4.5
3000 Science Operations Total	307,990	2.5	696,112	4.2	1,312,596	10.0	2,316,698	16.7	1,057,516	6.5	1,058,700	8.5	2,116,216	14.9	201,182	1.2	12,000	0.0	255,441	1.0	468,623	2.2	4,901,536	33.8
Grand Total	307,990	2.5	1,195,906	8.5	2,519,508	19.8	4,023,403	30.8	1,704,724	11.5	1,717,195	14.5	3,421,919	25.9	201,182	1.2	12,000	0.0	255,441	1.0	468,623	2.2	7,913,945	58.9

Data Management and Software Financial Chart (cont.)

Table 7.5.2: FY2015 Expenditures by Object



8.3 PMD CDL and ALMA

The PMD supports the Central Development Laboratory by providing systems engineering and project management support to research and development initiatives and projects involving the development or production of products and services to other organizations. This technical project effort usually begins at the proposal development stage in response to an RFP and goes through to the operation and support stages. The PMD will continue to provide this support through systems engineering and project management leadership, mentorship, and training and providing tools and templates to support the CDL staff as they work through the various stages of their product life cycles towards the realization of successful systems.

PMD also provides support to ALMA NA Operations through the ALMA Development (ALMA-D) activities. This typically includes the implementation of PMD standards, processes, tools and techniques into ALMA-D projects. The ALMA-D PMD POC helps synchronize planning cycles and incorporates ALMA-D studies and projects into the NRAO-wide development planning activities and reporting.

8.4 PMD Green Bank

The Green Bank PMD office supports the Green Bank Operations. In addition to the PMD support activities described in the preceding sections, the GB PMD Office will advance the implementation of PM/SE practices (including process, tools and techniques) within these departments. Green Bank efforts for the year will work to maintain a consistent project management methodology and process for all project management engagements across the company. This includes:

- Train, coach, and mentor local project leads in not only project management, but also project delivery to ensure skill mastery and consistency in planning and execution
- Provide centralized control, coordination, and reporting of scope, change, cost, risk, and quality across all Green Bank projects
- Reduce active project risk by regularly monitoring project status and implementing mitigation as required.

FY2015

PMD Headquarters

PMD will continue to enhance its decision support capabilities. Analytics derived from systems used by PMD are used to ensure that prior to new work being undertaken, impacts to NRAO existing work are well understood and that any new work is aligned with NRAO's strategic goals and objectives. PMD uses these tools to complete the various executive level reports that are required and will continue to drive these systems to improve performance in order to obtain better quality results.

The development of a PMD Standard Operating Procedures (SOP) document has been initiated, with an extensive set of templates and examples. This SOP document will be completed and distributed throughout NRAO in 2015. PMD will also develop and start implementing a cross-Observatory training program for broader NRAO on project management and systems engineering methods. This training may include high-quality video and web learning opportunities, on-site consultant delivered courses, informal learning sessions, and other training opportunities as requested by the site Assistant Directors.

PMD will organize and lead production of NSF deliverables, as requested. The FY2014 POP development includes a two-year FY2015-2016 POP. Therefore, no activity is required during this year.

PMD Green Bank

As the PM and SE processes mature, the goal for Green Bank in FY2016 will be to develop competency for the Green Bank Project Leads in initiating the PMD processes for projects, leading the team members in proper required reviews, risk mitigation, and reporting for project closeout. Competency will be evaluated by consideration of project "Lessons Learned" to determine the efficacy of training of project management and systems engineering practices. Informal learning sessions will continue to be hosted throughout FY2016.

8.6 Program Management Department Financial Chart

Table 8.6.1: FY2015 by Fund Source

Work Breakdown Structure	Internal Common Costs	
	Charlottesville	
	TOTAL	FTE's
5000 Director's Office		
5111 Program Mgmt	474,391	2.7
5000 Director's Office Total	474,391	2.7
Grand Total	474,391	2.7

Table 8.6.2: FY2015 Expenditures by Object

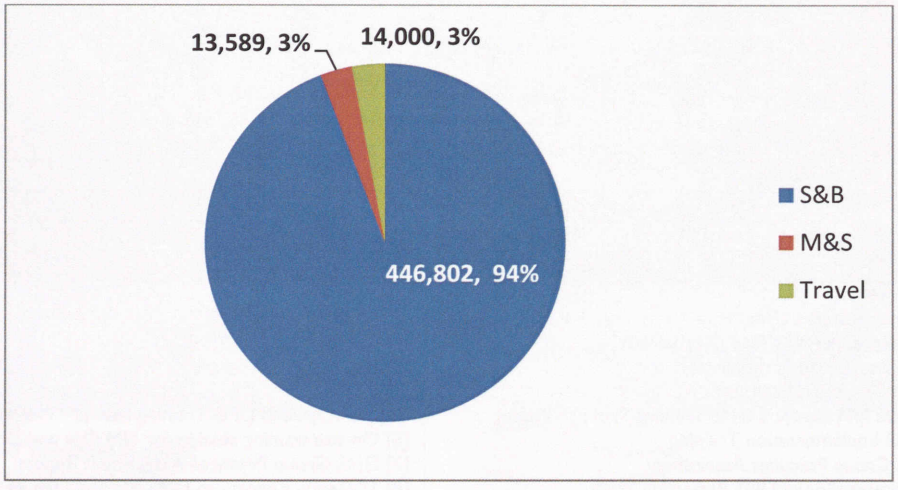


Table 8.6.3: FY2016 by Fund Source

Work Breakdown Structure	Internal Common Costs	
	Charlottesville	
	TOTAL	FTE's
5000 Director's Office		
5111 Program Mgmt	474,391	2.7
5000 Director's Office Total	474,391	2.7
Grand Total	474,391	2.7

NAOJ. During the same period, VLBA management will continue to promote support from its community for new development projects.

The financial challenges faced by the VLBA are not unique, and it is clear that the worldwide VLBI community (including both astronomers and geodesists) needs to increase cooperation. A VLBI roadmap will be developed early in the timeframe of this Plan to identify the most pressing technical and scientific problems.

Space Very Long Baseline Interferometry: Russia's RadioAstron mission operates a self-contained, space-borne astronomical VLBI station carrying a 10-meter antenna, a hydrogen maser, and P-, L-, C- and K-Band radio receivers aboard the SPEKTR-R spacecraft. The spacecraft was successfully launched from the Baikonur Cosmodrome in Kazakhstan July 18, 2011, continues (as of September 2014) to operate nominally, and has a design lifetime of at least five years; in the summer of 2014, the project operations lifetime was extended for at least an additional three years.

The project began routine science operations in FY2012, and established a peer-reviewed, open skies based process offering a group of international partnerships observing time. NRAO has long been a scientific partner in the RadioAstron project and under its normal peer-reviewed proposal process has begun to provide telescope time for either VLBI observations concurrent with, or radio astronomical observations complementary to, RadioAstron. A Memorandum of Understanding between the Lebedev Physical Institute in Moscow – which operates the RadioAstron mission – and AUI/NRAO, is being finalized that will provide a limited amount of additional observing time on NRAO telescopes to RadioAstron projects. Both the Socorro DiFX correlator and both the ASTRON and MPIfR software correlators are able to handle data on the space-ground baselines.

As in the case of the VLBA, NSF has advised NRAO that it will be necessary to supplement the limited operating available funds for Green Bank Telescope (GBT) operations with external revenues if the Green Bank site is to continue to stay open. One such revenue stream, which began in FY2013 comes from receiving and recording astronomical VLBI data downlinked by the RadioAstron satellite to the Green Bank site's 140-foot radio telescope antenna. The RadioAstron satellite was not designed to store radio astronomical observations and must downlink the data taken during VLBI observing sessions to a ground-based VLBI recorder system. To make maximum use of the satellite's on-orbit scientific mission, the Astro Space Center at Moscow's Lebedev Physical Institute expressed interest in establishing a second data downlink station for RadioAstron at the NRAO Green Bank site, so that coordinated VLBI observations of sources out of direct line of sight to the main RadioAstron downlink in Pushchino would be possible. A multiyear usage contract with the Lebedev Physical Institute to operate the 140m antenna as a second downlink station was signed in late 2012, and the downlink station began operating in Q4 of FY2013. Stipulating that RadioAstron's scientific productivity and the on-orbit health of the spacecraft continue, it is expected that this contract will be routinely extended through the mission's operational lifetime.

Strategic Mission: The NIO pursues, develops, and manages strategic partnerships and collaborations with academic, government, and non-profit organizations.

FY2015

Among the core NIO activities envisioned for FY2015 are to continue managing and further expanding the partnerships to sustain the scientific operations and unique technical capabilities of the VLBA and GBT.

9.2 New Initiatives Office Financial Chart

Table 9.2.1: FY2015 by Fund Source and Location

Work Breakdown Structure	Internal Common Costs Charlottesville TOTAL	FTE's
⊟2000 Development Programs		
⊟2100 Business Development		
⊞2110 Partnerships	392,775	1.8
2000 Development Programs Total	392,775	1.8
Grand Total	392,775	1.8

Table 9.2.2: FY2015 Expenditures by Object

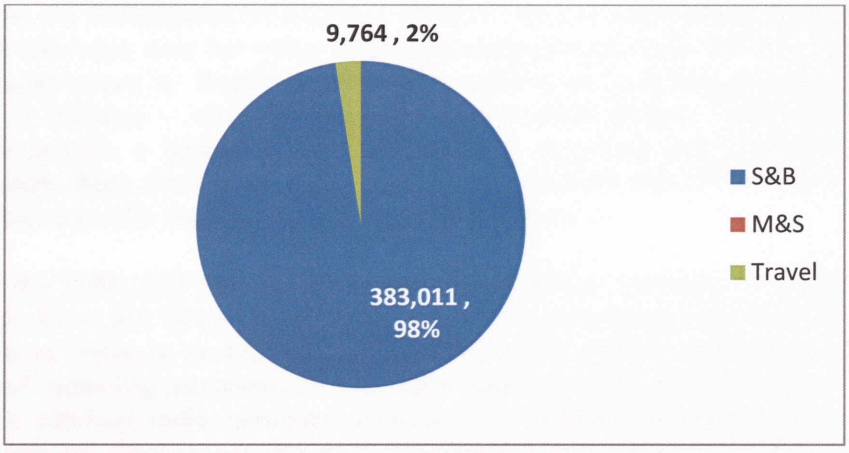


Table 9.2.3: FY2016 by Fund Source and Location

Work Breakdown Structure	Internal Common Costs Charlottesville TOTAL	FTE's
⊟2000 Development Programs		
⊟2100 Business Development		
⊞2110 Partnerships	456,461	1.8
2000 Development Programs Total	456,461	1.8
Grand Total	456,461	1.8

10 EDUCATION & PUBLIC OUTREACH

The Education and Public Outreach (EPO) department serves the public interest by (1) stimulating growth in public awareness and understanding of radio astronomy, the technology and people it employs, and the natural phenomena it reveals; and (2) channeling observatory resources to the national mission to improve Science, Technology, Engineering, and Mathematics (STEM) education and literacy. Additionally, EPO provides graphic design and layout services for internal observatory needs. The planning entails both pre-scheduled projects and preparedness for the kinds of opportunities that typically arise during the course of a year.

10.1 STEM Education

FY2015

Science/Visitor Center Operations: NRAO operates the Green Bank Science Center and the VLA Visitor Center public exhibits and tour program. A public admission charge will be instituted at the VLA Visitor Center this year. The motivation for upgrading the visitor experience was the desire to have visitors more fully appreciate what they are seeing through enhanced opportunities for personal engagement with knowledgeable staff members and volunteer docents through improvements that would be made to the visitor center public offerings. One of the most consistent requests from visitors to the VLA is for guided tours; in the past such tours have been available only on the first Saturday of each month and upon special request by advance appointment. During FY2015 the NM-based Education Officer and the newly created position of Visitor Center Specialist at the VLA will focus on upgrading the VLA visitor experience, as resources permit, by recruiting a corps of volunteers to give guided tours during peak visitation hours every day. (There will be a curtailment of offerings of community-based education events by our NM Education Officer during this time.) The VLA visitor center staff will pursue training and professional certification as Certified Interpretive Guides or Certified Interpretive Trainers, as appropriate. Some components of upgrading the tour program will require funding not yet identified.

Additional site-centric EPO activities will include:

- Special tours to educational and tourist groups
- Special community events in Green Bank, plus a regular schedule of scheduled activities
- Overnight Educational Field Trip program for schools, universities, and scouts in Green Bank, featuring student-conducted research using the 40-Foot Telescope
- Professional development opportunities for teachers through the Chautauqua Short Course program in WV and NM (subject to enrollment)
- Monthly First Saturday events and bi-annual Open House events at the VLA

New VLA Visitor/Education Center Project: The EPO department is planning for the development of a new Visitor/Education Center at the VLA. During FY2014 an initial feasibility and vision workshop was completed, along with an economic feasibility and impact analysis, preliminary architectural specification and planning, and initial thematic content brainstorming; specialized consulting for these activities was funded outside of the cooperative agreement by revenue earned through commercial filming fees at the VLA. During FY2015, this work will continue in two strands. First, a "vision document" and associated presentation and web pages will be produced. This document will encapsulate and project a vision for a new VLA visitor center as a resource valuable to STEM education, to the public understanding of science, to tourism (in NM, locally, and space-related), and to communities adjacent to the VLA. It will serve as a principal tool for enlisting the interest and support of potential contributors and sponsors at various levels. The second activity strand will entail additional

to consider careers in STEM. Students spend an extended period at NRAO in the summer, conducting research and doing other STEM tasks.

FY2016

Science/Visitor Center Operations: NRAO will operate the GBSC and the VLA Visitor Center public exhibits and tour program, largely as described in the previous year.

Additional site-centric EPO activities will include:

- Special tours to educational and tourist groups
- Special community events in Green Bank, plus a regular schedule of scheduled activities
- Overnight Educational Field Trip program for schools, universities, and scouts in Green Bank, featuring student-conducted research using the 40-Foot Telescope
- Professional development opportunities for teachers through the Chautauqua Short Course program in WV and NM (subject to enrollment)
- Monthly First Saturday events and bi-annual Open House events at the VLA

New VLA Visitor/Education Center Project: Work will continue on this project. Depending on progress made in the previous year (which will partially be a function of our ability self-fund certain components of the work via earned revenue or fundraising), it may be possible to commence the development of an exhibit/interpretive plan, exhibit design, and the next steps in architectural design.

Skynet Jr. Scholars (SJS): NRAO anticipates continuing the SJS program in FY2016 via a no-cost extension of the grant. Work will continue on completing the SJS Explorations Modules (activities) as well as educator training.

STEM Role Models: NRAO will participate in several activities in Charlottesville to introduce students to STEM career practitioners, including via Dominion Virginia Power's STEM Career Day and Piedmont Virginia Community College's 10 Grade Career Day (subject to invitation). Additionally, we will create approximately a dozen STEM career focus videos featuring NRAO staff or science users.

Space Public Outreach Team (SPOT): Contingent upon continued funding, NRAO will continue the SPOT program, potentially expanding the regions in Virginia that are covered by student ambassadors from another Virginia-based college or university. Additional presentations will be added to the repertoire.

Galaxy Science through Astronomy Role-Modeling (GSTAR): This program continues as described for FY2015.

Astronomy in Chile Educator Ambassadors Program (ACEAP): This program continues as described for FY2015 (subject to receipt of the anticipated grant funding).

NRAO Research Experiences for Teachers (RET): This program continues as described for FY2015 (subject to receipt of grant funding).

PING: Exploring the Cosmos with NRAO: This AUI-established program continues as described for FY2015.

Public Website Maintenance, User Support, and Improvements: NRAO will continue to maintain and upgrade our web server and website code as necessary to maintain compatibility with ever-changing operating system-browser combinations and capabilities, and with the latest version of our Joomla content management system (CMS). We will also implement upgrades to the site to enable better page indexing and searching, per the new capabilities of the CMS.

New Public Website Content: NRAO will produce a new online media feature entitled the Orion Explorer, which will include extensive videos about stellar and planetary system evolution.

Press Release Development, Distribution, and Monitoring: NRAO will continue reporting important NRAO-enabled science results and development milestones as described above.

NRAO Smartphone/Tablet Apps: NRAO will complete the Android version of our first NRAO app, entitled "RadioSky," and will release the iOS and Android versions on iTunes and Google Play respectively. We will begin work on the iOS version of our next app, entitled "Zombie Stars," featuring pulsar-focused interactive experiences that are linked to Next Generation Science Standards teaching standards.

Media and Public Inquiry Response: NRAO will continue to respond to inquiries from professional journalists and the media, and from the public.

10.3 Education and Public Outreach Major Milestones

Table 10.3.1: EPO FY2015 Major Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
STEM Education	Skynet Jr. Scholars	1	1	1,2	
	New VLA Visitor/Education Center	3	4	5	6
	VLA Visitor Center Operations	7	8	9	10
	STEM Role Models	11	12		13
	Space Public Outreach Team (SPOT)	14, 15			
News and Public Information	Public Website Upgrades	16		17	
	Public Website Content	18			19
	Smartphone/Tablet Apps	20		21	

Milestones:

1. Second round of SJS professional development meetings for educators
2. Curriculum development for SJS web portal complete
3. Develop "vision" for new VLA Visitor/Education Center
4. Develop plan for VLA Visitor/Education Center Capital Fundraising Campaign
5. Develop VLA Visitor/Education Center business/operations plan
6. Create VLA Visitor/Education Center exhibit theming plan.
7. Decide upon admission fee structure for existing VLA Visitor Center
8. Implement new admission fee at VLA Visitor center on 1 January 2015
9. Complete Interpretive Training for J. Stanley and L. Baric
10. Complete plan for recruitment and training of VLA Visitor Center volunteer guides
11. STEM Career Day at Dominion Virginia Electric
12. 10th Grade STEM Day at Piedmont Virginia Community College (if invited)
13. STEM Career Focus videos
14. SPOT: Introduce new feature presentation
15. SPOT: Recruit new UVa-based undergraduate ambassadors
16. Convert NRAO public website to Joomla 3 CMS
17. New server-based popular content caching
18. New planetary system content for The Milky Way Explorer
19. New Local Group content for The Milky Way Explorer
20. Functional spec and design completed for "RadioSky" app
21. iOS version of "RadioSky" app ready for beta testing

Deliverables:

[1] Educator meetings in October, January, March, and April
[2] Curriculum posted on SJS web portal
[3] VLA Visitor/Education Center vision document, Powerpoint presentation, and web pages.
[4] VLA Visitor/Education Center Fundraising Plan document
[5] VLA Visitor/Education Center Business/Operations Plan document
[6] VLA Visitor/Education Center Exhibit Theming Plan document
[7] VLA admission fee document approved by director
[8] New signs installed, new ticketing scheme, updated website, marketing partners informed
[9] J. Stanley and L. Barich are NAI Certified Interpretive Guides
[10] VLA Tour Guide Recruitment and Training Plan document
[11] NRAO representation at STEM Career Day
[12] NRAO representation at PVCC 10th Grade Career Day
[13] 12 Career Focus videos complete and posted to NRAO public website
[14] New SPOT presentation Powerpoint completed
[15] New SPOT Virginia undergraduate ambassadors recruited
[16] NRAO public website running on Joomla 3
[17] Public website popular content caching software running
[18] Planetary system content videos added to MW Explorer on NRAO public website
[19] Local Group content videos added to MW Explorer on NRAO public website
[20] Functional spec and design document ready for programming
[21] iOS version ready for beta testing

11.1 Observatory-Wide Support

CIS Helpdesk

FY2015

As part of the observatory-wide alignment of CIS resources, a unified staff supporting helpdesk was implemented in FY2014 with simplified priority scheme and an intuitive urgency (time) vs. Impact (scope) mapping. After cross training, in FY2015 (Q2) this tool will be leveraged for "follow-the-sun" support. In addition, the unified helpdesk adheres to the Information Technology Infrastructure Library (ITIL) guidelines for balancing the three core duties of IT; addressing outages, handling standard service support requests, and facilitating resources to support approved projects.

FY2016

No additional modifications to the CIS Helpdesk are anticipated for FY2016.

Common Computing Environments

FY2015

The CCE coordinates and prioritizes NRAO-wide computing projects and initiatives between the sites, facilitated by the annual system-administrators meeting (Q1) and staff skills improvement via computing conferences and training events. A major objective for FY2015 is the work to leverage system image management solutions for all platforms: Windows (System Center), Macintosh (Managed Software Update) and Red Hat Linux (Kickstart) with reliable testing and release management practices.

The planned end of support for the Windows XP systems has resulted in the expedited replacement of legacy systems, especially in engineering. It is expected that all Windows systems will be on Version 7 by the end of Q1, but some key legacy systems may be maintained in a secure/private network space if essential services cannot be migrated or upgraded due to cost or lack of vendor support. A review of Windows 8 and cloud/mobile resource access (including software) will be competed in Q3. It is also expected that the migration to RHEL (Unix) version 6 will be completed by the end of Q4.

Finally, CIS will perform a full requirements gathering exercise to capture and prototype a Document Management system capable of servicing the needs of reliable storage and retrieval of key business and engineering documents of record, including full revision control, approval workflows and re-validation lifecycle.

FY2016

The migration of the Windows platform to version 8 will also be initiated in FY2016 with a review of the unification of mobile and desktop OS and user interface.

11.3 Maintenance and Renewal

FY2015

Video Conference Hub refresh: A key risk was identified with the headquarters based video/audio conference hub system (Polycom MGC). Funds were identified at year-end in FY2014, but integration and implementation will wait until Q1 FY2015 to minimize risk and to allow for staff training. In order to keep up with growing performance and storage needs for the Green Bank site, an upgraded Network Attached Storage (NAS) system will be installed in Q3.

Meeting Room reservation software replacement: The legacy system used to coordinate and reserve the video conference/meeting rooms observatory-wide will be replaced to ensure supportability for this key coordination service, and to retire an identified risk (currently running on an unsupported operating system). Based on the experience of this exercise in which a commercial application was purchased in preference to custom built solutions, CIS will re-evaluate other software solutions with a preference for out-source or replacement with commercial solutions.

In order to reduce the cost of desktop systems, and to increase the access to capacity on demand from cluster computer resources, CIS will deploy thin clients to replace full desktop systems. These have the advantage of minimal 'state' and therefore have a low maintenance overhead, relying on system images stored on high-availability systems in the computer rooms at each site.

FY2016

Implementation of strategic investment in commercial software systems to retire multiple legacy services, most notably the BOS system and NRAOPapers will be made in Q2. It is projected that the NAS in Green Bank site will require an upgrade to increase the quota for staff as well as improve performance mid-year (Q2).

The BackupPC and CommVault and backup solutions employed at each site should be re-evaluated based on updated requirements, and those should in turn be cognizant of the needs of DMS. A review in early FY2016 will inform future solutions.

11.4 Computing & Information Services Major Milestones

Table 11.4.1: CIS FY2015 Major Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
CIS	CIS Helpdesk alignment		1		2
	System Administrator meeting	3			
	Planned OS upgrades	4	6	5	
	NAS replacement in GB			7	
	Installation of Document Management system		8		
	Multi-Gigabit Network options review		9		
	Network intrusion detection testing				10
	Service availability review				11
	Collaboration upgrades	12	13		
	Thin client deployment to replace desktops				14

Milestones:
1. Cross training for coverage between sites
2. ITIL training for staff
3. CCE coordination meeting
4. Migration to Windows 7 compete
5. Evaluation of Windows 8
6. Migration to RHEL 6
7. Replace Network Attached Storage in GB
8. Document Management system
9. Network upgrade review
10. Bro IDS installed at gigabit speeds
11. Service availability and location review
12. Replacement of end-of-life Video Hub
13. Replacement of legacy room reservation SW
14. Use of thin clients to replace desktops

Deliverables:
[1] Shared access and permissions for CIS staff
[2] Categorization of tickets to minimize service interruption
[3] Roadmap for 2-year strategic upgrade initiatives
[4] All windows XP systems removed from network
[5] Timeline and options for Windows 8 support established
[6] Standard cluster/desktop/laptop system image for Unix
[7] Doubling of speed/capacity for NAS storage
[8] Requirements based recommendation
[9] Cost/benefit analysis of network enhancements
[10] Intrusion detection service running in production
[11] Recommendations to Associate Director for Admin
[12] Replace end-of-life MGC system
[13] Installation of supported software solution
[14] Reduced total cost of ownership for desktops

Table 11.4.2: CIS FY2016 Major Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
CIS	Business software review		1		
	Windows 8 migration				2
	Bro running at 10Gbps			3	
	Key business services migration and consolidation		4		
	Review of IS backup architecture	5			

Milestones:
1. Business software review and strategic alignment
2. Migration to Windows 8
3. Bro security tool eval
4. OAS business services availability improvement
5. Review and consolidation of backup solutions

Deliverables:
[1] Engage CIS and DMS in business software portfolio review
[2] Standard system build moved to Windows 8
[3] Validation of Bro tool running at 10Gbps
[4] Measurable increase in service availability
[5] In-depth report based on CIS backup requirements

12 DIVERSITY

As a national observatory it is our mission to train the next generation of scientists and engineers. It is especially important to help build the STEM pipeline in minority and under-represented groups as this is the fastest growing sector of the U.S. population. Efforts described here are based on a two-year plan toward building a vibrant STEM pipeline with national and international partners. Diversity efforts across the Observatory for FY2015 and FY2016 will focus on the following key areas; broader impact, new/on-going pipeline initiatives, workforce hiring (process and policies), retention, training, and workplace culture. Continued integration of programs within and amongst Science Support and EPO will enable us to leverage existing talent and coordinate existing resources. The need to effectively communicate and actively engage and encourage increased participation in diversity efforts at the sites will be a key goal in ensuring that the diversity milestones are met.

The Diversity Strategic Plan will be fully implemented in Q4 of FY2014. The diversity and broader impact programs outlined in the plan encompass domestic and international outreach that are positively aligned with the Observatory's mission to train the next generation that is vital to our ongoing success in the Astronomical community. Programs moving forward will be expanded to include initiatives focused on the Native American population. We will continue to strengthen the programs that were implemented in FY2014 with focused attention on developing metrics to evaluate the effectiveness of the program. Additionally, the continuance of diversity training, enhanced diversity recruitment effort and assessment of workplace culture will remain a top priority.

Diversity Council

AUI and NRAO will create an office of Diversity Initiatives (ODI) - structure shown below. The ODI is staffed by the AUI-NRAO Diversity Lead, the AUI-NRAO STEM Development Officer, Assistant Director of Science Support and Research, and the NRAO Human Resources Manager/Diversity Officer. The panel will be recognized as the Diversity Council and each member of the panel will serve as chair on a rotating basis. ODI is responsible for coordinating the observatory wide efforts in improving and enhancing diversity in all aspects of observatory operations.

The ODI will meet weekly to coordinate efforts and report to the director and AUI president monthly on the Broader Impact efforts. The ODI members will travel to the NRAO sites and AUI Headquarters routinely to facilitate communication between all branches of the observatory. Another important task for the ODI will be to publicize the broader impacts efforts at the observatory to all stakeholders for the NRAO and AUI, and seek additional resources/funding as needed. The ODI will also interact with NRAO staff to generate new ideas and initiatives and make recommendations on what the AUI and NRAO may undertake in the future.

and Socorro we will host two yearly cohorts of four students each. Over the summer the students will interact with other REU students to take advantage of shared resources (colloquia, lectures, site visits, etc.).

The model will consist of two cohorts of four students each. The cohort will be hosted at NRAO-Socorro and NRAO-Charlottesville contingent upon funding resources and staff availability. The students will be recruited via visits to Minority Serving Institutions (MSIs) in the fall of 2015 and interactions at the AAS and possibly the SACNAS meetings. Applications will be due to participate in the NAC on Feb 1, 2015 and pre-summer orientation and preparation will be done in the spring of 2015. Students will be hosted at the NRAO sites for 10-12 weeks from June–August and will have the opportunity to interact with the REU students. The NAC may also add another cohort of four students at Wisconsin and some of the activities will be coordinated via the NAC lead in Charlottesville.

NAC Workshop: In September of 2015, a third annual NAC workshop will be held which will bring back NAC alumni and partners to continue discussing, collaborating, and learning from each other and expanding the program. The main purpose of the workshop is to maintain and increase participation from MSIs and Majority Serving Institutions and Universities to build and sustain an enduring, sustainable pipeline for training future STEM leaders from under-represented groups.

Socorro Employee Summer Youth Program: Each summer, the City of Socorro partners with area employers to provide work experience for high school age children in the community. The youth work at the Domenici Science Operations Center (DSOC) and are assigned tasks that will prepare them for future work opportunities. This is known as the Summer Youth Employment Program (SYEP). SYEP participants are assigned to partnering area employers where the student will gain 'real life' working experience. The program is fully sponsored by the City of Socorro (the city pays the students). The sessions run for six weeks.

Physics Inspiring the Next Generation (PING): Investigating the Universe at the National Radio Astronomy Observatory program is a joint venture between the National Society of Black Physicists (NSBP) and the NRAO, and AUI. The two part program is designed to support multiple levels of the physics and astronomy pipeline. PING includes a two-week summer program designed to expose middle school students to the fields of physics and astronomy and an eight-week program designed to cultivate interest in radio astronomy research in undergraduate students. The undergraduate students selected for the program, will begin an REU like experience at the NRAO in Green Bank around June 1, 2015 and will end their experience around August 1. As part of this program the undergraduates will serve as instructors and mentors for middle school students during a two-week summer camp. In addition to the summer camp, undergraduates will be partnered with an astronomer or engineer at the Green Bank facility where they will engage in various cutting edge research for the remainder of the eight-week experience.

Native American Outreach: NRAO will explore opportunities for establishing a partnership with Native Americans in an effort to extend pipeline opportunities starting with the Pathkeepers for Indigenous Knowledge Organization. Through this collaboration, it is our intention to seek STEM opportunities in Charlottesville and New Mexico.

African American Teaching Fellows (AATF): The mission of the AATF is to recruit, support, develop and retain a cadre of African American teachers to serve the schools of Charlottesville and Albemarle County. Nearly 30 percent of school-age children in Charlottesville and Albemarle County are African American, but less than 10 percent of their teachers are. The absence of African American

Framework and Essential Components of NINE

1. Co-mentoring and exchange of students and postdocs following the "posse" model
2. Exchange of faculty on short and long time scales
3. Yearly workshops to foster collaboration, professional development and networking
4. Quarterly meetings to evaluate progress, critique program and set goals
5. Several working meetings (e.g. JEDI) and virtual classrooms

An outcome of the NINE program will be partnerships with countries with fast growing radio astronomy communities with the intent of establishing stronger ties to them by exchanging faculty and co-mentoring Masters and PhD level students. In steady state we anticipate two Masters of Science students at each NRAO site for three months and one PhD student at each site for six months.

Partner Countries Chilean Student Partnership

In Chile, astrophysics and astronomy are rapidly growing fields due to the increase in outstanding new telescope facilities being constructed there. The opportunities for females, however, are lagging far behind as the historically conservative culture struggles to adapt traditional family roles to a modern egalitarian society. In 2012, according to La Nación newspaper, only three astronomy PhDs had been awarded to female students in the country's history. Astronomy students are increasingly aware of opportunities abroad, however, and particularly at NRAO and the UVA, due to active collaborations between the ALMA and the local universities in Santiago and Valparaiso. This provides us with the opportunity to support qualified female PhD candidates at UVA who can then take faculty jobs back in Chile and in turn support additional bright and motivated female graduate and undergraduate students at their local universities. This is a unique opportunity to use NRAO facilities to perceptibly improve the climate for females in one of our partner countries. At present we have one student who has passed her candidacy exam and would benefit greatly from 12-18 months of support to allow her to complete her PhD at UVA with an NRAO staff person as her research advisor utilizing faculty connections at Chilean universities to recruit beyond FY2015.

Diversity and Cultural Awareness Training

Multi-Cultural Workforce: Finding common ground in an environment rich with varying opinions and perspectives can be an organizational challenge. Education and awareness initiatives that teach employees how to succeed and perform optimally across a multi-cultural workforce can directly support diversity efforts in the workplace. Diversity education encourages thoughtfulness and consideration between co-workers of different nationalities and backgrounds. Cultural awareness is achieved when all employees in a company can appreciate the benefits of cultural diversity. The numerous benefits of cultural diversity stem from the fact that people from different cultures bring different perspectives to the table, introducing new ideas, perspectives and personalities into strategic planning processes and workplace activities in general. A culturally diverse and aware workforce can create a culture of mutual respect and dignity, garnering a reputation as a fair employer in the job market. Diversity awareness sessions will be offered across the Observatory utilizing a mixture of outside speakers and sessions which will be facilitated by NRAO staff and Diversity Advocates. Diversity awareness will also be incorporated in supervisor and management trainings.

13 HUMAN RESOURCES

The Human Resources Department provides professional service and administrative expertise in response to the changing needs of the organization, to optimize the contribution of our employees to its mission and to support their well-being. Human Resources activities and staff are headquartered in Charlottesville in support of NRAO and ALMA with additional HR staff support and offices in Green Bank and Socorro.

NRAO HR areas of responsibility include policy development and administration, training and development, compensation, benefits, employment (including recruitment and hiring, diversity), and human resources (including employee relations, Human Resource Information System (HRIS), regulatory compliance, HR oversight of NRAO International Staff in Chile, and support of HR staff in the JAO and OCA).

13.1 HR Policy Development and Administration

The Human Resources Department is responsible for ensuring HR policies are in place to establish and guide understanding of the privileges and parameters which employees can expect to operate within at NRAO. We provide/serve in an advisory role to managers and employees in the interpretation and administration of HR policies.

FY2015

Deliver Revised HR Policy Manual: Complete the delivery of the combined Supervisor's Manual, Employee Handbook and all new/updated policies into one document. HR Policy Manual will be posted to the internal HR website along with initiating a communications process to employees and acknowledgement of receipt from employees.

FY2016

Maintain the HR Policy Manual: Provide ongoing updates as necessary to support the Observatory and to ensure legal compliance.

13.2 Training & Development

Design and delivery of employee training is provided by the Human Resources Department in support of the development needs of supervisors, managers and employees in general. Certain training sessions are provided to ensure legal and/or program compliance.

FY2015

Management/Supervisory Development/Delivery: Deliver four NRAO developed/designed courses to managers/supervisors. Courses to be delivered cover: 1. Time and Attendance and Family Medical Leave, 2. Harassment, Bullying & Discrimination, 3. The Electronic Performance Evaluation Process (PEP) Process, 4. Effective Planning and Goal Setting.

Management/Supervisor Development/Design: Design two new management/supervisory courses. Courses will cover: 1. Performance Management – effective delivery of the Performance

Salary Review: Budget permitting, with the establishment of a salary increase pool NRAO HR creates the salary review process and mechanisms for pay decision managers to allocate merit review funds following completion of the performance evaluation process.

Salary Survey and Benchmark Jobs Analysis: NRAO HR participates in and acquires salary survey information in order to complete the analysis of the twenty (20) benchmark jobs for the organization. This analysis/data is used to review current status of pay ranges, how NRAO compares to market, and to make recommendations and determinations for change.

13.4 Benefits

The administration of benefits is a shared responsibility/service with AUI. NRAO Human Resources partners with AUI in the design and delivery of all health and welfare benefits on behalf of our employees. We are the interface with employees in responding to their day to day queries regarding the administration all benefit plans and offerings.

FY2015

Open Enrollment: Health benefits enrollment is labor intensive for HR as it is currently a manual process. HR prepares and distributes all open enrollment materials to employees and makes enrollment changes into the JD Edwards and with vendors.

Wellness Program: NRAO HR will participate with AUI Benefits Manager to create and deliver targeted wellness program and processes to address high frequency/high cost illness/injury areas to employees and the Observatory. We will proactively identify areas trending towards high frequency/high cost and engage employees in proactive and preventative programs/processes to foster a better quality of work life for employees.

Health Plan Design: NRAO HR partners with AUI to review and identify health plan design changes for the next calendar year with the goal of cost containment where possible with enhancements on behalf of the employee as a key consideration.

FY2016

Open Enrollment: Health benefits enrollment is labor intensive for HR as it is currently a manual process. HR prepares and distributes all open enrollment materials to employees and makes enrollment changes into the JDE and with vendors. Human Resources and the NRAO Management Information Systems Department are exploring an internal solution for automating the benefits enrollment with the existing JDE Enterprise One system. This exploration includes the potential for improvements to the self-service functions of benefits enrollment for new hires, qualifying events, and open enrollment. Testing of these improvements will begin late FY15 to determine if the system can be used for Open Enrollment for FY16. External options for these services are also being explored if JDE cannot support these functions.

13.5 Recruitment/Employment

The Recruitment/Employment function of the HR Department is the first point of contact prospective employees experience with NRAO. The strategies and tactics deployed in the recruitment and hiring of

qualified candidates are key in contributing not only our commitment to diversity but to achieving the overall mission of the Observatory.

FY2015

Workforce Management and Staffing Plan: Deliver an updated/revised Workforce Management Plan and the Staffing Plan.

FY2016

Workforce Management and Staffing Plan: This plan is reviewed annually to ensure it remains viable in support of the operational needs of the Observatory.

13.6 Human Resources

The Human Resources Department also provides programs and processes in support of ongoing employee engagement and employee relations, as well as the assessment of employees relative to filling/performing key/critical roles within the Observatory.

FY2015

During FY2015 the HR Department is furthering the employee engagement approach and enhancing the capabilities of the employees. NRAO HR will be advancing employee development with delivery of four key management/supervisory development courses and the design of two additional courses (detailed below). HR will initiate and lead the development of a succession planning process to ensure preparations are in place to identify and develop key leadership and technical staff pipeline talent. The recent implementation of the electronic performance evaluation system ensures engagement at all levels (up, down, and across) with real time interaction online in tracking, providing feedback and supporting completion of functional and development goals. The HR department will continue to support the total rewards philosophy (compensation, benefits, and employee development) of the organization through delivery of research and program recommendations for attaining a balance between cost effectiveness and employee satisfaction.

Succession Planning: Implement Phase I Succession Planning to identify top 5-7 key/critical roles and create a succession plan (readiness assessment, development plan, recruiting plan). Phase I involves the design/creation of a Succession Planning Guide which addresses the process of succession planning and career progression at varying levels in the organization (i.e. Executive, Management, Supervisory and career progression within all job families). Creation of this guide/process is followed on by identification of key leadership and technical succession candidates for the top 5-7 key/critical roles identified. Next steps incorporate the readiness assessment, development plans for candidates and finally strategic recruiting plans absent any readily identified internal candidates.

FY2016

Succession Planning: Implement Phase II Succession Planning to review effectiveness of new process, made adjustments as necessary. Identify additional critical roles and create a succession plan accordingly (readiness assessment, development plan, recruiting plan). Phase II is an extension, refresh and course correct of Phase I activities of the prior year.

13.7 Human Resources Major Milestones

Table 13.7.1: HR FY2015 Major Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Policy	NRAO HR Policy Manual	1			
Training	Deliver Management/Supervisory Development courses		2		
	Design 2 New Management/Supervisor Development courses			3	
Compensation	Complete first 'just in time' electronic (PEP) performance appraisal process cycle	4			
	Salary Review Process		5		
	Benchmarking and Survey Participation				6
	Job Description Builder Module added to Halogen			7	
Benefits	Health Benefits Open Enrollment	8			
	Comprehensive Benefits Wellness Program			9	
	Health Plan Design/Review				10
Employment	Workforce Management/Staffing Plan		11		
Human Resources	Succession Planning			12	

Milestones:

1. Complete the final revisions, formatting and refinement of the combined Supervisor's Manual and Employee Handbook and ensure posting readiness to NRAO internal website. Obtain appropriate legal review and final review/ approval from NRAO and AUI.
2. Deliver 4 newly designed Mgmt/Supervisory courses. Courses are: 1. Time off/Attendance/FML, 2. Harassment /Bullying/Discrimination, 3. The Electronic PEP Process, and 4. Effective Planning and Goal Setting
3. Design 2 new Mgmt/Supervisory courses.
4. Ensure all reconfiguration changes/improvements are complete in order to launch the electronic PEP process for the FY2014 performance period.
5. All preparations complete and salary review worksheets are open to pay decision managers for final merit review decisions.
6. Participate in all credible/scheduled salary survey sources and conduct analysis of benchmark jobs.
7. Job Description Builder module added to Halogen System. HR Staff will be trained on how to be administrators/users.
8. HR prepares and distributes all open enrollment materials to employees and makes enrollment changes into JDE and with vendors.
9. Create and deliver targeted wellness program and processes to address high frequency/high cost illness/injury areas to employees and the Observatory. Proactively identify others trending towards high frequency/high cost.
10. NRAO HR partners with AUI to review and identify health plan design changes for the next calendar year.
11. Update WFM and Staffing Plans
12. Implement Phase I Succession Planning

Deliverables:

1. Updated HR Policy Manual posted to the NRAO internal website. Begin communications to employees and process of acknowledgement from employees.
2. All employees supervising other employees scheduled for/attend courses.
3. Design of 2 new courses complete and ready for delivery: 1. Performance Management – effective delivery of the Performance Appraisal, the (PIP) Performance Improvement Process, and the (IDP) Individual Development Plan Process, and 2. Compensation 101 – how do we determine and deliver compensation at NRAO.
4. All electronic PEPs are complete for NRAO covering performance for FY2014.
5. Merit pay increases delivered to employees on time.
6. Updated report of 20 benchmark jobs complete.
7. Job Description Builder Module is available to begin loading and updating NRAO job descriptions.
8. All employee records are updated and accurate with new employee benefit information for payroll and vendor processing.
9. Wellness programs and processes which engage employees in proactive and preventative measures yielding lower frequency/lower cost over time and better quality of life for Observatory employees.
10. Health Plan changes resulting in cost containment/cost reduction for the Observatory ensuring any/all enhancements for the benefit of the employee are a key consideration.
11. Revised WFM and Staffing Plans
12. Identify top 5-7 key/critical roles and create succession plan (readiness assessment, development plan, recruiting plan)

Table 13.7.2: HR FY2016 Major Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Training	Deliver 2 New Management/Supervisor Development courses		1		
Benefits	Health Benefits Open Enrollment	2			
Compensation	Performance Evaluation Process	3			
	Salary Review Process		4		
	Benchmarking and Survey Participation				5
Human Resources	Succession Planning			6	
	Employee Climate Survey			7	

Milestones:

1. Deliver two new Management/Supervisor development courses: 1. Performance Management, and 2. Comp 101
2. HR prepares and distributes all open enrollment materials to employees and makes enrollment changes into JDE and with vendors.
3. Annual Performance Review Process
4. All preparations complete and salary review worksheets are open to pay decision managers for final merit review decisions.
5. Participate in all credible/scheduled salary survey sources and conduct analysis of benchmark jobs.
6. Evaluate/refine/expand the process
7. Employee Climate Survey Design and Delivery

Deliverables:

1. All employees supervising other employees scheduled for/attend courses.
2. All employee records are updated and accurate with new employee benefit information for payroll and vendor processing.
3. All electronic PEPs are complete for FY2015 performance against objectives
4. Merit pay increases delivered to employees on time.
5. Updated report of 20 benchmark jobs complete.
6. Identify more critical jobs for succession planning
7. Feedback and Action Planning to address areas for improvement

13.8 Human Resources Financial Charts

Table 13.8.1: FY2015 by Fund Source and Location

Work Breakdown Structure	Internal Common Costs						GRAND TOTAL	
	Charlottesville		Green Bank		Socorro			
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟4000 Administrative Services								
⊟4100 Business Services								
⊞4160 HR	563,748	4.4	98,456	1.0	153,757	2.0	815,961	7.4
4000 Administrative Services Total	563,748	4.4	98,456	1.0	153,757	2.0	815,961	7.4
Grand Total	563,748	4.4	98,456	1.0	153,757	2.0	815,961	7.4

Table 13.8.2: FY2015 Expenditures by Object

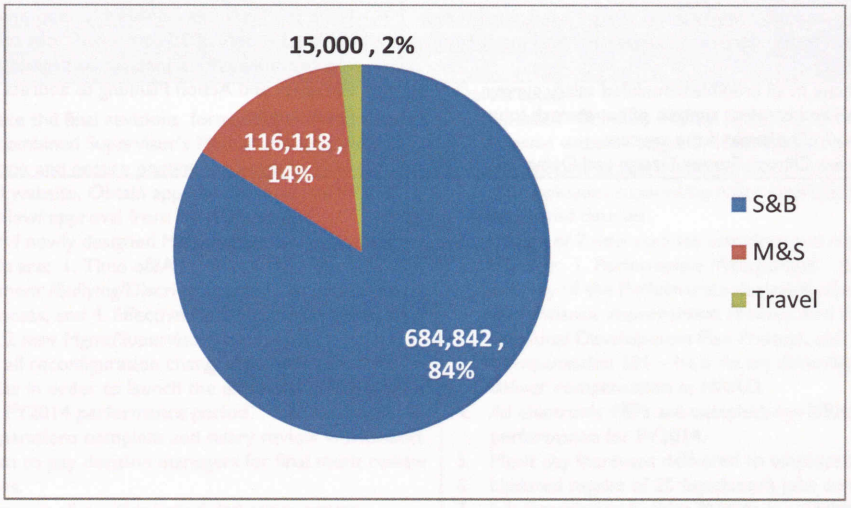


Table 13.8.3: FY2016 by Fund Source and Location

Work Breakdown Structure	Internal Common Costs						GRAND TOTAL	
	Charlottesville		Green Bank		Socorro			
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟4000 Administrative Services								
⊟4100 Business Services								
⊞4160 HR	563,748	4.4	98,456	1.0	153,757	2.0	815,961	7.4
4000 Administrative Services Total	563,748	4.4	98,456	1.0	153,757	2.0	815,961	7.4
Grand Total	563,748	4.4	98,456	1.0	153,757	2.0	815,961	7.4

14 COMMUNICATIONS

The Communications Office (COM) collaborates with scientific staff and the Director's Office to communicate NRAO science, vision, accomplishments, and plans to the science community, NRAO/AUI staff, and key external stakeholders, including NRAO advisory committees, the NSF, and the U.S. Congress. Specific activities for COM in FY2015 and FY2016 are described below.

FY2015

In FY2015, COM will organize an effective Observatory presence at major FY2015 science community meetings, beginning with the 4-8 January 2015 AAS meeting in Seattle, WA. Two COM proposals have already been accepted for this AAS meeting: (1) a proposal for a two-hour evening NRAO Town Hall on 6 January 2015; and (2) a proposal for a daylong U.S. Radio Futures Workshop on 4 January 2015. This Workshop will provide a forum for community discussion of the long-term scientific, technological, and community development for the Jansky VLA and ALMA, and the successors to current long-wavelength arrays such as the HERA, MWA, LWA. COM will also redesign the NRAO exhibit for the January 2015 AAS, improving its visual appeal and reducing its weight.

In place of its usual summer 2015 meeting, the AAS will organize and host the XXIXth International Astronomical Union General Assembly 3-14 August 2015 in Honolulu, HI. In addition to scientific staff participation, COM will organize the NRAO exhibit for this major tri-annual astronomy community meeting.

To help communicate NRAO science to the broader scientific community, a science symposium proposal was submitted by COM at the late April 2014 deadline for the 2015 AAAS Annual Meeting (12-16 February 2015) in San Jose, California. This proposal was peer-reviewed and accepted in July 2014. Titled *Building Galaxies: Some Assembly Required*, this 3-hour symposium will feature six speakers who will explore how the new generation of radio telescopes is revolutionizing our understanding of galaxy formation. Another science symposium proposal will be organized and submitted by the late April 2015 deadline for the 2016 AAAS Annual Meeting (11-15 February 2016, Washington, DC). This symposium will feature a diverse set of speakers who will present the most compelling new science emerging from the NRAO user community.

COM and CIS will collaborate and organize an NRAO exhibition and technical presence at the International Conference for High Performance Computer Networking, Storage, and Analysis (SC14) that will be held 16-21 November 2014 in New Orleans, Louisiana.

COM will design and publish a *2014 NRAO Annual Report* in FY2015. This Report will feature calendar year 2014 science highlights from the community and NRAO scientific staff; major accomplishments at NRAO operational facilities; construction project status; R&D progress for next-generation facilities; community support activities; and public outreach and diversity highlights. This Report will be widely distributed on-line and in hardcopy.

In collaboration with the SSR team and scientific staff across the Observatory, COM will continue to design, manage, and improve the high-level content of the NRAO science web site in FY2015. COM will also continue to edit, improve, publish, and expand the subscription base for the Observatory's monthly electronic newsletter, *NRAO eNews*, and the periodic electronic announcements series, *NRAO Announcements*, which enter FY2015 with 7,000+ subscribers in North America and around the world.

14.2 Communications Financial Charts

Table 14.2.1: FY2015 by Fund Source

Work Breakdown Structure	CSA-1 NRAO Ops		CSA-2 ALMA Ops		Internal Common Costs		Grand Total	
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟5000 Director's Office								
⊞5300 Communications	176,724	0.8	223,296	0.9	145,732	1.5	545,752	3.3
5000 Director's Office Total	176,724	0.8	223,296	0.9	145,732	1.5	545,752	3.3
Grand Total	176,724	0.8	223,296	0.9	145,732	1.5	545,752	3.3

Table 14.2.2: FY2015 Expenditures by Object

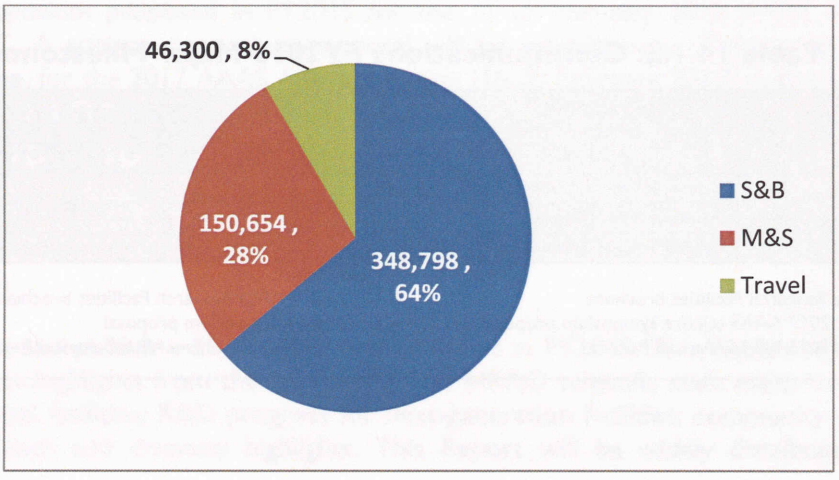


Table 14.2.3: FY2016 by Fund Source

Work Breakdown Structure	CSA-1 NRAO Ops		CSA-2 ALMA Ops		Internal Common Costs		Grand Total	
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟5000 Director's Office								
⊞5300 Communications	176,724	0.8	173,595	0.9	145,732	1.5	496,051	3.3
5000 Director's Office Total	176,724	0.8	173,595	0.9	145,732	1.5	496,051	3.3
Grand Total	176,724	0.8	173,595	0.9	145,732	1.5	496,051	3.3

FY2016

Complete Chart of Accounts development and implementation: The new chart of accounts design should be completed by the end of the third quarter. The fourth quarter will be dedicated to loading the chart of accounts to JD Edwards, testing, and training.

Prepare for CSA Close-outs: The process of reconciling and closing the current cooperative agreements and SPOs will begin in FY2016 and be finished after the books of the fiscal year are closed. Coordination with NSF will be required to assure a smooth close-out. This effort will be jointly managed with AUI Fiscal.

Prepare for the new Cooperative Agreement (if awarded): The new CA will begin on October 1, 2016. The administrative staff will and need to familiarize themselves with the agreement and prepare for the new fiscal year. A compliance matrix will be built to assure that all sections are understood and NRAO and AUI staff designated for responsibilities for each section.

15.2 Contracts and Procurement

The Contracts and Procurement Division seeks to procure for NRAO products and services in an efficient manner, utilizing competition to obtain the best product at the lowest price consistent with the specifications, performance, and delivery schedule. The goal is for the result of all procurements to provide the best overall value to NRAO. The division has a procurement manual in place to promote a common understanding of procurement objectives, to insure uniform interpretation of Cooperative Agreement requirements, NRAO policies, and other government laws and regulations in order to provide a basis for establishing management control, and to serve as a document for standard procedures and developing contracts and procurement personnel.

FY2015

Consultant Approval and Contracting Policy: This new policy section in the CAP manual will delineate the differences between contractors, consultants, and vendors.

Grants Life-cycle Training Program: This training program will take Principal Investigators from proposal preparation and submittal through closeout.

FY2016

Revise Contracts and Procurement Policy Manual: The manual had a thorough review and renewal in FY2012. This review will determine what changes and updates are required.

Revise Export Compliance Manual: The most recent changes were completed and implemented in 2013 and 2014. This review will determine what changes and updated are required.

15.3 Environmental, Safety and Security

The mission of the NRAO Environment, Safety and Security (ES&S) Office is to support NRAO's long-term commitment to its safety and security responsibilities to NRAO employees, visitors, contractors and casual visitors. The mission of ES&S includes support of NRAO's commitment to environmental protection of the Observatory facilities. Site Safety Officers are located at each NRAO Facility.

FY2015

Implement Safety Data Sheet (SDS) Hazard Communication database: Implementation of centralized record keeping for compliance with the OSHA requirements for Hazard Communication for employees will be a major effort in FY2015. The centralized records will consist of the utilization of a Safety Data Sheet database that will be accessible to all NRAO staff. The system will enable access from any site including the NRAO remote facilities. Successful implementation will include production of training documentation to ensure competency in use of the system. System administrators within the ES&S staff will be responsible for maintenance of the system. The targeted implementation of this system is by the end of Q2, FY2015.

Complete training modules for Supervisory ES&S training: The training of supervisory and management staff is an essential part of an effective ES&S culture. In FY2015, ES&S will complete supervisory safety training to include potential multiple modules for roles and responsibilities, workers compensation management, and OSHA compliance. The ES&S training will be offered to all supervisors and will commence by Q3, FY2015.

FY2016

Select and implement ES&S recordkeeping system: Efforts for ES&S in FY2016 include the selection and implementation of a safety training recordkeeping database. The recordkeeping requirements for ES&S activities are clearly identified in regulatory compliance legislation and NRAO policy requirements. In this year, alternatives for recordkeeping systems will be reviewed, evaluated, and selections made. The system will be fully implemented and populated with existing records. In addition, the record system will be evaluated for ability to maintain confidential ES&S medical records. The full implementation of the Safety Training Records Database will be complete by Q1, FY2016.

Complete all offered ES&S training for supervisory staff: The continued training of supervisory and management staff will be fully completed in FY2016. The sessions will be offered in accordance with ES&S Safety Training Plan and attendance recorded. The objective of the required training will be to support managerial competencies in ES&S processes and management methodologies. The Supervisor Safety Training will be completed by Q3, FY2016.

15.4 Management Information Systems

Management Information Systems (MIS) is responsible for all ERP (Enterprise Resource Planning) Business Software for AUI and NRAO. This includes the Oracle JD Edwards ERP software. These systems support a variety of areas, including AUI Fiscal and Payroll, reporting, timekeeping, and cost pool calculations.

FY2015

Enterprise Resource Planning software - A top-level gap analysis review of the JD Edwards enterprise resource planning (ERP) system, which we began this year in conjunction with AUI, will be received in by FY15 Q2. That analysis will be reviewed for its operational and compliance significance and we will be considering any necessary enhancements that are identified as required. New modules will be reviewed with key stakeholders (AUI Fiscal, CAP, HR and Business Services) to determine their value. Budget and risk analysis will be take place before any significant changes (AUI has already signaled

Commercialize one additional technology: Potential technologies will be identified from the Intellectual Property register. A selection committee will review the technologies and submit one or more for approval to the Director. Commercialization efforts will then begin.

Investigate holding second NRAO Astronomy and Biomed Imaging conference: If the first conference is held and is successful, consideration will be given to making it an annual event.

15.6 Department Wide

Recent budget constraints have led to a reduction or elimination of travel by Administration staff for business and training. The number of site visits that can be supported have fallen to once a year; an appropriate or ideal level would be two-three visits per year. Training and attendance at conferences can only be offered to department managers, or on a rotating basis to other staff if the manager does not attend. The clear result is a negative impact on professional development.

Grants Management/Internal Audit Position: In conjunction with AUI, we believe it would be beneficial to add a Grants Manager position to the Budgets Division to provide further depth to our grant and award management processes. The Grant Manager would assist in pre- and post-award activities, assisting PIs in their grant applications, monitoring expenses and progress during the grant term, and assuring that renewals, grant close-out, and final reports are completed before the required deadlines. Additionally, the person will be used to perform internal audit projects. This position is not funded and at present is on hold pending receipt of the final 2015 budget from NSF.

OMB "Super Circular" compliance: Our plan contemplates further training for key NRAO staff and reviews of internal controls and processes in order to ensure the amended administrative requirements, cost principle reforms and audit requirements brought about by the introduction of the OMB Uniform Administrative Requirements, Cost Principles and Audit Requirements for Federal Awards (the "Super Circular" or "Omni Circular") are properly embedded.

Table 15.7.2: Administration FY2016 Major Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Business Services	Complete chart of accounts development and implementation				1
	Prepare for CSA Close-outs				2
	Prepare for new CA (if awarded)				3
	Prepare GB and VLBA finances for semi-autonomous operations				4
CAP	Revise Contracts and Procurement Manual		5		
	Revise Export Compliance Manual			6	
ES&S	Select and implement ES&S recordkeeping system	7			
	Complete all offered ES&S training for supervisory staff			8	
MIS	Load new Chart of Accounts				9
	Review, consider and prepare a report to recommend enhancements for JD Edwards applications, such as electronic timekeeping, payroll uploads, and a tools release.		10		
	Move Servers to Charlottesville				11
TTO	Commercialize one additional technology				12
	If NRAO Astronomy and Biomed Imaging conference held in 2015, hold follow-up conference			13	

Milestones:

1. Complete and test new chart of accounts. Provide training.
2. Review balances in CSA and SPO Accounts and prepare for closing.
3. Familiarization with new Cooperative Agreement (if awarded) and preparation for budget loading.
4. Separate and balance Green Bank and VLBA accounts.
5. Update manual. Review and approval by Assoc. Director of Administration. Training.
6. Update manual. Review and approval by Assoc. Director of Administration and AUI.
7. Determine technical solution to Safety Recordkeeping requirements.
8. Complete ES&S supervisory training.
9. Load and testing of new Chart of Accounts.
10. Prepare list of possible improvements, upgrades and additions. Calculate effort, cost, and benefit of each change.
11. MIS servers relocated from Green Bank to Charlottesville
12. Identify from IP Asset Register, review choices through selection committee, begin commercialization efforts.
13. Prepare follow-up program based on prior year agenda.

Deliverables:

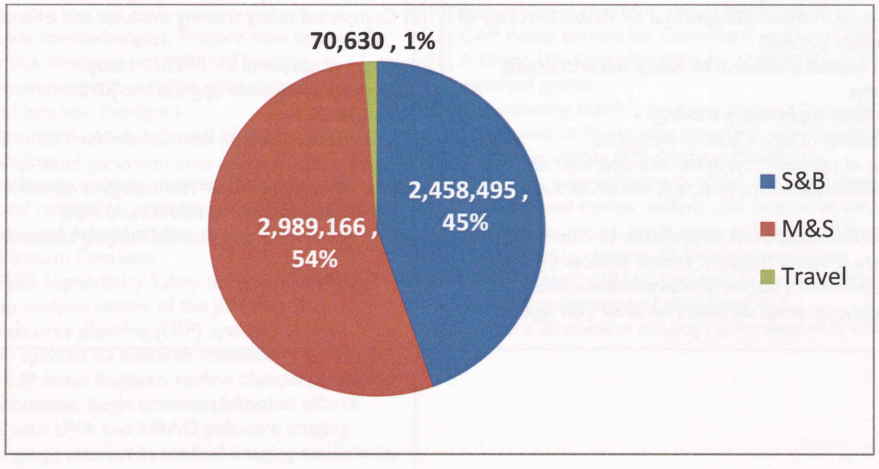
[1] New Chart of Accounts for FY2017.
[2] Accounts will be closed after the end of FY2016
[3] New CA set-up in budgeting and accounting systems.
[4] GB and VLBA accounts separated and prepared for divestiture.
[5] Updated version of the CAP Manual.
[6] Updated version of the Export Compliance Manual.
[7] Populated safety recordkeeping database.
[8] Completed safety training modules and offered training sessions.
[9] Chart of accounts for FY2017 ready.
[10] Report of possible upgrades to JD Edwards systems and applications.
[11] Purchase and install new servers for MIS in Charlottesville and establish a real-time mirroring back-up system.
[12] An additional NRAO Technology is commercialized and providing income to NRAO and AUI.
[13] 2nd Astronomy and Biomed imaging conference held.

15.8 Administration Financial Charts

Table 15.8.1: FY2015 by Location

	ICC - Internal Common Costs									
	Charlottesville		Green Bank		Socorro		Observatory Wide		TOTAL, ICC	
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟2000 Development Programs										
⊟2100 Business Development										
⊟2120 Commercialization	156,000	1.0							156,000	1.0
2121 Commercialization	156,000	1.0							156,000	1.0
2000 Development Programs Total	156,000	1.0							156,000	1.0
⊟4000 Administrative Services										
⊟4100 Business Services										
⊞4110 Business Office	956,920	5.5					160,058	0.0	1,116,978	5.5
⊞4130 CAP	504,510	5.0	41,264	1.0	152,667	3.0			698,441	9.0
⊞4140 MIS			523,849	3.5	75,600	1.0			599,449	4.5
⊞4150 ESS	80,734	0.0	235,695	2.3	154,789	2.0			471,218	4.3
⊟4200 Facilities										
⊞4220 Communication							519,711	0.0	519,711	0.0
⊞4240 Leases	1,938,848	1.0							1,938,848	1.0
⊞4260 Vehicles	17,646	0.0							17,646	0.0
⊞4800 NRAO Internal Common Costs	(0)	0.0							(0)	0.0
4000 Administrative Services Total	3,498,658	11.5	800,808	6.8	383,056	6.0	679,769	0.0	5,362,291	24.3
Grand Total	3,654,658	12.5	800,808	6.8	383,056	6.0	679,769	0.0	5,518,291	25.3

Table 15.8.2: FY2015 Expenditures by Object (excluding revenue and recoveries)



16.5 Spectrum Management Major Milestones

Table 16.5.1: Spectrum Management FY2015 Major Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Spectrum management	Iridium	1			
	ITU-R	2			
	ITU-R	3			
	ITU-R			4	
	IUCAF				5
WV Radio Quiet Zone	Replace propagation software				6

Milestones:	Deliverables:
1. Initial discussions	1. Background materials
2. SG7 WP 7D meetings	2. Draft recommendation; revised reports
3. WP 5B meeting	3. Revised radar report
4. CPM15-2	4. Consensus radio astronomy views
5. Assume IUCAF chair at IAU GA	5. Assume IUCAF chair at IAU GA
6. Replace propagation software for WV quiet zones	6. Software in place, being tested

Table 16.5.2: Spectrum Management FY2016 Major Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Spectrum management	ITU-R	1			
WV Radio Quiet Zone	Replace propagation software		2		

Milestones:	Deliverables:
1. WRC-15	1. Briefing papers
2. WV Radio Quiet Zones	2. Fully documented software

16.6 Spectrum Management Financial Chart

Table 16.6.1: FY2015 by Fund Source and Location

Work Breakdown Structure	CSA-1 NRAO Ops						Internal Common Costs		Grand Total	
	Green Bank		Socorro		Subtotal, CSA-1		Charlottesville			
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟1000 Telescope Operations										
⊟1300 Spectrum Management										
⊞1310 Interference Suppression	89,886	0.9	2,000	-	91,886	0.9			91,886	0.9
⊞1320 NRQZ Management	156,232	1.9			156,232	1.9			156,232	1.9
⊞1330 Anechoic Chambers	21,870	0.2			21,870	0.2			21,870	0.2
⊞1340 International Spectrum Management							68,419	0.3	68,419	0.3
1000 Telescope Operations Total	267,988	3.0	2,000	-	269,988	3.0	68,419	0.3	338,407	3.3
Grand Total	267,988	3.0	2,000	-	269,988	3.0	68,419	0.3	338,407	3.3

Table 16.6.2: FY2015 Expenditures by Object

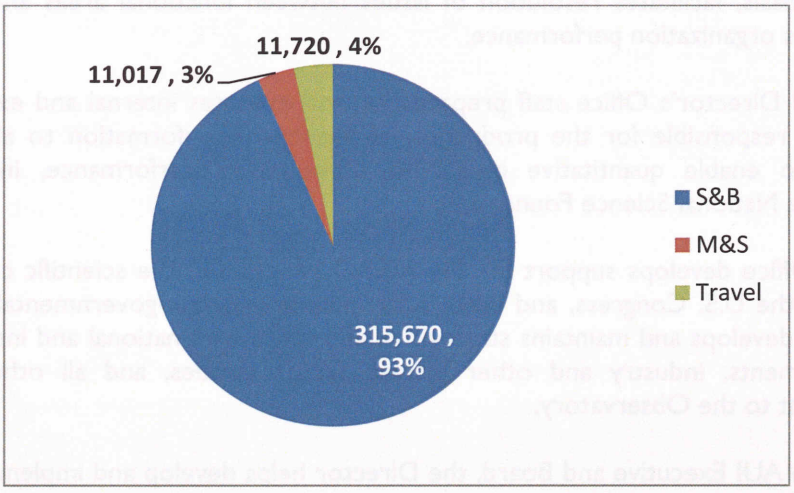


Table 16.6.2: FY2016 by Fund Source and Location

Work Breakdown Structure	CSA-1 NRAO Ops						Internal Common Costs		Grand Total	
	Green Bank		Socorro		Subtotal, CSA-1		Charlottesville			
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟1000 Telescope Operations										
⊟1300 Spectrum Management										
⊞1310 Interference Suppression	89,886	0.9	2,000	-	91,886	0.9			91,886	0.9
⊞1320 NRQZ Management	156,232	1.9			156,232	1.9			156,232	1.9
⊞1330 Anechoic Chambers	21,870	0.2			21,870	0.2			21,870	0.2
⊞1340 International Spectrum Management							68,419	0.3	68,419	0.3
1000 Telescope Operations Total	267,988	3.0	2,000	-	269,988	3.0	68,419	0.3	338,407	3.3
Grand Total	267,988	3.0	2,000	-	269,988	3.0	68,419	0.3	338,407	3.3

17 DIRECTOR'S OFFICE

The NRAO Director's Office establishes, refines, and disseminates the mission, vision and overall strategic goals of NRAO through a proactive and continuous assessment of needs and priorities of the organization and the scientific community. The Director's Office plays a significant role in formulating and executing national priorities for research in radio astronomy and other areas of astronomy and strives to grow the radio astronomy community and improve the scientific relevance of radio techniques and observations.

Providing strong leadership to NRAO management, including recruiting and supervising senior staff, the Director works with the senior staff to ensure that the Observatory's science mission and operational requirements are appropriately translated into the specific plans and deliverables and executed effectively, including appropriate delegation of roles, resources and responsibilities throughout the organization. The Director's Office nurtures collaboration amongst NRAO staff, communicating openly with staff at all levels, seeking input, creating an environment of trust across the Observatory, and providing positive feedback in a timely and constructive manner. The Director manages the Observatory on a day-to-day basis, facilitates resolution of issues between functional areas and departments, and routinely monitors organization performance.

The Director and Director's Office staff prepares for and executes internal and external Observatory reviews, and are responsible for the production of appropriate information to all stakeholders in a timely manner to enable quantitative insight to Observatory performance, including the annual deliverables to the National Science Foundation.

The Director's Office develops support for the NRAO program in the scientific community and with funding agencies, the U.S. Congress, and local, state, federal and non-governmental organizations. The Director's Office develops and maintains strategic relationships with national and international agencies, partners, governments, industry and other private sector entities, and all other stakeholders or customers relevant to the Observatory.

Working with the AUI Executive and Board, the Director helps develop and implement AUI's vision for the NRAO scientific mission and organizational management. The Director informs the AUI Board of Trustees about all NRAO strategic and policy issues through regular and appropriate communications, bringing emerging issues forward in a timely fashion.

To continue to facilitate the alignment of AUI Corporate priorities and operational priorities at NRAO, we will perform joint capacity planning for the joint initiatives which are considered key, reviewing their risks, their key activities and the timing, milestones and resources required. In this way, we increase the mutual understanding of each entity's needs, clarify direction and generate consensus and teamwork.

FY2015

The Director's Office will represent NRAO and the North American science community interests to the ALMA Director's Council and the ALMA Board. The AUI Visiting Committee meets every other year; a comprehensive update on NRAO progress against the Committee recommends from their FY2014 report will be delivered to AUI and the Committee. The Director's Office will organize the annual face-to-face meeting with the NRAO Users Committee, as well as a mid-year telecon update. New Users Committee members will be appointed early in the year. The Director's Office will organize and host the annual NSF Program Review and will participate in the ALMA Completion Review.

Director's Office personnel meet with each of the AUI Board of Trustees and the AUI Executive Committee three times per year.

FY2016

The Director's Office will represent NRAO and the North American science community interests to the ALMA Director's Council and the ALMA Board. The AUI Visiting Committee will hold a face-to-face meeting at NRAO. The Director's Office will organize the annual face-to-face meeting with the NRAO Users Committee, as well as a mid-year telecon update. New Users Committee members will be appointed early in the year. Director's Office personnel meet with each of the AUI Board of Trustees and the AUI Executive Committee three times per year.

APPENDIX A: FINANCIAL PLAN

The financial charts presented in the body of the POP have been produced with an organizational view of the Observatory. Most charts are organized as:

Organization – Observatory Department

Fund Source – CSA-1 NRAO Ops; CSA2 ALMA Ops; the Internal Common Cost (ICC) pool; or Development funds

Location – the site at which the activity is taking place or which controls the budget.

Fund Sources

The POP tracks activity through four fund sources. These are:

- NSF AST CSA-1 NRAO Operations – for the operations, maintenance and management of NRAO including the GBT, VLA, VLBA and CDL.
- NSF AST CSA-2 ALMA Operations – for the operations, maintenance and management of ALMA and the NAASC.
- Internal Common Cost Pool – the mechanism used to allocate common and management expenses across the total pool of observatory activity (further described below).
- Development Funds – these are funds available as net proceeds from work for others (WFO) and ALMA development awards. Development projects for FY2016 have not yet been assigned by the Observatory or awarded by ALMA. Anticipated expenditures are reserved in WBS2200-Technology Development. CSA funded development activity is shown in the WBS 2xxx series under the relevant fund source.

In addition to these fund sources which comprise the direct NSF mandated mission of the Observatory, NRAO will also receive and do work on approximately $3.5M (in each of FY2015 and FY2016) in external grants and contracts which are not reported in the POP.

Compensation Assumptions

Compensation amounts are the salary and benefits allocation for the actual staff proposed to do the work. Due to funding constraints there is no raise pool budgeted in FY2015 or FY2016.

Many staff positions perform work for multiple work objectives (see Work Breakdown Structure). In those cases, the expected FTE and prorated salary are associated with the work objective. Thus it is possible for portions of the salary of one position to be shown in multiple places in the budget.

Benefits Assumptions

The costs for the following employee benefits are treated as a pool: employer retirement contributions, FICA, employer paid medical and dental plan contributions, wellness initiatives, worker's compensation, unemployment, life insurance, and tuition. This pool is liquidated across AUI to all salary, wage, and leave expenditures, excluding the JAO and LSM staff. The benefits rate is a budget allocation and recovery mechanism and applies whether or not the incumbent is eligible for/receives all the noted benefits.

The FY2015 and FY2016 benefits rate is 35%.

Paid time off (PTO) benefits, e.g. vacation, sick time, etc. are not separately budgeted or pooled for NRAO staff. Each position is budgeted, within its organizational structure, to receive full salary. Payroll expenditures are recorded as a combination of worked time and PTO charged to the budgetary unit according to AUI's 'Pay as you Go' Leave Policies and payroll practice.

Observatory-wide Departments

There are several departments which provide programmatic support and services to all the telescopes and/or sites. These units are: Data Management Services (DMS); Education and Public Outreach (EPO); Science Support and Research (SSR); and the Central Development Laboratory (CDL). This section will describe the mechanism by which these groups are funded and how that appears in the budget for each CSA.

In keeping with the common cost approach, the lead executive of each department participates in overall Observatory Management. Their compensation, but not their support costs which are categorized as direct costs depending on the specific expense, are included in the ICC pool.

Data Management Services: Archive storage equipment and media is charged to the CSA for which it stores data. Algorithm development operations are split based on the science application that they serve.

Education and Public Outreach: Core competency staff and equipment (graphics, web designers, illustrators, exhibit designers) are allocated to each CSA. In practice and real time, staff will charge to the programs as they work on them. Public Information Officers are designated for each instrument and charged to that CSA. Tour and gift shop revenue from the visitor centers in Green Bank and at the VLA offsets the costs of operating the visitor center. FY2015 is the first year that visitors will be charged at the VLA. The revenue is shown in the revenue section on the summary sheet. Throughout the year, the sites may host film crews for commercial shoots. That revenue is recorded as program income and used by EPO to improve the program. Note that the Assistant Director for EPO is directly charged to the CSA's rather than the common cost pool.

Science Support and Research: Senior science leadership and support which administers the scientific staff according to a common set of principles and guidelines is charged to common costs. In general, science staff is designated to a specific CSA. Library materials are charged to common costs. Page charges, which also show up under the Library WBS, are charged to the individual CSA's.

Central Development Lab: This department includes the senior functional leadership, core disciplinary coverage, Chem and Cryo lab support and equipment, and certain core technician support. CSA-2 includes funding for Offsite-Hardware Maintenance. Some of the staff that perform this work are organizationally aligned with the CDL. CDL staffing levels and disciplinary mix assumes that a conservative 50% of the ALMA (CSA-2) development awards will be made to the CDL and that not all awarded funding will be expended in the same fiscal year. The CDL also performs WFO, component sales and externally funded research which contribute to supporting its overall staffing and resource level. The CDL sells amplifiers, receivers, and other miscellaneous parts or components to other radio astronomy organizations. These sales are booked as program income and directly offset equipment and supply purchases.

Auxiliaries

EPO, Green Bank and New Mexico operate auxiliary operations captured in WBS 4300. These include the NM Guest House, Visitor Centers and Gift Shops in both Green Bank and at the VLA site, and multiple food service and housing programs in Green Bank. These operations are managed to break even overall.

ALMA

The JAO contribution of $16.8M (FY2015) is shown in CSA-2 in WBS 1510, Telescope Operations Management. This includes the Canadian contribution to the JAO. Note that the Canadian contribution to the ALMA project ($1.657M) is shown as revenue in addition to the NSF allocation in the Financial Plan. The Canadian contribution supplies 7.25% of ALMA development funding and JAO operations.

The $2.4M (FY2015) and $1M (FY2016) equipment budgets are North America's final contributions to the permanent power supply in Chile. The Office of Chile Affairs (OCA) is budgeted to be $1M and can be found in WBS 4110, Administrative Services, Business Office.

Cost Recovery

NRAO's current ICC practices are described below. While NRAO is statutorily exempt from A-122, nonetheless, this practice complies with OMB Circular-A122, "Cost Principles for Non-Profit Organizations."

AUI/NRAO uses a two tiered structure to recover overhead and distribute common costs, the AUI Indirect Cost rate (IDC) and the NRAO ICC. The AUI IDC recovers AUI corporate costs, including fiscal operations, associated with the administration and management of the National Radio Astronomy Observatory. The ICC distributes costs that apply to all NRAO activities. These costs are charged as 'Other Direct Costs' and allocated to all fund sources (e.g. CSA-1, CSA-2, plus any other NRAO development, WFO projects or external grants) in accord with the Direct Allocation Method as described in A-122.

For FY2015 and FY2016 the ICC rate is 30% and shown in WBS 4800. External recoveries are shown as revenues. The general approach taken by NRAO in charging and allocating costs to awards is as follows:

- All allowable direct costs are charged directly to awards.
- Allowable direct costs that can be identified to more than one program are pro-rated individually as direct costs using a base most appropriate to the particular cost being prorated.
- Costs that cannot be readily identified with a particular final cost objective – those costs included in the Internal Cost Rate - are allocated to modified total direct costs (MTDC) within the NRAO's general ledger.

Elements in the Internal Common Cost (ICC) Pool

The ICC rate is applicable to a specified fiscal year and is based on an estimate of costs to be incurred during that period. ICC are defined as those allowable costs associated with the management, administrative, facilities, and service functions of NRAO which benefit all fund sources.

The NRAO ICC include the following NRAO functions:

- Management and Administration

- Human Resources
- Procurement
- Management Information Systems
- Departmental Management
- Environment Safety and Security
- Technology Transfer Office
- Site warehouses (with observatory wide functions)
- Internal Communications
- Offsite Vehicles
- Observatory Metrics/Stats
- HQ Visiting and User's Committee
- Site Specific Management and Administration
- Computer Information Systems
- Legal/Broker Fees
- Insurances
- Archives
- Facility, utilities and plant maintenance for specified facilities
- Division of Science and Academic Affairs – Management and Library Services
- Allocation of Fringe Benefits Cost Pool
- Allocation of Employee Leave Costs

Utilities expenses for NRAO's office buildings are shown in Internal Common Costs. Power expense for the telescopes is budgeted as a telescope expense in WBS 4230.

Allocation Base

The NRAO Indirect Cost Recovery (ICR) is developed and applied to all final cost objectives including unallowable direct costs. The ICR is applied to a MDTC base. MTDC consists of all salaries and wages, fringe benefits, materials and supplies, services, travel, and subgrants and subcontracts up to the first $25,000 of each subaward (regardless of the period covered by the subaward).

MTDC excludes the following costs:

- Participant support costs
- Equipment and capital expenditures over $5,000
- The portion in excess of $25,000 of each subgrant or subcontract
- Recovery and allocation of ICC incurred

Identification of MTDC and ICC

To identify and classify MTDC and ICC, AUI/NRAO follows the guidance contained in the direct allocation method as stated in the Cost Principles for Non-Profit Organizations (OMB Circular A–122 Revised May 10, 2004).

In general, after MTDC has been identified and assigned directly to all final cost objectives, as appropriate, ICC are those remaining costs. AUI/NRAO maintains internal controls to ensure that no cost is charged to both MTDC and as an ICC to any award. The NRAO Head of Observatory Budgets and AUI Chief Financial Officer will make determinations, as necessary, related to identification and reporting of MTDC and ICC.

Contract End Salary Accrual Reserve: At present, exempt staff at NRAO are paid on the last day of each month for a work period that ends on the 20th of that month. This leaves an eight day period at the end of the cooperative agreement which must be booked to the current CA's. This reserve addresses a portion of that accrual. No adjustment is required for the non-exempt staff.

Other: Miscellaneous external revenue sources. In FY2015 and FY2016 these include funds from the VLA visitor center entry fees and sales of IP addresses.

Work Breakdown Structure (WBS)

NRAO tracks activity and associated budgets and expenditures utilizing a Work Breakdown Structure (WBS). The WBS allows like activities to be tracked across multiple sites, instruments or fund sources allowing for comparison of work, effort, and costs. The WBS definitions were created in conjunction with the operating units of the Observatory assuring that the definitions correspond with actual work units. WBS effort captured includes FTE's, salary and benefits budgets, travel budgets, and materials, equipment and supplies. The WBS dictionary is included here Appendix F.

Table A.1: FY2015 Financial Plan

Funding	CSA-1		CSA-2		Development		ICC		TOTAL	
NSF Allocations	40,000,000		40,171,000						80,171,000	
Carry-Over	1,660,000		4,046,000		2,130,000				7,836,000	
Canadian ALMA Contr.			1,657,000						1,657,000	
Sale of Telescope Time: VLBA	1,081,000						313,490		1,394,490	
Sale of Telescope Time: GBT	1,310,000								1,310,000	
External Common Cost Recovery							879,254		879,254	
ALMA Development Awards					2,200,000				2,200,000	
WFO Proceeds					887,739				887,739	
Other	90,000								90,000	
Grand Total	44,141,000		45,874,000		5,217,739		1,192,744	-	96,425,483	
	Expense	FTE's	Expense	FTE's	Expense	FTE's	Expense	FTE's	Expense	FTE's
⊟1000 Telescope Operations										
⊞1100 Maintenance	6,877,293	78.6	2,342,396	14.1					9,219,689	92.7
⊞1200 Operations	5,573,695	59.9	1,982,828	14.0					7,556,523	73.8
⊞1300 Spectrum Management	269,988	3.0					68,419	0.3	338,407	3.3
⊞1400 Infrastructure Mods & Upgrades	1,567,413	12.3	2,400,000	0.0	0	0.0			3,967,413	12.3
⊞1500 Management	3,677,211	26.9	16,881,813	0.5					20,559,024	27.4
1000 Telescope Operations Total	17,965,601	180.7	23,607,037	28.6	0	0.0	68,419	0.3	41,641,057	209.6
⊟2000 Development Programs										
⊞2100 Business Development							548,775	2.8	548,775	2.8
⊞2200 Technology Development	1,839,670	15.2	5,359,202	0.0	3,624,063	5.0			10,822,935	20.2
⊞2300 R&D Support	426,419	4.5							426,419	4.5
⊞2400 Software Development	299,784	2.3							299,784	2.3
⊞2500 Management	220,682	0.3	266,799	1.0			230,369	1.0	717,850	2.3
2000 Development Programs Total	2,786,555	22.2	5,626,001	1.0	3,624,063	5.0	779,144	3.8	12,815,763	32.0
⊟3000 Science Operations										
⊞3100 Observatory Time Allocation	156,074	1.2							156,074	1.2
⊞3200 Reference	65,000	0.0	97,500	0.0			496,151	2.8	658,651	2.8
⊞3300 Broader Impacts	598,020	4.6	646,794	0.3					1,244,814	4.9
⊞3400 Scientific Staff	699,093	6.2	710,766	6.5					1,409,859	12.7
⊞3500 Management	139,635	1.6	558,364	2.7			1,225,403	5.7	1,923,402	10.0
⊞3600 Scientific User Services	3,817,296	26.8	4,613,496	37.0					8,430,792	63.8
3000 Science Operations Total	5,475,118	40.3	6,626,920	46.5			1,721,554	8.5	13,823,592	95.3
⊟4000 Administrative Services										
⊞4100 Business Services	684,494	5.1	1,063,185	9.1			6,443,007	54.8	8,190,685	68.9
⊞4200 Facilities	4,273,942	29.5					3,915,091	2.6	8,189,032	32.1
⊞4300 Auxiliaries	68,621	13.4							68,621	13.4
⊞4500 Management	194,690	2.2					552,067	3.0	746,756	5.2
⊞4800 NRAO Internal Common Costs	9,032,766	0.0	3,397,083	0.0	1,223,921	0.0	(13,653,770)	0.0	(0)	0.0
4000 Administrative Services Total	14,254,512	50.1	4,460,268	9.1	1,223,921	0.0	(2,743,607)	60.4	17,195,094	119.5
⊟5000 Director's Office										
⊞5100 Program Management							474,391	2.7	474,391	2.7
⊞5200 Public Outreach	729,244	8.7	706,622	5.0					1,435,866	13.7
⊞5300 Communications	176,724	0.8	223,296	0.9			145,732	1.5	545,752	3.3
⊞5500 Administration	0	0.0					747,110	3.1	747,110	3.1
⊞5800 AUI Fee and IDC	2,582,076	0.0	2,018,690	0.0	369,755	0.0			4,970,521	0.0
5000 Director's Office Total	3,488,044	9.5	2,948,608	5.9	369,755	0.0	1,367,232	7.3	8,173,639	22.7
Grand Total	43,969,830	302.8	43,268,834	91.0	5,217,739	5.0	1,192,743	80.3	93,649,146	479.0
NET	171,170		2,605,166		0		1		2,776,337	

Table A.2: FY2016 Financial Plan

Funding	CSA-1, NRAO Ops		CSA-2 ALMA Ops		Development		Common Cost Recovery		TOTAL	
NSF Allocations	42,230,000		40,350,000						82,580,000	
Carry-Over	171,170		2,605,166						2,776,336	
Canadian ALMA Contr.			1,706,710						1,706,710	
Sale of Telescope Time: VLBA	1,102,150						198,797		1,300,947	
Sale of Telescope Time: GBT	1,287,500								1,287,500	
External Common Cost Recovery							1,073,755		1,073,755	
ALMA Development Awards					2,741,421				2,741,421	
WFO Proceeds					1,300,000				1,300,000	
Contract End Salary Accrual Reserve	(664,347)		(241,500)						(905,847)	
Other	50,000								50,000	
Grand Total, Funding	44,176,473		44,420,376		4,041,421		1,272,552	-	93,910,822	
	Expense	FTE's	Expense	FTE's	Expense	FTE's	Expense	FTE's	Expense	FTE's
1000 Telescope Operations										
⊞1100 Maintenance	6,870,860	78.5	2,203,811	14.1					9,074,671	92.6
⊞1200 Operations	5,790,793	61.8	1,678,204	13.0					7,468,997	74.7
⊞1300 Spectrum Management	269,988	3.0					68,419	0.3	338,407	3.3
⊞1400 Infrastructure Mods & Upgrades	1,365,464	10.7	1,000,000	0.0	0	0.0			2,365,464	10.7
⊞1500 Management	3,770,232	27.5	17,221,451	0.5					20,991,683	28.0
1000 Telescope Operations Total	18,067,337	181.5	22,103,466	27.6	0	0.0	68,419	0.3	40,239,222	209.4
⊟2000 Development Programs										
⊞2100 Business Development							612,461	2.8	612,461	2.8
⊞2200 Technology Development	1,839,670	15.2	5,084,812	0.0	2,891,207				9,815,689	15.2
⊞2300 R&D Support	426,419	4.5							426,419	4.5
⊞2400 Software Development	299,784	2.3							299,784	2.3
⊞2500 Management	187,800	0.0	278,190	1.0			230,369	1.0	696,359	2.0
2000 Development Programs Total	2,753,673	21.9	5,363,002	1.0	2,891,207		842,830	3.8	11,850,712	26.7
⊟3000 Science Operations										
⊞3100 Observatory Time Allocation	156,074	1.2							156,074	1.2
⊞3200 Reference	65,000	0.0	63,000	0.0			496,151	2.8	624,151	2.8
⊞3300 Broader Impacts	598,020	4.6	632,687	0.3					1,230,707	4.9
⊞3400 Scientific Staff	699,093	6.2	653,861	6.0					1,352,954	12.2
⊞3500 Management	139,635	1.6	577,313	2.7			1,235,740	5.7	1,952,688	10.0
⊞3600 Scientific User Services	3,808,296	26.8	4,600,717	36.8					8,409,013	63.5
3000 Science Operations Total	5,466,118	40.3	6,527,578	45.7			1,731,891	8.5	13,725,587	94.5
⊟4000 Administrative Services										
⊞4100 Business Services	612,193	5.1	1,065,270	9.1			6,450,752	54.8	8,128,214	68.9
⊞4200 Facilities	4,267,535	29.5					3,922,862	2.6	8,190,396	32.1
⊞4300 Auxiliaries	48,621	13.4							48,621	13.4
⊞4500 Management	234,076	2.5					552,067	3.0	786,142	5.5
⊞4800 NRAO Internal Common Costs	9,219,224	0.0	3,559,293	0.0	884,984	0.0	(13,663,501)	0.0	0	0.0
4000 Administrative Services Total	14,381,648	50.4	4,624,563	9.1	884,984	0.0	(2,737,821)	60.4	17,153,374	119.8
⊟5000 Director's Office										
⊞5100 Program Management							474,391	2.7	474,391	2.7
⊞5200 Public Outreach	729,244	8.7	662,957	5.0					1,392,201	13.7
⊞5300 Communications	176,724	0.8	173,595	0.9			145,732	1.5	496,051	3.3
⊞5500 Administration							747,110	3.1	747,110	3.1
⊞5800 AUI Fee and IDC	2,601,729	0.0	2,082,411	0.0	265,230	0.0			4,949,370	0.0
5000 Director's Office Total	3,507,697	9.5	2,918,963	5.9	265,230	0.0	1,367,232	7.3	8,059,122	22.7
Grand Total	44,176,473	303.7	41,537,572	89.2	4,041,421	0.0	1,272,552	80.3	91,028,018	473.1
NET	(0)		2,882,804		-		(0)		2,882,804	

APPENDIX B: FUNDING BY DEPARTMENT AND OBJECT

Table B.1: FY2015 Funding by Department and Object

	Salaries & Benefits	Materials & Supplies	Equipment	Travel	Internal Transfers	Revenue	TOTAL
ALMA Operations *	5,104,328	23,343,516	2,400,000	691,565		-	31,539,409
Business Administration	2,458,495	2,989,166	-	70,630	-	-	5,518,291
Central Development Laboratory	5,681,508	1,660,979	-	307,327		-	7,649,814
CIS	1,403,221	805,164	-	21,712		-	2,230,097
Communications	348,798	150,654	-	46,300		-	545,752
Data Management & Software	6,962,569	827,245	-	149,638		-	7,939,452
Director's Office	561,485	103,831	-	81,795	4,970,521	-	5,717,631
Education & Public Outreach	1,178,602	536,396	-	43,200		(383,620)	1,374,577
Grants & WFO	608,342	70,210	-	-		-	678,552
Human Resources	684,842	116,118	-	15,000		-	815,961
New Initiatives Office	383,011	-	-	9,764		-	392,775
New Mexico Operations	11,933,633	4,308,736	-	134,885		-	16,377,254
Project Management Office	446,802	13,589	-	14,000		-	474,391
Scientific Support & Research	3,564,216	631,147	8,000	268,959		-	4,472,321
Spectrum Management	315,670	11,017	-	11,720		-	338,407
West Virginia Operations	6,212,237	1,704,525	-	82,700		(415,000)	7,584,462
Grand Total	47,847,760	37,272,291	2,408,000	1,949,194	4,970,521	(798,620)	93,649,146
FY15 Expenditures by Fund Source and Object							
	Salaries & Benefits	Materials & Supplies	Equipment	Travel	Internal Transfers	Revenue	TOTAL
C01	26,471,551	6,130,161	8,000	543,896	11,614,842	(798,620)	43,969,830
C02	9,746,172	24,908,711	2,400,000	798,178	5,415,773	-	43,268,834
DEV	2,421,407	961,656	-	241,000	1,593,676	-	5,217,739
OH1	9,208,630	5,271,764	-	366,120	(13,653,770)	-	1,192,743
Grand Total	47,847,760	37,272,291	2,408,000	1,949,194	4,970,521	(798,620)	93,649,146

*NAASC and JAO Ops only

Table B.2: FY2016 Funding by Department and Object

	Salaries & Benefits	Materials & Supplies	Equipment	Travel	Internal Transfers	Revenue	TOTAL
ALMA Operations*	5,004,061	24,312,307	-	569,265		-	29,885,633
Business Administration	2,464,240	3,008,469	-	70,630	-	-	5,543,340
Central Development Laboratory	3,480,168	3,427,554	-	66,327		-	6,974,049
CIS	1,403,221	805,164	-	21,712		-	2,230,097
Communications	354,097	95,654	-	46,300		-	496,051
Data Management & Software	7,087,062	677,245	-	149,638		-	7,913,945
Director's Office	561,485	103,831	-	81,795	4,949,369	-	5,696,480
Education & Public Outreach	1,198,139	471,396	-	43,200		(383,620)	1,329,114
Grants & WFO	614,557	66,149	-	-		-	680,706
Human Resources	684,842	116,118	-	15,000		-	815,961
New Initiatives Office	446,697	-	-	9,764		-	456,461
New Mexico Operations	11,944,091	4,296,123	-	134,885		-	16,375,100
Project Management Office	446,802	13,589	-	14,000		-	474,391
Scientific Support & Research	3,564,216	596,647	8,000	268,959		-	4,437,821
Spectrum Management	315,670	11,017	-	11,720		-	338,407
West Virginia Operations	6,150,776	1,581,986	-	82,700		(435,000)	7,380,462
Grand Total	45,720,125	39,583,248	8,000	1,585,894	4,949,369	(818,620)	91,028,018
FY16 Expenditures by Fund Source and Object							
	Salaries & Benefits	Materials & Supplies	Equipment	Travel	Internal Transfers	Revenue	TOTAL
C01	26,574,852	6,047,391	8,000	543,896	11,820,953	(818,620)	44,176,473
C02	9,856,875	25,363,115	-	675,878	5,641,703	-	41,537,572
DEV		2,891,207	-		1,150,214	-	4,041,421
OH1	9,288,398	5,281,535	-	366,120	(13,663,501)	-	1,272,552
Grand Total	45,720,125	39,583,248	8,000	1,585,894	4,949,369	(818,620)	91,028,018

*NAASC and JAO Ops only

APPENDIX C: ALL CSA-1 EXPENDITURES

Table C.1: FY2015 ALL CSA-1 Expenditures (Part 1 of 2)

	NRAO Ops, CSA-1											
	GBT		VLA		VLBA		Other		NON- TELESCOPE		GRAND TOTAL	
Work Breakdown Structure	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟1000 Telescope Operations												
⊟1100 Maintenance												
⊟1110 Corrective												
1111 Unscheduled			1,762,113	20.0	1,311,483	14.6					3,073,597	34.6
1112 Scheduled	60,741	0.6	1,010,438	11.1	585,538	6.6	1,000	0.0			1,657,717	18.3
1114 Software					200	0.0					200	0.0
⊟1120 Preventive												
1121 Scheduled	246,879	3.2	1,386,412	18.5	60,873	0.3	8,476	0.1			1,702,641	22.0
1122 Painting	203,171	3.0					1,000	0.0			204,171	3.0
1123 Inspections	175,000	0.0									175,000	0.0
1125 Telescope Structure	63,968	0.8									63,968	0.8
⊟1200 Operations												
⊞1210 Scheduling	39,195	0.3	55,979	0.4	67,729	0.6			3,997	0.0	166,901	1.4
⊟1220 Operating												
1221 Observing	346,564	5.7	345,121	6.0	821,976	10.2	500	0.0			1,514,161	21.9
1222 Recording & Media Distribution			13,368	0.2	93,755	0.8					107,123	1.0
⊟1230 Support & Testing												
1231 Calibration	134,171	1.4	2,175	0.0	61,460	1.0					197,806	2.4
1232 Antenna Moves/Repositioning			72,195	1.1							72,195	1.1
1235 Systems Hardware Support	1,850,646	18.4									1,850,646	18.4
1236 Scientific Support	160,848	2.4	1,035,991	7.1	84,967	0.6					1,281,806	10.1
⊞1240 M&C Software	312,695	3.0	26,752	0.3	43,610	0.4					383,057	3.6
⊟1300 Spectrum Management												
⊞1310 Interference Suppression			1,400	0.0	600	0.0			89,886	0.9	91,886	0.9
⊞1320 NRQZ Management									156,232	1.9	156,232	1.9
⊞1330 Anechoic Chambers									21,870	0.2	21,870	0.2
⊟1400 Infrastructure Mods & Upgrades												
⊞1410 Small Scale R&D					202,829	1.5					202,829	1.5
⊞1420 Modifications	650,824	4.8	659,656	5.6	54,104	0.5					1,364,584	10.8
⊟1500 Management												
⊞1510 Telescope operations Mgmt	251,541	2.0	79,002	0.8	123,756	0.8			84,004	0.5	538,302	4.1
⊞1520 Science Support Mgmt	189,812	1.0	166,636	1.0	106,425	0.6					462,873	2.6
⊞1530 Mechanical Engineering Mgmt	75,149	0.5	608,277	4.2	31,273	0.2					714,699	4.9
⊞1540 Electronics Mgmt	175,269	1.5	307,003	2.0	175,074	1.4					657,347	4.8
⊞1550 Software Mgmt	97,078	0.8	1,103,621	8.9	103,291	0.9					1,303,990	10.5
1000 Telescope Operations Total	5,033,553	49.0	8,636,138	87.2	3,928,944	40.9	10,976	0.1	355,989	3.5	17,965,601	180.7
⊟2000 Development Programs												
⊟2200 Technology Development												
⊟2210 Enabling Technologies												
2211 Low Noise Amplifiers									293,110	3.0	293,110	3.0
2214 Receivers									362,235	2.6	362,235	2.6
2217 Phased Array Feeds									113,314	1.5	113,314	1.5
⊟2220 Production												
2221 Low Noise Amplifiers									379,658	3.7	379,658	3.7
2222 MM/SubMM Detectors									246,084	1.2	246,084	1.2
2223 Optics & EM Components									250,697	1.8	250,697	1.8
⊟2230 Next Generation Facilities												
2231 PAPER/HERA									194,572	1.4	194,572	1.4
⊟2300 R&D Support												
⊞2310 Machining									314,175	3.7	314,175	3.7
⊞2320 Chemistry Lab									112,244	0.8	112,244	0.8
⊞2400 Software Development									299,784	2.3	299,784	2.3
⊞2500 Management	32,882	0.3							187,800	0.0	220,682	0.3
2000 Development Programs Total	32,882	0.3							2,753,673	21.9	2,786,555	22.2

*All CSA-2 Expenditures are shown in Tables 2.7.1-2.7.3.

Table C.1: FY2015 ALL CSA-1 Expenditures (Part 2 of 2)

	NRAO Ops. CSA-1											
	GBT		VLA		VLBA		Other		NON-TELESCOPE		GRAND TOTAL	
Work Breakdown Structure	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟3000 Science Operations												
⊟3100 Observatory Time Allocation												
⊞3110 Tools & Documentation									60,575	0.5	60,575	0.5
⊞3120 Proposal Review & Time Allocat									95,500	0.7	95,500	0.7
⊟3200 Reference												
⊞3210 Library									65,000	0.0	65,000	0.0
⊟3300 Broader Impacts												
⊟3310 Student Programs												
3311 Undergraduate									95,714	1.0	95,714	1.0
3312 Graduate									185,781	1.0	185,781	1.0
⊞3320 Visitor Support									316,524	2.6	316,524	2.6
⊟3400 Scientific Staff												
⊟3410 Staff Research												
3411 NRAO Staff									207,935	0.0	207,935	0.0
3412 Jansky Fellows									325,196	4.2	325,196	4.2
3413 NRAO Postdocs									165,962	2.0	165,962	2.0
⊞3500 Management									139,635	1.6	139,635	1.6
⊟3600 Scientific User Services												
⊟3610 Community Support												
3611 User Assistance			3,428	0.1	47,216	0.7			1,006,662	5.9	1,057,306	6.7
3613 Workshops & Conferences									61,500	0.0	61,500	0.0
⊟3620 Science Data Processing												
3621 Data Processing Operations	445,648	2.1	281,655	0.7	36,469	0.3			97,478	1.1	861,250	4.2
⊟3630 Science Software												
3631 Post-Processing Software	222,395	1.9							801,203	6.5	1,023,598	8.3
3633 Data Access Software									627,892	6.1	627,892	6.1
3634 Application Software									185,749	1.5	185,749	1.5
3000 Science Operations Total	668,042	4.0	285,083	0.8	83,685	1.0			4,438,308	34.6	5,475,118	40.3
⊟4000 Administrative Services												
⊟4100 Business Services												
⊟4110 Business Office												
4111 Business Office									673,994	5.1	673,994	5.1
4112 Visitor Support									10,500	0.0	10,500	0.0
⊟4200 Facilities												
⊞4210 Plant Maintenance			304,718	6.0	65,000	0.0			477,287	12.3	847,004	18.3
⊞4220 Communication			27,000	0.0	60,500	0.0			262,692	0.0	350,192	0.0
⊞4230 Utilities	100,120	0.0	1,211,715	0.0	442,790	0.0	30,000	0.0	123,198	0.0	1,907,823	0.0
⊞4240 Leases					42,581	0.0					42,581	0.0
⊞4260 Vehicles			377,525	3.0	43,000	0.0			30,466	0.4	450,991	3.4
⊞4270 Central Instrument Shop			297,651	3.6	26,197	0.5			351,503	3.9	675,351	7.9
⊟4300 Auxiliaries												
⊞4310 Visitor Centers									72,765	1.2	72,765	1.2
⊟4320 Housing												
4321 Dorms									(11,000)	0.0	(11,000)	0.0
4322 Residence Hall									(68,438)	0.5	(68,438)	0.5
4323 Houses									(79,256)	0.9	(79,256)	0.9
⊟4330 Food Handling												
4331 Cafeteria									105,101	4.6	105,101	4.6
4332 Cafe									61,239	2.6	61,239	2.6
⊞4340 Gift Shops									(64,630)	2.9	(64,630)	2.9
⊞4350 Management									52,840	0.9	52,840	0.9
⊟4500 Management												
⊞4510 AD Mgmt									184,690	2.2	184,690	2.2
⊞4520 Community Relations									10,000	0.0	10,000	0.0
⊞4800 NRAO Internal Common Costs									9,032,766	0.0	9,032,766	0.0
4000 Administrative Services Total	100,120	0.0	2,218,608	12.6	680,068	0.5	30,000	0.0	11,225,716	37.1	14,254,512	50.1
⊟5000 Director's Office												
⊞5200 Public Outreach									729,244	8.7	729,244	8.7
⊞5300 Communications									176,724	0.8	176,724	0.8
⊞5500 Administration									0	0.0	0	0.0
⊞5800 AUI Fee and IDC									2,582,076	0.0	2,582,076	0.0
5000 Director's Office Total									3,488,044	9.5	3,488,044	9.5
Grand Total	5,834,598	53.2	11,139,829	100.5	4,692,697	42.4	40,976	0.1	22,261,730	106.7	43,969,830	302.8

*All CSA-2 Expenditures are shown in Tables 2.7.1-2.7.3.

Table C.2: FY2016 ALL CSA-1 Expenditures (Part 2 of 2)

Work Breakdown Structure	NRAO Ops, CSA-1											
	GBT		VLA		VLBA		Other		NON-TELESCOPE		GRAND TOTAL	
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟3000 Science Operations												
⊟3100 Observatory Time Allocation												
⊞3110 Tools & Documentation									65,052	0.5	65,052	0.5
⊞3120 Proposal Review & Time Allocat									91,022	0.7	91,022	0.7
⊟3200 Reference												
⊞3210 Library									65,000	0.0	65,000	0.0
⊟3300 Broader Impacts												
⊟3310 Student Programs												
3311 Undergraduate									95,714	1.0	95,714	1.0
3312 Graduate									185,781	1.0	185,781	1.0
⊞3320 Visitor Support									316,524	2.6	316,524	2.6
⊟3400 Scientific Staff												
⊟3410 Staff Research												
3411 NRAO Staff									207,935	0.0	207,935	0.0
3412 Jansky Fellows									325,196	4.2	325,196	4.2
3413 NRAO Postdocs									165,962	2.0	165,962	2.0
⊞3500 Management									139,635	1.6	139,635	1.6
⊟3600 Scientific User Services												
⊟3610 Community Support												
3611 User Assistance			3,428	0.1	47,216	0.7			1,006,662	5.9	1,057,306	6.7
3613 Workshops & Conferences									61,500	0.0	61,500	0.0
⊟3620 Science Data Processing												
3621 Data Processing Operations	445,648	2.1	281,655	0.7	36,469	0.3			97,478	1.1	861,250	4.2
⊟3630 Science Software												
3631 Post-Processing Software	222,395	1.9							792,203	6.5	1,014,598	8.3
3633 Data Access Software									627,892	6.1	627,892	6.1
3634 Application Software									185,749	1.5	185,749	1.5
3000 Science Operations Total	668,042	4.0	285,083	0.8	83,685	1.0			4,429,308	34.6	5,466,118	40.3
⊟4000 Administrative Services												
⊟4100 Business Services												
⊟4110 Business Office												
4111 Business Office									601,693	5.1	601,693	5.1
4112 Visitor Support									10,500	0.0	10,500	0.0
⊟4200 Facilities												
⊞4210 Plant Maintenance			304,718	6.0	65,000	0.0			466,819	12.3	836,536	18.3
⊞4220 Communication			27,000	0.0	60,500	0.0			262,692	0.0	350,192	0.0
⊞4230 Utilities	100,120	0.0	1,211,715	0.0	446,851	0.0	30,000	0.0	123,198	0.0	1,911,884	0.0
⊞4240 Leases					42,581	0.0					42,581	0.0
⊞4260 Vehicles			377,525	3.0	43,000	0.0			30,466	0.4	450,991	3.4
⊞4270 Central Instrument Shop			297,651	3.6	26,197	0.5			351,503	3.9	675,351	7.9
⊟4300 Auxiliaries												
⊞4310 Visitor Centers									72,765	1.2	72,765	1.2
⊟4320 Housing												
4321 Dorms									(11,000)	0.0	(11,000)	0.0
4322 Residence Hall									(78,438)	0.5	(78,438)	0.5
4323 Houses									(79,256)	0.9	(79,256)	0.9
⊟4330 Food Handling												
4331 Cafeteria									95,101	4.6	95,101	4.6
4332 Cafe									61,239	2.6	61,239	2.6
⊞4340 Gift Shops									(64,630)	2.9	(64,630)	2.9
⊞4350 Management									52,840	0.9	52,840	0.9
⊟4500 Management												
⊞4510 AD Mgmt									224,076	2.5	224,076	2.5
⊞4520 Community Relations									10,000	0.0	10,000	0.0
⊞4800 NRAO Internal Common Costs									9,219,224	0.0	9,219,224	0.0
4000 Administrative Services Total	100,120	0.0	2,218,608	12.6	684,128	0.5	30,000	0.0	11,348,791	37.4	14,381,648	50.4
⊟5000 Director's Office												
⊞5200 Public Outreach									729,244	8.7	729,244	8.7
⊞5300 Communications									176,724	0.8	176,724	0.8
⊞5800 AUI Fee and IDC									2,601,729	0.0	2,601,729	0.0
5000 Director's Office Total									3,507,697	9.5	3,507,697	9.5
Grand Total	5,907,440	53.8	11,136,613	100.4	4,695,986	42.4	40,976	0.1	22,395,458	107.0	44,176,473	303.7

*All CSA-2 Expenditures are shown in Tables 2.7.1-2.7.3.

Table D.1: FY2015 Funding by Instrument (Part 2 of 2)
(Includes Development Funding)

	ALMA		GBT		VLA		VLBA		Other		NON-TELESCOPE		GRAND TOTAL	
	Total	FTE's	Total	FTE's	Total	FTE's	Total	FTE's	Total	FTE's	Total	FTE's	Total	FTE's
⊟3000 Science Operations														
⊟3100 Observatory Time Allocation														
⊞3110 Tools & Documentation											60,575	0.5	60,575	0.5
⊞3120 Proposal Review & Time Allocat											95,500	0.7	95,500	0.7
⊟3200 Reference														
⊞3210 Library	97,500	0.0									435,668	2.0	533,168	2.0
⊞3220 Historical Archives											38,560	0.3	38,560	0.3
⊞3230 Metrics / Statistics											86,923	0.5	86,923	0.5
⊟3300 Broader Impacts														
⊟3310 Student Programs														
3311 Undergraduate											95,714	1.0	95,714	1.0
3312 Graduate	152,000	0.0									185,781	1.0	337,781	1.0
3313 Student Observing Support	280,000	0.0											280,000	0.0
⊞3320 Visitor Support	214,794	0.3									316,524	2.6	531,318	2.9
⊟3400 Scientific Staff														
⊟3410 Staff Research														
3411 NRAO Staff	120,000	0.0									207,935	0.0	327,935	0.0
3412 Jansky Fellows	393,944	4.0									325,196	4.2	719,140	8.2
3413 NRAO Postdocs	196,822	2.5									165,962	2.0	362,784	4.5
⊟3500 Management														
⊟3510 Management														
3511 Management	558,364	2.7									1,365,038	7.3	1,923,402	10.0
⊟3600 Scientific User Services														
⊟3610 Community Support														
3611 User Assistance	795,041	9.2			3,428	0.1	47,216	0.7			1,006,662	5.9	1,852,347	15.9
3612 Education & Training	366,796	2.1											366,796	2.1
3613 Workshops & Conferences	12,000	0.0									61,500	0.0	73,500	0.0
⊟3620 Science Data Processing														
3621 Data Processing Operations	1,520,413	10.0	445,648	2.1	281,655	0.7	36,469	0.3			97,478	1.1	2,381,663	14.2
3622 Data Analysis Tools	131,358	0.8											131,358	0.8
⊟3630 Science Software														
3631 Post-Processing Software	1,053,210	8.5	222,395	1.9							801,203	6.5	2,076,808	16.8
3633 Data Access Software											627,892	6.1	627,892	6.1
3634 Application Software	359,367	3.0									185,749	1.5	545,116	4.5
3635 Software Testing	375,311	3.4											375,311	3.4
3000 Science Operations Total	6,626,920	46.5	668,042	4.0	285,083	0.8	83,685	1.0			6,159,862	43.1	13,823,592	95.3
⊟4000 Administrative Services														
⊟4100 Business Services														
⊟4110 Business Office														
4111 Business Office	1,063,185	9.1									2,301,834	18.0	3,365,019	27.1
4112 Visitor Support											10,500	0.0	10,500	0.0
⊞4120 CIS											2,230,097	16.6	2,230,097	16.6
⊞4130 CAP											698,441	9.0	698,441	9.0
⊞4140 MIS											599,449	4.5	599,449	4.5
⊞4150 ESS											471,218	4.3	471,218	4.3
⊞4160 HR											815,961	7.4	815,961	7.4
⊟4200 Facilities														
⊞4210 Plant Maintenance					304,718	6.0	65,000	0.0			1,310,062	12.3	1,679,780	18.3
⊞4220 Communication					27,000	0.0	60,500	0.0			782,403	0.0	869,903	0.0
⊞4230 Utilities			100,120	0.0	1,211,715	0.0	442,790	0.0	30,000	0.0	606,229	0.0	2,390,854	0.0
⊞4240 Leases							42,581	0.0			1,938,848	1.0	1,981,429	1.0
⊞4260 Vehicles					377,525	3.0	43,000	0.0			171,191	2.0	591,715	5.0
⊞4270 Central Instrument Shop					297,651	3.6	26,197	0.5			351,503	3.9	675,351	7.9
⊟4300 Auxiliaries														
⊞4310 Visitor Centers											72,765	1.2	72,765	1.2
⊟4320 Housing														
4321 Dorms											(11,000)	0.0	(11,000)	0.0
4322 Residence Hall											(68,438)	0.5	(68,438)	0.5
4323 Houses											(79,256)	0.9	(79,256)	0.9
⊟4330 Food Handling														
4331 Cafeteria											105,101	4.6	105,101	4.6
4332 Cafe											61,239	2.6	61,239	2.6
⊞4340 Gift Shops											(64,630)	2.9	(64,630)	2.9
⊞4350 Management											52,840	0.9	52,840	0.9
⊞4400 Program Management											474,391	2.7	474,391	2.7
⊟4500 Management														
⊞4510 AD Mgmt											736,756	5.2	736,756	5.2
⊞4520 Community Relations											10,000	0.0	10,000	0.0
⊞4800 NRAO Internal Common Costs	3,397,083	0.0									(3,397,083)	0.0	(0)	0.0
4000 Administrative Services Total	4,460,268	9.1	100,120	0.0	2,218,608	12.6	680,068	0.5	30,000	0.0	10,180,421	100.1	17,669,485	122.2
⊟5000 Director's Office														
⊞5200 Public Outreach	706,622	5.0									729,244	8.7	1,435,866	13.7
⊞5300 Communications	223,296	0.9									322,456	2.4	545,752	3.3
⊞5500 Administration											747,110	3.1	747,110	3.1
⊞5800 AUI Fee and IDC	2,018,690	0.0									2,951,831	0.0	4,970,521	0.0
5000 Director's Office Total	2,948,608	5.9									4,750,641	14.2	7,699,249	20.0
Grand Total	46,203,897	91.0	6,038,598	54.5	11,139,829	100.5	4,692,697	42.4	40,976	0.1	25,533,149	190.7	93,649,146	479.0

APPENDIX E: COMMON COST EXPENSES BY LOCATION

Table E.1: FY2015 Common Cost Expenses by Location

Work Breakdown Structure	Charlottesville		Green Bank		Socorro		Observatory Wide		GRAND TOTAL	
	Total	FTE's	Total	FTE's	Total	FTE's	Total	FTE's	Total	FTE's
⊟1000 Telescope Operations										
⊟1300 Spectrum Management										
⊞1340 International Spectrum Management	68,419	0.3							68,419	0.3
1000 Telescope Operations Total	68,419	0.3							68,419	0.3
⊟2000 Development Programs										
⊟2100 Business Development										
⊞2110 Partnerships	392,775	1.8							392,775	1.8
⊞2120 Commercialization	156,000	1.0							156,000	1.0
⊞2500 Management	230,369	1.0							230,369	1.0
2000 Development Programs Total	779,144	3.8							779,144	3.8
⊟3000 Science Operations										
⊟3200 Reference										
⊞3210 Library	370,668	2.0							370,668	2.0
⊞3220 Historical Archives	38,560	0.3							38,560	0.3
⊞3230 Metrics / Statistics	86,923	0.5							86,923	0.5
⊞3500 Management	741,085	3.7	12,000	-	472,318	2.0			1,225,403	5.7
3000 Science Operations Total	1,237,236	6.5	12,000	-	472,318	2.0			1,721,554	8.5
⊟4000 Administrative Services										
⊞4100 Business Services	2,832,225	20.0	1,416,891	12.5	1,314,812	18.7	879,079	3.6	6,443,007	54.8
⊟4200 Facilities										
⊞4210 Plant Maintenance			464,776	-	368,000	-			832,776	-
⊞4220 Communication							519,711	-	519,711	-
⊞4230 Utilities			176,031	-	307,000	-			483,031	-
⊞4240 Leases	1,938,848	1.0							1,938,848	1.0
⊞4260 Vehicles	17,646	-	29,681	0.6	93,397	1.0			140,725	1.6
⊞4500 Management			202,780	1.0	349,287	2.0			552,067	3.0
⊞4800 NRAO Internal Common Costs	(13,653,770)	-							(13,653,770)	-
4000 Administrative Services Total	(8,865,052)	21.0	2,290,159	14.1	2,432,496	21.7	1,398,790	3.6	(2,743,607)	60.4
⊟5000 Director's Office										
⊞5100 Program Management	474,391	2.7							474,391	2.7
⊞5300 Communications	145,732	1.5							145,732	1.5
⊞5500 Administration	747,110	3.1							747,110	3.1
5000 Director's Office Total	1,367,232	7.3							1,367,232	7.3
Grand Total	(5,413,021)	38.9	2,302,159	14.1	2,904,814	23.7	1,398,790	3.6	1,192,743	80.3

Observatory Work Breakdown Structure (WBS) Dictionary

WBS Number	Observatory Development Programs
2	Observatory Development Programs
2.1	Business Development — The development of external partnerships, contracts, and funding streams .
2.1.1	Partnerships — Activities that seek to build development and operating relationships with external organizations.
2.1.1.1	Projects — BU's added as projects are defined
2.1.2	Commercialization — Activities that seek intellectual property protection and commercialization of NRAO technology.
2.1.2.1	Projects — BU's added as projects are defined
2.1.3	Technical Services — Provide technical services to external organizations.
2.1.3.1	Repair — Repair services for non-NRAO organizations
2.1.3.2	Production — Component production and sales to non-NRAO organizations
2.1.3.3	Technical Support — Provide technical services to non-NRAO organizations
2.2	Technology Development — The research, development and production of technology components for radio astronomy
2.2.1	Enabling Technologies — The development of the core enabling components and subsystems required by radio telescopes.
2.2.1.1	Low Noise Amplifiers — Cryogenic low-noise amplifiers development
2.2.1.2	Millimeter/Sub-MM Detectors — SIS mixers, HEB mixers, direct detectors, etc. development
2.2.1.3	Optics & EM Components — Optics & EM Components development
2.2.1.4	Receivers — Receiver development
2.2.1.5	Digital Signal Processing — Digital Signal Processing development
2.2.1.6	MMIC R&D — MMIC R&D
2.2.1.7	Phased Array Feeds — Phased Array Feeds Development
2.2.1.8	Unallocated Projects — BU's added as projects are defined, or funds reserved for TBD projects
2.2.2	Production — The incremental production of the core enabling components and subsystems required by radio telescopes.
2.2.2.1	Low Noise Amplifiers — Production of Low Noise Amplifiers
2.2.2.2	MM/SubMM Detectors — Production of MM/SubMM Detectors
2.2.2.3	Optics & EM Components — Production of Optics & EM Components
2.2.2.4	Receivers — Production of Receivers
2.2.2.5	Technical Support — Provide technical services to NRAO organizations
2.2.2.6	Repair and Maintenance — Repair services for NRAO organizations
2.2.3	Next Generation Facilities — Investigations into innovative concepts for the next generation radio facilities, e.g. HERA, nanoGRAV, SKA, etc.
2.2.3.1	PAPER/HERA — Research for the Precision Array to Probe the Epoch of Reionization (PAPER)
2.2.3.2	DARE — Research for the Dark Ages Radio Explorer (DARE)
2.2.3.3	NANOGrav — Research for the North American Nanohertz Observatory for Gravitational Waves (NANOGrav)
2.2.3.4	FASR — Research for the Frequency Agile Solar Radio telescope (FASR)
2.2.3.5	Projects — BU's added as projects are defined
2.2.3.6	SKA — Research in support of the Square Kilometer Array (SKA)
2.3	R&D Support — Infrastructure, administration, and services in support of R&D activities
2.3.1.1	Machining — Provide specialized high-precision machining capability for R&D activities
2.3.2.1	Chemistry Lab — Provide specialized plating and electroforming services for R&D activities
2.3.3.1	R&D Infrastructure — R&D infrastructure such as data links
2.4	Software Development — This element contains all software development activities for the ODP for the entire software development lifecycle: requirements development, architecture, software development, documentation, and internal testing by software developers (not users).
2.4.1	Software Development — This element contains all software development exclusive of visualization tools.
2.4.1.1	User Interface Development — This element includes both general purpose user-interface infrastructure development for enforcing similar look and feel on a variety of NRAO applications, and the development of small internal and external user facing web applications which are not captured under other WBS elements.
2.4.1.2	Pipeline Processing — Design, development, and developer testing of automated astronomical data reduction tasks. Includes filling, flagging, calibration, and editing functions (although not necessarily all for every observing mode). Also includes the production of log messages, web logs and plots, and quality assurance parameters.
2.4.2	Visualization Tools — This element contains software for the visualization of astronomical datasets by users of NRAO data outside of that provides part of post-processing software (e.g., CASA). As of the time of this writing (Jan 2014) there is no effort in this element.
2.4.2.1	Projects — BU's added as projects are defined
2.5	Management — Supervisory & Management Costs for ODP
2.5.1	R&D Management — Expenses such as Travel and Conferences for ODP Management and Supervisors, Software, Manuals, Books and other incidentals.
2.5.1.1	R&D Management — Expenses such as Travel and Conferences for ODP Management and Supervisors, Software, Manuals, Books and other incidentals.

Observatory Work Breakdown Structure (WBS) Dictionary

WBS Number					Observatory Admin Services
4.4	Program Mgmt				Oversight of the cooperative agreement activities. Coordination of reporting and planning.
4.4.1		Program Mgmt			Oversight of the cooperative agreement activities. Coordination of reporting and planning.
4.5	Management				Supervisory & Management Costs for OAS
4.5.1		AD Mgmt			Activities related directly to the support of the Site and administrative AD's Offices.
4.5.1.1			DO Operations		Administrative/Professional support of the Site Directors.
4.5.2.1			Community Relations		Support of local schools, clubs, sporting events, etc. with contributions of labor or materials for specific needs. May include unallowable expenses.
4.8	NRAO Overhead				Overhead fees/costs related to NRAO Administrative & Common Activities.
4.8.1.1		NRAO Overhead			Overhead fees/costs related to NRAO Administrative & Common Activities.
WBS Number					**Overall and NRAO Director's Office**
5	**NRAO Director's Office**				
5.2.1.1		Public Outreach			Education and engagement of students and the science-interested public in STEM concepts, the appeal of STEM careers, and insights into the nature of the universe provided by our science users and enabled by our facilities.
5.3.1.1		Communications			Communicate NRAO science, vision, accomplishments, and plans to key stakeholders
5.4.1.1		Academic Affairs			Management and oversight of the scientific staff and their career path activity.
5.5.1.1		Administration			Overall management staff and effort for the Observatory
5.8.1.1		AUI Fee and IDC			Payments to AUI for management services and oversight

FY2015 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
3.4		**New Mexico Operations**	
		VLA Science Operations	
	1	Define VLA capabilities to be offered for semester 2015B	12/31/2014
	2	Define VLA capabilities to be offered for semester 2016A	06/30/2015
	3	Update VLA documentation to support 2015B Call for Proposals, perform proposal technical reviews	03/31/2015
	4	Update VLA documentation to support 2016A Call for Proposals, perform proposal technical reviews	09/30/2015
	5	Determine baselines and pointing for antennas moving into their C configuration locations	12/31/2014
	6	Determine baselines and pointing for antennas moving into their CnB and B configuration locations	03/31/2015
	7	Determine baselines and pointing for antennas moving into their BnA and A configuration locations	06/30/2015
	8	Subarray observing automated and incorporated into dynamic scheduler	06/30/2015
	9	Incorporate 4-element API into regular operations	06/30/2015
	10	Complete VLITE tests requiring B configuration and integrate VLITE into operations	03/31/2015
	11	Testing and evaluation of new 3-bit samplers complete	09/30/2015
	12	Make frequency averaging available in the CBE to lower data rate	03/31/2015
		VLA Array Operations	
	13	Reconfigure array to C configuration	12/31/2014
	14	Reconfigure array to CnB, then B configuration	03/31/2015
	15	Reconfigure array to BnA, then A configuration	06/30/2015
	16	Reconfigure array to D configuration (part)	09/30/2015
	17	Establish DSOC control room for VLA Operations	03/31/2015
	18	Commence DSOC VLA Operations	06/30/2015
		VLA Antenna Maintenance	
	19	Perform 7 antenna overhauls during the course of the year	09/30/2015
	20	Replace one antenna azimuth bearing during the source of the year	09/30/2015
	21	Perform preventive maintenance on each of two transporters prior to array reconfiguration	12/31/2014
	22	Perform preventive maintenance on each of two transporters prior to array reconfiguration	06/30/2015
	23	Perform preventive maintenance on each of two transporters prior to array reconfiguration	09/30/2015
		VLA Track Maintenance	
	24	Identify and replace 5000 aging or damaged cross-ties during the course of the year	09/30/2015
	25	Identify and replace 5 antenna pad intersections during the course of the year	09/30/2015
		VLA Site Infrastructure Maintenance	
	26	Perform preventive maintenance on all VLA site transformers during the course of the year	09/30/2015
		VLA Technical Upgrades and Enhancements	
	27	L-Band solar upgrade, 2 additional receivers with full RF upgrade installed	03/31/2015

FY2015 Major Milestones			
POP Section Number	POP Milestone	Task Name	Completion Date
	28	X-Band solar upgrade, 3 additional receivers with 20 dB switched attenuators on outputs only, no solar Tcals, installed	06/30/2015
	29	X-Band solar upgrade, 3 additional receivers with solar Tcal path plus 20 dB switched attenuators installed	09/30/2015
	30	Ku-Band solar upgrade, 1 additional receiver with 20 dB switched attenuators on outputs only, no solar Tcals, installed	03/31/2015
	31	Ku-Band solar upgrade, 3 additional receivers with solar Tcal path plus 20 dB switched attenuators installed	09/30/2015
	32	S-Band solar upgrade, 3 additional receivers with solar Tcal path plus 20 dB switched attenuators installed	09/30/2015
	33	FE card cage upgrades, 35 units installed	03/31/2015
	34	C-Band thermal gap retrofits, 4 additional installed	09/30/2015
	35	L-Band thermal gap retrofits, 6 additional installed	09/30/2015
	36	FE cal board upgrades, 20 installed	09/30/2015
	37	Prototype FE noise diode temperature stabilization assembly tested	06/30/2015
	38	Replace the remaining legacy Q-Band receiver interface hardware sets	09/30/2015
	39	Install 3rd replacement ACU	06/30/2015
	40	Install 13 additional DTS transmitter modules with new 3-bit sampler boards	06/30/2015
	41	Install prototype F318 module in antenna	12/31/2014
	42	Install 10 production F318 modules in antennas	06/30/2015
		VLA Observing Capability Enhancements	
	43	Commission and document P-Band spectroscopy and polarimetry for 2016B	09/30/2015
	44	Commission and document pulsar observing modes for 2016B	09/30/2015
	45	Evaluate 6 MJP feeds and write performance memo	06/30/2015
		VLA Operational Enhancements	
	46	Improve robustness of reference pointing solutions	09/30/2015
	47	Implement old-style VLA (stepped) tipping scans	06/30/2015
	48	Commission and document use of switched power calibration in CASA	09/30/2015
	49	Develop heuristics for polarization calibration for the VLA calibration pipeline	06/30/2015
	50	Commission and document improvements to ionospheric calibration	03/31/2015
	51	Development in support of VLA Sky Survey, as specified in the VLASS Technical Implementation Plan	09/30/2015
		VLBA Science Operations	
	52	Define VLBA capabilities to be offered for semester 2015B	12/31/2014
	53	Define VLBA capabilities to be offered for semester 2016A	06/30/2015
	54	Update VLBA documentation to support 2015B Call for Proposals, perform proposal technical reviews	03/31/2015
	55	Update VLBA documentation to support 2016A Call for Proposals, perform proposal technical reviews	09/30/2015
		VLBA Antenna Maintenance	
	56	Tiger Team maintenance campaign to OV	06/30/2015
	57	Tiger Team maintenance campaign to SC	09/30/2015

FY2015 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
	39	Implement PST updates for Semester 2016A Call for Proposals	06/30/2015
	40	Implement PHT updates for Semester 2015B TAC Meeting	03/31/2015
	41	Implement PHT updates for Semester 2016A TAC Meeting	09/30/2015
	42	Implement OPT updates for Semester 2015A VLA Observing	12/31/2014
	43	Implement OPT updates for Semester 2015B VLA Observing	06/30/2015
	44	Create Architecture for Observatory Tools	03/31/2015
	45	Expand CASA Test Scope	06/30/2015
	46	Hand over ALMA Testing to Chile	09/30/2015
8.5		**Program Management Department**	
		Headquarters	
	1	SOP and Templates available	03/31/2015
	2	Quarterly Status Updates	12/31/2014
			03/31/2015
			06/30/2015
			09/30/2015
	3	Program Operating Plan (if required)	09/30/2015
	4	Long Range Plan (if required)	09/30/2015
	5	Annual Progress Summary	09/30/2015
		New Mexico	
	6	Finalize NM Ops and DMS Training Plan (1st Phase)	12/31/2014
	7	PM 101 Training	03/31/2015
	8	SE 101 Training	09/30/2015
	9	Retrospective Analysis of CASA 4.4 Release	06/30/2015
	10	Host learning session	12/31/2014
	11	Host learning session	03/31/2015
	12	Host learning session	06/30/2015
	13	Host learning session	09/30/2015
		Central Development Laboratory	
	14	Develop Training Plan	12/31/2014
	15	Training lessons provided	12/31/2014
	16	Training lessons provided	03/31/2015
	17	Training lessons provided	06/30/2015
	18	Training lessons provided	09/30/2015
	19	Facilitate Concept Feasibility Gate	06/30/2015
	20	Call for Study Proposals	03/31/2015
		Green Bank	
	21	Finalize Green Bank Training Plan	12/31/2014
	22	PM/SE Implementation Training	03/31/2015
	23	Host learning session	12/31/2014
	24	Host learning session	03/31/2015
	25	Host learning session	06/30/2015
	26	Host learning session	09/30/2015
10.3		**Education and Public Outreach**	
		STEM Education	
	1	Second round of SJS professional development meetings for educators	12/31/2014
			03/31/2015
			06/30/2015

FY2015 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
	2	Curriculum development for SJS web portal complete	06/30/2015
	3	Develop "vision" for new VLA Visitor/Education Center	12/31/2014
	4	Develop plan for VLA Visitor/Education Center Capital Fundraising Campaign	03/31/2015
	5	Develop VLA Visitor/Education Center business/operations plan	06/30/2015
	6	Create VLA Visitor/Education Center exhibit theming plan.	09/30/2015
	7	Decide upon admission fee structure for existing VLA Visitor Center	12/31/2014
	8	Implement new admission fee at VLA Visitor center on 1 January 2015	03/31/2015
	9	Complete Interpretive Training for J. Stanley and L. Baric	06/30/2015
	10	Complete plan for recruitment and training of VLA Visitor Center volunteer guides	09/30/2015
	11	STEM Career Day at Dominion Virginia Electric	12/31/2014
	12	10th Grade STEM Day at Piedmont Virginia Community College (if invited)	03/31/2015
	13	STEM Career Focus videos	09/30/2015
	14	SPOT: Introduce new feature presentation	12/31/2014
	15	SPOT: Recruit new UVa-based undergraduate ambassadors	12/31/2014
		News and Public Information	
	16	Convert NRAO public website to Joomla 3 CMS	12/31/2014
	17	New server-based popular content caching	06/30/2015
	18	New planetary system content for The Milky Way Explorer	12/31/2014
	19	New Local Group content for The Milky Way Explorer	09/30/2015
	20	Functional spec and design completed for "RadioSky" app	12/31/2014
	21	iOS version of "RadioSky" app ready for beta testing	06/30/2015
11.4		**Computing & Information Services**	
	1	Cross training for coverage between sites	03/31/2015
	2	ITIL training for staff	09/30/2015
	3	CCE coordination meeting	12/31/2014
	4	Migration to Windows 7 compete	12/31/2014
	5	Evaluation of Windows 8	06/30/2015
	6	Migration to RHEL 6	03/31/2015
	7	Replace Network Attached Storage in GB	06/30/2015
	8	Document Management system	03/31/2015
	9	Network upgrade review	03/31/2015
	10	Bro IDS installed at gigabit speeds	09/30/2015
	11	Service availability and location review	09/30/2015
	12	Replacement of end-of-life Video Hub	12/31/2014
	13	Replacement of legacy room reservation SW	03/31/2015
	14	Use of thin clients to replace desktops	09/30/2015
12.3		**Diversity**	
		Diversity Council	
	1	Office of Diversity Initiatives/Diversity Council	03/31/2015
	2	ODI review diversity portfolio/programs, plans to establish metrics	06/30/2015
	3	ODI – host external diversity review committee, coordinate logistics of NAC III workshop, prepare budget	09/30/2015

FY2015 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
14.1		**Communications**	
		Science Communications	
	1	Complete science meeting exhibit re-design	12/31/2014
	2	Update Research Facilities brochure	12/31/2014
	3	Submit 2016 AAAS science symposium proposal	06/30/2015
	4	Publish 2014 NRAO Annual Report	09/30/2015
15.7		**Administration**	
		Business Services	
	1	Index and box ALMA Construction documents. Identify and contract with an off-site storage facility	09/30/2015
	2	Establish a time-line and strategize the design of a new chart of accounts.	03/31/2015
	3	Gather and enter all final revenues, expenses, and adjustments	06/30/2015
	4	Review current methodologies. Prepare new ones and review with site directors and NRAO Director	03/31/2015
		CAP	
	5	Design policy, review and socialize with assistant directors and business managers	12/31/2014
	6	Design program and obtain approval of Assoc. Director of Administration	03/31/2015
	7	Design a purchasing training program for users of the purchasing and requisition systems and obtain approval of Assoc. Director of Administration	06/30/2015
		ES&S	
	8	Implement Hazcom Database	03/31/2015
	9	Complete ES&S Supervisory Safety training modules	06/30/2015
		MIS	
	10	Top-level gap analysis review of the JD Edwards enterprise resource planning (ERP) system	03/31/2015
	11	Load new or updated JD Edwards modules	09/30/2015
		TTO	
	12	Identify from IP Asset Register, review choices through selection committee, begin commercialization efforts	09/30/2015
	13	Collaborate with UVA and NRAO software imaging designers to gauge interest in medical imaging conference. Raise money for conference	06/30/2015
16.5		**Spectrum Management**	
		Spectrum Management	
	1	Iridium: Initial discussions	12/31/2014
	2	ITU-R: SG7 WP 7D meetings	12/31/2014
	3	ITU-R: WP 5B meeting	12/31/2014
	4	ITU-R: CPM15-2	06/30/2015
	5	IUCAF: Assume IUCAF chair at IAU GA	09/30/2015
		WV Radio Quiet Zone	
	6	Replace propagation software for WV quiet zones	09/30/2015

FY2015 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
17.1		**Director's Office**	
		ALMA	
	1	ALMA Board Meeting	12/31/2014
			03/30/2015
			06/30/2015
			09/30/2015
	2	ALMA Director's Council	12/31/2014
			03/30/2015
			06/30/2015
			09/30/2015
	3	ALMA Completion Review	03/31/2015
		Corporate Meetings	
	4	AUI Board of Trustees meetings	12/31/2014
			03/30/2015
			06/30/2015
	5	AUI Executive Committee meetings	12/31/2014
			06/30/2015
			09/30/2015
		Science Community	
	6	Appoint new Users Committee members	12/31/2014
	7	Users Committee meeting	06/30/2015
		Management Review	
	8	NSF Annual Program Review	12/31/2014
	9	All Hands presentation	12/31/2014
			06/30/2015
		Reports	
	10	New Strategic Plan	06/30/2015

FY2016 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
2.6		**Atacama Large Millimeter/submillimeter Array (ALMA)**	
		Operations	
	1	Cycle 3 observing & operations begin Q1, ongoing through Q4	12/31/2015
			03/31/2016
			06/30/2016
			09/30/2016
	2	Cycle 3 JAO Support: AoD support shifts at the OSF	12/31/2015
			03/31/2016
			06/30/2016
			09/30/2016
	3	Support Extension of Capability efforts at the JAO	12/31/2015
			03/31/2016
			06/30/2016
			09/30/2016
	4	Cycle 4: Participate in the Obsmode go / no-go meeting	12/31/2015
	5	Cycle 4: s/w tests, documentation, CfP	03/31/2016
	6	Offer data reduction workshop in Charlottesville	03/31/2016
	7	Cycle 4: CDEs, User Support, Proposal Deadline Supp.	06/30/2016
	8	Cycle 4: Tech Assessment, Tech Sec Supp.	06/30/2016
	9	Cycle 5: Capabilities Planning	06/30/2016
	10	Cycle 4: P2G and CS Assignments	09/30/2016
	11	Cycle 4: SBs validated	09/30/2016
		Development	
	12	NAASC Interferometry Summer School	09/30/2016
	13	NA ALMA Development Projects for FY2014/2015 will be completed	03/31/2016
	14	NA ALMA Development Projects – Next Call for Proposals	06/30/2016
3.4		**New Mexico Operations**	
		VLA Science Operations	
	1	Define VLA capabilities to be offered for semester 2016B	12/31/2015
	2	Define VLA capabilities to be offered for semester 2017A	06/30/2016
	3	Update VLA documentation to support 2016B Call for Proposals, perform proposal technical reviews	03/31/2016
	4	Update VLA documentation to support 2017A Call for Proposals, perform proposal technical reviews	09/30/2016
	5	Determine baselines and pointing for antennas moving into their D configuration locations	12/31/2015
	6	Determine baselines and pointing for antennas moving into their DnC and C configuration locations	03/31/2016
	7	Determine baselines and pointing for antennas moving into their CnB and B configuration locations	06/30/2016
	8	Determine baselines and pointing for antennas moving into their BnA and A configuration locations	09/30/2016
		VLA Array Operations	
	9	Complete reconfiguring array to D configuration	12/31/2015
	10	Reconfigure array to DnC, then C configuration	03/31/2016
	11	Reconfigure array to CnB, then B configuration	06/30/2016

FY2016 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
	12	Reconfigure array to BnA, then A configuration	09/30/2016
	13	Release Operations GSA vehicle(s)	12/31/2015
		VLA Antenna Maintenance	
	14	Perform 8 antenna overhauls during the course of the year	09/30/2016
	15	Replace one antenna azimuth bearing during the source of the year	09/30/2016
	16	Perform preventive maintenance on each of two transporters prior to array reconfiguration	12/31/2015
	17	Perform preventive maintenance on each of two transporters prior to array reconfiguration	06/30/2016
	18	Perform preventive maintenance on each of two transporters prior to array reconfiguration	09/30/2016
		VLA Track Maintenance	
	19	Identify and replace 5000 aging or damaged cross-ties during the course of the year	09/30/2016
	20	Identify and replace 5 antenna pad intersections during the course of the year	09/30/2016
		VLA Site Infrastructure Maintenance	
	21	Perform preventive maintenance on VLA site hatch gear	12/31/2015
	22	Perform preventive maintenance on all VLA site transformers during the course of the year	09/30/2016
		VLA Technical Upgrades and Enhancements	
	23	L-Band solar upgrade, 2 additional receivers with full RF upgrade installed	03/31/2016
	24	X-Band solar upgrade, 6 additional receivers with 20 dB switched attenuators on outputs only, no solar Tcals, installed	09/30/2016
	25	Ku-Band solar upgrade, 2 additional receivers with solar Tcal path plus 20 dB switched attenuators installed	06/30/2016
	26	Ku-Band solar upgrade, 4 additional receivers with 20 dB switched attenuators on outputs only, no solar Tcals, installed	09/30/2016
	27	S-Band solar upgrade, 4 additional receivers with solar Tcal path plus 20 dB switched attenuators installed	09/30/2016
	28	FE card cage upgrades, 35 units installed	03/31/2016
	29	C-Band thermal gap retrofits, 4 additional installed	06/30/2016
	30	L-Band thermal gap retrofits, 4 additional installed	09/30/2016
	31	Upgraded Ku FE noise diodes installed in 15 receivers	09/30/2016
	32	Install 10 production F318 modules in antennas	09/30/2016
		VLA Observing Capability Enhancements	
	33	Commission remaining P-Band functionality in the OPT for 2016B	06/30/2016
	34	Commission pulsar observing in the OPT for 2016B	06/30/2016
		VLA Operational Enhancements	
	35	Investigate combining sub-bands for reference pointing using weaker pointing calibrators	09/30/2016
	36	Implement continuous slew tipping scans	03/31/2016
	37	Develop heuristics for ionospheric calibration for the VLA calibration pipeline	03/31/2016
	38	Development in support of VLA Sky Survey, as specified in the VLASS Technical Implementation Plan	03/31/2016

FY2016 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
	24	Host learning session	06/30/2016
	25	Host learning session	09/30/2016
10.3		**Education & Public Outreach**	
		STEM Education	
	1	Translation of SJS curriculum to 4H project books complete	12/31/2015
	2	SJS instructional videos complete	12/31/2015
	3	Final round of SJS professional development meetings for educators	12/31/2015
			03/31/2016
			06/30/2016
	4	Skynet 2.0 for SJS complete	09/30/2016
	5	Afterglow 2.0 for SJS complete	09/30/2016
	6	VLA Visitor/Education Center Education and Interpretive Plan completed (subject to available funding)	09/30/2016
	7	VLA Visitor/Education Center architectural schematic design completed	09/30/2016
	8	VLA Visitor Center volunteer tour guide recruitment begins	12/31/2015
	9	VLA Visitor Center volunteer tour guide applicants selected	03/31/2016
	10	VLA Visitor Center volunteer tour guide applicants on-site	06/30/2016
	11	STEM Career Day at Dominion Virginia Electric	12/31/2015
	12	10th Grade STEM Day at Piedmont Virginia Community College (if invited)	03/31/2016
	13	STEM Career Focus videos	09/30/2016
	14	Recruit additional SPOT undergraduate ambassadors	12/31/2015
	15	Additional training for SPOT ambassadors	03/31/2016
	16	Seek additional SPOT funding	09/30/2016
		News & Public Information	
	17	Joomla 3-enabled indexing and searching for public website	06/30/2016
	18	Orion Explorer specification and scripts completed	12/31/2015
	19	Orion Explorer debuts on public.nrao.edu	09/30/2016
	20	Beta version of Android edition of "RadioSky" app ready for testing	12/31/2015
	21	Specification and design for "Zombie Stars" interactive pulsar app completed	12/31/2015
	22	"RadioSky" app ready for distribution	03/31/2016
	23	"Zombie Stars" iOS app ready for alpha testing	06/30/2016
11.4		**Computing & Information Services**	
	1	Business software review and strategic alignment	03/31/2016
	2	Migration to Windows 8	09/30/2016
	3	Bro security tool evaluation	06/30/2016
	4	OAS business services availability improvement	03/31/2016
	5	Review and consolidation of backup solutions	12/31/2015
12.3		**Diversity**	
		Diversity Council	
	1	Office of Diversity Initiatives/Diversity Council	03/31/2016
	2	ODI Program and metrics review	06/30/2015

FY2016 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
		National/Domestic Outreach	
	3	LSAMP, NAC, SOC Summer Youth Employment Program, Native American Outreach, SOC Engineering Internship, UVA/NRAO PhD Sponsorship, PING, etc.	06/30/2015
		International Outreach	
	4	NINE- NRAO Staff and student exchanges	03/31/2016
	5	UVA/NRAO Chilean PhD Sponsorship	03/31/2016
		Improve Workplace Culture	
	6	Diversity and Cultural Awareness Training #1	03/31/2016
	7	Diversity and Cultural Awareness Training #2	09/30/2016
13.7		**Human Resources**	
		Training	
	1	Deliver two new Management/Supervisor development courses: 1. Performance Management, and 2. Comp 101	03/31/2016
		Benefits	
	2	HR prepares and distributes all open enrollment materials to employees and makes enrollment changes into JDE and with vendors.	12/31/2015
		Compensation	
	3	Annual Performance Review Process	12/31/2015
	4	All preparations complete and salary review worksheets are open to pay decision managers for final merit review decisions.	03/31/2016
	5	Participate in all credible/scheduled salary survey sources and conduct analysis of benchmark jobs.	09/30/2016
		Human Resources	
	6	Evaluate/refine/expand the process	06/30/2016
	7	Employee Climate Survey Design and Delivery	06/30/2016
14.1		**Communications**	
		Science Communications	
	1	Update Research Facilities brochure	12/31/2015
	2	Submit 2017 AAAS science symposium proposal	06/30/2016
	3	Publish 2015 NRAO Annual Report	09/30/2016
15.7		**Administration**	
		Business Services	
	1	Complete and test new chart of accounts. Provide training	09/30/2016
	2	Review balances in CSA and SPO Accounts and prepare for closing	09/30/2016
	3	Familiarization with new Cooperative Agreement (if awarded) and preparation for budget loading	09/30/2016
	4	Separate and balance Green Bank and VLBA accounts	09/30/2016
		CAP	
	5	Update manual. Review and approval by Assoc. Director of Administration. Training	03/31/2016
	6	Update manual. Review and approval by Assoc. Director of Administration and AUI	06/30/2016
		ES&S	
	7	Determine technical solution to Safety Recordkeeping requirements	12/31/2015
	8	Complete ES&S supervisory training	06/30/2016

Acronym	Definition
CDM	Cold Dark Matter
CfP	Call for Proposals
CIS	Computing and Information Services
CLOA	Central Local Oscillator Article
cm	Centimeter
CMB	Cosmic Microwave Background
CMMS	Computerized Maintenance and Management System
C0, C1, C2, C3	ALMA Cycles
COM	NRAO Communications Office
CORF	Committee on Radio Frequencies
COSPAR	Committee on Space Research
CPLD	Complex Programmable Logic Device
CS	Contact scientist
CSA	Cooperative Support Agreement
CSSC	CASA Science Steering Committee
CSV	Commissioning and Science Verification (ALMA)
CTS	CCA test set
CV	Charlottesville, VA
DARE	Dark Ages Radio Explorer
DARPA	Defense Advanced Research Projects Agency
DASI	Degree Angular Scale Interferometer
dB	Decibel
DCR	Digital Continuum Receiver
DDC	Digital Down-Converter
DiFX	Distributed FX correlator
DMS	Data Management and Software Department
DO	Director's Office
DOMT	Digital Orthomode Transducer
DRXA	Data Receiver Articles
DSB	Double Sideband Receiver
DSN	Deep Space Network
DSO	Division of Science Operations - ALMA
DSOC	Domenici Science Operations Center
DSP	Digital Signal Processing
DTS	Data Transmission System
EHT	Event Horizon Telescope
EM	Electromagnetic
EOC	Optimization of Capabilities
EoR	Epoch of Reionization
EPO	Education and Public Outreach
ESO	European Southern Observatory
ES&S	Environment, Safety, and Security
EVLA	Expanded Very Large Array Project
EVN	European VLBI Network
FASR	Frequency-Agile Solar Radiotelescope
FAST	Five hundred meter Aperture Spherical Telescope

Acronym	Definition
IT	Information Technology
ITAR	International Traffic in Arms Regulations
ITIL	Information Technology Infrastructure Library
ITU-R	International Telecommunication Union-Radio (communications sector)
IUCAF	Scientific Committee on Frequency Allocations for Radio Astronomy and Space Science
JAO	Joint ALMA Observatory
JD	Job Description
JDE	JD Edwards
JPL	Jet Propulsion Laboratory
JWST	James Webb Space Telescope
K	1,000
k	kilo
kHz	kiloHertz
km	kilometer
km/s	kilometer per second
kpc	kiloparsecs
LBR	Low Band Receiver
LEDA	NSF-funded LEDA experiment at LWA1
LIGO	Laser Interferometer Gravitational-Wave Observatory
LISA	Laser Interferometer Space Antenna
LMT	Large Millimeter Telescope
LNA	Low Noise Amplifier
LoFASM	Low Frequency All-Sky Monitor Project
LO	Local Oscillator
LO/IF	Local Oscillator/Intermediate Frequency
LOPR	Local oscillator photonics receivers
LSAMP	Louis Stokes Alliance for Minority Participation
LSM	Local staff members
LSST	Large Synoptic Survey Telescope
LWA	Long Wavelength Array
m	meter
M	Million
Mbps	Mega-bits per second
MCAF	Meta-data Capture and Format
MEASURE	Magnetometers along the Eastern Atlantic Seaboard for Undergraduate Research and Education
MeerKAT	Meer Karoo Array Telescope
MHEMT	Metamorphic High Electron Mobility Transistor
MHz	Megahertz
MIC	Microwave Integrated Circuit
MIS	Management Information Services
MIT	Massachusetts Institute of Technology
MJP	Modified J-Pole
mm	millimeter
mm/submm	Millimeter/submillimeter
MMIC	Monolithic Millimeter-wave Integrated Circuit

Acronym	Definition
MPIfR	Max Planck Institut für Radioastronomie
msec	millisecond
MTDC	Modified total direct costs
MWA	Murchison Wide-field Array
μas	Micro-arcsecond
μJy	microJansky
MUSTANG	Multiplexed SQUID/TES Array for Ninety Gigahertz
NA	North American
NAASC	North American ALMA Science Center
NAC	National Astronomy Consortium
NAIC	National Association of Insurance Commissioners
NANOGrav	North American NanoHertz Observatory for Gravitational Waves
NAOJ	National Astronomical Observatory of Japan
NAS	Network Attached Storage
NASA	National Aeronautics and Space Administration
Nb	Niobium
NBT	Next Big Thing
NGAS	Next Generation Archive System
nHz	nanoHertz, a frequency of one cycle per 10^9 seconds (about 32 years)
NINE	NRAO International and National Exchange Program
NIO	New Initiatives Office
NIST	National Institute of Standards and Technology
NM	New Mexico
NRAO	National Radio Astronomy Observatory
NRC	National Research Council
NRC-HIA	National Research Council of Canada - Herzberg Institute of Astrophysics
NRL	Naval Research Laboratory
NRQZ	National Radio Quiet Zone
NSBP	National Society of Black Physicists
NSF	National Science Foundation
NSF-AST	National Science Foundation – Division of Astronomical Sciences
NTIA	National Telecommunications and Information Administration
NTC	NRAO Technology Center (Charlottesville, VA)
NWNH	2010 Decadal Survey "New World New Horizons"
OCA	Office of Chile Affairs
OMT	OrthoMode Transducer
OPT	Observation Preparation Tool
OSF	Operations Support Facility (ALMA, Chile)
OSHA	Occupational Safety and Health Administration
OT	Observing Tool
OTFM	On-The-Fly-Mosaicing
OTO	Observatory Telescope/Array Operations
PAF	Phased Array Feed
PAPER	Precision Array to Probe the Epoch of Reionization
pc	parsec
PEP	Performance Evaluation Process

Acronym	Definition
PFB	Polyphase Filterbank
PHT	Proposal Handling Tool
PI	Principle Investigator
PING	Physics Inspiring the Next Generation
PIP	Performance Improvement Process
PM/SE	Project Manager/Systems Engineer
PMD	Program Management Department
PMI	Project Management Institute
POP	Program Operating Plan
PRL	President's Request Level
PSC (EPO)	Pulsar Search Collaboratory
PSC (DMS)	Pittsburgh Supercomputing Center
PST	Proposal Submission Tool
PT	Pie Town
PTO	Paid time off
Q1	Quarter 1 (October – December)
Q2	Quarter 2 (January – March)
Q3	Quarter 3 (April – June)
Q4	Quarter 4 (July – September)
QA	Quality Assurance
R&D	Research and Development
RDBE	ROACH Digital Backend
RET	Research Experiences for Teachers
REU	Research Experiences for Undergraduates
RF	Radio Frequency
RFI	Radio-Frequency Interference
RMS	Radio, Millimeter and Submillimeter
ROACH	Reconfigurable Open Architecture Computing Hardware
RPI	Pipeline Reprocessing Interface
RSRO	Resident Shared Risk Observing
SACNAS	Society for Advancement of Chicanos and Native Americans in Science
SB	Scheduling Block
SE	Systems Engineering
SCO	Santiago Central Office
SCR	Silicon Controlled Rectifier
SDS	Safety Data Sheet
SHAO	Shanghai Astronomical Observatory
SIS	Superconductor–Insulator–Superconductor
SJS	Skynet Jr. Scholars
SKA	Square Kilometre Array
SMBH	Supermassive Black Hole
SOP	Standard Operating Procedure
SOS	Student Observing Support
SPO	Scientific Program Orders (NSF)
SPOT	Space Public Outreach Team
SQUID	Superconducting Quantum Interference Device

Acronym	Definition
SRO	Shared Risk Observing
SRP	Science Review Panel
SSO	Single Sign-On
SSR	Science Support and Research
STEM	Science, Technology, Engineering, and Mathematics
sub-kpc	Sub-kiloparsec
submm	submillimeter
SUBTEL	Subsecretaria de Telecomunicaciones (Chile)
SUS	Science User Support
SYEP	Summer Youth Employment Program
SZ	Sunyaev–Zel'dovich
TAC	Time Allocation Committee
TBytes	Terabytes
THz	TeraHertz
TPA	Total Power Array
TTA	Telescope Time Allocation
TTO	Technology Transfer Office
UIP	Undergraduate Intern Program
URSI	International Union of Radio Science
U.S.	United States of America
USNO	United States Naval Observatory
UPS	Uninterruptible Power Supply
UVA	University of Virginia
UVML	University of Virginia Microfabrication Laboratory
v	Volt
VA	Virginia
VEGAS	VErsatile GBT Astronomical Spectrometer
VLA	Very Large Array
VLASS	VLA Sky Survey
VLBA	Very Long Baseline Array
VLBI	Very Long Baseline Interferometry
VLITE	VLA Low Band Ionospheric and Transient Experiment
VME	Versa Module Europa
WBS	Work Breakdown Structure
WCA	Warm Cartridge Assembl
WFO	Work for Others (non-NSF CSA, SPO grants)
WIDAR	Wideband Interferometric Digital ARchitecture
WMAP	Wilkinson Microwave Anisotropy Probe
WRC	World Radiocommunication Conference
WV	West Virginia
WVR	Water Vapor Radiometry
WVRAZ	West Virginia Radio Astronomy Zone
WVU	West Virginia University
XRBs	X-ray binaries
yr	year

15 ADMINISTRATION

The Observatory Administration (ADMIN) Services department provides administrative management, budgeting, and non-programmatic services to NRAO and ALMA. Administration activities are headquartered in Charlottesville in Stone Hall on Edgemont Road on the grounds of the University of Virginia (UVA). UVA Astronomy Department faculty and students use public spaces at NRAO for colloquia and other meetings, and some pre- and post- doctoral individuals have offices at NRAO. Other administrative offices are at the CDL on Ivy Road; in Green Bank in the Jansky Building; and in Socorro in the DSOC.

NRAO ADMIN areas of responsibility include Business Services, Contracts and Procurement, Environmental, Safety and Security, Management Information Systems, and the Technology Transfer Office.

15.1 Business Services

The Observatory Administration Services department provides administrative management, human resources management and non-programmatic services to NRAO and ALMA. Administration activities are headquartered in Charlottesville in Stone Hall on Edgemont Road (ER) at the University of Virginia. Other administrative offices are at the Central Development Lab (CDL) on Ivy Road; in Green Bank in the Jansky Building; and in Socorro in the Domenici Science Operations Center (DSOC).

Observatory-wide Savings

Over the past two years the administration department has negotiated or coordinated lease reductions in excess of $100,000 per year for the facilities at Edgemont Road and the CDL. These savings have been passed back to the program and are no longer in the Administration budget. Additionally, a $35,000 valued upgrade to the Edgemont Road lighting (hallway lighting motion sensors and re-lamping of entire building with lower watt bulbs) was negotiated with the UVA facilities department and received at no cost to NRAO. The annual savings in electricity is projected to be about $8,000 a year. Support was solicited from the UVA for Edgemont Road to support the leasehold improvement of a generator. UVA agreed to provide $50,000 toward the $140,000 project, freeing the difference for programming.

The modest fleet of vehicles available at headquarters and at the sites has been reduced. These cars and vans were used by employees for errands, deliveries, short trips (such as Socorro to Albuquerque or Charlottesville to Green Bank) and by NRAO hosts providing transportation to academic visitors and students. The result is that employees are more frequently using personal cars and charging the observatory the maximum IRS rate for use of personal cars.

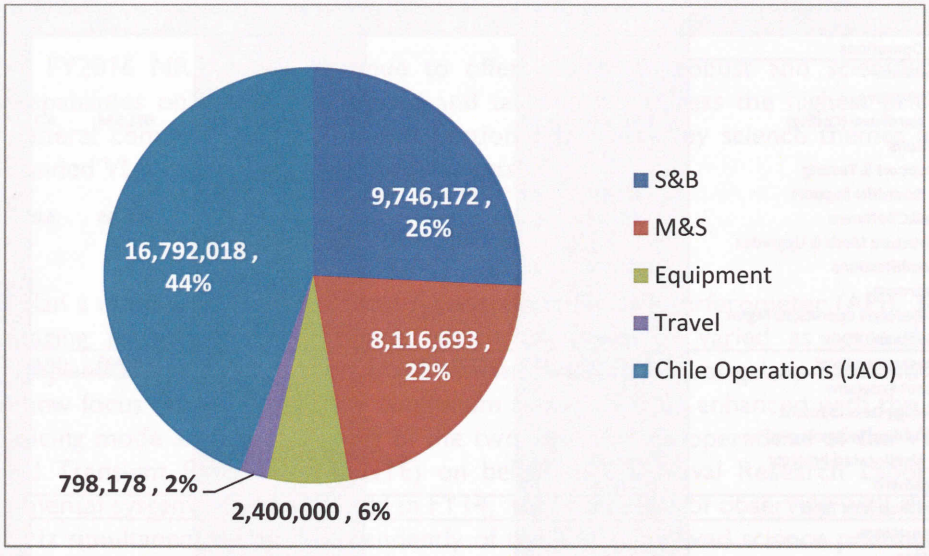
FY2015

ALMA Construction Documents: ALMA Construction Documents will be organized for storage. An off-site storage company will be identified and the documents will be moved.

New Chart of Accounts: With the impending divestiture of Green Bank and the VLBA, and the hoped for start of a new cooperative agreement, a new chart of accounts is required. This project will be a joint effort of the NRAO Budget team, the MIS Division and AUI Fiscal. This project will take up to 21 months and appears in both FY2015 and FY2016, beginning in January 2015.

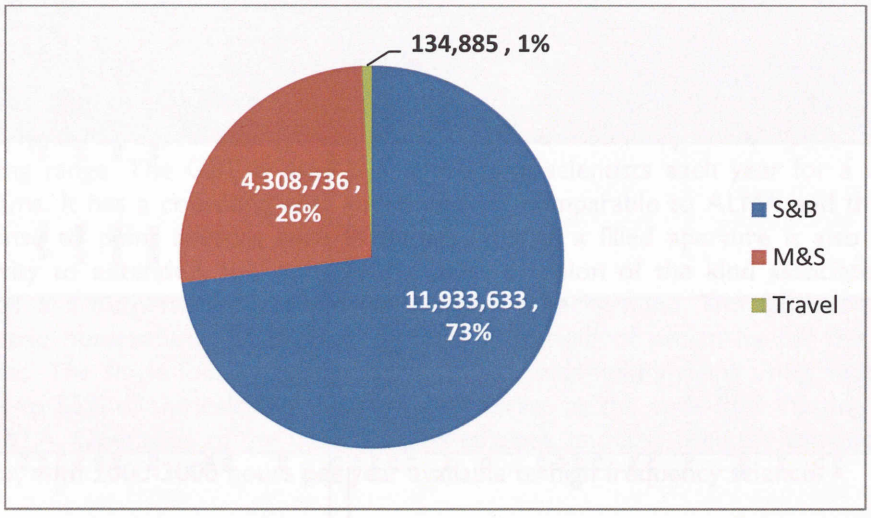
ALMA Financial Charts (cont.)

Table 2.7.2: ALMA Operations, FY2015 Expenditures by Object excluding Internal Transfers & Fees



New Mexico Operations Financial Chart (cont.)

Table 3.5.2: FY2015 Expenditures by Object



3.2.3. *Development*

At the time of writing no new development projects have been approved for the VLBA in FY2015 within the current funding profile. However, NM Operations has several development projects ready to be undertaken, should funding become available. NRAO will access the development project prioritization for FY2016 as per the standard schedule mid-spring. The following projects will be assessed for potential funding at that time.

Ka-Band Receivers: There exists a strong interest within the scientific community to outfit the VLBA with state-of-the-art Ka-Band (26-40 GHz) receivers. Detailed engineering plans exist for the construction of a dual Ka/X Band system, should funding become available. The main science driver for such a system would be for astrometric applications, but high-resolution imaging would also benefit as well (e.g., AGN jet evolution). VLBA observations of a grid of radio sources could be used to improve the celestial reference frame, used in scientific, commercial and military applications. Initial estimates are that the VLBA could contribute to a factor of three improvement over existing reference frames.

All potential new development projects are reviewed by local scientific and engineering staff and evaluated based on science impact, technical readiness, and cost. The engineering cost of NM Operations development projects includes personnel costs, to enable the backfilling of technical support to minimize the impact on maintenance, operations, and technical upgrades. In contrast, it is very difficult to hire temporary scientific staff to backfill the functionality of scientific staff engaged in development projects, so new development effort is balanced against other upgrade and enhancement work. Key elements considered in evaluating the impact of transferring scientific staff from other activities to new development work are: safety; operational efficiency; impact on data quality and delivery of science; impact on overall NRAO strategic goals.

3.2.4. *Maintenance and Renewal*

Electronics Maintenance and Renewal

The New Mexico Electronics Division is responsible for maintaining all VLBA electronic components and the DiFX Correlator. Each VLBA antenna contains eight cooled receivers, two compressors and numerous other electronics components. Although some of these components are supported in the Socorro labs, for efficiency, many are sent to the 20 VLBA site technicians for repair and maintenance.

The site technicians carry out the bulk of the routine maintenance tasks at the VLBA sites. For FY2015 and FY2016 this will consist of the following:

- Inspection and lubrication of FRM, Az/El drive motors, encoder and pintle bearings, elevation gears, elevation hoist, change gearbox oil, etc.
- Check/test encoder motor tachometers, servo limits, ACU, vacuum pumps, all heating, ventilation, and air conditioning (HVAC) systems, dry air system, weather station equipment, etc.
- Ensure safety equipment such as UPSs and generators, emergency power, fire alarm systems, fire extinguishers, security systems, etc. are operating normally.
- Ensure all other preventive maintenance tasks such as checking motor brushes and commutators are checked and replaced, check of Azimuth wheel position, check for metal in grease samples, cable wrap maintenance, replace oil filters, etc., completed in a timely fashion.
- Repair some VLBA specific modules to relieve some of this task from the technical staff at the DSOC and the VLA sites.

FY2015

The FY2015 Broadening Participation initiatives will be done in collaboration with EPO and SSR Divisions. In Q2, we will establish a formal undergraduate intern program for the Socorro Electronics Division under the guidance of the Division Head and the Student Program Coordinator. Also in Q2, The Student Program Coordinator and a UVA faculty member will mentor and advise a female Chilean student pursuing a PhD. In Q3, we will continue our partnerships with LSAMP, NAC, SOC Summer Youth Employment Program, PING, and the African American Teaching Fellows. These programs have been instrumental in training the next generation of scientists and engineers and the outreach to underrepresented minorities has resulted in an increase of diverse students from a wide demographic area. Establishing a partnership with the Native American community is a new initiative that NRAO will explore. We will establish point of contacts to serve as representatives from SOC and Charlottesville in Q3. In Q4, the AUI/NRAO Diversity Lead will continue to oversee the teaching, recruitment and exchange effort with South Africa and other international partnerships associated with the NINE Program. In Q2 and Q3, The Diversity Officer will continue diversity training across the Observatory on Diversity and Cultural Awareness topics.

FY2016

The FY2016 Broadening Participation initiatives will be a continuation of the programs in FY2015. NRAO will continue to strengthen our partnerships with national and international institutions with our focus on the continuation of training the next generation. Our focus will continue to be on reaching into the underrepresented populations to provide opportunities at all levels across the Observatory. Again, this program will be done in collaboration with EPO and SSR Divisions. In Q2, we will establish a formal undergraduate intern program for the Socorro Electronics Division under the guidance of the SOC Electronics Division Head and the Student Program Coordinator. Also in Q2, the Student Program Coordinator and a UVA faculty member will mentor and advise a female Chilean student pursuing a PhD. In Q3, we will continue our partnerships with LSAMP, NAC, SOC Summer Youth Employment Program, PING, and the African American Teaching Fellows. These programs have been instrumental in training the next generation of scientists and engineers and the outreach to underrepresented minorities has resulted in an increase of diverse students from a wide demographic area. Establishing a partnership with the Native American community is a new initiative that NRAO will explore. We will establish point of contacts to serve as representatives from SOC and Charlottesville in Q3. In Q4, AUI/NRAO Diversity Lead will continue to oversee the teaching, recruitment and exchange effort with South Africa and other international partnerships associated with the NINE Program. In Q2 and Q3, The Diversity Officer will continue diversity training across the Observatory on Diversity and Cultural Awareness topics.

FY2016

The land lease for the Pie Town, NM VLBA site is due to expire January 1, 2016. Negotiations with the U.S. Bureau of Land Management (BLM) for the renewal will begin in FY2015, with the lease renewal to be completed by FY2016 Q1.

2.6 ALMA Major Milestones

Table 2.6.1: ALMA FY2015 Major Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Operations	Ongoing Ops: 14 AoD Shifts (3-4/quarter)	1	1	1	1
	Hire two New Data Analysts and two Scientists	2			
	Cycle 2 Status Update	3			
	Support EOC Long Baseline Campaign	4			
	Cycle 2 Data Reduction – Eliminate Backlog	5			
	Cycle 3 Obsmode go/no-go meeting	6			
	ALMA Conference and PD Symposium	7			
	ALMA Ops Review		8		
	Offer Data Reduction Workshop in Charlottesville		9		
	Cycle 3 s/w tests, doc prep, cfp		10		
	Cycle 3 CDEs, User Support for Proposal Deadline			11	
	Cycle 3 Tech Assessment, Tech Secretary Supp.			12	
	Cycle 4 Capabilities Planning			13	
	Cycle 3 P2G and CS Assignments				14
	Cycle 3 SBs (first batch) validated				15
	Offer Data Reduction Workshop in Charlottesville				16
	Input to Pipeline on Ref Imaging	17			
	Input to Pipeline on improved calib. heuristics		18		
Development	FY2014 Studies Completion		19		
	FY2016 Studies Call for Proposals (CfP)		20*		
	FY12/14 Projects Completed	21			
Maint. and Renewal	Commission FE Test Cryostat		22		
	Commission One FETIM Module			23	
	Conduct on-site re-training				24
NRAO-Chile Office	Hire NRAO-Chile Chief of Staff	25			
	Support ALMA HR Department	26	26	26	
	Prepare for Upcoming Union Negotiations			27	27
	Study Alternative Office Locations	28			

Milestones:

1. Carry out AoD shifts at the OSF
2. Hire two data analysts and two scientists
3. Cycle 2 Status Update
4. Support Long Baseline Campaign
5. Eliminate Backlog in Cycle 2 Data Reduction
6. Participate in Cycle 3 Obsmode go / no-go meeting
7. Participate in ALMA Intl Science Conference and Postdoc Symposium
8. Participate in ALMA Operations Readiness Review
9. Offer Data Processing Workshop in Charlottesville
10. Cycle 3 Prep: S/W tests, Documentation Prep, Call for Proposals
11. Cycle 3 Prep: Community Day Events, User Support for Deadlines
12. Cycle 3: Technical Assessments, Tech Secretary Support
13. Cycle 4: Capabilities Planning
14. Cycle 3: P2G and CS Assignments
15. Cycle 3: First batch of SBs validated
16. Offer Data Processing Workshop in Charlottesville
17. Pipeline Heuristics: Input on Reference Imaging
18. Pipeline Heuristics: Input on Improved Calibration heuristics
19. NA ALMA Development Studies initiated in FY2014 will

Deliverables:

[1] 3-4 AoD shifts per quarter
[2] New staff
[3] NA contribution to the ALMA-wide status update (text, stats, graphs)
[4] Provide 4 domain experts to support testing.
[5] Cycle 2 data sets taken prior to the September 2014 long baseline campaign delivered to PIs
[6] Decisions will be made on the readiness of the Cycle 3 S/W for Cycle 3 observations
[7] Staff and Postdocs travel to meetings and deliver papers
[8] Presentations at review and support of JAO presentations
[9] Two day workshop: staffing, presentations and tutorials
[10] Documents. S/W test reports
[11] Event presentations and tutorials; helpdesk responses
[12] Written proposal assessments; review meeting staffing
[13] Meetings and analysis leading to a decision on the planned capabilities for Cycle 4
[14] Staffing assignments for campaign to schedule Cycle 3 observations

3.5 New Mexico Operations Financial Chart

Table 3.5.1: FY2015 by Fund Source and Instrument

	CSA-1 NRAO Ops								CSA-2 ALMA Ops		Internal Common Costs			
	VLA		VLBA		NON-TELESCOPE		TOTAL, CSA-1		ALMA		NON-TELESCOPE		GRAND TOTAL	
Work Breakdown Structure	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
1000 Telescope Operations														
1100 Maintenance														
1110 Corrective														
1111 Unscheduled	1,762,113	20.0	1,311,483	14.6			3,073,597	34.6					3,073,597	34.6
1112 Scheduled	1,010,438	11.1	585,538	6.6			1,595,976	17.8					1,595,976	17.8
1113 Hardware (Config)									601,934	4.3			601,934	4.3
1114 Software			200	-			200	-					200	-
1120 Preventive														
1121 Scheduled	1,386,412	18.5	60,873	0.3			1,447,285	18.8					1,447,285	18.8
1200 Operations														
1210 Scheduling														
1211 Telescope Status & Scheduling	55,979	0.4	67,729	0.6	3,997	0.0	127,706	1.0					127,706	1.0
1220 Operating														
1221 Observing	345,121	6.0	143,424	2.4			488,545	8.4					488,545	8.4
1222 Recording & Media Distribution	13,368	0.2	93,755	0.8			107,123	1.0					107,123	1.0
1230 Support & Testing														
1231 Calibration	2,175	0.0	61,460	1.0			63,635	1.0					63,635	1.0
1232 Antenna Moves/Repositioning	72,195	1.1					72,195	1.1					72,195	1.1
1236 Scientific Support	1,035,991	7.1	84,967	0.6			1,120,958	7.7					1,120,958	7.7
1240 M&C Software	26,752	0.3	43,610	0.4			70,362	0.6					70,362	0.6
1400 Infrastructure Mods & Upgrades														
1410 Small Scale R&D														
1411 Projects			202,829	1.5			202,829	1.5					202,829	1.5
1420 Modifications														
1421 Projects	659,656	5.6	54,104	0.5			713,760	6.1					713,760	6.1
1500 Management														
1510 Telescope operations Mgmt	79,002	0.8	123,756	0.8	84,004	0.5	286,761	2.1					286,761	2.1
1520 Science Support Mgmt	166,636	1.0	106,425	0.6			273,061	1.6					273,061	1.6
1530 Mechanical Engineering Mgmt	608,277	4.2	31,273	0.2			639,550	4.4					639,550	4.4
1540 Electronics Mgmt	307,003	2.0	175,074	1.4			482,077	3.4					482,077	3.4
1000 Telescope Operations Total	7,531,117	78.2	3,146,501	32.2	88,001	0.5	10,765,619	111.0	601,934	4.3			11,367,553	115.3
3000 Science Operations														
3300 Broader Impacts														
3320 Visitor Support					3,600	-	3,600	-					3,600	-
3600 Scientific User Services														
3610 Community Support														
3611 User Assistance	3,428	0.1	47,216	0.7			50,644	0.7					50,644	0.7
3000 Science Operations Total	3,428	0.1	47,216	0.7	3,600	-	54,244	0.7					54,244	0.7
4000 Administrative Services														
4100 Business Services														
4110 Business Office														
4111 Business Office					421,492	3.0	421,492	3.0			204,118	4.5	625,610	7.5
4200 Facilities														
4210 Plant Maintenance	304,718	6.0	65,000	-			369,718	6.0			368,000	-	737,718	6.0
4220 Communication	27,000	-	60,500	-	192,000	-	279,500	-					279,500	-
4230 Utilities	1,211,715	-	442,790	-			1,654,505	-			307,000	-	1,961,505	-
4240 Leases			42,581	-			42,581	-					42,581	-
4260 Vehicles	377,525	3.0	43,000	-			420,525	3.0			93,397	1.0	513,922	4.0
4270 Central Instrument Shop	297,651	3.6	26,197	0.5			323,847	4.0					323,847	4.0
4300 Auxiliaries														
4320 Housing														
4322 Residence Hall					4,000	-	4,000	-					4,000	-
4500 Management					117,486	1.5	117,486	1.5			349,287	2.0	466,773	3.5
4000 Administrative Services Total	2,218,608	12.6	680,068	0.5	734,979	4.5	3,633,655	17.5			1,321,802	7.5	4,955,456	25.0
Grand Total	9,753,154	90.8	3,873,785	33.4	826,579	5.1	14,453,518	129.3	601,934	4.3	1,321,802	7.5	16,377,254	141.0

The pace of development for capability enhancements is matched to the available FTEs who are not fully engaged with daily operations. For FY2015 and FY2016 the capability enhancements focus on increasing the number of compatible observing modes on stations of the HSA, and on starting to include the LMT in the HSA for 3mm VLBI.

FY2015

In FY2015 scientific and operations staff will work with colleagues at Effelsberg and the LMT on the following items to expand the available observing modes on the HSA:

- Collaborate with Effelsberg staff to commission and document DDC-8 observing at that telescope, for inclusion in HSA observations, with the goal of offering this mode through the SRO program in 2016B (Q4).
- Collaborate with LMT staff to commission and document PFB observing at that telescope, for inclusion in HSA observations through the SRO program in 2016B (Q4).

FY2016

In FY2016 scientific and operations staff will continue to expand the available observing modes on the HSA:

- Collaborate with Arecibo staff to enable DDC-4 observing at that telescope, for inclusion in HSA observations in semester 2016B through the RSRO program.

3.3 Site Operations

The facilities for which NM Operations is responsible comprise two leased buildings on the campus of the New Mexico Institute of Mining and Technology (DSOC, and the NRAO Guest House), the VLA telescope site, and the ten VLBA stations. At the DSOC and the NRAO Guest House, NRAO supports building maintenance, communications, and utilities. At the VLA site, NRAO supports all communications, utilities, building maintenance, and telescope maintenance. At the VLBA stations, expenses include communications, utilities, building and site maintenance, land leases, and telescope maintenance. One of the largest components of the overall facility expenses is the cost of electrical power. Year-specific items related to the facility and site operations are described further below.

Site Operations Milestones

FY2015

The installation of an electronic door access system in Socorro to match the systems in place in Charlottesville and Green Bank is expected to be completed in FY2015 (Q1). This work is required to upgrade the DSOC to be compatible with other North American NRAO sites, and to facilitate implementing the Denied Party Access requirements in the Socorro building.

Progress continues toward renewing the land use leases for the Owens Valley, CA and St. Croix, VI VLBA sites will be made in FY2015. NRAO is awaiting responses from the landlords of these leases (City of Los Angeles Department of Water and Power, and the Government of the Virgin Islands) before the new agreements can be finalized.

Primer" and introductory videos. Activities will shift to intensive user support through the helpdesk and Community Day Events (CDE) between the release of the call for Proposals by the JAO (end of Q2 FY2015) and the proposal deadline four weeks later. In coordination with the SUS, the NAASC will support three-to-six CDEs prior to the call, offering the opportunity to institutions to host the event with the support of one or more NAASC experts. The events will be driven by demand, and the number will be limited by the availability of NAASC support staff. We will only host events that can promise at least 25 attendees and will favor proposals that promise to draw in scientists from a significant geographical area. These events have been very popular and successful in previous cycles.

The NAASC will support the Cycle 3 proposal review process in Q3 FY2015 by providing technical secretaries and technical assessors. Meanwhile NAASC staff will also contribute effort to the definition of the requirements for the Cycle 3 SB preparation software and testing of that software. Starting in Q4 FY2015, NAASC staff will prepare the SBs for all successful NA-supported proposals, an activity requiring the effort of four NAASC staff for ~six months beginning with attendance at a training "bootcamp" in Santiago. CS staff will review the SBs with their assigned PI projects throughout this period.

Visits by Cycle 1 and 2 PI teams may occur throughout the year and will be supported by the CS staff. Visits and remote support for scientists using non-proprietary archival Cycle 0, 1 and 2 ALMA data will require CS support throughout the year.

NAASC staff will support an SUS-led data reduction workshop in Charlottesville every six to 12 months, depending on community demand and availability of resources. Previous workshops have been highly popular and successful. They are limited to about 25 attendees so that all can have a personal terminal to the in-house cluster processor and personal attention from NAASC staff for hands-on experience.

A major activity for the first half of FY2015 is to support the initial rollout of the ALMA calibration pipeline. The initial pipeline will be used for calibration only, and not imaging, pending the development of initial imaging heuristics. Additionally, it will only calibrate "standard" observations; it will not work for data reduction procedures that are still in the process of being finalized (such as polarization, total power, band-width transfer, or high-frequency/low signal-to-noise cases). We anticipate that pipeline assisted data reduction will be approved in Q4 of FY2014 and its first heavy use will occur in Q1 of FY2015. The science observing cadence increased at the end of Cycle 1, with early science observations taking place two weeks out of every three (with the third week dedicated to EOC activities). As a result of this increased cadence prior to the commissioning of the data reduction pipeline, there is a serious backlog of completed Cycle 1 carry-over and Cycle 2 datasets that must be worked through in Q1 FY2015 (when there is a hiatus in Early Science observing due to the EOC Long Baseline campaign).

In the basic model, all pipeline-compliant datasets will be run through the calibration pipeline at the JAO, and the products posted for imaging and final packaging and delivery by the ARCs. Non pipeline-compliant datasets will be posted immediately upon completion for manual data reduction at the ARCs, as was done in all previous ALMA cycles.

Starting at the end of FY2014 and continuing through FY2015, the NAASC will have two teams supporting the Cycle 2 pipeline-assisted data reduction – the current data reduction team (composed of ~five to ten Staff Scientists and Data Analysts in any given week) will continue the by-hand reduction of pipeline non-compliant datasets using the process used in Cycles 0, 1 and 2, as well as the imaging component of pipeline-calibrated datasets. The second team is composed of 3-4 experts who will investigate and redirect cases in which the pipeline calibration fails. If these can be calibrated through the pipeline with simple fixes (e.g. additional flagging), they will be fixed and re-run through the NA pipeline,

7 FPGA processor. 17. Demonstrate de-interleaving of multiple data sources on a shared fiber-optic link using a CPLD keyed to gain mismatch. 18. Implement advanced topologies and miniaturized packaging of reflectionless filters. 19. Prototype and evaluate redesigned low noise amplifiers. 20. Integrate and test the digital downconverter with PAF front end 21. Digital receiver development: Prototype photoreceiver PC board and test with Roach 2 firmware 22. Improve PAF electromagnetic and beamforming model 23. Feasibility study for improved PAF receiver	[22] Deliverable is a paper describing the model [23] Deliverable is a paper describing the receiver concept

Communications and Network

FY2015

With the successful completion of the 10 Gb/sec link to the Green Bank site in FY2014, it is clear that both headquarters and NM will need to move to multi-gigabit speed in the next two years to support both general Internet access, and Science Support for large dataset access. To inform this decision, a cost/benefit analysis will be performed in Q2 along with recommendations on which of the eight VLBA sites still using 1.5Mbps T1 circuits can be upgraded with project/work for others sponsorship.

FY2016

During FY2016 the move to multi-gigabit networks will be executed as funds allow.

Computing Security

FY2015

CIS will focus its holistic risk management strategy along two complementary vectors: increased staff accountability for appropriate use of cyber-infrastructure and increased monitoring of network payload for malicious content. To mitigate the risk of malicious network activity over increasingly high capacity links, the Bro Network Security Monitoring solution will also be implemented in FY2015, with a sustained effort on 'securing the human' with multi-tier staff training enforced.

FY2016

The full Bro implementation will follow with alerts and automated event mitigation to address both external attacks, and malicious use of NRAO resources if an internal compromise occurs. This will in some way address the persistent threat of damage to reputation that can occur during a security event.

11.2 Site Specific Facilities Infrastructure

FY2015

During FY2014, critical maintenance was successfully completed on the NM computing facilities, including the re-enabling of multi-stage fire suppression to protect essential computing and storage equipment and the installation of Uninterruptible Power Supply (UPS) isolation circuitry. In addition a 150k Watt generator was installed in support of the NAASC archive and computing resources, and access was approved to a Class A Data Center on the UVA campus with 99.99% service availability expected. As a result, it is timely to evaluate the location of essential business and science supporting resources. This will be performed during FY2015.

FY2016

A re-balance and consolidation of key services will occur throughout FY2016 to ensure both availability and supportability following the conclusion of the Cooperative Agreement recompetition.

Proposal Handling Tool: The PHT will be updated to support required functionality for the TAC meetings for the 2016B and 2017A observing semesters.

Observation Preparation Tool: The OPT for the VLA will be updated to support new instrumental capabilities during each observing semester. This includes support for commissioning (including RSRO) observations, and once commissioned for general observing. Updates for commissioning occur in the semester prior to when they are needed for general observing. New capabilities for the VLA, along with their status for the 2015B, 2016A, and 2016B observing semesters are listed in section 3.1.2 above.

Reprocessing: The capability of reprocessing NRAO and ALMA data with a common interface will be provided.

Tool Redesign: The first phase of the redesigned toolset will be delivered. Requirements and architecture choices determined in the FY2015 review will drive the improvements made to the existing tools.

Mobile: The DMS software team will deliver the NRAO informational iOS mobile app as a public outreach tool, in collaboration with the EPO department.

Testing: In FY2016 additional scope will be included in the automated testing, including testing of GUI's and programs written in C++.

Administration Financial Charts (cont.)

Table 15.8.3: FY2016 by Location

	ICC - Internal Common Costs									
	Charlottesville		Green Bank		Socorro		Observatory Wide		TOTAL, ICC	
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟2000 Development Programs										
⊟2100 Business Development										
⊞2120 Commercialization	156,000	1.0							156,000	1.0
2000 Development Programs Total	156,000	1.0							156,000	1.0
⊟4000 Administrative Services										
⊟4100 Business Services										
⊞4110 Business Office	956,920	5.5					160,058	0.0	1,116,978	5.5
⊞4130 CAP	504,510	5.0	41,264	1.0	152,667	3.0			698,441	9.0
⊞4140 MIS			523,849	3.5	75,600	1.0			599,449	4.5
⊞4150 ESS	80,734	0.0	235,695	2.3	154,789	2.0			471,218	4.3
⊟4200 Facilities										
⊞4220 Communication							519,711	0.0	519,711	0.0
⊞4240 Leases	1,938,848	1.0							1,938,848	1.0
⊞4260 Vehicles	17,646	0.0							17,646	0.0
⊞4800 NRAO Internal Common Costs	(0)	0.0							(0)	0.0
4000 Administrative Services Total	3,498,658	11.5	800,808	6.8	383,056	6.0	679,769	0.0	5,362,291	24.3
Grand Total	3,654,658	12.5	800,808	6.8	383,056	6.0	679,769	0.0	5,518,291	25.3

discovery of the cool gas accretion onto nearby galaxies from the 'cosmic web', and the next two years should see the maturing of this important line of research.

The VLA and ALMA are making important contributions to the study of the baryon cycle in distant galaxies through the direct observation of outflows of cool gas driven by starbursts and AGN in distant galaxies, and the infall of massive gas clumps onto star forming galaxies in the high redshift Universe. The [CII] 158μm line, in particular, has the potential to delineate gas over large (tens of kpc) scales around forming galaxies in the early Universe.

Precision Astrometry: The field of ultra-high precision astrometry has reached maturity, relying fundamentally on the capabilities of the VLBA. Revolutionary results have been produced in the last year in areas ranging from Galactic structure and the dynamics of star forming regions, to proper motions in local galaxies, to obtaining a key cosmological benchmark measurement of the local expansion rate of the Universe. The coming two years will see the completion of the Bar and Spiral Structure Legacy Survey (BeSSeL) project on the VLBA, an unparalleled study of Galactic spiral structure and dynamics. Over this time a start will also be made on the truly remarkable program of direct proper motion measurements of nearby galaxies, thereby determining the three-dimensional motions of the local group, and hence constraining the dynamical mass model of our nearby Universe.

Testing Gravity: A major goal in modern physics is to open up a totally new window on the Cosmos through the detection of gravitational waves. The GBT has begun a search for nanoHertz (nHz) gravitational waves from SMBH throughout the Universe, using a network of pulsars as ultra-high precision clocks spread across the Galaxy. These pulsars act as the far ends of the arms of a Galactic-scale gravitational wave detector. The North American program, known as NANOGrav (nanoHertz Observatory for Gravitational Waves), is a collaborative effort between Universities and the NRAO.

Using the significantly improved sensitivity of new pulsar detectors and timing techniques, NANOgrav will reach limits capable of detecting the stochastic background of gravitational waves expected from merging binary supermassive black holes. NANOGrav's objectives and technology will complement the higher frequency laser interferometer searches such as Advanced Laser Interferometer Gravitational Wave Observatory (LIGO), and Laser Interferometer Space Antenna (LISA).

In parallel, searches for new pulsars continue with the GBT, with the hope of finding a black hole-pulsar binary. A search is also underway for pulsars orbiting the SMBH at the Galactic center. Either of these will provide a unique laboratory for the study of strong field General Relativity. The study of binary millisecond pulsars continues to push the boundaries of degenerate matter physics, with the discovery of neutron stars well above the Chandrasekar limit.

Extrasolar planets: The field of extrasolar planets has entered a new age, with the discovery of hundreds of planets and proto-planetary disks at optical, near-infrared (IR), and radio wavelengths. Observations with the VLA and ALMA are playing a unique role in the study of the early phases of planet formation, by imaging the dust and gas in protoplanetary disks, potentially down to Astronomical Unit (AU)-scales. These studies have attained new relevance with the increasing number of terrestrial-type planets being discovered with Kepler and ground-based spectroscopy and photometry. The VLA and ALMA provide the key information on early planet formation, including the high resolution required to image dust gaps cleared by forming planets in protoplanetary disks. ALMA may make a direct detection of the warm dust associated with forming Jupiter-like planets. The VLA is crucial for probing the most optically thick inner regions of protoplanetary disks and is sensitive to the growth of dust to pebbles, on the way to planets. The GBT in 2015 will perform large-scale surveys for dark,

be completed 20. NA ALMA Development Studies Call for Proposals date – next round (preliminary date)* 21. NA ALMA Ongoing Development Projects initiated in FY12 will be completed 22. Commission the FE test cryostat at the NTC. 23. Install and test one FETIM module in an antenna receiver cabin. 24. Execute on-site (re) training. 25. Hire NRAO-Chile Chief of Staff 26. Support ALMA HR Department 27. Prepare for Upcoming Union Negotiations 28. Study Alternative Office Locations	[15] Scheduling blocks (scripts) for Cycle 3 telescope operation [16] Two day workshop: staffing, presentations and tutorials [17] Written requirements for reference imaging submitted to pipeline developers [18] Written requirements for heuristics for low signal-to-noise heuristics submitted to pipeline developers [19] Six (6) Study Programs initiated in FY2014 will be completed. They are "Advanced Solar Observing Techniques," "Concept Study of a Millimeter Camera for ALMA," A 2nd Generation Receiver for ALMA Band 10," "A 2nd Generation Receiver for ALMA Band 6,"Kindling Community Science Tool Development," and "Calibration Refinements for ALMA Imaging." [20]* The Call for Proposals for the next round of Study Programs will be released (preliminary date). Note: per agreement with NSF, the release date of this call depends upon the status of the FY2015 federal budget. [21] Three (3) ongoing development projects initiated in FY12 will be completed. They are: "Band 5 Local Oscillator," ALMA Phasing Project," and "Fiber Optic Connectivity." [22] FE test cryostat integrated with the FE tilt table and the test and measurement system and available for use. [23] First of the delivered FETIM modules integrated with the FE assembly in the antenna and operational. [24] One training session for each of the FE and BE ASG groups at the OSF. [25] Hire Chief of Staff (and implement new succession and management plan) [26] Support the ALMA HR Dept in the transition period to a new Head of HR. [27] Prepare analyses and provide support for upcoming union negotiations scheduled for August 2015. [28] Analyze alternatives to the physical location of NRAO-Chile, including the possibility of moving the office to the ALMA SCO in 2015

the starburst along with detailing its kinetic properties. Measurement of gas acceleration should provide key insights into the mass-loading mechanisms of the flow. ALMA's sharp view will provide unprecedented insight into the fundamental processes in this nearest starburst galaxy accessible with ALMA. The closest galactic nucleus is our own, splendidly placed for ALMA observation. Using ALMA's polarization capability and sensitivity, variations in the accretion environment on short timescales may be measured to infer the dynamical activity of the accretion flow on the scale of the event horizon.

ALMA's sensitive high angular resolution provides insight into galactic processes also. Near the Galactic Center lies the enigmatic "Brick" molecular complex, G0.25+0.02. In Cycle 0 observations of this object, broad-line absorption filaments were seen, only in the optically thick HCO+ J=1-0 transition. Those observations failed to spatially resolve the filaments, which had a length to thickness ratio of more than an order of magnitude, and a velocity breadth of more than 20 km/s. Are these structures ram-pressure confined shocks or are the ions magnetically confined? ALMA Cycle 2 observations may provide insight. Already ALMA has provided detailed sensitive images of disks around protostars; those protoplanetary disks link their host stars and planets chemically as well as physically. Deuterium chemistry provides an effective probe of cold chemical processes where the abundance of heavy hydrogen can be enhanced by orders of magnitude. Observations to date vexingly suggest radically different patterns in two well-studied disks. A Cycle 2 project will provide a survey of a half dozen disks spanning a range of characteristics to explore the intrinsic deuterium chemistry variation in them and to characterize the links between variability and disk structure, age and radiation fields.

In Cycle 0, ALMA provided extraordinary observations of strong CO and SiO emission toward SN1987A, the closest supernova observed to Earth since 1604. Using ALMA's high resolution and sensitivity, three-dimensional images of these molecules will be measured in the ejecta, providing temperatures and densities. Clumps will be resolved, providing important constraints on instabilities in the ejecta. The relative abundances of dust and carbon and silicon containing molecules will suggest the formation physics of these components. A spectral index image will provide insight on where particle acceleration in the remnant occurs, how it varies with location, and what the nature of the compact remnant is.

In the nearby TW Hya system a young planetary mass object orbits a low mass brown dwarf at a distance of only 40 AU. ALMA's sensitivity and resolution will enable the characterization of the physical environment of this object, sensitive to thermal emission from dust in the lunar mass range. The more massive disk around the brown dwarf will also be characterized to explore disk structure at the extreme low mass end of the spectrum. A second object, a 15 Jupiter mass object only 330 AU from its host star, shows accretion activity and infrared excess emission, suggesting a circumplanetary disk envelops it. ALMA will measure the mass of this disk with lunar mass sensitivity, providing insight into the origin of gas giants in extreme orbits.

ALMA is currently providing astrometric observations of the Pluto-Charon system to improve knowledge of its location in order to guide the New Horizons spacecraft and to properly sequence its on-board instrumentation for observations of the system. ALMA observations will provide improvements in knowledge of the location of Pluto of a factor of two. Separate ALMA observations will provide characterizations of its atmosphere and surface, providing complementary observations of upper atmospheric structure and surface emissivity as well as distinct thermal and astrochemical data.

planning for a capital fundraising campaign, development of a business/operations model, and creation of an exhibit theming plan. Some elements of this second strand will require the service of consultants not presently budgeted via the cooperative agreement; EPO will endeavor to secure such funding.

The motivation for pursuing a new center is predicated on three factors: (a) the recent technical upgrade and 'rebirth' of the VLA; (b) the recognition that the current visitor center cannot handle the number of visitors (nor properly orient them) that could be potentially drawn to the site; (c) the growth of space-themed tourism in New Mexico, as is especially possible with the impending commencement of flight and tourism operations at Spaceport America.

Skynet Jr. Scholars (SJS): NRAO partners with the University of North Carolina, Chapel Hill, The University of Chicago Yerkes Observatory, 4-H Clubs, and the Astronomical Society of the Pacific in an NSF-funded program to develop educational activities in which 4H youth nationwide will conduct experiments and observations using Skynet robotic telescopes, one of which—and the only radio telescope—is NRAO's automated 40 Meter Telescope. During FY2015 work will continue on developing the SJS Explorations Modules (activities) as well as continue development and testing of the Skynet interface.

STEM Role Models: NRAO will participate in several activities in Charlottesville to introduce students to STEM career practitioners, including via Dominion Virginia Power's STEM Career Day and Piedmont Virginia Community College's 10 Grade Career Day (subject to invitation). Additionally, we will create approximately a dozen STEM career focus videos featuring NRAO staff or science users.

Space Public Outreach Team (SPOT): NRAO will expand the grant-funded SPOT network, which enlists and trains undergraduate student volunteers to become make STEM presentations at K-12 schools, with an additional new presentation and with a new recruitment of students from the University of Virginia (subject to student interest), enabling schools in central Virginia to request SPOT presentations. (In its first year, SPOT functioned only in West Virginia.)

Galaxy Science through Astronomy Role-Modeling (GSTAR): In this program, funded by a grant from STScI, Charlottesville teachers and students will be paired with University of Virginia (UVA) graduate students in astronomy and researchers at NRAO with authentic research experiences in astronomy, as well as the development of a standards-based curriculum module that is related to the science research. NRAO EPO will assist this program with video recording and editing.

Astronomy in Chile Educator Ambassadors Program (ACEAP): This AUI-led effort, for which NSF funding has been awarded, will bring amateur astronomers, planetarium personnel, and K-college astronomy educators to U.S. astronomy facilities in Chile, including ALMA, **Cerro Tololo Inter-American Observatory,** and Gemini. These ambassadors will receive extensive training about the facilities and communicating science to students and the public, and will go into schools and community groups across the U.S. to share their experiences and broadly disseminate NRAO, National Optical Astronomy Observatory, and Gemini resources.

NRAO Research Experiences for Teachers (RET): NRAO is awaiting the posting of the solicitation from NSF-Engineering. If our grant request is approved, we will provide teachers with eight-week summer internships working with astronomers or engineers on research.

PING: Exploring the Cosmos with NRAO: This AUI-established program is a collaboration between AUI-NRAO and the National Society of Black Physicists targeting underrepresented minorities

protoplanetary disks, and study the composition of debris disks. With its increased sensitivity the VLBA can detect planets by their astrometric signatures on nearby radio-emitting stars.

The radio observations complement the studies of proplyds, or the dusty shadows of protoplanetary disks as imaged in the optical, and the near-IR studies of dust spectra. Such comparative near-IR – radio studies at tens of milliarcsecond resolution will become common with the advent of the James Webb Space Telescope (JWST), working with ALMA and the VLA.

Astrochemistry and biology: Discovery of terrestrial planets, many within the habitable zone, has spurred interest in the search for extraterrestrial life. Radio facilities play a unique role in the study of chemistry, and in particular, pre-biotic chemistry, in the Cosmos. The new broad band systems at the GBT have shown their power in discovering amino acid precursors in Galactic molecular clouds, and the Primos survey at the GBT will continue in the vanguard of Galactic biochemistry. ALMA and the VLA supply the critical spatially resolved observations of the chemistry in proto-planetary disks that potentially fosters the formation of life.

Solar system: All the NRAO facilities see a steady, healthy demand for solar system observations. Understanding our Solar system has taken on new import with the rapidly growing interest in extrasolar planets. The VLA is routinely used to image magnetic reconnection in the inner Solar corona on sub-second timescales and spatial scales of hundreds of kilometers. Planetary radar using the GBT and Arecibo provides meter-scale resolution of the surfaces of the Moon and rocky planets as well as studies of near-earth asteroids. ALMA and the VLA are providing detailed images of the dynamics of the gaseous constituents of the atmospheres of the giant planets, and even studying volcanism on planetary moons. The VLBA has demonstrated the remarkable ability to track distant satellites, such as Voyager 2, to an unprecedented accuracy of ten's of miles. At low frequencies, the VLA is performing unique studies of space weather and ionospheric physics. We expect all these areas to continue to expand in scope over the coming years. There is keen interest in the detection and characterization of near-Earth asteroids, and space weather has become a major issue for Mankind. The GBT and the low frequency developments at the VLA provide unique and powerful tools for studying these phenomena and their effect on the Earth.

A new era in surveys: The new capabilities of VLA and ALMA have opened a new era in radio surveys, both wide and deep. A major conceptual break has occurred with the realization that the wide-band systems allow for deep searches for spectral lines over huge cosmic volumes. Pilot surveys in both CO and HI have been performed, with impressive results. Spectral line deep fields are now becoming a standard tool at the VLA and ALMA, and the coming two years will see a detailed delineation of the evolution of the cool gas content of galaxies – the fuel driving the evolution of cosmic star formation rate.

Continuum surveys with the VLA are reaching μJy sensitivity at sub-arcsecond resolution over degree-area fields. These surveys provide a dust-unobscured view of the star formation history of the Universe, as well as of the evolution of the supermassive black holes. ALMA deep fields over smaller areas are tracing out the dust properties of galaxies back to the formation of the first galaxies in the Universe. The coming two years will see improved imaging techniques that allow for wide field mosaics in total and polarized intensity, allowing for the determination of a large-scale rotation measure grid to study the distribution of magnetic fields throughout the Cosmos. These programs will be synoptic by design, and hence reveal the temporal behavior of the radio sky to μJy depth. The GBT is making extremely deep, wide field surveys of faint gas in the Local Group and around nearby galaxies to identify past galaxy interactions and the source of galaxy growth.

14.1 Communications Major Milestones

Table 14.1.1: Communications FY2015 Major Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Science Communications	Science meeting exhibit	1			
	Research Facilities brochure	2			
	AAAS science symposia			3	
	NRAO Annual Report				4

Milestones:	Deliverables:
1. Complete science meeting exhibit re-design 2. Update Research Facilities brochure 3. Submit 2016 AAAS science symposium proposal 4. Publish 2014 NRAO Annual Report	1. New NRAO exhibit display for science community meetings 2. 2015 NRAO Research Facilities brochure 3. Science symposium proposal 4. Hardcopy and online NRAO Annual Report

Table 14.1.2: Communications FY2016 Major Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Science Communications	Research Facilities brochure	1			
	AAAS science symposia			2	
	NRAO Annual Report				3

Milestones:	Deliverables:
1. Update Research Facilities brochure 2. Submit 2017 AAAS science symposium proposal 3. Publish 2015 NRAO Annual Report	1. 2016 NRAO Research Facilities brochure 2. Science symposium proposal 3. Hardcopy and online NRAO Annual Report

its commitment to investigate funding scenarios, should we develop consensus that a significant overhaul or replacement of the installed ERP system would be beneficial).

JD Edwards upgrade of Business Reporting modules, web application servers. Investigate single sign-on: The MIS division installs JD Edwards in a timely manner and keeps all licensed software current. NRAO uses several web applications, which must regularly be synched with the JD Edwards system to assure NRAO staff can work on the platform best suited for their position. Present systems may require an individual to sign-in several times as they move through various NRAO computing sources. The installation of a universal or single sign-on system will be investigated.

FY2016

Load new Chart of Accounts: The new chart of accounts will go live on October 1, 2017. It will be loaded and tested in the fourth quarter of FY2016.

Review, consider and prepare a report to recommend enhancements for Observatory Management Information System: New modules are offered periodically by JD Edwards. These offerings will be reviewed with key stakeholders (AUI Fiscal, CAP, HR and Business Services) to determine interest. A budget analysis will be required before new modules are added.

Move MIS servers to Charlottesville from Green Bank: With the divestiture of the Green Bank site from the NRAO CSA, it may be necessary to move the MIS servers to Charlottesville. This will be done in the fourth quarter and will require establishment of a new real-time mirroring system.

15.5 Technology Transfer Office

The NRAO Technology Transfer Office has three main objectives which are designed to meet the mission and purpose of the Observatory and to fulfill the Congressional directive to support commercialization of federally funded research and technology development: actively seek entrepreneurs and new product development teams to commercialize our technology, marketing certain laboratory resources for broader scientific and commercial use, when appropriate., and solicit sponsors of research where technical development may yield new innovations and technology.

FY2015

Commercialize one additional technology: One of the primary missions of the TTO as part of the Bayh-Dole Act is to move technologies to commercialization. Potential technologies will be identified from the Intellectual Property register. A selection committee will review the technologies and submit one or more for approval to the Director. Commercialization efforts will then begin.

Investigate holding first NRAO Astronomy and Biomed Imaging conference: There are similarities between the software used for radio-astronomy imaging and biomedical imaging. If interest can be identified in holding a joint conference, a steering committee will be formed and funding sought. The goal will be to hold a meeting in the April-June 2015 time frame.

5.3 Central Development Laboratory Major Milestones

Table 5.3.1: CDL FY2015 Major Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Repair, Maintenance, Production, Support	Band 6 Spare Mixer Production				1
	Deliver 4 ALMA Band 2 amplifiers	2			
	Deliver 10 ALMA Band 1 amplifiers		3		
	ALMA Band 2 optics design including feed horn, lens and reflective mirrors (if feasible)	4			
	Measurement of Band 2 optics	5			
	Delivery of Band 2 OMT	6			
	ALMA Phasing	7			
	PAPER				8
Research and Development	THz SIS Mixers				9
	Cryogenically test MMIC amplifier modules using NGC 35nm PHEMT process			10	
	Cryogenically test MMIC amplifier module using BAE 50nm MHEMT process			11	
	HERA				12,13
	DARE				14,15
	Implement a six-channel "IRD Backend" using a Kintex-7 FPGA processor			16	
	De-interleave multiple sources of data on an unformatted serial link				17
	Implement advanced topologies and miniaturized packaging of reflectionless filters				18
	Low Noise Amplifiers			19	
	Digital Downconverter Upgrade			20	
	Digital Receiver Development				21
	PAF Analysis and Modeling		22		23

Milestones:

1. Complete repair of eight spare Band 6 SIS mixers
2. Design, build and test Qty. 4 MIC LNAs
3. Build and test Band 1 amplifiers
4. Design ALMA Band 2 optical system
5. Test Band 2 optical system
6. Deliver Band 2 optical system
7. Complete ALMA Phasing System hardware and firmware acceptance tests.
8. Fabricate, evaluate, and deliver spare components to the PAPER-128 site.
9. Demonstrate balanced low-noise 4-12 GHz amplifier with superconducting hybrids
10. Cryogenically test MMIC amplifier modules using NGC 35nm PHEMT process
11. Cryogenically test MMIC amplifier module using BAE 50nm MHEMT process
12. Develop a new feed for the 14 meter diameter paraboloidal reflector antenna. This will be based on the PAPER dipole. The work will include electromagnetic design and analysis.
13. Mentor pre-doctoral student to measure the beam pattern of a new HERA prototype antenna using satellite downlink signals.
14. Develop the DARE radiometer proof-of-concept and calibration procedure.
15. Mentor Reber pre-doctoral graduate student to examine the influence of the ionosphere on the measurement of Dark Ages hydrogen
16. Implement a six-channel "IRD Backend" using a Kintex-

Deliverables:

[1] Repaired and tested eight spare Band 6 SIS mixers
[2] Qty. 4 MIC based Band 2 LNAs
[3] Qty. 10 MIC based Band 1 LNAs
[4] Band 2 optics system design for integration into cartridge
[5] Test data for Band 2 optics system
[6] Band 2 optics system for integration into cartridge
[7] Test data for ALMA Phasing system
[8] The number of components will depend on the availability of funds – TBD.
[9] Test data for balanced low-noise 4-12 GHz amplifier with superconducting hybrids
[10] Cryogenic test data for NGC 35nm MMIC module
[11] Cryogenic test data for BAE 50 nm MHEMT amplifier module
[12] The deliverable for this effort is a report.
[13] Best effort – no deliverable.
[14] The deliverable for this effort is a report and instrument deployed in Green Bank
[15] Best effort – no deliverable.
[16] Experiment results
[17] Experiment results
[18] Experiment results
[19] Test Results with go/further development required/no-go decision
[20] Mechanical and electronic design and integration report
[21] Digital receiver prototype hardware/firmware, test report, and decision gate on feasibility

Other facilities and programs: NRAO will continue working with the MeerKAT and the five hundred meter Aperture Spherical Telescope (FAST) project in China, to explore new telescopes and techniques, leading to the next generation major radio facilities. We are involved with in a scientific and technical collaboration with the Shanghai Observatory (SHAO) for single dish and VLBI development, including a potential space VLBI mission.

Perhaps most importantly, our current facilities and scientific and engineering staff are at the forefront of attacking the most difficult problems facing next generation instruments, including: (i) Big Data archiving, processing, and analysis, (ii) complex, three dimensional visualization, (iii) wide-field, wide-band, high dynamic range polarimetric imaging, (iv) massively integrated receiver modules and THz receiver technology, (v) phased array feeds, and many other areas. These basic technology developments will prove vital to the long-range future of all of radio astronomy.

NRAO is working with the community to realize these exciting goals, providing leadership in areas ranging from world-recognized scientific and technical expertise, to well established management skills, operating in partnership with the University community. The NRAO has demonstrated its dedication to helping scientists explore the Universe and answer fundamental questions about astronomy and astrophysics for the past 50 years. As a cornerstone of the current and future multi-wavelength suite of ground- and space-based observatories, the major NRAO facilities will continue to enable and serve the scientific vision of its community, as captured in NWNH.

through peer-reviewed proposals, provides resources to help with testing and scientific verification, and helps to ready new capabilities for end-to-end operation. Once a capability has been demonstrated and tested, and can be prepared with the standard Observation Preparation Tool (OPT) and dynamically scheduled, it is offered through the SRO program pending full testing and documentation. When a mode is robust and well tested, it is offered as GO. The GO program therefore comprises a suite of robust observational capabilities designed and tailored to address the highest priority scientific needs of the general community. The SRO program allows users access to capabilities that can be set up via the OPT and run through the dynamic scheduler (without intervention), but are not as well tested as GO capabilities.

The RSRO program will continue to provide access to more extended capabilities of the VLA in FY2015 and FY2016. RSRO capabilities are those that require additional testing, and are provided to the community in exchange for a period of residence to help test and verify those capabilities. The requirements for the RSRO residency have relaxed since the completion of the EVLA Construction Project. A minimum residency is no longer required, and there is increased flexibility in the length and timing of visits. In the past, NRAO was able to provide some financial support for RSRO visits. This will no longer be possible in FY2015 and FY2016 due to declining budgets. The kinds of capabilities available through the RSRO program include, e.g., correlator dump times shorter than 50 msec, data rates above 60 Mbps, use of recirculation beyond a factor of 64 in the correlator, use of the P-Band system (see list below for a guide to VLA frequency bands) for polarimetry or spectroscopy, more than three sub-arrays or sub-arrays with the 3-bit system, and complex phased array observations (e.g., pulsar and complex VLBI observing modes). The commissioning of the new Solar-capable receivers being installed in FY2015 and FY2016 will be through resources provided by the RSRO program.

Capabilities to be offered for each observing semester are defined approximately four months ahead of the associated proposal submission deadline, to allow them to be incorporated into the various software tools associated with the Call for Proposals.

Band	Designation	Range
4m	4	0.058-0.084
90cm	P	0.23-0.47
20cm	L	10-2.0
13cm	S	2.0-4.0
6cm	C	4.0-8.0
3cm	X	8.0-12.0
2cm	Ku	12.0-18.0
1.3cm	K	18.0-26.5
1cm	Ka	26.5-40.0
0.7cm	Q	40.0-50.0

Scientific Support of Receiver, Antenna, and Array Performance: A large fraction of the scientific support goes toward maintaining receiver, antenna, and array performance and ensuring that our user community has access to quality instrumentation and updated information to effectively use the VLA. Operational tasks that are carried out by the scientific staff every semester in support of these functions are listed below. Additional items specific to FY2015 and FY2016 are called out separately by year later in this section.

- Support Calls for Proposals: Prepare user documentation for offered capabilities before the call goes out, provide scientific testing of user tools needed to prepare proposals (e.g., Proposal

Change Record

VERSION	DATE	REASON
Final	02/18/15	Edits made from the 90 Questions received by NSF • Budget Overview (page 8) • Section 1 – ALMA Ops (page 21, 25) • Section 3 – NM Ops (pages 33, 34, 39, 42, 43, 46) • Section 4 – WV Ops (pages 63, 67, 71) • Section 5 – CDL Section (pages 76,78, 80) • Section 6 – SSR (pages 92, 95) • Section 7 – DMS (pages 106, 107, 109) • Section 8 – PMD (page 126) • Section 10 – EPO (page 131) • Section 13 – HR (pages 155, 156) • Section 16 – Spectrum Management (page 176, 177) • Section 17 – Director's Office (page 182) • Appendix A • Appendix E
1.0	10/15/14	Draft Report Complete

- Pipeline Heuristic Development: Heuristics will be defined for inclusion of ionospheric calibration in the calibration pipeline (Q2).
- Support for the VLA Sky Survey (VLASS): Should the VLASS be approved for observing, it could start to be observed in FY2016. High-level VLASS data products, including catalogs, will need to be delivered through the NRAO Archive (Q2).

3.2 Very Long Baseline Array

3.2.1. Science

In FY2015 and FY2016 the VLBA will remain the world's pre-eminent facility for microarcsecond astrometric studies, and submilliarcsecond imaging. A wide range of science returns will be achieved through precision astrometry including fundamental cosmology, Galactic spiral structure, distances to local star forming regions and clusters, and local galaxy dynamics (Section 1.1). Imaging applications include the time-evolution of the black hole/accretion disk/jet environments of AGN, carried out in parallel with high energy National Aeronautics and Space Administration (NASA) missions such as the Swift, Fermi and Chandra satellites. New capabilities will continue to be added with a focus on increasing the number of compatible observing modes of the various stations of the High Sensitivity Array, and to include the Large Millimeter Telescope for 3mm VLBI. The emphasis in telescope operations for FY2015 and FY2016 will be to improve the reliability of the array through the retirement of legacy hardware and software, and on-going infrastructure maintenance.

FY2015

In FY2015 there will be improvements in sensitivity and flexibility, primarily through expanding the number of compatible observing modes available through the HSA.

FY2016

Pending funding availability, NRAO would like to outfit the VLBA with a state-of-the-art Ka-Band (26-40 GHz) system. Such a system could represent a significant improvement in astrometric accuracy of the VLBA, and could be used, for example, to improve the fundamental celestial reference frame (ICRF3) used by other astrometric missions, including the European Gaia mission.

3.2.2. Operations

Science Operations

Observing Programs: The VLBA will offer the same three types of observing programs that the VLA offers for users in FY2015 and FY2016: RSRO, SRO, and GO. The VLBA GO program comprises access to well-tested observing modes using the new Sensitivity Upgrade equipment that provides data rates up to 2 Gbps. Two observing systems are available within the ROACH Digital Backend (RDBE) units: the relatively limited Polyphase Filterbank (PFB) and the more flexible Digital Down-Converter (DDC). Two RDBEs using the DDC observing system offer 8-channel modes that are equivalent to what was available with the legacy system. The new C-Band receivers provide wider bandwidth coverage than previously possible and allows for observations of the excited OH line at 6.0 GHz and the methanol line at 6.7 GHz. In addition, it is possible to combine the VLBA with the phased VLA (phasing all VLA antennas together, "Y27"), GBT, Arecibo and Effelsberg in so-called HSA observations. The observing system that

spectrum management in order to protect and improve observing conditions for all astronomers and has done so since its inception.

The spectrum manager's spectrum management portal is at http://www.cv.nrao.edu/~hliszt/RFI/

FY2015

A national dialog with the satellite-telephone company Iridium will be opened regarding protection of the 1612 MHz OH band from RFI generated by the next generation of the Iridium constellation satellites that will be launched in the next few years. The factual basis for this discussion was recently prepared by NRAO for use by the U.S. astronomy community.

Geneva meetings of the radio astronomy groups SG7 and WP 7D will occur 09/30/14 – 10/08/14 and in spring 2015. At these meetings, the assembled group will progress or finalize various astronomy-related ITU-R documents including an important new recommendation, originating at NRAO, to protect passive service bands from spurious emissions. The ITU-R group WP 5B dealing with 4mm vehicular and other radars will meet in Geneva 10/27/14 – 11/08/14 to finalize its summary of issues dealing with protection of radio astronomy. Geneva meetings are preceded by monthly U.S.-only telecons.

The Conference Preparatory Meeting CPM15-2 will be held in Geneva 3/23/15 – 4/02/15 to prepare final input for the World Radio Conference in FY2016. In advance of the Conference Preparatory Meeting, the radio astronomy community, led by NRAO and IUCAF, will develop consensus views on preferred methods of satisfying the conference agenda items (essentially, which spectrum allocations to make or deny) to its best advantage.

The NRAO spectrum manager, currently vice-Chair of IUCAF, is due to assume the chairmanship at the International Astronomical Union (IAU) General Assembly in August 2015.

FCC comments will be filed on matters as they arise.

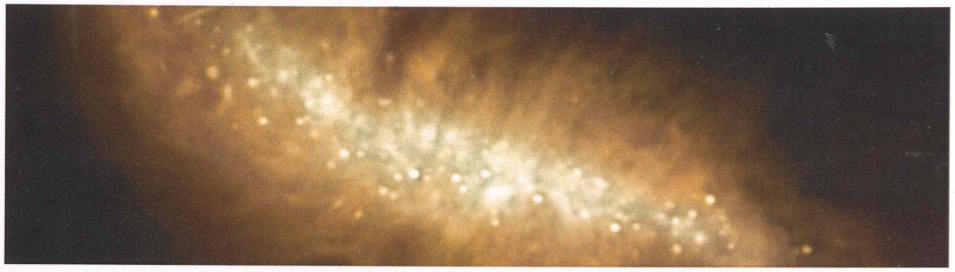
FY2016

The month-long World Radio Conference (WRC)-15 will be held in Geneva in 11/02/15-11/15/1 and the NRAO spectrum manager will attend as the representative of IUCAF. Other Geneva meetings will be held at dates to be determined.

Assuming the IUCAF chair will oblige attendance at major assemblies of the sponsoring groups IAU, International Union of Radio Science (URSI), and Committee on Space Research (COSPAR).

FCC comments will be filed on matters as they arise.

National Radio Astronomy Observatory



Program Operating Plan

FY2015 - FY2016

Technical Upgrades and Enhancements

The primary technical upgrade for the VLBA in FY2015 and FY2016 focuses on moving key functionality from the old VME control computers, which can no longer be replaced and are becoming increasingly unreliable, to the new station control computers. The details of what this will entail are given below by year. Technical upgrades are chosen based on whether they improve array performance, increase observing efficiency, or retire some form of technical or operational risk. In addition, there are several upgrades for which funding has not yet been identified, also summarized in the FY2015 section below. The decision of which potential upgrades are carried out within the existing operations budget of a given year is based on consideration of: safety; operational efficiency; ease of maintenance; impact on data quality and delivery of science; cost; impact on overall NRAO strategic goals.

FY2015

- Replacement of VME Control Computer Functionality: The legacy VME computers that control the operation of the VLBA antennas are reaching end-of-life. As part of the Sensitivity Upgrade project, new hardware has been installed at the VLBA stations; all of this new hardware is controlled with a modified version of the EVLA Executor. The computer that hosts the Executor will be used to replace the VMEs, but is not currently able to communicate with the legacy VLBA hardware. An interface box (M450) has been designed and tested in the laboratory; an operational (production) unit will be installed at a VLBA site for testing in FY2015 (Q3).

Unfunded Upgrades

- Maser Lab Upgrade: The Maser Lab presently has an unsupported and cumbersome Allan Variance Test Fixture, which is used to measure long-term stability. The test fixture uses proprietary analysis software that runs on an unsupported operating system and is twenty years old. In addition, it is restricted to signals with a frequency of 100MHz. The Maser Laboratory Upgrade Plan consists of the acquisition of a suite of test equipment and development of associated software to operate a new Allan Variance Test Fixture ($40k for hardware, plus software effort).
- Phase III of the Synthesizer Replacement, Build and Installation: Phase III of the VLBA synthesizer replacement plan covers the build and installation of dual synthesizer modules (L404) in nine VLBA antennas, along with a full set of spares (5 units). The new synthesizers provide improved tuning flexibility and ease of maintenance. The total cost for the new hardware is $86k.

FY2016

- Replacement of VME Control Computer Functionality: Software to replicate the monitor data stream from the VME computer and send it to the station control computer will be put in place, and that stream will be processed and put into the new VLBA Monitor Archive Database (Q2). This will facilitate replacement of functionality related to Pulse-Cal and reference pointing, and eventually removal of formatter and Base Band Converter (BBC) hardware.

Observing Capability Enhancements

The VLBA continues to provide capability enhancements to the user community in an effort to increase the ease of use and the science that can be done with the array. To this end, NRAO continues to provide incremental capability enhancements above and beyond the operational efforts outlined above.

16 SPECTRUM MANAGEMENT

The NRAO participates heavily in spectrum management in order to protect and improve observing conditions for all astronomers, and has done so since its inception.

16.1 ALMA Spectrum Management

ALMA Site Radio Frequency Interference Mitigation

The ALMA radio quiet zone law was recently renewed for another 5-year period following a request to SUBTEL (the Chilean telecommunication authority) by the ALMA executives. A Scientific Committee on Frequency Allocations for Radio Astronomy and Space Science (IUCAF) spectrum management school was held in Santiago during April, 2014, which was attended by ALMA staff and representatives of SUBTEL.

FY2015

Several areas have been identified as possibilities to implement a program of spectrum management and RFI mitigation:

1. Strengthen the relations with SUBTEL by providing them periodically with data on interference, if any, or report of its absence. We are not formally mandated to submit annual reports, but it would be useful to do so.
2. Establish a preventive study of potential impact of vehicle radars on the Jama road and especially the far pads. This requires modeling including knowledge of the topography.
3. Prepare and update periodically a list of potential satellite sources of interference and make sure the Science team has them considered on the scheduling.
4. Interact with the Science team to identify interference on data being reduced and find its source in order to circle back to SUBTEL, if needed.
5. Prepare a detailed plan on how to make ALMA personnel aware of the problem in order to limit internal sources of interference.

FY2016

As for FY2015.

16.2 NM Spectrum Management

Activities at the VLA site, links to resources for observers, RFI scans of the spectrum, etc., are described at http://science.nrao.edu/evla/observing/RFI. Similar resources for the VLBA antennas may be found at http://www.vlba.nrao.edu/astro/rfi.

NM Site Radio Frequency Interference Mitigation

FY2015

The NM Operations Interference Protection Office coordinates spectrum usage for the VLA and VLBA sites by:

1. Responding to requests for Special Temporary Authority submitted through the NSF from the National Telecommunications and Information Administration (NTIA). The requests are

a wider 4-12 GHz IF, and (2) SIS mixers with NbTiN electrodes for lower noise above the superconducting band gap of Nb (suitable for frequencies above ~600 GHz).

Development of upgraded Band 6 mixers with AlN tunnel barriers and a wider 4-12 GHz IF band will continue. To be considered for use in ALMA front ends, the wider IF requires the development of a 4-12 GHz balanced LNA with sufficiently low power dissipation to meet the ALMA dewar's thermal budget constraints. The development of an operational balanced multi-junction SIS mixer will also benefit from improved magnetic field suppression of the Josephson effect, which we will continue to explore during this period.

For the higher frequency ALMA bands, the CDL and UVML will continue development of Nb/Al-AlN/NbTiN SIS junctions suitable for operation above 1 THz. Initial evaluation of these devices will be done at 385-500 GHz using existing test equipment, and by the end of FY2016 we expect to demonstrate a sideband-separating mixer as a possible upgrade for the existing ALMA Band 10 Double Sideband Receiver (DSB).

Low Noise Amplifiers: Our collaborations with Caltech/JPL, Chalmers, and BAE will continue in FY2016, possibly to include follow-up wafer runs and new MMIC designs based on the performance of those tested in FY2015. It is hoped that the Chalmers process will support ultra-low power LNA designs, facilitating balanced-amplifier architectures which can be used on 4K stages in conjunction with SIS mixers. We will also target the cryogenic evaluation of additional MHEMT amplifiers provided by BAE, who are actively developing amplifiers in similar frequency ranges for their own programs.

Optics and Electromagnetic Components: Development work on feeds and polarizers for THz frequencies will be continued during this period. The fabrication of components in this frequency regime is a significant challenge and new techniques will be pursued. A polarizer for ALMA Band 8 will be developed and tested. Work on broadband components at lower frequencies will continue in parallel as will the support for the second generation ALMA Band 6 and Band 10 receivers.

Digital Signal Processing: The DSP group will develop systems for high speed data acquisition of radio astronomy data. We will continue our involvement in the digital and signal processing aspects of the NRAO Phased Array Feed Project. As has been the case in previous years, we will continue to track developments in digital signal processing technologies and tailor them for suitable radio astronomical applications.

Hydrogen Epoch of Reionization Array (HERA): The definition of tasks and deliverables are pending availability of funds.

Dark Ages Radio Explorer (DARE): The definition of tasks and deliverables are pending availability funds.

FY2016

Integrated Receiver Development (IRD): Efforts in FY2016 will focus on extension of the unformatted photonic link concept by synchronizing parallel data streams, and by exploring new and more effective ways of calibrating the Digital Orthomode Transducer (DOMT). Some specific activities include:

- Synchronize parallel data streams on an unformatted serial link using FIFO buffering.
- Tapered waveguide calibration of DOMT.

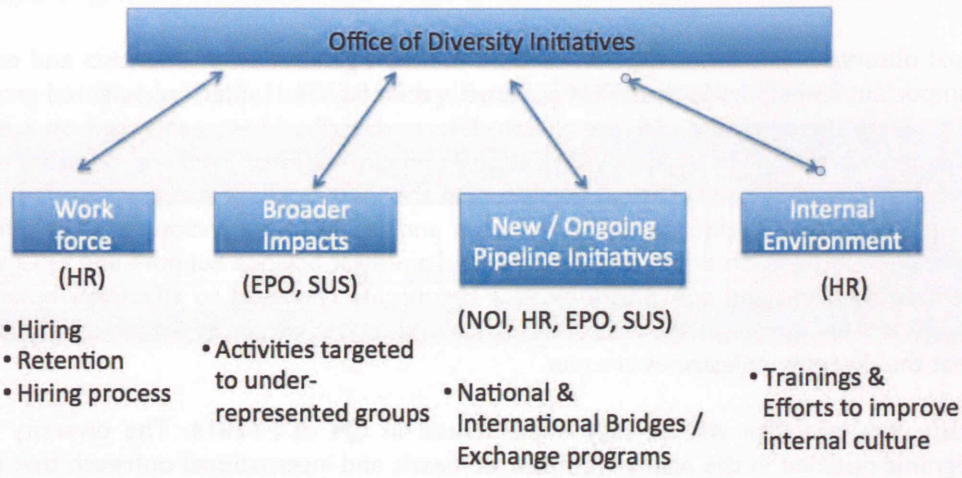


Figure 12.1 Office of Diversity Initiatives structure

12.1 National Programs

SEDUIP: The Socorro Electronics Division has been utilizing the Undergraduate Intern Program (UIP) to involve students in the production of NRAO hardware, software, and in drafting and design activities. Over 50 students have participated in the UIP in the last 12 years, many of whom are Hispanic engineering students native to New Mexico. This program is extremely beneficial to the students, introducing them to a professional laboratory environment, and providing mentors to guide them while they make meaningful contributions to ongoing technical design, assembly, and documentation projects at the Observatory. An added benefit of the program is that it increases the visibility of NRAO and AUI in the community in New Mexico, and trains potential future employees who will be well qualified to help NRAO retain its current world-class status for cutting edge radio signal processing technology. At present, this program is limited to the New Mexico Institute of Mining and Technology students who hear about the opportunity through word-of-mouth. This program would allow us to actively recruit students from a larger number of HSIs in New Mexico, such as the University of New Mexico and New Mexico State University, and would support one or two additional positions which we would use to increase the diversity within the program, targeting particularly female and Native American students attending these universities. We would also make use of these recruiting avenues to attract Hispanic and Native American students to the existing astronomy programs at all NRAO sites.

VA-NC Louis Stokes Alliance for Minority Participation (LSAMP): The LSAMP (NSF funded) program is targeted to under-represented minorities in STEM. MSIs are solidly established and UVA is the lead collaborator. Summer Research students will conduct hands-on research using the state of art lab facilities, observe at GB and the VLA, use advanced software applications and participate in classroom activities. NRAO's funding commitment will be to sponsor two students who will be named NRAO-LSAMP fellows. The LSAMP students have combined many aspects of their program into the NRAO REU program. This partnership has resulted in optimizing resources from UVA that has benefited the NRAO Astronomy Consortium Cohort and the NRAO Summer REU program.

National Astronomy Consortium (NAC) for Creating Future STEM leaders: The mission of the NAC is to build a pipeline for future STEM leaders from under-represented groups using a cohort model, multiple mentors, professional development and life-long career mentoring. At Charlottesville

teachers leaves many African American students feeling disconnected from school, and the disparity creates misperceptions and stereotypes that disadvantage all students, regardless of race.

The absence of diverse teaching staffs affects every one of our children. They rarely witness cross-cultural collaboration, hardly benefit from diverse mentorship. A generation is growing up without an appreciation of cultural differences, without understanding that despite our varied experience, our similarities unite us. African American students suffer the most: in Charlottesville and Albemarle County, they are three times more likely to drop out of school than their white peers. They lack mentors who share their sociological and cultural roots, who can address the needs of a diverse student population.

NRAO would like to establish a partnership with AATF to provide financial support for two Fellows. One of the Fellows will be awarded the NRAO Science Fellow to support teaching in the STEM area. This initiative will assist NRAO to build a pipeline to support science careers in the community and aligns with our broader impact initiatives.

12.2 International Partnerships

The NRAO International and National Exchange Program (NINE)

In the United States (and across the planet), the NRAO has been the leader in enabling cutting edge scientific research with its world leading radio facilities. Today, the landscape of radio astronomy is fast changing as countries such as China, South Africa, Chile and India are fast developing the next generation of radio astronomy facilities. These nations are also keen in developing the human capacity that will be essential to build, innovate, and operate these facilities. In the U.S. there is also a strong desire to develop further our human capacity in the STEM fields, especially within traditionally under-represented groups. Within the mandate and mission statement of NRAO we define under-represented groups to mean all of the following but not limited to people of color, women, economically disadvantaged and first-generation college students. The challenges and obstacles faced by under-represented groups in the U.S. and overseas are similar. Increasing diversity and improving the environment for diversity are essential ingredients for human capacity development. The program, NINE, described below is geared towards building the next generation of scientists and engineers in STEM fields nationally and internationally.

NINE Partners

U.S.: NRAO, NSBP, Cornell, University Wisconsin-Madison, University Maryland, Howard University

Potential International: South Africa (SKA-HCD, UCT, UWC, UNW, UKZN, Wits); China (Shanghai, others); Chile (U. Chile, PUC, Concepcion); India (RRI, NCRA, TIFR, IUCAA)

At each NINE node there will be a designated NINE faculty or staff member who will be responsible for helping to coordinate the local logistics, keep everyone in the program up to date on the local news, needs and developments. Ideally for each of the international partners there would be a designated (or elected) representative for the country. For the U.S., the NINE NRAO office will coordinate the efforts stateside and the overall coordination of the program.

6.6 Scientific Support and Research Financial Chart

6.6.1: FY2015 by Fund Source and Location

Work Breakdown Structure	CSA-1 NRAO Ops										CSA-2 ALMA Ops		Internal Common Costs						GRAND TOTAL	
	Charlottesville		Green Bank		Socorro		Observatory Wide		TOTAL, CSA-1		Charlottesville		Charlottesville		Socorro		TOTAL, ICC			
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
2000 Development Programs																				
2400 Software Development																				
2410 Software Development																				
2412 Pipeline Processing	163,683	1.1			136,100	1.2			299,784	2.3									299,784	2.3
2000 Development Programs Total	163,683	1.1			136,100	1.2			299,784	2.3									299,784	2.3
3000 Science Operations																				
3100 Observatory Time Allocation																				
3110 Tools & Documentation	60,575	0.5							60,575	0.5									60,575	0.5
3120 Proposal Review & Time Allocat			55,864	0.4	39,636	0.3			95,500	0.7									95,500	0.7
3200 Reference																				
3210 Library	65,000	-							65,000	-	97,500	-	370,668	2.0			370,668	2.0	533,168	2.0
3220 Historical Archives													38,560	0.3			38,560	0.3	38,560	0.3
3230 Metrics / Statistics													86,923	0.5			86,923	0.5	86,923	0.5
3300 Broader Impacts																				
3310 Student Programs																				
3311 Undergraduate					95,714	1.0			95,714	1.0									95,714	1.0
3312 Graduate	100,088	1.0	28,642	-	57,051	-			185,781	1.0									185,781	1.0
3320 Visitor Support	278,549	2.6	8,526	-	25,849	-			312,924	2.6									312,924	2.6
3400 Scientific Staff																				
3410 Staff Research																				
3411 NRAO Staff	59,205	-	31,505	-	117,225	-			207,935	-									207,935	-
3412 Jansky Fellows	98,751	1.0			226,445	3.2			325,196	4.2									325,196	4.2
3413 NRAO Postdocs					145,962	2.0			145,962	2.0									145,962	2.0
3500 Management	55,666	1.0			83,969	0.6			139,635	1.6			296,833	1.7	216,878	1.0	513,710	2.7	653,346	4.3
3600 Scientific User Services																				
3610 Community Support																				
3611 User Assistance	660,309	3.4	87,936	0.7	258,418	1.9			1,006,662	5.9									1,006,662	5.9
3613 Workshops & Conferences	15,000	-			16,500	-	20,000	-	51,500	-									51,500	-
3620 Science Data Processing	7,000	-	17,763	0.2	28,229	0.5			52,992	0.7									52,992	0.7
3630 Science Software																				
3631 Post-Processing Software	128,054	1.3	35,527	0.3	156,219	1.2			319,800	2.8									319,800	2.8
3000 Science Operations Total	1,528,196	10.7	265,763	1.5	1,251,217	10.7	20,000	-	3,065,176	22.9	97,500	-	792,984	4.5	216,878	1.0	1,009,861	5.5	4,172,538	28.4
Grand Total	1,691,879	11.8	265,763	1.5	1,387,317	11.9	20,000	-	3,364,960	25.1	97,500	-	792,984	4.5	216,878	1.0	1,009,861	5.5	4,472,321	30.6

During FY2015, the CDL will continue to support the offsite maintenance of the ALMA Band 6 receivers originally built by NRAO, with its main focus on maintaining a sufficient quantity of spare mixers and preamps. During the same period, the CDL will continue to support community projects, such as the Arizona Radio Observatory (ARO) radio telescope on Mt Graham (formerly the Heinrich Hertz Telescope), the South Pole Telescope, the Taiwanese Greenland Telescope (based on the Vertex ALMA prototype antenna), and outfitting of other submm telescopes for the sub-mm VLBI. Nearly all of this activity will be carried out on a work for others basis and will be undertaken only when it does not interfere with work required under the CSA-1 and CSA-2 NSF awards.

Low Noise Amplifiers: The CDL has, for the past thirty years, provided NRAO and the radio astronomical community at large with the world's lowest noise amplifiers in the frequency range 0.1-115 GHz. These amplifiers have not only been responsible for the high sensitivity and success of the VLA, GBT, VLBA, and ALMA telescopes, but they have also been used by nearly every other astronomical instrument requiring low-noise amplifiers built in the last thirty years; these include the Wilkinson Microwave Anisotropy Probe (WMAP), the Combined Array for Research in Millimeter-wave Astronomy (CARMA), the Degree Angular Scale Interferometer (DASI), the Cosmic Background Imager (CBI), Planck, and many others.

In FY2014 the CDL completed production of spare low noise amplifiers (LNAs) required for the VLA (a project that started in 2012) and began rebuilding the VLA's L-Band amplifiers. FY2015 is expected to mark the start of production of about 150 of the 35-52 GHz LNAs for ALMA Band 1 receivers. In addition, several amplifiers for prototype ALMA Band 2 receivers will be produced.

Continued support will be provided for all existing VLA, GBT and VLBA receivers. The VLBA amplifiers, which are now about a quarter century old, can no longer be repaired upon failure due to the unavailability of obsolete components. As a result, there is a need to produce replacement amplifiers whose design is based on currently available components. These replacements will also significantly improve the system noise (at K-Band, in some cases the improvement has been as much as 30 K). Where resources permit, the CDL LNA group will also continue to provide amplifiers for the general radio astronomical community on a work for others basis; in FY2014 such work was performed for Observatories in China, Sweden, Finland, Poland, Italy, and for U.S. institutions like the Naval Research Laboratory (NRL), Jet Propulsion Laboratory Deep Space Network (JPL DSN), CARMA-Caltech, Arecibo, and the University of Washington.

Optics and Electromagnetic Components: Optimizing the design of receiver optics and EM components is essential to fulfill the promise of the state-of-the-art active components in low-noise receivers. Examples of passive components include feed horns, OMT, and phase shifters. Over the years, components that were not available commercially for the VLA receiver upgrades were developed and manufactured by the CDL. In the past, such development efforts have yielded not only broader bandwidths but also simpler mechanical designs that have led to lower manufacturing costs and improved service robustness.

In FY2015 continued support will be provided to meet the needs of the GBT, VLA and VLBA; where possible, components for other community partners will be provided on a work for others basis. The design and development of a Ku-Band (12-18 GHz) feed for the SHAO 65-m telescope during FY2014 is an example of such support provided by the CDL in the past.

In FY2015, the design of optics for ALMA Band 2 will be completed and the design verified by measurements of a prototype which is to be fabricated at the CDL. Refinement of the preliminary optics

15. Replace one antenna azimuth bearing during the source of the year. 16. Perform preventive maintenance on each of two transporters prior to array reconfiguration. 17. Perform preventive maintenance on each of two transporters prior to array reconfiguration. 18. Perform preventive maintenance on each of two transporters prior to array reconfiguration. 19. Identify and replace 5000 aging or damaged cross-ties during the course of the year. 20. Identify and replace 5 antenna pad intersections during the course of the year. 21. Perform preventive maintenance on VLA site hatch gear. 22. Perform preventive maintenance on all VLA site transformers during the course of the year. 23. L-Band solar upgrade, 2 additional receivers with full RF upgrade installed. 24. X-Band solar upgrade, 6 additional receivers with 20 dB switched attenuators on outputs only, no solar Tcals, installed. 25. Ku-Band solar upgrade, 2 additional receivers with solar Tcal path plus 20 dB switched attenuators installed. 26. Ku-Band solar upgrade, 4 additional receivers with 20 dB switched attenuators on outputs only, no solar Tcals, installed. 27. S-Band solar upgrade, 4 additional receivers with solar Tcal path plus 20 dB switched attenuators installed. 28. FE card cage upgrades, 35 units installed. 29. C-Band thermal gap retrofits, 4 additional installed. 30. L-Band thermal gap retrofits, 4 additional installed. 31. Upgraded Ku FE noise diodes installed in 15 receivers. 32. Install 10 production F318 modules in antennas. 33. Commission remaining P-Band functionality in the OPT for 2016B. 34. Commission pulsar observing in the OPT for 2016B. 35. Investigate combining sub-bands for reference pointing using weaker pointing calibrators. 36. Implement continuous slew tipping scans. 37. Develop heuristics for ionospheric calibration for the VLA calibration pipeline. 38. Development in support of VLA Sky Survey, as specified in the VLASS Technical Implementation Plan. 39. Define VLBA capabilities to be offered for semester 2016B. 40. Define VLBA capabilities to be offered for semester 2017A. 41. Update VLBA documentation to support 2016B Call for Proposals, perform proposal technical reviews. 42. Update VLBA documentation to support 2017A Call for Proposals, perform proposal technical reviews. 43. Tiger Team maintenance campaign to KP. 44. Tiger Team maintenance campaign to MK. 45. Replicate monitor data stream to the station control computer. 46. Offer DDC-4 observing with Arecibo on HSA under RSRO program for 2016B. 47. Renew lease for Pie Town (PT).	[45] Software tested. [46] Commissioning and documentation. [47] Lease renewed.

Milestones:	Deliverables:
1. Define VLA capabilities to be offered for semester 2015B. 2. Define VLA capabilities to be offered for semester 2016A. 3. Update VLA documentation to support 2015B Call for Proposals, perform proposal technical reviews. 4. Update VLA documentation to support 2016A Call for Proposals, perform proposal technical reviews. 5. Determine baselines and pointing for antennas moving into their C configuration locations. 6. Determine baselines and pointing for antennas moving into their CnB and B configuration locations. 7. Determine baselines and pointing for antennas moving into their BnA and A configuration locations. 8. Subarray observing automated and incorporated into dynamic scheduler. 9. Incorporate 4-element API into regular operations. 10. Complete VLITE tests requiring B configuration and integrate VLITE into operations. 11. Testing and evaluation of new 3-bit samplers complete. 12. Make frequency averaging available in the CBE to lower data rate. 13. Reconfigure array to C configuration. 14. Reconfigure array to CnB, then B configuration. 15. Reconfigure array to BnA, then A configuration. 16. Reconfigure array to D configuration (part). 17. Establish DSOC control room for VLA Operations. 18. Commence DSOC VLA Operations. 19. Perform 7 antenna overhauls during the course of the year. 20. Replace one antenna azimuth bearing during the source of the year. 21. Perform preventive maintenance on each of two transporters prior to array reconfiguration. 22. Perform preventive maintenance on each of two transporters prior to array reconfiguration. 23. Perform preventive maintenance on each of two transporters prior to array reconfiguration. 24. Identify and replace 5000 aging or damaged cross-ties during the course of the year. 25. Identify and replace 5 antenna pad intersections during the course of the year. 26. Perform preventive maintenance on all VLA site transformers during the course of the year. 27. L-Band solar upgrade, 2 additional receivers with full radio frequency (RF) upgrade installed. 28. X-Band solar upgrade, 3 additional receivers with 20 decibel switched attenuators on outputs only, no solar Tcals, installed. 29. X-Band solar upgrade, 3 additional receivers with solar Tcal path plus 20 dB switched attenuators installed. 30. Ku-Band solar upgrade, 1 additional receiver with 20 dB switched attenuators on outputs only, no solar Tcals, installed. 31. Ku-Band solar upgrade, 3 additional receivers with solar Tcal path plus 20 dB switched attenuators installed. 32. S-Band solar upgrade, 3 additional receivers with solar Tcal path plus 20 dB switched attenuators installed. 33. FE card cage upgrades, 35 units installed. 34. C-Band thermal gap retrofits, 4 additional installed. 35. L-Band thermal gap retrofits, 6 additional installed. 36. FE cal board upgrades, 20 installed. 37. Prototype FE noise diode temperature stabilization assembly tested. 38. Replace the remaining legacy Q-Band receiver interface hardware sets. 39. Install 3rd replacement ACU. 40. Install 13 additional DTS transmitter modules with new 3-bit sampler boards. 41. Install prototype F318 module in antenna. 42. Install 10 production F318 modules in antennas. 43. Commission and document P-Band spectroscopy and polarimetry for 2016B. 44. Commission and document pulsar observing modes for 2016B.	[1-2] Software requirements and documentation. [3-4] Documentation and reviews. [5-10] Operational functionality. [11] Memo. [12] Operational functionality. [13-16] Array reconfigured and antennas operational. [17-18] Operational functionality. [19-20] Antennas overhauled and returned to array. [21-23] Preventive maintenance. [24-25] Track maintenance. [26] Preventive maintenance. [27-32] Upgraded receivers. [33] Upgraded card cages. [34-35] Upgraded receivers. [36] Upgraded cal boards. [37] Test report. [38] Interfaces replaced. [39-42] Hardware installed. [43-44] Commissioning and documentation. [45] Memo. [46-48] Commissioning and documentation. [49] Software requirements and documentation. [50-51] Commissioning and documentation. [52-53] Software requirements and documentation. [54-55] Documentation and reviews. [56-57] Antennas overhauled and returned to array. [58] Hardware installed. [59-60] Commissioning and documentation. [61] Hardware installed. [62] Leases renewed.

sufficiently low power dissipation to meet the ALMA thermal budget constraints and be considered usable as a front-end receiver component. For this project, a superconducting quadrature IF hybrid will also be developed on a small quartz chip.

For the even higher-frequency ALMA bands, the CDL and UVML will continue to develop Nb/Al-AlN/NbTiN SIS junctions suitable for operation above 1 THz. Initial evaluation of these devices will be done at 385-500 GHz using existing test equipment. Devices for ALMA Band 10 will be produced and evaluated in FY2016 (see section 5.1).

Low Noise Amplifiers: Research will continue on the fundamental noise properties of microwave transistors, with special emphasis on the limits of the noise performance of Indium Phosphide (InP) HFETs. This work will focus especially on further scaling of the gate length and "gate induced noise," and will also address the so-called "noise cancellation techniques" used in CMOS transistors. Although this last research topic will have no significant impact on the state-of-the-art low noise receivers for radio astronomy, it may have a significant impact on the direction of SKA development work.

CDL is also collaborating with Caltech/JPL to develop MMIC low-noise amplifiers using Northrop Grumman's 35nm InP process. This process has previously demonstrated results comparable to the best CRYO3 devices in the mm-wave frequency range. Current effort is focused on evaluating the maturity and repeatability of the process, particularly with regard to the cryogenic performance of devices. The outcome of this research will be crucial for the next generation of radio astronomy instrumentation, including, but not limited to, the proposed ALMA Band 2 receivers.

In FY2015 the CDL, will continue to evaluate MMIC processes at other foundries, including Chalmers and British Aerospace (BAE). Using a longer gate-length, the Chalmers process has demonstrated performance that is at least as good as CRYO3 in the cm-wave range, and appears to be repeatable. Although Chalmers is not prepared to offer foundry service for external designers at the present time, we are staying in contact with them regarding our needs, and have established a symbiotic relationship with the exchange of samples and information.

We have submitted layouts for MMIC amplifiers in the 60-90 GHz range to BAE using their 50nm metamorphic high electron mobility transistor (MHEMT) process. This process has already shown exceptionally good performance at room temperature. When available, these will be the first amplifiers from this MHEMT process to be evaluated cryogenically.

Digital Signal Processing (DSP): The focus of the DSP group is to develop technology and techniques for signal processing in radio astronomy. Digital technology continues to evolve at a rapid pace in terms of both device density and operating frequency. As a result, some aspects of astronomical signal processing that could only be performed using analog components a decade ago can now be carried out more accurately and economically using digital hardware. At the CDL, we continue to track developments in this field and to tailor them for suitable radio astronomical applications.

One of the recent notable products of this effort is the ALMA Baseline Correlator. Since its formal delivery in 2012, this instrument has become one of the most reliable of ALMA's sub-systems. As more of the correlator's capabilities are brought fully on-line, the DSP group will increasingly be needed to support these new modes. As the original designers of the correlator, the CDL's DSP group plays an increasingly important role in maintaining the operational state of the correlator and in extending its capabilities.

The VLA Sky Survey is well into the planning stage, with the community-led working groups designing both deep and wide components of this next-generation mega-survey in the radio. We expect this survey will play a major role in the scientific program at the VLA in the coming years. We note that, even with the advent of wide field survey interferometers like Australian Square Kilometre Array (SKA) Pathfinder (ASKAP) and Meer Karoo Array Telescope (MeerKAT), the VLA will still provide by far the highest spatial resolution, as well as the best sensitivity for fields of order a few square degrees.

Time-domain: Exploring the time-domain is a key area of discovery in astronomy, with rapidly increasing community interest and the advent of the Large Synoptic Survey Telescope (LSST) and Euclid. The dramatically improved and unique power of the NRAO facilities will play a dominant role in studies of the variable radio sky. We are adopting operational models and developing technical capabilities that will enable rapid response studies with μJy sensitivity at both the VLA and the GBT. The NRAO is a member of the LSST consortium.

An area where radio astronomy has played a particularly important role is in the physical analysis of high energy sources, such as those identified with the Fermi gamma-ray observatory. Many have been detected as millisecond pulsars with the GBT. Very Long Baseline Interferometry (VLBI) imaging has proven to be the most incisive method with which to probe the physics behind extreme high energy phenomena and the engines driving the process, from Galactic X-ray binaries (XRBs) and related, to distant Blazar AGN gamma-ray sources. The VLBA in the next two years will exploit its new fast response capability to study the early stages of time evolution of Gamma Ray Bursts by measuring sources within minutes of a high-energy trigger.

The biggest discovery in the field of radio transients in the last decade may be the Fast Radio Bursts (FRBs). If these are really extragalactic and as common as suggested, the FRBs are a game-changer in the study of the transient sky, with many important implications for the source physics (stellar collapse to black holes), and cosmology (e.g. Dark energy, missing baryons). Unfortunately, there remains the issue of verifying and locating these sources, and identifying their host galaxies if they are extragalactic. The VLA has implemented new techniques to search for transients on millisecond (msec) timescales, and in the coming two years, the VLA provides the best opportunity to determine the reality and nature of the FRBs.

The future of radio astronomy: Looking beyond our major facilities, the NRAO is fulfilling its role of fostering the future of radio astronomy through a number of development programs exploring high priority areas from NWNH.

Cosmic Reionization: Exploring cosmic reionization, when light from the first galaxies acts to reionization the pervasive neutral intergalactic medium left over from recombination, represents the last frontier in studies of large scale structure formation. NRAO is involved with the development of low frequency radio arrays to image the HI 21 cm signal from the neutral gas at this epoch of cosmic evolution. We are collaborators on the Hydrogen Epoch of Reionization Array (HERA), as the next natural follow-up to the current generation of path-finder reionization experiments (PAPER and MWA). NRAO also maintains a discussion forum for the various low frequency projects (e.g. LWA, LEDA), to share ideas and consider parallel developments. The goal is a coordinated, community driven approach to large low frequency radio instrumentation in the next decade.

Frequency Agile Solar Radiotelescope (FASR): The FASR project represents the next major step in studies of the Sun and space weather. The project is technically ready, and rated as one of the highest science priorities in NWNH. NRAO is a founding institutional member of the FASR consortium.

FY2016

- Solar Capable Receiver Installation: The process of installing solar-capable receivers at L, X, Ku, and S-Band will continue in FY2016, as specified in Section 3.4.
- Card Cage Upgrades: An additional 35 units will be installed in FY2016.
- C and L-Band Thermal Gap Retrofits: Four additional C-Band and 4 L-Band receivers will be modified with the new thermal gap design in FY2016.
- Temperature Stabilization of the VLA Receiver Noise Diodes: Fifteen temperature-stabilized noise diode assemblies will be installed in Ku-Band receivers in FY2016.
- F318 Installation: Ten more F318 control modules will be deployed in FY2016.

Observing Capability Enhancements

The VLA continues to provide new capabilities to the user community to optimize and enhance the science that can be done with the array. This strategy has proven to be effective in keeping users engaged, and it is a critical factor in keeping the scientific productivity of the VLA high. To this end, NRAO continues to provide incremental capability enhancements above and beyond our operational efforts. The pace of development of new capabilities is matched to the available FTEs who are not fully engaged with daily operations.

Note that the rate at which a capability moves from RSRO to SRO to GO depends upon the complexity of the task, the available staff of RSRO participants, funding for hardware (in some cases) and the available FTEs within NRAO. Some assumptions about effort from participants in the RSRO program have been made in the schedule below; since these resources lie outside NRAO's control, the delivery schedule for these capabilities may vary from that outlined below. Given those uncertainties, the observing capability enhancements for FY2015 and FY2016 are described below by year.

FY2015

We expect scientific staff effort on the following observing capability enhancements in FY2015:

- P-Band spectroscopy and polarimetry will be commissioned and documented, in preparation for offering this observing as SRO in semester 2016B (Q4).
- Pulsar observing modes will continue to be developed, including pulsar binning with WIDAR, and search and fold observations using the phased VLA (and separate software on CBE nodes). Capabilities will be documented in preparation for offering as SRO for semester 2016B (Q4).
- The MJP feeds that were installed in FY2014 will be evaluated when the VLA is in the B-configuration in FY2015, and a memo written on their performance (Q3).

FY2016

We expect scientific staff effort on the following observing capability enhancements in FY2016:

- Commissioning of P-Band spectroscopy and polarimetry functionality in the Observation Preparation Tool (OPT), in preparation for moving this capability to SRO for semester 2016B (Q3).
- Commissioning of pulsar observing modes in the OPT and dynamic scheduler, in preparation for moving this capability to SRO for semester 2016B (Q3).

traveling to Chile. The Chile Business Manager is the common link with all of the AUI, NRAO and the ALMA business functions, with a direct line of authority to the NRAO Associate Director of Administration.

Contracts: Ensures that all the terms and conditions are met in every contract required by NRAO and the JAO, and that NRAO is always compliant of its legal obligations. This task requires a Contracts Supervisor working directly for the NRAO Contracts and Procurement (CAP) Officer.

Procurement: Local and international procurements and imports are performed for the JAO using a web-based requisitioning system. Communication among buyers and logistics staff is essential for minimizing the costs and increasing the effectiveness of the processes involved. The Contracts and Procurement Officer reports directly to the NRAO Contracts and Procurement Manager. Buyers work under a direct reporting line to the NRAO Chile CAP Officer.

HR – international and local staff: NRAO manages its responsibilities and legal obligations as sole employer of AUI/NRAO-Chile and JAO local staff members (LSM). These include monitoring the application of the Chilean legal rules and regulations, responsibility for payroll activities, and NRAO-ALMA union matters. A division of responsibilities whereby legally mandated tasks are the purview of NRAO and operational functions, including compensation policies and recruitment as well as interaction with local personnel are delegated by NRAO to the JAO, under the provisions of the tri-lateral ALMA Management Agreement.

Likewise, NRAO-Chile provides enhanced support to the international staff and their families. The NRAO-Chile HR group coordinates closely with the JAO Human Resources (HR) Department and the JAO Directors Office.

Labor Union: Following the creation by LSM of an AUI-ALMA Union, a negotiation was conducted with the Union, under the jurisdiction of the Chilean Labor Department, leading in 2010 to a three-year Collective Contract. AUI signed a new Collective Contract valid for a period of two years in September 2013. Preparations for a new collective negotiation to start in August 2015 are underway.

Safety and Health: Given its role as the sole employer of the JAO's LSMs, AUI/NRAO coordinates closely with the JAO's Safety Office. Office of Chile Affairs (OCA) manages the establishment of Joint Peer committees on Health and Safety, as mandated by Chilean law.

EPO: NRAO-Chile's EPO Officer and the Representative constitute the liaison with the local community and the JAO to facilitate an understanding of the ALMA, AUI, and the NRAO, throughout Chile. It assists broad participation in the wider Chilean society in the scientific and technological (STEM) aspects in which AUI/NRAO has an impact in Chile. This includes recruitment of students and professionals into our scientific activities and, primordially, establishment of outreach educational activities directed to the formation of effective high-school teachers in the area of Astronomy in collaboration with U. of California, Berkeley. It promotes NRAO and ALMA NA visibility at professional meetings, prepares press releases and other educational documentation, designs and implements visitors centers, provides presentations at schools and institutions throughout Chile, and organizes activities in Chile.

NRAO-Chile also coordinates several important functions with AUI-Chile, specifically including the Fiscal functions. These include accounts payable, accounts receivable, travel reimbursements, payroll, time and attendance of LSM staff, and inventory and property management.

Table 7.4.2: DMS FY2016 Major Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Scientific Information Services					
SIS	XSEDE access for capacity				1
	NGAS upgrade	2			
	Green Bank archive integration			3	
	Multi-core coprocessor architecture		4		
	Redesigned NRAO User Portal V1			5	
ALMA System Software					
ALMA	Fall 2015 Release	6			
	Spring 2016 Release			7	
VLA/VLBA System Software					
VLA/VLBA	Support 2015B Observing		8		
	Support 2016A Commissioning		9		
	Support 2016A Observing				10
	Support 2016B Commissioning				11
	VLBA – VME Replacement				12
GBT System Software					
Green Bank	Operations Software Update				13
	Vegas Pulsar Modes		14		
	NRQZ Software				15
	M&C Release				16
	CLEO Port				17
GBTPP - Pipeline	Pipeline Improvements				18
	Test with PSC			19	
Software Development					
New NRAO Archive	Deliver V2		20		
CASA Pipeline	ALMA Cycle 3 Release	21			
	Reference Imaging				22
CASA	4.5 Release	23			
	4.6 Release			24	
PST	Updated for 2016B Call for Proposals	25			
	Updated for 2017A Call for Proposals			26	
PHT	Updated for 2016B TAC Meeting		27		
	Updated for 2017A TAC Meeting				28
OPT	2016A VLA Observing Updates	29			
	2016B VLA Observing Updates			30	
Reprocessing	Integrate ALMA and NRAO RPI		31		
Tool Redesign	Deliver Phase 1	32			
Mobile	iOS App for Public Outreach		33		
Testing	Expand CASA Test Scope			34	

Milestones:

1. XSEDE access
2. Align version of NGAS
3. Leverage NGAS for Green Bank data archive
4. Recommendation of multi-core co-processor systems
5. User Portal Redesign
6. ALMA Fall 2015 Release
7. ALMA Spring 2016 Release
8. Deploy software to support Semester 2015B observing.
9. Deploy software to support Semester 2016A commissioning.
10. Deploy software to support Semester 2016A observing.
11. Deploy software to support Semester 2016B commissioning.
12. VME Replacement
13. Operations Software Update
14. Vegas Pulsar Modes

Deliverables:

1. Run CASA pipeline on XSEDE resources
2. Unified NGAS installation for NRAO and ALMA
3. Move Green Bank archive from Lustre to NGAS
4. Adoption recommendation delivered for leveraging Cuda and MIC systems
5. Redesigned portal deployed
6. ALMA System Software released
7. ALMA System Software released
8. Semester 2015B observing software
9. Semester 2016A commissioning software
10. Semester 2016A observing software
11. Semester 2016B commissioning software
12. Software for VLBA monitor data stream replication

3.4 New Mexico Operations Major Milestones

Table 3.4.1: New Mexico Operations FY2015 Major Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
VLA Science Operations	Define capabilities to be offered for GO and SRO	1		2	
	Scientific support for Call for Proposals		3		4
	Support array reconfigurations	5	6	7	
	Automate subarray observing			8	
	4-element API operational			9	
	Integrate VLITE into operations		10		
	Scientific evaluation of new 3-bit samplers				11
	Implement frequency averaging in CBE		12		
VLA Array Operations	Reconfigure array	13	14	15	16
	Establish DSOC control room for VLA Ops		17		
	Begin DSOC VLA Operations			18	
VLA Antenna Maintenance	Antenna overhauls				19
	Replace azimuth bearing				20
	PM on transporters	21		22	23
VLA Track Maintenance	Replace 5000 cross-ties				24
	Replace 5 antenna pad intersections				25
VLA Site Infrastructure Maintenance	PM on VLA site transformers				26
VLA Technical Upgrades and Enhancements	Solar upgrade, L-Band		27		
	Solar upgrade, X-Band			28	29
	Solar upgrade, Ku-Band		30		31
	Solar upgrade, S-Band				32
	Front End card cage upgrades		33		
	Thermal gap retrofits, C-Band				34
	Thermal gap retrofits, L-Band				35
	Front End cal board upgrades				36
	Noise diode prototype			37	
	Replace legacy Q-Band hardware				38
	Install 3rd replacement ACU			39	
	Install new 3-bit sampler boards			40	
	F318 installation	41		42	
VLA Observing Capability Enhancements	P-Band spectroscopy and polarimetry				43
	Pulsar modes				44
	4-Band performance evaluation			45	
VLA Operational Enhancements	Reference pointing				46
	Tipping scans			47	
	Switched power calibration				48
	Pipeline heuristics			49	
	Ionospheric calibration		50		
	VLA Sky Survey support				51
VLBA Science Operations	Define capabilities to be offered for GO and SRO	52		53	
	Scientific support for Call for Proposals		54		55
VLBA Antenna Maintenance	Major maintenance campaigns			56	57
VLBA Technical Upgrades and Enhancements	Replace some VME functionality			58	
VLBA Observing Capability Enhancements	DDC-8 on Effelsberg				59
	PFB on LMT				60
Site Operations	Electronic door access	61			
	Renew leases	62			

Improving internal communication will continue to be a priority. COM will work with the management team to develop and implement more effective, timely, and accurate communication across the Observatory. Content and tools for the NRAO Intranet will be further developed to improve internal communication.

FY2016

In FY2016, COM will collaborate with scientific staff and the Director's Office to organize an effective Observatory presence at major FY2016 science community meetings, beginning with the 3-7 January 2016 AAS meeting in Kissimmee, Florida. Proposals will be submitted to the AAS for an NRAO Town Hall and a 2nd U.S. Radio Futures Workshop that will continue the community discussion of the long-term scientific, technological, and community development for the VLA and ALMA, and the successors to current long-wavelength arrays. COM will also organize the NRAO presence at the summer AAS meeting, which will take place 12-16 June 2016 in San Diego, California.

To help communicate NRAO science to the broader scientific community, COM will organize and lead the science symposium proposed in FY2015 for the 11-15 February 2016 AAAS Annual Meeting in Washington, DC. A science symposium proposal will be submitted by COM in late April 2016, the expected deadline, for the 2017 AAAS Annual Meeting (16-20 February 2017) in Boston, Massachusetts. This symposium will feature a diverse set of speakers who will present the most compelling new science emerging from the NRAO user community.

COM and CIS will organize an NRAO exhibition and technical presence at the International Conference for High Performance Computer Networking, Storage, and Analysis (SC15) that will be held in mid-November 2015.

COM will design and publish a *2015 NRAO Annual Report* in FY2016. This Report will feature calendar year 2015 science highlights from the community and NRAO scientific staff; major accomplishments at NRAO operational facilities; R&D progress for next-generation facilities; community support activities; and public outreach and diversity highlights. This Report will be widely distributed on-line and in hardcopy.

In collaboration with the SSR team and scientific staff across the Observatory, COM will continue to design, manage, and improve the high-level content of the NRAO science web site in FY2016. COM will also continue to edit, improve, publish, and expand the subscription base for the Observatory's monthly electronic newsletter, *NRAO eNews*, and the periodic electronic announcements series.

Improving internal communication will continue to be a priority. COM will work with the management team to develop and implement more effective, timely, and accurate communication across the Observatory. Content and tools for the NRAO Intranet will be further developed to improve internal communication.

with feedback on the fix sent back to the JAO. If they failed due to pipeline errors, bug reports will be filed, and the data held for the bug fix (if expedient), otherwise redirected to the manual data reduction team. If the pipeline failed due to the lack of appropriate heuristics in the pipeline, the problem will reported to an international pipeline heuristics working group, and the data redirected to the manual data reduction team.

The NAASC will also have several aperture synthesis calibration experts from across NRAO participate in the pipeline heuristics working group, examining the pipeline-failed datasets to improve the calibration heuristics. Based on extensive testing during FY2014, it is expected that the initial pipeline will be able to calibrate ~50% of the ALMA Cycle 2 "standard" datasets. The goal of the heuristics working group is to provide input to the pipeline developers to steadily increase this percentage, as well develop the calibration procedures for the non-standard modes. At the same time, the heuristics working group (or a subset of them, supplemented by synthesis imaging experts) will work on improving the imaging pipeline.

In Q2 FY2015 the ALMA Operations management team will participate in an ALMA Board-requested ALMA Operations Review. In addition, planning for ALMA Cycle 4 will begin in Q3 FY2015 with the Cycle 4 Obsmode "capabilities" meeting, followed by revised software requirements and prioritization of development targets.

FY2016

ALMA Cycle 4 will follow the same timeline as Cycle 3. We expect that a significantly larger number of hours will be offered at the proposal call (perhaps twice as much). How much the workload will increase is hard to judge, as the average requested time may also increase. The extra workload will be mitigated by a more capable pipeline, which should be producing final imaging products for the first time, at least for standard observing modes. We will also have our Data Analysts contribute to more support tasks, such as schedule block preparation and perhaps AoD duties (depending on ALMA policies). If the workload increase is too large, we will scale back efforts devoted to EOC and data reduction workshops. Work on pipeline heuristics (imaging and calibration) will not be compromised, as a capable pipeline is the best solution for keeping the workload manageable.

Mirroring the activities for Cycle 3, support of ALMA Cycle 4 observations in Q1 FY2016 begins with NAASC participation in the Cycle 4 Obsmode "go/no-go" meeting, during which the capabilities to be offered for Cycle 4 are defined. NAASC or NRAO experts may continue to participate in EOC activities, although the work effort has not yet been defined. Even though ALMA construction is complete, there are still many observing modes and ALMA Development projects that will require a long-lasting EOC effort at the JAO.

Support of the ALMA Cycle 4 proposal process continues in Q2 FY2016 with testing of all proposal-related software subsystems (Observing Tool, Phase I Manager, Project Tracker, ALMA Science Archive, Science Portal) and preparation and review of all call-related documentation, especially the Technical Handbook, Proposers Guide, Capabilities, proposal "roadmap" and the NRC-lead "ALMA Primer" and introductory videos. Activities will shift to intensive user support through the helpdesk and Community Day Events between the release of the call for Proposals by the JAO (end of Q2 FY2016) and the proposal deadline four weeks later.

The NAASC will support the Cycle 4 proposal review process in Q3 FY2016 by providing technical secretaries and technical assessors. Meanwhile NAASC staff will also contribute effort to the definition of the requirements for the Cycle 4 SB preparation software and testing of that software. Starting in Q4

15.7 Administration Major Milestones

Table 15.7.1: Administration FY2015 Major Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Business Services	Move ALMA construction documents to storage				1
	Begin new chart of accounts development		2		
	ALMA Construction closeout			3	
	Formalize telescope rate methodology and structure		4		
CAP	Develop an NRAO Consultant approval and Contracting Policy to award consulting agreements	5			
	Grants Life-cycle Training Program		6		
	Purchasing Training Program for users			7	
ES&S	Implement SDS Hazard Communication database		8		
	Complete training modules for Supervisory ES&S training			9	
MIS	Top-level gap analysis review of the JD Edwards enterprise resource planning (ERP) system		10		
	JD Edwards upgrade of Business Reporting modules, web application servers. Investigate single sign-on				11
TTO	Commercialize one additional technology				12
	Investigate holding first NRAO Astronomy and Biomed Imaging conference			13	

Milestones:

1. Index and box ALMA Construction documents. Identify and contract with an off-site storage facility.
2. Establish a time-line and strategize the design of a new chart of accounts.
3. Gather and enter all final revenues, expenses, and adjustments.
4. Review current methodologies. Prepare new ones and review with site directors and NRAO Director.
5. Design policy, review and socialize with assistant directors and business managers.
6. Design program and obtain approval of Assoc. Director of Administration.
7. Design a purchasing training program for users of the purchasing and requisition systems and obtain approval of Assoc. Director of Administration.
8. Implement Hazcom Database
9. Complete ES&S Supervisory Safety training modules.
10. Top-level gap analysis review of the JD Edwards enterprise resource planning (ERP) system
11. Load new or updated JD Edwards modules
12. Identify from IP Asset Register, review choices through selection committee, begin commercialization efforts.
13. Collaborate with UVA and NRAO software imaging designers to gauge interest in medical imaging conference. Raise money for conference.

Deliverables:

[1] Move ALMA Construction documents to off-site storage.
[2] Two-year project. New COA to be complete by close of FY2016.
[3] All financial records and accounts for ALMA Construction closed and balanced.
[4] Standard rate sheet for sale of telescope time.
[5] CAP Policy section for Consultant Approval and Contracting.
[6] A Grant Life-Cycle Program for training PIs in managing their external grants.
[7] A purchasing training program that can be used for new employees or those who may have new responsibilities.
[8] Online accessible SCS database for all sites
[9] Complete safety training modules for Supervisory staff
[10] Receive and review analysis and determine adoption of recommendations, set budget, and timing of installation.
[11] Upgraded to current JD Edwards modules
[12] An additional NRAO Technology is commercialized and providing income to NRAO and AUI.
[13] Offer a Biomedical imaging conference with UVA and NRAO.

Kindling Community Science Tool Development (Lead Institution: NRAO): A study aimed at kick-starting community development of spectral cube domain analysis tools for use with ALMA data. Study completion is scheduled Q1 FY2015.

Calibration Refinements for ALMA Imaging (Lead Institution: Naval Research Laboratory): To study additional atmospheric corrections beyond the use of fast switching and water vapor radiometers by; determining the change of phase across the 8 GHz wide receiver bandwidths; incorporating a variant of self-calibration; and modeling clouds in all forms. Study completion is scheduled Q2 FY2015.

Ongoing Projects

Band 5 Local Oscillator (LO) (Lead Institution: NRAO): The NRAO is collaborating with the European Southern Observatory (ESO) to develop and deliver the ALMA Band 5 receiver (163 – 211 Hz). The NRAO CDL is producing an LO (also known as a Warm Cartridge Assembly [WCA]) for each Band 5 cold cartridge. The project is proceeding on schedule with delivery of seventy-five (75) Band 5 WCAs completing in the first quarter of FY2015. NRAO is also responsible for providing cold multipliers and these will also be delivered in the first quarter of FY2015.

ALMA Phasing Project (Lead Institution: MIT Haystack Observatory): The North American ALMA Development Program is providing $461,686 in supplemental FY2014 funding to a pre-established, NSF Major Research Instrumentation project. Altogether, the project goal is to make the ALMA observatory fit for VLBI. The software development, hardware/software installation, and commissioning at the Operations Support Facility and the Array Operations Site will be completed in the first quarter of FY2015.

Fiber Optic Connectivity (Lead Institutions: JAO/NRAO; Subcontractors: Silica Networks, Telefónica Empresas Chile S.A., and REUNA): The NRAO is funding the construction of an optical path from the Array Operations Site (AOS) to Calama, and the upgrade of an existing optical path from Calama to Antofagasta (which will enable the use of a dedicated channel on one fiber of this cable). The project commenced in Q4 FY2012, experienced major delays in obtaining construction permits and is now scheduled to complete in Q1 FY2015.

FY2016

Studies

A total of $1.0M will be available for funding Studies during the FY2016 Development Program cycle (subject to the FY2015 and FY2016 Federal Budget and allocation of funds). The NRAO expects to fund several Studies in FY2016; no individual Study will be funded in excess of $200K.

The FY2016 Call for Study Proposals will be released on 01 January 2015. The Proposal submittal deadline will be 1 April 2015 and notification of awards will be made prior to 30 September 2015.

FY2016

The operations of the GBT in FY2016 will remain roughly the same for the NSF CSA work as in FY2015. The one exception is the anticipated retirement of the GUPPI pulsar backend as it is replaced with pulsar observing modes on VEGAS. The total amount of science on the GBT in FY2016 is expected to remain at roughly 6,500 hours. Of these hours, though, there will be a continued decrease in the time available under NRAO's "open skies" as the hours under private contract increases. For FY2016 we anticipate between 3,000-5,000 hours being available general use to all qualified astronomers. Of the open skies time, typically 10% will be spent as part of the VLBI array, 30% on pulsar science, 5% doing continuum studies, and the remaining time on spectral line projects.

4.1.3. Development

The GBT was designed to allow ready upgrades and changes to all aspects of its hardware and software. A specialty (or PI-driven) instrument can be installed on the telescope with relative ease, making it feasible for an individual or group of researchers to outfit the telescope to meet their particular science goals. The GBT has historically had a vigorous development program in collaboration with university groups to take advantage of the latest technology and provide our user community with a constantly improving facility. Recent development projects have already led to important discoveries in a number of areas, including:

- Constraining the Nuclear Equation of State through detection of the most massive neutron star known.
- Probing Dark Energy through HI intensity mapping.
- Imaging the Large Scale Structure in Galaxy Clusters by creating the highest resolution, most sensitive images of the SZ effect.
- Understanding the Solar System through radar maps of the Moon, probing the atmosphere of Titan, passive and radar observations of asteroids, and bi-static radar observations of Mercury, Venus and Europa.

As outlined below, the path forward for new discoveries with the GBT is built upon the collaborative development of new instruments which will open new pathways into our understanding of the Universe. All new instrumentation and development for the GBT is built in collaboration with research groups at universities and colleges throughout the country. This not only leverages efforts of Observatory staff and supports University faculty, it provides a valuable training ground for students to become future instrument builders. The program has been highly successful both in training excellent scientists and engineers and in providing the instruments necessary to provide the best possible scientific results from the site telescopes.

The current development program for the GBT is now waning, largely due to the divestiture recommendation given to the NSF in 2013 by the Portfolio Review Committee. As a result, any new project undertaken in FY2015 and FY2016 will be the result of new partnerships formed and new operational models for the telescope and facility. As such partnerships are not yet secured; these projects remain unknown and cannot be listed.

45. Evaluate 6 MJP feeds and write performance memo. 46. Improve robustness of reference pointing solutions. 47. Implement old-style VLA (stepped) tipping scans. 48. Commission and document use of switched power calibration in CASA. 49. Develop heuristics for polarization calibration for the VLA calibration pipeline. 50. Commission and document improvements to ionospheric calibration. 51. Development in support of VLA Sky Survey, as specified in the VLASS Technical Implementation Plan. 52. Define VLBA capabilities to be offered for semester 2015B. 53. Define VLBA capabilities to be offered for semester 2016A. 54. Update VLBA documentation to support 2015B Call for Proposals, perform proposal technical reviews. 55. Update VLBA documentation to support 2016A Call for Proposals, perform proposal technical reviews. 56. Tiger Team maintenance campaign to OV. 57. Tiger Team maintenance campaign to SC. 58. Install production M450 in a VLBA antenna for testing. 59. Commission and document DDC-8 on Effelsberg for 2016B. 60. Commission and document PFB on LMT for 2016B. 61. Complete electronic door access for the DSOC. 62. Renew leases for OV and SC.	

12.3 Diversity Major Milestones

Table 12.3.1: Diversity FY2015 Major Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Diversity Council	Office of Diversity Initiatives Established		1	2	3
National/Domestic Outreach	SOC Electronics Engineering Internship with HSI		4		
	VA-NC Louis Stoke Alliance for Minority Participation, NRAO Astronomy Consortium, (NAC) Socorro Summer Youth Employment, Physics Inspiring the Next Generation (PING) African American Teaching Fellows Partnership			5	
	Native Americans Outreach			6	
International Outreach	The NRAO International and National Exchange Program		7		
	Chilean Student Partnership		8		
Improve Workplace Culture	Diversity and Cultural Awareness Training			9	10

Milestones:	Deliverables:
1. Office of Diversity Initiatives/Diversity Council	1. Formalize ODI/Diversity Council - develop roles, communicate initiative, site visits, create charter
2. ODI review diversity portfolio/programs, plans to establish metrics	2. Report provided to Director/AUI President
3. ODI – host external diversity review committee, coordinate logistics of NAC III workshop, prepare budget	3. External Diversity Review Panel; Host NAC III workshop and prepare budget
4. Undergraduate Intern Program for SOC Electronics Division	4. Recruitment of underrepresented engineering students from HSIs for electronics internship opportunities for FY15 Summer Program
5. LSAMP, NAC, SOC Summer Youth Employment Program, PING, African American Teaching Fellows coordination	5. Finalize logistics, select students and work with partners to identify advisors and students for each of the programs
6. Partnership with Native American point of contact and designate representative from CV and SOC	6. Contacts identified and development of a strategy to establish and maintain a partnership with Native American group
7. NINE- NRAO Staff to South Africa – teaching and recruitment	7. NRAO Staff travel to South Africa for teaching and recruiting students for summer research projects
8. UVA/NRAO Chilean PhD Sponsorship	8. Recruitment of female Chilean student to participate in 12 -18 month PhD program at NRAO/UVA
9. Diversity and Cultural Awareness Training #1	9. Provide diversity and cultural awareness training to staff and students across the Observatory (Part 1 of 2)
10. Diversity and Cultural Awareness Training #2	10. Provide diversity and cultural awareness training to staff and students across the Observatory (Part 2 of 2)

CONTENTS

FY2016

Cycle 3 of ALMA science operations is presently planned to begin on 1 October 2015 and last for one year, and so will be concurrent with FY2016. Many results from Cycle 2 will appear during this period. While the suite of capabilities available from ALMA for Cycle 3 is not yet determined, they will almost certainly include higher sensitivity, additional wavelength coverage and higher resolution.

2.2 Operations

North American ALMA Operations (NA ALMA Ops) is the NRAO department that provides North America's scientific and technical partnership support to the international ALMA Observatory and supports the North American community in their use of ALMA. Specifically, NA ALMA Ops ensures that the North American scientific community has the tools, information, support, and access to make optimal scientific use of ALMA. It also provides scientific, technical, and business support to observatory operations in Chile in concert with the Joint ALMA Observatory (JAO) staff and our international partners. In addition, it supports a long-term development program for the technical enhancement of ALMA.

NA ALMA Ops consists of four divisional elements that were brought into one NRAO department in FY2013. These divisions are the North American ALMA Science Center (NAASC), the Offsite Technical Maintenance and Support groups (software and hardware), the NA ALMA Development Program, and the NRAO-Chile Office.

The North American ALMA Science Center

The NAASC is the scientific support arm of NA ALMA Ops. The NAASC is the North American scientific community's interface to the ALMA Observatory for expert advice and assistance in the use of ALMA, including proposal preparation and submission, data reduction and reprocessing, ALMA-specific documentation, and on-line tools and resources. Embedded within the NAASC is the North American ALMA Regional Center (NA ARC), which provides the core services specified by the ALMA Observatory for scientific support in the regions and contributed support for Chile operations. The NAASC also coordinates with the science operations of the other ALMA partners in Europe and East Asia.

The NAASC has three groups – the Telescope Support Group (telescope-facing), the User Support Group (user-facing, ALMA-specific), and the Science User Support (SUS) Group, which consists of NAASC staff matrixed to the NRAO-wide science operations group that unifies common support programs across the NRAO (section 6.2). The NAASC specifies its requirements for science operational support, and contributes staff into this pool, which can then be effectively leveraged for best economy of scale and uniformity of approach.

NA ALMA Telescope Support

The NAASC provides support for JAO operations, both from NA and through temporary deployments to Chile. The NAASC provides domain-expert assistance to the JAO "Extension and Optimization of Capabilities" effort (EOC – the operations incarnation of the former construction Commissioning and Science Verification – CSV) in areas where the NAASC has key expertise that is not available at the JAO. This includes two full time staff on re-deployment to EOC, one through the end of FY2015, and the other through the end of FY2016. Additionally, the NAASC sends other domain experts on temporary duty (2-3 month tours) for specific EOC campaigns (e.g. four NAASC-supported NRAO

9 NEW INITIATIVES OFFICE

The New Initiatives Office (NIO) pursues, develops, and, as necessary, manages strategic partnerships and collaborations with academic, government, and non-profit organizations. Among the essential NIO activities envisioned for the period covered by this Plan are managing and expanding the partnerships to sustain the scientific operations and unique technical capabilities of the VLBA and GBT. These partnerships already include the U.S. Naval Observatory (USNO), the Max-Planck Institut für Radioastronomie (MPIfR), and several observatories in China. NIO will also play a central role in managing the technical aspects of NRAO's self-assessment process for Department of Defense International Traffic in Arms Regulations (ITAR) compliance.

The NIO was specifically charged with establishing collaborations with community groups to respond to the Astro2010 NWNH Decadal Survey Report recommendations. Helping to fulfill the science-driven and evolving Astro2010 recommendations for the coming decade in partnership with the community is a central component of NRAO's mission. In FY2015 and beyond, NIO will continue to pursue, develop, and manage partnerships and collaborations that have the potential to lead to additional funding and/or benefit the Observatory mission to enable science, and serve the strategic interests of the nation. It is also expected that several viable new collaborations will follow the 'FASR model', in which NRAO will function as one of several institutional partners by bringing its own unique scientific, technical, and managerial expertise to the planning, design, construction, and operational phases of these new instruments.

Some of the emerging projects that already enjoy NRAO collaborative participation and that will be carefully examined by NIO for further integration and partnership opportunities follow.

VLBA Partnerships: The 2006 NSF Senior Review recommended that the VLBA be closed by FY11 unless funding partners able to support 50% of the array's direct operating costs could be found. This partnership recommendation required that NRAO raise ~$3M/yr from non-NSF sources. This goal was not met after NASA's commitment to contribute $2M/yr in exchange for spacecraft tracking services, was cancelled. A January 2011 meeting brought together many VLBA stakeholders to evaluate the situation and solicit support. This meeting demonstrated that the VLBA is performing diverse, cutting-edge research of increasing scientific importance, particularly in astrometry and geodesy. The instrument's international user community emphasized the importance of keeping the VLBA operating as a 10-antenna array, and pledged to help contribute directly to its operational support.

Since that meeting, several agreements for external funding have been signed, and more than $1.5M in annual support was received for FY2013. The USNO is providing $1M/yr towards operating costs in exchange for daily 1.5 hour observations using the Mauna Kea and Pie Town antennas for rapid determination of (UT1-UTC), a parameter describing the spin phase of the Earth required for maintenance of the GPS reference frame. An agreement originally signed in 2011 with the SHAO to provide partial support for VLBA operations, was amended in May 2014 by raising SHAO's annual contribution from $100,000 to RMB 1,100,000 (currently, about $180,000). A partnership for $200K/yr over five years in operations support from the MPIfR was signed March 2012, and a second contract with the USNO to provide a "clone" of the VLBA's DiFX software correlator was signed April 2012 (with phase 1 of the project dedicated in February 2013), and is expected to provide an additional $100K-$200K per year for VLBA operations over several years. Over the tenure of this plan, NIO will continue to assist NRAO management in pursuing possible partnerships with other organizations including Defense Advanced Research Projects Agency (DARPA), USNO, NASA, and, possibly, the

17.2 Director's Office Financial Charts

Table 17.2.1: FY2015 by Fund Source and Location

Work Breakdown Structure	CSA-1 NRAO Ops		CSA-2 ALMA Ops		Development		Internal Common Costs		GRAND TOTAL	
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟5000 Director's Office										
5500 Administration	0	0.0					747,110	3.1	747,110	3.1
5800 AUI Fee and IDC	2,582,076	0.0	2,018,690	0.0	369,755	0.0			4,970,521	0.0
Grand Total	2,582,076	0.0	2,018,690	0.0	369,755	0.0	747,110	3.1	5,717,631	3.1

Table 17.2.2: FY2015 Expenditures by Object (excluding fee and IDC)

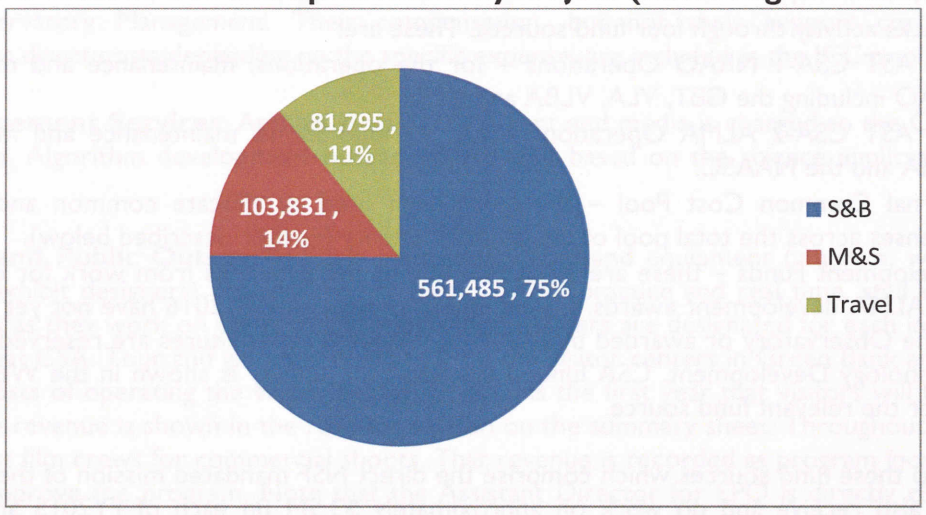


Table 17.2.3: FY2016 by Fund Source and Location

Work Breakdown Structure	CSA-1 NRAO Ops		CSA-2 ALMA Ops		Development		Internal Common Costs		Grand Total	
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟5000 Director's Office										
5500 Administration							747,110	3.1	747,110	3.1
5800 AUI Fee and IDC	2,601,729	0.0	2,082,411	0.0	265,230	0.0			4,949,370	0.0
Grand Total	2,601,729	0.0	2,082,411	0.0	265,230	0.0	747,110	3.1	5,696,480	3.1

11.5 Computing & Information Services Financial Chart

Table 11.5.1: FY2015 by Fund Source and Location

Work Breakdown Structure	Internal Common Costs								GRAND TOTAL	
	Charlottesville		Green Bank		Socorro		Observatory Wide			
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟4000 Administrative Services										
⊟4100 Business Services										
⊞4120 CIS	726,312	5.1	210,883	1.7	573,882	6.2	719,021	3.6	2,230,097	16.6
4000 Administrative Services Total	726,312	5.1	210,883	1.7	573,882	6.2	719,021	3.6	2,230,097	16.6
Grand Total	726,312	5.1	210,883	1.7	573,882	6.2	719,021	3.6	2,230,097	16.6

Table 11.5.2: FY2015 Expenditures by Object

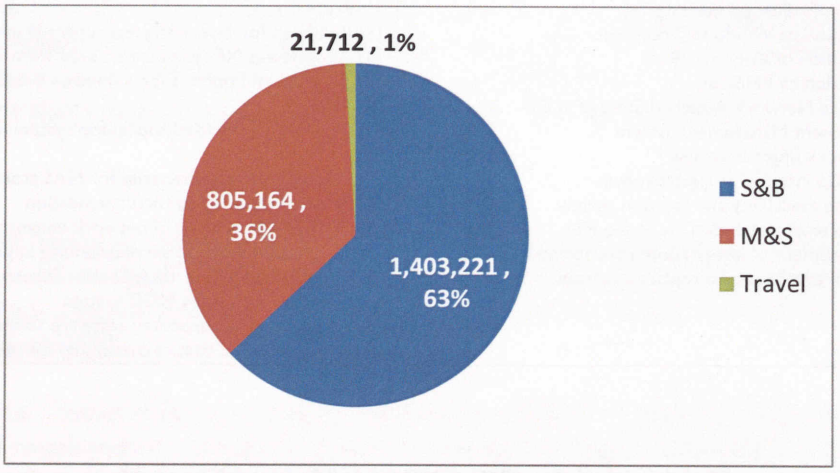


Table 11.5.3: FY2016 by Fund Source and Location

Work Breakdown Structure	Internal Common Costs								GRAND TOTAL	
	Charlottesville		Green Bank		Socorro		Observatory Wide			
	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟4000 Administrative Services										
⊟4100 Business Services										
⊞4120 CIS	726,312	5.1	210,883	1.7	573,882	6.2	719,021	3.6	2,230,097	16.6
4000 Administrative Services Total	726,312	5.1	210,883	1.7	573,882	6.2	719,021	3.6	2,230,097	16.6
Grand Total	726,312	5.1	210,883	1.7	573,882	6.2	719,021	3.6	2,230,097	16.6

7 DATA MANAGEMENT AND SOFTWARE

The NRAO DMS department in FY2015 and 2016 will make key contributions to the NRAO. The new NRAO archive interface will be deployed. Pipeline capabilities will be further enhanced, most notably through the further development and initial commissioning of imaging capabilities, but also including operational improvements such as automatic invocation for ALMA and QA parameters and displays for the VLA. The ALMA Systems group will support Cycle 2 observing, while preparing the needed capabilities for later cycles (subarrays, fast-scanning/nutator). As ALMA moves into routine operations the emphasis will continue to shift from adding new features to improving system stability, reliability, and diagnostic information. The Green Bank and New Mexico Systems groups will provide support for observing and the planned new observing capabilities, including for the very high data rate VEGAS spectrometer. NRAO will make its computing facilities available to the external community both through direct cluster access, and for ALMA and the VLA through a reprocessing user interface. CASA High Performance Computing (HPC)/parallelization facilities will be turned on and made available, both for in-house pipeline operations and external users. DMS will continue to investigate and roll-out common cross-observatory technologies and services (for example, integrating Next Generation Archive System (NGAS) into GB operations).

7.1 Scientific Information Services

The Scientific Information Services (SIS) division is matrixed into the Information Technology (IT)-centric Computing and Information Services division. This enables transparent sharing of highly skilled Information Services resources for both telescope supporting science responsibilities (SIS), as well as general staff IT support duties (CIS). There are 5 major functional groups in SIS:

Computing Operations (NAASC, NM, GB): These (site centric) groups directly support the day-to-day telescope operations and reliable delivery of data to the archive. They ensure that telescope capability development projects are appropriately staffed, with resources being assigned based on commitments and timelines defined within the PMD and at the site. Project and milestones for these resources are tracked under the appropriate telescope support sections.

Archive and Cluster Processing: This group is responsible for the support of the production archive, parallel processing clusters, and user storage resources needed in support of pipeline processing and science data analysis. It defines their operational model for these shared resources (e.g. with batch and resource scheduling) and works closely with the Software Division. There is substantial staffing and skills overlap with Common Computing Environment (CCE) Unix (CIS). This group will ensure sufficient storage is provisioned throughout FY2015 and FY2016 to keep up with observations, and within the budget envelope.

Science Computing Infrastructure: This group provides technology driven Computer Engineering support, and is tasked with delivering the next generation of data processing solutions, working in close cooperation with the Software Division, CDL and external CyberInfrastructure partners (e.g. XSEDE, National HPC centers, Internet2/REUNA). This group is responsible for escalations from Archive and Cluster Processing and CIS in the event of systematic performance issues with the production infrastructure.

Some additional experiments and alternative approaches may also be pursued, depending on the outcome of earlier experiments. For example, if the DOMT calibration shows that the baseline ripple is a consequence of the tapered waveguide calibration input, an alternative approach would be to use an external wire grid quasi-optically illuminated by hot and cold targets. To test this, we would need to build a smaller version of the DOMT at a higher frequency. Similarly, if our second-generation filter topologies in chip form are unsuccessful, a different fabrication approach, such as thin-film on glass or Low Temperature, Co-fired Ceramic (LTCC), may need to be attempted.

Phased Array Feeds: Based on what we learn in FY2015, we will devote majority of our effort in FY2016 towards final system testing and improvement, and in particular, on the following tasks:

- Improvement to the L-Band Cryogenic Receiver and instrumentation.
- System testing of PAF with the 150 MHz backend.

10.4 Education and Public Outreach Financial Chart

Table 10.4.1: FY2015 by Fund Source and Location

	CSA-1 NRAO Ops								CSA-2 ALMA Ops							
	Charlottesville		Green Bank		Socorro		TOTAL, CSA-1		Charlottesville		Chile		TOTAL, CSA-2		GRAND TOTAL	
Work Breakdown Structure	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟4000 Administrative Services																
⊟4300 Auxiliaries																
⊞4310 Visitor Centers			55,890	1.1	4,000	-	59,890	1.1							59,890	1.1
⊞4340 Gift Shops			(35,077)	1.4	(29,553)	1.5	(64,630)	2.9							(64,630)	2.9
4000 Administrative Services Total			20,813	2.5	(25,553)	1.5	(4,740)	4.0							(4,740)	4.0
⊟5000 Director's Office																
⊞5200 Public Outreach	268,281	2.2	222,201	3.9	238,761	2.6	729,244	8.7	590,789	4.5	59,284	0.1	650,073	4.6	1,379,317	13.3
5000 Director's Office Total	268,281	2.2	222,201	3.9	238,761	2.6	729,244	8.7	590,789	4.5	59,284	0.1	650,073	4.6	1,379,317	13.3
Grand Total	268,281	2.2	243,015	6.5	213,208	4.0	724,504	12.7	590,789	4.5	59,284	0.1	650,073	4.6	1,374,577	17.2

Table 10.4.2: FY2015 Expenditures by Object (excludes revenue)

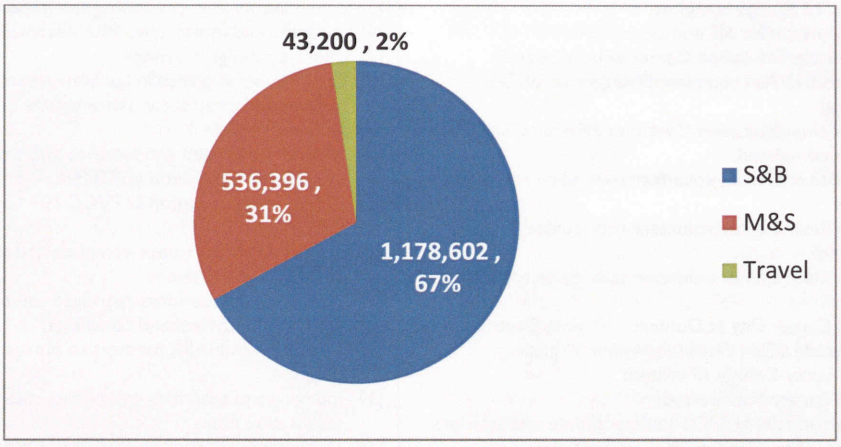


Table 10.4.3: FY2016 by Fund Source and Location

	CSA-1 NRAO Ops								CSA-2 ALMA Ops							
	Charlottesville		Green Bank		Socorro		TOTAL, CSA-1		Charlottesville		Chile		TOTAL, CSA-2		GRAND TOTAL	
Work Breakdown Structure	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟4000 Administrative Services																
⊟4300 Auxiliaries																
⊞4310 Visitor Centers			55,890	1.1	4,000	0.0	59,890	1.1							59,890	1.1
⊞4340 Gift Shops			(35,077)	1.4	(29,553)	1.5	(64,630)	2.9							(64,630)	2.9
4000 Administrative Services Total			20,813	2.5	(25,553)	1.5	(4,740)	4.0							(4,740)	4.0
⊟5000 Director's Office																
⊞5200 Public Outreach	268,281	2.2	222,201	3.9	238,761	2.6	729,244	8.7	544,912	4.5	59,698	0.1	604,610	4.6	1,333,854	13.3
5000 Director's Office Total	268,281	2.2	222,201	3.9	238,761	2.6	729,244	8.7	544,912	4.5	59,698	0.1	604,610	4.6	1,333,854	13.3
Grand Total	268,281	2.2	243,015	6.5	213,208	4.0	724,504	12.7	544,912	4.5	59,698	0.1	604,610	4.6	1,329,114	17.2

goals require the inclusion of baselines to large-aperture and/or distant facilities. Scheduling and correlation of these observations requires coordination with local schedulers at each participating observatory, a significantly more complex process than normal VLBA-only observations require.

As for the VLA, support for the Calls for Proposals and associated documentation updates and software testing have milestones on a timescale matched to the proposal cycle. Unlike the VLA, the VLBA does not reconfigure its antennas so the measurement and characterization of system health, gain curves, receiver collimations, etc., is a continuous effort tied to the regular maintenance activities.

Array Operations

The VLBA is operated twenty four hours a day, seven days a week, supported by five operators stationed at the operations center in Socorro and by two site technicians per station (20 total) who live within driving distance of their site. The array operators concurrently operate the distributed FX Correlator (DiFX). Two data analysts prepare the proper scripts for the DiFX correlation and perform quality checks on the correlated data. The supervisor for the VLBA operator also dynamically schedules the array from a list of approved projects, and manages the logging of maintenance and hardware problem reports for both the VLA and the VLBA. A media specialist ensures that recording media are available at the sites and manages the program used to track the media. Data are recorded at the VLBA sites on the disk packs on the Mk5C recorders and shipped to the Correlator for processing. The media are returned to the sites. The VLBA site technicians perform all manner of maintenance and diagnostics tasks, as well as ensuring the recording media is loaded and then shipped to the appropriate Correlator. The techs are available for after-hours call-outs to address failures that impact antenna performance as well as issues related to the safety of the antenna (power outages, severe weather conditions, etc.).

Additional Operations Milestones by Year

FY2015

Science Operations

Observing Programs: An overview of the VLBA capabilities being offered for GO for FY2015 is given below. An "IF" is one of the four 512-MHz signals carried on cables from the antenna's vertex to the control building, and a "channel" refers to a single contiguous frequency range, of any bandwidth, observed in a single polarization, that is sampled, filtered, and recorded as a separate entity. The two data systems operated on the VLBA comprise the following:

- The PFB observing system provides sixteen 32-MHz channels, with a fixed 2048-Mbps recording rate. The channels can be selected flexibly between two VLBA IF inputs. Channel placement is restricted to 32-MHz steps along the frequency axis.
- The Digital Downconverter (DDC) observing system is considerably more flexible than the PFB. As many as eight channels can be selected arbitrarily from up to four VLBA IFs, and placed at 15.625-kHz steps on the frequency axis with bandwidths ranging from 1 MHz to 128 MHz by factors of 2. Extremely narrow bands can be accommodated by observing at 1 MHz bandwidth and selecting a narrower range using the DiFX correlator's spectral zoom mode. All bandwidths must be identical, and channels cannot span either of two zone boundaries within the IF band, at 640 and 896 MHz. Use of 128 MHz bandwidth is limited to 4 (or fewer) channels by the 2048-Mbps recording rate limitation.

6.5 Science Support and Research Major Milestones

Table 6.5.1: SSR FY2015 Major Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Telescope Time Allocation (TTA)	Call for proposals		1		2
	Science and technical review		3		4
	TAC meeting	5		6	
	Software requirements & testing	7	8	9	10
	Documentation		11		12
Science User Support (SUS)	Education, training, & outreach	13	14	15	
	Science meetings & conferences	16,17	18,19		
	Software requirements & testing	20,21		22	
	Broadening impact		23,24	25	26,27
	Documentation	28	29	30	
SSR services	Library & Archives		31		
	Metrics		32		

Milestones:	Deliverables:
1. CfP for semester 2015B	[1] eNews announcement
2. CfP for semester 2016A	[2] eNews announcement
3. SRP and tech review process, semester 2015B	[3] Science and technical reviews
4. SRP and tech review process, semester 2016A	[4] Science and technical reviews
5. TAC meeting for semester 2015A	[5] TAC meeting
6. TAC meeting for semester 2015B	[6] TAC meeting
7. Update SW tools requirements for TAC support 2015A	[7] Requirements for PHT and GBSE
8. Update SW tools requirements for PST 2015B	[8] Requirements for PST
9. Update SW tools requirements for TAC support 2015B	[9] Requirements for PHT and GBSE
10. Update SW requirements tools for PST 2016A	[10] Requirements for PST
11. Update documentation for CfP and tools 2015B	[10] User documentation
12. Update documentation for CfP and tools 2016A	[12] User documentation
13. 4th VLA data reduction tutorial	[13] Tutorial
14. SPF 1 CDE	[14] CDE
15. ALMA cycle 3 CDE planning	[15] Cycle 3 CDE plan
16. Filaments workshop	[16] Science workshop
17. Revolution in Astronomy	[17] Science meeting
18. AAAS session on Galaxy Assembly	[18] Science meeting
19. SPF 1 meeting	[19] Science meeting
20. Integrated HD requirements	[20] Science requirements
21. RPI and NRAO archive user testing	[21] RPI and NRAO archive user testing
22. Integrated science portal requirements	[22] Science requirements
23. Summer student selection	[23] Summer student selection
24. Summer student offers	[24] Summer student offers
25. Summer student program begins	[25] Summer student program begins
26. Summer student program complete	[26] Summer student program ends
27. SOS selection begins	[27] SOS selection begins
28. Update CASAGUIDES	[28] User documentation
29. Review ALMA user documents	[39] User documentation
30. Update CASAGUIDES	[20] User documentation
31. Library contracts negotiated	[31] Library service
32. Metrics web interface requirements	[32] Software requirements

8 PROGRAM MANAGEMENT DEPARTMENT

The Program Management Department (PMD) is located at NRAO Headquarters, and has a Project Management Institute (PMI) certified/International Council on Systems Engineering (INCOSE) trained employee located at each NRAO site. Cross-Observatory PMD activities are summarized below. PMD activities that are unique to the site are described in sections 8.1-8.3.

8.1 PMD Headquarters

The primary areas of PMD responsibility include:

- ensuring best practices in the management of projects
- performing project management and systems engineering on projects
- developing program and grant documentation
- facilitating proposal development
- providing analytics for NRAO executive decision support

For the area of proposal development, PMD is responsible for processing and tracking technical proposals. Proposals that contain only science time, or science time with a minor amount of support (post doc, office space, etc.) are processed through SSR.

PMD implements proposal development processes and procedures, and provides workflow/configuration management throughout the proposal development. Once the proposal is complete, PMD verifies the quality and completeness, obtains Director's Office approval, and submits the proposal to NRAO Contracts and Procurement for additional processing.

PMD tracks proposal status and when the contract has been obtained, identifies it as a formal project. Standards are set for project management and systems engineering by PMD, using PMI and INCOSE standards. The PMD site POCs assist the Principle Investigator in using these standards, tools and templates to establish a baseline for their project, monitor performance, identify and address risk and opportunities, address change and configuration control, manage documentation, and other standard Project Manager/Systems Engineer (PM/SE) activities. In some cases, they directly perform PM/SE work on the project. A summary compilation of project status is provided monthly to the Director's Office and the NRAO Assistant Directors.

Observatory documentation, program operating plans, long range plans, quarterly and annual performance reports, etc., for NSF and non-NSF technical project grants are developed by PMD in collaboration with all other departments at NRAO. The PMD will organize and lead the production of all NSF deliverables, including the Annual Program Operating Plan, an update of the Strategic and Long Range Plans (if required), the Annual Progress Summary, and the four Quarterly Status Updates. A document status tracking report is generated monthly.

8.2 PMD New Mexico

The New Mexico PMD office supports both the New Mexico Operations and Data Management and Software departments. In addition to the PMD support activities described in the preceding sections, the NM PMD Office will advance the implementation of PM/SE practices (including process, tools and techniques) within these departments.

PMD New Mexico

Department-wide training of Project Management and Systems Engineering practices will be a focal point of FY2015 activities. PM and SE will provide introductory on-site training, explaining both the purpose and focus of typical PM and SE practices while encouraging a common vocabulary. In addition, informal learning sessions will be hosted by the site PMD POC with interested parties. Standard PM and SE topics will be covered over the course of the fiscal year, driven in part by identified gaps in knowledge, as well as specific topic requests from the site staff.

DMS support will include implementation of PM/SE practices for the CASA 4.4 release. The effectiveness of the implementation, lessons learned, and next steps will be documented for consideration in future development cycles.

Support for the CASA project will include requirements capture and elaboration for new features, planning and tracking of the release cycle, and management of targeted sub-projects such as the High Performance Computing / CASA Parallelization effort.

PMD CDL and ALMA

PMD will continue to play a large role in the research and development of Phased Array Feeds and Integrated Receiver Development by providing systems engineering and project management leadership, mentorship, and training and providing tools and templates. PMD will facilitate the decision gates for these initiatives and work with the principal investigators on the design of experiments for the future depending on the decision gate outcomes.

The CDL is involved in the following ALMA Development projects with PMD support in 2015; Band 5 Local Oscillator with project completion scheduled Q1 of FY2015; ALMA Phasing Project with project completion scheduled Q1 of FY2015; Prototype Band 2 Cartridge with project completion scheduled Q2 FY2016; and Expansion of the ALMA Central LO Article to 5 Sub-arrays with project completion scheduled Q1 FY2016.

Training of project management and systems engineering practices will be a focal point of FY2015 activities. This training is intended to increase awareness of the benefits of the processes and tools to enable realization of successful projects, systems and components. The PMD will provide introductory on-site training to a targeted audience, explaining both the purpose and focus of typical PM and SE practices while continuing to provide project specific training to principal investigators of projects. In addition, informal learning sessions will be hosted by the site PMD POC for anyone interested in the topic. Standard PM and SE topics will be covered over the course of the fiscal year, driven in part by identified gaps in knowledge, as well as specific topic requests from the site.

The FY2016 ALMA Development Call for Study Proposals will be released on 01 January 2015. The Proposal submittal deadline will be 1 April 2015 and notification of awards will be made prior to 30 September 2015. This will provide three months for Principal Investigators to prepare submittals and ensure that they are vetted through the PMD processes.

PMD Green Bank

Department-wide training of Project Management and Systems Engineering practices will be a focal point of FY2015 activities. PM and SE will provide introductory on-site training, explaining both the purpose and focus of typical PM and SE practices while encouraging a common vocabulary. In addition, informal

4 WEST VIRGINIA OPERATIONS

4.1 Green Bank Telescope

4.1.1. Science

The GBT is the world's premier single-dish radio telescope operating at meter to millimeter wavelengths. Its enormous 100-meter diameter collecting area, its unblocked aperture, and its excellent surface accuracy provide unprecedented sensitivity across the telescope's full 0.1 - 116 GHz (3.0m - 2.6mm) operating range. The GBT is used by hundreds of scientists each year for a large and varied series of programs. It has a collecting area and sensitivity comparable to ALMA and the VLA and thus excellent response to point sources such as pulsars. But as a filled aperture it also has the highest possible sensitivity to extended, low surface-brightness emission of the kind associated with comets, molecular clouds, and distortions of the cosmic microwave background. The GBT also joins the VLBA for interferometric observations to provide a critical threshold of sensitivity for the highest angular resolution studies. The single focal plane is ideal for rapid, wide-field imaging using multi-pixel cameras, and with access to 85% of the celestial sphere it also serves as the wide-field imaging complement to ALMA and the VLA. Operation of the GBT is highly efficient, and it is used for astronomy about 6500 hours every year, with 2000-3000 hours per year available to high frequency science.

The GBT is flexible and easy to use, and can respond to new ideas from the scientific community rapidly. It is straightforward for a small group to build and install a new instrument, providing them access to a world-class research facility. State-of-the-art instruments now under development in collaboration with university groups will continue to keep the GBT equipped with the latest technology. Graduate students use the GBT to gain hands-on experience with a major telescope, an increasingly rare opportunity and critical for their training.

The telescope is typically oversubscribed by a factor of 2-3 but sometimes reaches over-subscriptions rates >4. The degree of over-subscription varies considerably with frequency band and source location. High frequencies and, for example, the galactic center region are much more highly over-subscribed than the average suggests. It is scheduled dynamically to match project needs to the available weather. Green Bank has several thousand hours of clear skies with a perceptible water vapor content <10mm throughout the year, allowing extensive operations at short wavelengths. Since 2010 about 2000 hours have been available for weather-dependent high-frequency observations, a number which should increase as telescope control is improved.

The GBT has the best protection of any U.S. observatory from many forms of man-made radio frequency interference as it is located in the National Radio Quiet Zone (NRQZ) and the West Virginia Radio Astronomy Zone (WVRAZ). The facility's location in a lightly populated valley in the Monongahela National Forest, surrounded by extensive ranges of mountains in all directions, provides further protection from interfering signals.

The Green Bank facility is also a major resource for education and public outreach, and as such is an outstanding advocate for basic research and the work of the NSF. The facility produces nationally-acclaimed programs in education, and the training of science and engineering students and teachers. These activities operate from the Green Bank Science Center, and with its auditorium, classrooms, and large exhibit hall, is visited by 50,000 people every year. Thousands of K-12 teachers and students partake of residential educational programs using older radio telescopes no longer involved in research.

Submission Tool (PST), General Observing Spectral line Tool, Exposure Calculator), provide technical reviews for proposals and evaluate proposals for RSRO contributions.

- Hardware, Software, and Operational Documentation: Write technical documentation detailing hardware and software functionality for staff and users, develop and improve operational procedures and write documentation for the operations staff. This includes updating the VLA "Observational Status Summary" before each Call for Proposals and providing content for the "Guide to Observing with the VLA" on the NRAO web site.
- Track and Measure VLA Performance: Sensitivity, Gain Curves, Holography, Antenna Positions, Collimation, Pointing:
    - Characterize the sensitivity and gain response of each antenna at each band. This must be done periodically as receivers and equipment are replaced (e.g., due to failures in the field) or as software is upgraded that may change the system performance.
    - Check the surface accuracy with holography periodically to ensure optimal efficiency at the highest frequency bands.
    - Determine antenna positions, collimation offsets and pointing accuracy when the array is moved into a new configuration.
- Scientific Testing of Antennas Completing Major Maintenance:
    - Determine antenna positions, collimation offsets and pointing accuracy each time an antenna comes out of the Antenna Assembly Building after a maintenance overhaul.
    - Evaluation of new Antenna Control Units (ACUs). As new ACUs are installed they will undergo testing and evaluation by scientific staff.
- System Health and Maintenance Feedback: Run routine health checks to determine if there are any hardware failures that must be followed up with maintenance tickets. Troubleshoot problems found and confirm fixes are implemented. Run Radio-Frequency Interference (RFI) tests to characterize and help mitigate RFI contamination in the bands.
- Data Quality Assurance Checks: Evaluate data quality based on the Pipeline results and run test observations to identify and diagnose problems that are not caught by the standardized tests and engineering checks.
- Calibration Data:
    - Flux calibrator models, flux density run: Develop and maintain the infrastructure needed by users to establish an accurate absolute flux density calibration scale for the VLA at each observing frequency. Extensive, multi-configuration observations of calibrators are made to develop models that can be applied during the data calibration process.
    - Polarization and bandpass stability and service calibration tests: Develop and maintain optimal polarization and bandpass calibration infrastructure and tools for our users. In FY2015 and FY2016 this will include documentation, full polarization source models and measurements of the polarization and bandpass stability of the system. Service observations are also made for VLBA polarization observations to enable better calibration of VLBA data.

Support for the Calls for Proposals and associated documentation updates and software testing have milestones on a cyclic timescale that is matched to the proposal cycle. Understanding and characterizing, e.g., antenna positions, gain curves, collimation and pointing have a high impact during and just after each array re-configuration and then decrease to a lower level of effort that is needed to support antennas coming back to the array after major maintenance. System health and data Quality Assurance (QA) evaluation along with polarization service observations and support of phased-array observations require an on-going level of effort that is expected to remain relatively constant throughout each year.

Appraisal, the (PIP) Performance Improvement Process, and the (IDP) Individual Development Plan Process, and 2. Compensation 101 – how we determine and deliver compensation at NRAO.

FY2016

Management/Supervisory Development Delivery: NRAO HR will deliver the remaining management/supervisory training modules and any necessary refresher training. Deliver two (2) NRAO developed/designed courses to managers/supervisors of NRAO. Courses to be delivered cover: 1. Performance Management – effective delivery of the Performance Appraisal, the (PIP) Performance Improvement Process, and the (IDP) Individual Development Plan Process, and 2. Compensation 101 – how we determine and deliver compensation at NRAO.

13.3 Compensation

The HR Department's Compensation function analyzes market data and provides program solutions in support of the Observatory's philosophy of "pay for performance" and "market based pay". In the absence of funded increases to employee compensation, HR looks for other avenues to address employee job satisfaction, reward exceptional merit, and provide a positive workplace environment.

FY2015

Electronic Performance Appraisal Process: Complete first 'just in time' electronic appraisal process for FY2014 performance against objectives/goals. This is a follow on process to the completion of the NRAO first electronic PEP experience to learn the process by putting a past appraisal into the system and working it through the process steps. NRAO HR will create and guide four separate groups through the process this year: NRAO, AUI, OCA, and NRAO ISMs. AUI and OCA will be new to the electronic process.

Salary Review: Budget permitting, with the establishment of a salary increase pool NRAO HR creates the salary review process and mechanisms for pay decision managers to allocate merit review funds following completion of the performance evaluation process.

Salary Survey and Benchmark Jobs Analysis: NRAO HR participates in and acquires salary survey information in order to complete the analysis of the 20 benchmark jobs for the organization. This analysis/data is used to review current status of pay ranges, how NRAO compares to market, and to make recommendations and determinations for change.

Job Description Builder Module: Add the Job Description Builder module to the Halogen System in order to enhance the functionality of the eRecruit and eAppraisal modules. HR staff will be trained as administrators and how to effectively use/interface this module.

FY2016

Electronic Performance Appraisal Process: Complete electronic appraisal process for FY2015 performance against objectives/goals. NRAO HR creates and guides four separate groups through the process: NRAO, AUI, OCA, and NRAO ISMs.

8.5 Program Management Department Major Milestones

Table 8.5.1: PMD FY2015 Major Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
HEADQUARTERS					
SOP and Templates	Complete Standard Operating Plan and Templates and distribute		1		
Deliverables	Quarter Status Updates	2	2	2	2
	Program Operating Plan				3
	Long Range Plan				4
	Annual Progress Summary				5
NEW MEXICO					
NM and DMS PM/SE Training	Finalize NM Ops and DMS Training Plan (1st Phase)	6			
	PM 101 Training		7		
	SE 101 Training				8
DMS Support	Retrospective Analysis of CASA 4.4 Release			9	
	PM/SE Learning Sessions	10	11	12	13
CDL/ALMA					
	Develop training plan for the CDL	14			
	Provide tailored PM/SE Training lessons	15	16	17	18
	Facilitate Concept feasibility gate 1: Limits in performing sideband-separation, polarization synthesis, and unformatted link management with current FPGA technology. FPGA processor to the high-speed serial links interface.			19	
ALMA D Support	ALMA Development Call for Study Proposals.		20		
GREEN BANK					
GB PM/SE Training	Finalize Green Bank Training Plan	21			
	PM/SE Implementation Training		22		
	PM/SE Learning Sessions	23	24	25	26

Milestones:	Deliverables:
1. SOP and Templates Available 2. Quarterly Status Updates 3. Program Operating Plan (if required) 4. Long Range Plan (if required) 5. Annual Progress Summary 6. Finalize NM Ops and DMS Training Plan (1st Phase) 7. PM 101 Training 8. SE 101 Training 9. Retrospective Analysis of CASA 4.4 Release 10-13. Host learning session 14. Develop Training Plan 15-18. Training lessons provided 19. Facilitate Concept Feasibility Gate 20. Call for Study Proposals 21. Finalize Green Bank Training Plan 22. PM/SE Implementation Training 23-26. Host learning session	[1] SOP and Templates [2] Quarterly Reports [3] Report [4] Report [5] Report [6] NM Ops and DMS Training Plan (1st Phase) [7] On-site training session for NM Ops and DMS Staff [8] On-site training session for NM Ops and DMS Staff [9] Lessons Learned report of CASA 4.4 release (methodology, tools, processes, etc.) [10-13] Completed number, and outcomes of learning sessions [14] CDL Training Plan [15-18] Training [18] Decision gate [20] Study Proposals vetted through NRAO processes [21] Final approved version Training Plan [22] On-site training session for GB Project Leads [23-26] Completed number, and outcomes of learning sessions

continue to track and categorize each reported NA antenna maintenance item to identify recurring items that may require special attention.

- Front End (FE) Group: This group is located at the CDL in Charlottesville and is responsible for maintaining the Band 6 Cold Cartridges (including mixer-preamplifier subassemblies, horn, Orthomode transducers (OMTs), and warm Intermediate Frequency (IF) amplifiers), a majority of FE components (including various electronic sub-assemblies such as IF switches, several different monitor and control units, and several mechanical parts) as well as providing software support for the ALMA FE Monitor and Control firmware. In addition to supporting and maintaining telescope Front End hardware and software, the responsibility of this NA IET group includes maintenance of test systems at the CDL including the Band 6 SIS mixer test set (MTS), the Band 6 Cold Cartridge Assembly (CCA) test set (CTS), and test systems for several other FE component and sub-assemblies (this work is needed to maintain the proper functioning of the necessary test systems to be able to carry out repair and requalification of components and modules). This NA IET group is also responsible for the hardware and software support of the two Front End Test and Measurement Systems (including noise temperature apparatus, tilt tables, and beam scanners), and the Band 6 CCA test set situated at the ALMA Operations Support Facility (OSF) as well as their respective associated test operation and measurement software suites. The FE group also provides management support, product assurance, and other administrative activities (e.g. export/import functions) in Charlottesville.
- Front End Local Oscillator (FE LO) Group: This group is located at the CDL and is responsible for maintaining the WCAs for all receiver bands (including active multiplier chains, power amplifiers and phase lock modules), as well as FE LO cryogenic multipliers which are physically integrated into the CCAs. This group is also responsible for operation and maintenance of the necessary bench test sets to be able to carry out repair and requalification of FE LO components and modules.
- Back End (BE) Group: This group is located in Socorro, NM, and is responsible for offsite maintenance of its Antenna Articles (AAs), including Fiber Optic Wraps (FOWs), Data Receiver Articles (DRXAs), and support of some Line Replaceable Units (LRUs) in the Central LO Article (CLOA). The BE group also provides management support, product assurance, and other administrative activities (e.g. export/import functions) at Socorro.
- Back End Photonics Local Oscillator: This group is located at the CDL and is responsible for maintaining the CLOA as well as local oscillator photonics receivers (LOPR) in the front end assemblies.
- Correlator Group: This group is also located at the CDL and is responsible for high-level debugging of control/correlator software used for ALMA data taking. Most routine maintenance of the correlator is planned to be handled by the OSF staff in Chile. However, if a particularly difficult problem arises, the correlator staff in NA IET may be called upon to provide assistance. Additionally, some advanced features of the correlator were not within the scope of the construction project and have not been implemented by the Integrated Computing Team (ICT). During the implementation and test phases of these advanced features, the NA correlator staff is required to assist in troubleshooting of any problems that may occur. This effort may require firmware modifications if bugs or performance issues are uncovered.

ALMA hardware maintenance follows a three-tiered approach with the three tiers being defined in the ALMA Maintenance Plan as follows:

- Tier-1 repair: The task of repairing the highest-level assemblies by simply replacing the LRU in question with a working spare. This is mostly executed by the Array Maintenance Group (AMG) staff in Chile.

Ongoing Projects

FY2014 – FY2015 Project starts were delayed by six months while obtaining ALMA board approval. The FY2014 – FY2015 projects will now carry over into FY2016 by six months.

Prototype Band 2 Cartridge (Lead Institution: NRAO): The NRAO is working on the development of a Band 2 Cartridge Prototype. Period of performance is April 2014 through April 2016. Cost: $ 1,493969.

Band 3 Cold Cartridge Assembly Magnet and Heater (Lead Institution: NRC - Herzberg): NRC - Herzberg will produce deflux heaters and permanent magnets to be installed in the Band 3 cold cartridge as a way to reduce the azimuth-dependent total power variations observed in the ALMA antennas. Period of performance is April 2014 through April 2016. Cost: $ 248,409.

ALMA Data Mining Toolkit (Lead Institution: University of Maryland): The University of Maryland is working to create a value-added software package which integrates with the ALMA archive and CASA to provide scientists with quick access to traditional science data products such as moment maps, and with new innovative tools for exploring data cubes. Period of performance is April 2014 through April 2016. Cost: $ 991,160.

The Next Generation ALMA Image Viewer (Lead Institution: University of Alberta): The University of Alberta is collaborating with the NRAO to address the need for exploring large data sets where the visualization of the data is mediated through the ALMA science portal, and the computation required for visualizing the data takes place on dedicated servers using optimized software. Period of performance is April 2014 through April 2016. Cost: $ 887,666.

Expansion of the ALMA Central LO Article to 5 Sub-arrays (Lead Institution: NRAO): The NRAO is working to equip the ALMA Observatory with an additional complete Photonic LO sub-array, identical to the four sub-arrays already in use. Period of performance is April 2014 through April 2016. Our next Call for Project Proposals will be in April 2016 for projects to begin in FY2017, subject to funding availability. Cost: $ 339,056.

2.4 Maintenance and Renewal

This section covers offsite hardware maintenance and renewal. Offsite software is described in the Data Management and Software section.

The maintenance and renewal of the hardware on the ALMA telescope is the responsibility of the Integrated Engineering Team(s) that are primarily divided / defined by their geographic locations i.e. North America, Europe and East Asia. The NRAO ALMA Offsite Hardware Maintenance Division is a subset (in addition to other entities like NRC-Herzberg) of the North American ALMA Integrated Engineering Team (IET) and is comprised of the following technical groups (located in Charlottesville and Socorro):

- Antenna Group: The efforts of NA antenna staff are focused on supporting antenna corrective maintenance issues and support of the Antenna Maintenance Group (AMG) of the JAO with the goal of ensuring a high level of operational capability for the complete ALMA array. NA antenna staff helps to troubleshoot the identified maintenance issues (mostly JIRA ticket driven) and provide recommendations for corrective actions. In Charlottesville, the ongoing efforts will

- Tier-2 repair: The task of repairing the LRU in question by replacing a sub-assembly within it with a spare working sub-assembly. Depending on the nature and complexity of the LRU, this work is assigned in the ALMA Configuration Item Responsibility Matrix to either the AMG staff in Chile or the IET staff with the executives.
- Tier-3 repair: The task of repairing the broken sub-assemblies at the component level. This is mostly a responsibility of the owner IET.

The following list captures a subset of tasks that form the core of the off-site maintenance activity:

- Planning the level and type of hardware maintenance support based on available resources and a continuous analysis of operational failure rate data.
- Assisting with on-site troubleshooting and repair through regular coordination with the Chilean AMG staff and other hardware support staff from our international partners (i.e. European and East Asian IETs).
- Troubleshooting and repair of items returned to NRAO that require NRAO expertise and facilities.
- Coordination and oversight of maintenance contracts for vendor-built modules supplied by NRAO during construction.
- Troubleshooting and maintenance, including software support, of test systems used by Chilean maintenance staff designed and/or delivered by NRAO as part of the Construction project.
- Training of Chilean maintenance staff in troubleshooting and repair of both ALMA hardware deliverables and the systems to test them.
- Procurement, assembly, and testing of spare components to maintain an appropriate stock consistent with observed failure rates.
- Continued improvement of testing and repair procedures in collaboration with on-site Chilean staff.
- Supporting the ICT in implementing new correlator modes.
- Shipping and receiving of equipment between NRAO, vendors, and Chile.

It should be noted that most of the NRAO personnel who are members of the NA IET and execute the tiered maintenance/support activities described above are also members of the ALMA development teams executing projects described in section 2.3.

In addition to the above functions, the ALMA IETs are jointly responsible for maintaining a technical oversight of all ALMA hardware – both existing and under development. In that role, the NA IET executes these support functions (e.g. participating in design study review or a development project design review) by providing the NRAO personnel whose knowledge/expertise is relevant for a particular review in question.

Additional Maintenance and Renewal Activities by Year

FY2015

In addition to the regular maintenance and technical support for various pieces of telescope hardware, the following activities are planned for FY2015. The activities listed are heavily dependent on external partners who typically dictate the scheduling; hence, specific quarter milestones are not listed. We anticipate activity during the fiscal year period, however.

- Improve the off-site interface to the ALMA Computerized Maintenance and Management System (CMMS) to more effectively utilize the tool for managing and planning the maintenance activities and procurement or spares and/or execution of Tier-3 repair work.

Table 12.3.2: Diversity FY2016 Major Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Diversity Council	Office of Diversity Initiatives		1	2	
National/Domestic Outreach	SOC Electronics Engineering Internship with HSI VA-NC Louis Stoke Alliance for Minority Participation, NRAO Astronomy Consortium, (NAC) Socorro Summer Youth Employment, Physics Inspiring the Next Generation (PING) African American Teaching Fellows Partnership, Undergraduate Engineering Internship Program, UVA/NRAO Chilean student PHD sponsorship			3	
International Outreach	The NRAO International and National Exchange Program		4		
	Chilean Student Partnership		5		
Improve Workplace Culture	Diversity and Cultural Awareness Training		6		7

Milestones:	Deliverables:
1. Office of Diversity Initiatives/Diversity Council 2. ODI Program and metrics review 3. LSAMP, NAC, SOC Summer Youth Employment Program, Native American Outreach, SOC Engineering Internship, UVA/NRAO PhD Sponsorship, PING, etc. 4. NINE- NRAO Staff and student exchanges 5. UVA/NRAO Chilean PhD Sponsorship 6. Diversity and Cultural Awareness Training #1 7. Diversity and Cultural Awareness Training #2	1. Evaluate effectiveness of ODI and elect new Chair 2. Provide report to Director and AUI President 3. Provide metrics to demonstrate the effectiveness of pipeline efforts in increasing underrepresented groups for integration STEM related fields across the Observatory 4. Visits and exchange of faculty and students from international partnerships 5. Recruitment of female Chilean student to participate in 12 -18 month PhD program at NRAO/UVA 6. Continue to deliver diversity and cultural awareness training to staff and students across the Observatory (Part 1of 2) 7. Continue to deliver diversity and cultural awareness training to staff and students across the Observatory (Part 2 of 2)

12.4 Diversity Financial Information

Diversity initiatives are funded from a combination of external grant monies, AUI funds and approximately $10K in funding from internal HR sources. Additionally, NRAO contributes approximately 1 FTE of effort split among multiple staff members. The NRAO monies and effort are represented in other departments and are not double counted here.

The NRAO Archives actively seeks out, collects, organizes, and preserves institutional records, personal papers, multimedia materials, and oral histories of enduring value that document NRAO development, institutional history, and instrument construction. As the national facility for radio astronomy, the Archives also includes materials on the history and development of radio astronomy in the United States, and our growing reputation have made our Archives the de facto repository for U.S. radio astronomy history.

Statistics and Metrics

The metrics database, available to all internal staff via a simple web interface, contains data used for contractual reporting to the NSF with consistent information pertaining to the operation of all telescopes: ALMA, GBT, VLA, and VLBA. The database is also used to provide monthly reports to NRAO management. Also the metrics suite in support of Annual reports are generated and made available on the web. The information is gathered by differing means, from fully automatic to semi-manual. Making this process more fully automated has been and will continue to be an ongoing task – see below. Similarly, synergy of these metrics with other domains will continue to be pursued and improved. These include Library services for publication metrics, PhD theses using NRAO instruments, and student support.

Science Support and Research Services Milestones by Year

FY2015

Library contracts for eJournals packages and eJournals access will be negotiated in Q2, FY2015. Expanded access will be sought.

Given the high maintenance costs of NRAOPapers, commercial alternatives will be sought for evaluation and possible replacement of NRAOPapers.

Requirements for a more general and richer metrics web interface, and for more automatic aggregation of the underlying data, will be developed by Q2 FY2015 and conveyed to DMS. Implementation is anticipated by the end of FY2015.

FY2016

Contracts for eJournals packages and eJournals access will be negotiated in Q2, FY2016.

6.4 NRAO Scientific Staff Support

A productive and scientifically active staff is a prerequisite for the successful operation of cutting-edge observational facilities. The scientific staff is key to telescope testing, operations, user support, and long-range development and planning. NRAO has a world-class staff of about 74 astronomers, computer scientists, and research engineers, recognized internationally for their excellence in telescope design and support, as well as their technical and scientific knowledge and leadership.

The scientific staff is fully integrated into Observatory operations. All staff members have clear functional duties relating to the major mission and facilities, as outlined in the other sections of this report. Staff members also lead efforts in education of the professional community, as well as public outreach, fostering a scientifically literate society. A vibrant scientific support staff, engaged with the community, is

large number of receiving elements. This approach sacrifices sensitivity but recovers observing efficiency by making large gains in field of view. By contrast, the R&D project at NRAO, aims to use cooled detectors with as little sacrifice in noise temperature as possible, while using a more modest number of receiving elements and formed beams. We believe that this approach is better suited for PAFs on single-dish telescopes, and that it will compete well with other approaches for PAFs deployed on new telescope arrays.

In the past, NRAO PAF R&D effort has included successful test and observing runs on the 20m telescope and on the GBT. These efforts have led to improved expertise in observing, telescope control software as well as in monitor and control, data acquisition, correlation, and beamforming. The FY2015-2016 plan aims to leverage this base of expertise as follows:

- In FY2015, planned instrumentation upgrades will improve the noise temperature of the receiver, increase the bandwidth of the RF, IF, and digitizers (100-fold), and will improve the reliability of the instrumentation.
- In parallel with the instrumentation work, in FY2015 we will continue existing efforts in modeling and analysis. The goal of this effort will be to fully understand prior results, gain confidence in our models so that we can build a PAF system to specification, and to help to guide and inform our plan for improving the PAF receiver in FY2016.
- This development path will track in parallel with the Beamformer project, which has the aim of extending the bandwidth and capability of the digital backend.

Hydrogen Epoch of Reionization Array (HERA): The HERA is a scientific road map investigation aimed at exploring the large-scale structure in the baryonic universe via the 21cm line of hydrogen.

An NSF Mid-Scale Innovations Program (MSIP) proposal for HERA was submitted in FY2014. This project received about $2M of which $107k was awarded to the NRAO in FY2014 for feed electromagnetic design and antenna structural analysis. This work will be carried out in FY2015.

Dark Ages Radio Explorer (DARE): DARE is a proposed lunar orbiter mission intended to detect the highly-redshifted hyperfine 21-cm transition of neutral hydrogen to track the formation of the first stars, black holes, and galaxies through their impact on the intergalactic medium during the end of the Dark Ages and the subsequent Cosmic Dawn (redshifts 11-35). Using the moon as its RFI shield, DARE will uniquely complement the efforts of the Wilkinson Microwave Anisotropy Probe (WMAP), the JWST, and the Atacama Large Millimeter Array (ALMA) by bridging the nearly billion-year gap between the smooth Universe seen via the Cosmic Microwave Background and the rich web of galaxy structures imaged at more recent times.

The DARE proposal is being led by PI Jack Burns of the University of Colorado. The NRAO/CDL is assisting with the development of the antenna and radio frequency electronics. An engineering prototype was previously fabricated and deployed at the NRAO site in Green Bank, WV and subsequently at the Murchison Wide-field Array (MWA) site in Australia. In FY2015, the antenna and front-end electronics designs will be refined using the results of electromagnetic modeling and prototype measurements.

FY2016

Millimeter and Submillimeter Detectors: In FY2016, the CDL will continue working with UVML to develop the next generation of SIS mixers for future ALMA receivers. We will continue our development of (1) an improved ALMA Band 6 mixer with a balanced sideband-separating topology and

NRAO Chile Office Milestones

FY2015

Most of the NRAO-Chile Office work is steady-state business and operational activities. However, some important milestones are planned for FY2015. These include:

- Implementation of a succession and management plan 2015-2016 (elaborated in August 2014), including the incorporation of a Chief of Staff.
- Providing support to the JAO in developing a well-structured ALMA HR department under a new head of HR.
- Analysis and implementation of possible alternatives to the physical location of NRAO-Chile, including the possibility of moving the office to the ALMA SCO in 2015.

FY2016

Apart from the steady-state business noted above, an additional important milestone for FY2016 is the preparation and execution in collaboration with the JAO and the other Executives of a collective negotiation with the AUI Union, which will take place in August 2015.

10.2 News and Public Information

FY2015

Social Media Engagement: NRAO will continue its aggressive program to engage followers in the excitement of radio astronomy via tools such as Facebook, Twitter, Google+, Youtube, and Vimeo. We will continue to research and post material nearly every business day, a practice that has generated a 35-fold increase in our social media audience over the past five years.

Public Website Maintenance, User Support, and Improvements: The content management system that supports NRAO's public website (https://public.nrao.edu), Joomla 2.x, has reached the end of its life and will no longer be supported by the Joomla organization as of the end of 2014. EPO will work to upgrade the website to the new Joomla 3.x system during FY2015. This upgrade will bring a number of new technical possibilities to the public website, including the ability to have an adaptive mobile-device version of the site (as pioneered by EPO in FY2014 in the new www.nrao.edu storefront/portal), as well as indexing and search upgrades; a version for mobile devices (smartphones) will be scheduled for FY2015, with progress on indexing and searching as resources allow. In April 2014 an NRAO press release on the public site became so popular that our sever was unable to keep up with the demand. A new server caching software solution has been identified, one that can potentially increase throughput of popular pages by 100x. This software will be performance- and security-tested during FY2015, and installed on the server if it passes the test.

New Public Website Content: NRAO will produce additional planned modules for the Milky Way Explorer (https://public.nrao.edu/explorer/milkyway/TheMilkyWayExplorer.php), featuring videos about planetary systems and the Local Group of galaxies.

Press Release Development, Distribution, and Monitoring: NRAO enjoys an extensive network for distribution of press releases, press announcements, and news "tip sheets" developed according to the process described at https://science.nrao.edu/observing/news-release. We will continue to distribute news via the NSF, AAS, AAAS, and commercial newswire services, and monitor impact via a professional news monitoring service. We will continue to pursue stories aggressively, which has in recent years dramatically increased the number of stories we report.

NRAO Smartphone/Tablet Apps: NRAO will develop our first-ever app for iOS and Android devices, a project that will entail media design and learning the authoring/development systems for such devices, which are different than what it used in webpage design. The first NRAO app, entitled "RadioSky," will be a self-guided tour of radio astronomy and NRAO facilities. An iOS version of this app will be created in FY2015.

Media and Public Inquiry Response: NRAO receives multiple requests annually from the news media and documentary producers for support that ranges from image recommendations and permissions to accompanying a film crew to an NRAO facility. We allocate resources to accommodate these requests. Similarly, we receive numerous public inquiries and allocate staff time to answering them.

FY2016

Social Media Engagement: NRAO will continue its engagement with its social media audience, keeping abreast of the latest developments and new opportunities in this fluid area.

Wideband science is possible using either the PFB or DDC observing systems. Spectroscopic and other narrow-band observations are generally best supported by the DDC system.

For the HSA not all observing systems are available on all stations, and some station combinations are not fully commissioned and tested, but will be made available through the various VLBA shared risk observing programs as shown in Table 3.2.1.

Table 3.2.1: HSA Capabilities in FY2015

HSA station	Observing System		
	PFB	**DDC-4**	**DDC-8**
VLBA	GO	GO	GO
GBT	GO	GO	GO
Y27	SRO	GO	SRO
Arecibo	GO	–	–
Effelsberg	GO	SRO	RSRO
LMT	RSRO	–	–

DDC-4 refers to a 4-channel, 2-IF mode, and DDC-8 to the full 8-channel, 4-IF case. The observing system must be identical for all stations in an observation.

Array Operations

No additions or modifications to VLBA array operations compared with the description above are expected in FY2015.

FY2016

Science Operations

Observing Programs: The VLBA capabilities being offered for GO for FY2016 are as for FY2015 above. However, the capabilities being offered for the HSA will be expanded to those shown in Table 3.2.2 below by the end of FY2016:

Table 3.2.2: HSA Capabilities in FY2016

HSA station	Observing System		
	PFB	DDC-4	DDC-8
VLBA	GO	GO	GO
GBT	GO	GO	GO
Y27	GO	GO	GO
Arecibo	GO	RSRO	–
Effelsberg	GO	GO	SRO
LMT	SRO	–	–

Array Operations

The effort in FY2015 to move the VLA evening and night shift operations to the DSOC may make possible the cross-training of VLA and VLBA operators in FY2016, to enable each group to be familiar with the others' functions and tools.

In FY2015 the NRAO will begin replacing the existing commercial software used for the radio wave propagation studies with custom software to be written by NRAO software engineers to provide a better, more reliable software and a reduced workload on the local staff. Identified improvements to the model used will not be made due to funding shortfalls.

FY2016

Most work within the radio quiet zones will remain the same in FY2016, with the exception of the propagation modeling software, which will be used in earnest in FY2016.

WV Site Radio Frequency Interference Mitigation

On the Green Bank Site, our protection policy differentiates two zones, one for the laboratory, housing, and visitor facilities (Zone 2), and one for the Radio Astronomical Instruments (Zone 1). In Zone 1, the 'ground zero' of the scientific instruments, the general philosophy for interference mitigation is a preventative, proactive approach; interference potential is assessed through testing within NRAO anechoic chamber, and equipment is shielded, filtered, etc. as necessary before installation. All installed equipment is required to comply with the limits stated in International Telecommunication Union-Radio (ITU-R) RA.769, assessed with respect to the prime focus point of the GBT at its highest elevation. This zone is also protected by limiting motorized traffic to diesel vehicles to avoid strong broadband emissions from spark plugs. Tourists and other site visitors are instructed to leave their electronic devices behind when they go on the site tour, whether by bus tour or foot traffic.

In Zone 2, the laboratory, housing, and visitor areas, NRAO differentiates between intentional radiators and unintentional radiators. An intentional radiator is any electronic device that intentionally transmits radio waves. All intentional radiators except for a select list of coordinated devices that are absolutely necessary for safety (the 43 MHz site radios, for instance) are strictly prohibited in Zone 2. Prohibited devices include cordless telephones and wireless networking devices.

FY2015

During FY2015 we will monitor and maintain the site at its current emission level. Plans to further clean the observing bands through, e.g. shielding the GBT warehouse (currently the largest source of site-based interference for the GBT) and tracking down and shielding other local sources of interference is unlikely to occur due to budget shortfalls.

FY2016

As with FY2015, in FY2016 we will monitor and maintain the site at its current emission level. Plans to further clean the observing bands through, e.g. shielding the GBT warehouse (currently the largest source of site-based interference for the GBT) and tracking down and shielding other local sources of interference is unlikely to occur due to budget shortfalls.

16.4 International Spectrum Management

The ability to observe without harmful RFI is fundamental to the NRAO science. The methods whereby spectrum is apportioned into bands, bands are allocated to users, and rules for band use are formulated to shield users from interference, are called 'spectrum management.' The NRAO participates heavily in

Array Operations

Array Configurations: Over a 16-month period, the VLA cycles between four primary configurations, and three "hybrid" configurations, in order to provide sensitivity to different spatial scales as needed to achieve various science goals. Re-configurations occur every four months, to ensure that a particular configuration cycles through all the seasons averaged over multiple configuration cycles. These antenna moves require most of the site staff (typically 10 persons for each of two transporters), and can require anywhere from one to three weeks each, depending on which configuration is being set. Array configuration changes along with transportation for antenna overhauls results in approximately 60 antennas being relocated annually. All moves require track crew, antenna mechanics, transporter operators, electricians, and receiver, cryogenic, fiber optic, and LO/IF technicians. Personnel involved in the array reconfigurations are used to perform maintenance activities (antenna overhauls, track maintenance, electrical infrastructure maintenance, receiver, fiber optic, and LO/IF maintenance) at other times, and are highly integrated with the rest of operations.

In FY2015 NRAO will investigate the potential scientific impact of eliminating the hybrid configurations, which could result in substantial operational benefits. It is possible, therefore, that the reconfiguration schedules for both FY2015 and FY2016 will be modified considerably from those given.

Operating Model: Currently, the VLA is staffed 24 hours per day, seven days per week from the VLA site. Additionally, custodians and security guards are present for all evening and night shifts as well as weekend day shifts. Modifications to this model will be considered during FY2015 and FY2016, as described below.

Additional Operations Milestones by Year

FY2015

Science Operations

Observing Programs: An overview of the capabilities being offered for GO for FY2015 is given in Table 3.1.1 below.

Table 3.1.1: VLA Capabilities in FY2015

Capability	Description
8-bit samplers	• Standard default setups for: o 2 GHz bandwidth continuum observations at S/C/X/Ku/K/Ka/Q-Bands o 1 GHz bandwidth continuum observations at L-Band o 256 MHz bandwidth continuum observations at P-Band • Flexible setups for spectroscopy, using two independently tunable 1 GHz basebands, each of which can be split into up to 16 flexibly tunable subbands • Single, dual, and full polarization products • Number of channels summed over all polarization products up to 16,384 (no recirculation) or 65,536 (with recirculation x4)
3-bit samplers	• Standard default setups for: o 8 GHz bandwidth continuum observations at K/Ka/Q-Bands o 6 GHz bandwidth continuum observations at Ku-Band o 4 GHz bandwidth continuum observations at C/X-Bands • Flexible setups for spectroscopy, using four independently tunable 2 GHz basebands, each of which can be split into up to 16 flexibly tunable subbands

FY2016

Community Education and Outreach Services

Helpdesk Services: Helpdesk services are expected to be fully integrated in FY2016.

Community Days, Tutorials, Schools and Training workshops: CDEs will be organized in Q3 in advance of the ALMA Cycle 4 CfP and proposal submission deadline and the NRAO NA semester 2017A CfP and proposal submission deadline. As before, SUS expects to organize 3-6 such CDEs. One or two data reduction tutorials will be organized in Socorro and/or Charlottesville as needed. The 15th Synthesis Imaging Summer School will take place in Socorro.

Face-to-face Visitor Support, Contact Scientists, Data Delivery: The SUS will continue to provide expert, "hands on" support in FY2016 at a level similar to that provided in FY2015.

User Documentation, Web Material, and Online Training Material: Given the anticipated Cycle 4 CfP in March, a review and final edits of all user documentation will be completed before being deployed off the ALMA Science Portal in Q2. As with previous Cycles a User Survey will occur in Q3 soon after the proposal deadline to assess the ease of use of the tools, the proposal preparation process, and interactions with ARC staff.

In anticipation of the next CASA releases in FY2016, all CASAGUIDES will be reviewed, edited and deployed after being fully tested on the new versions of CASA. The deployment of the new CASAGUIDES will take place in Q1 and Q3 FY2016.

Scientific workshops and conferences: Several workshops and conferences will be supported in FY2016, including a NAASC-sponsored science workshop in the fall of 2016 (Q1).

User Data and Scientific Software Services

ALMA Pipeline Support: SUS staff will support the release of the CASA pipeline for ALMA Cycle 3 in Q1, as well as reprocessing requests and manual reduction of complex observing set-ups.

VLA Pipeline Processing: In FY2016 the focus of the VLA pipeline processing effort will be to start incorporating polarization calibration. Heuristics will be developed by NM Operations during FY2015, with a goal of releasing a scripted pipeline for polarization calibration in Q2 of FY2016. In parallel, the polarization calibration heuristics will be implemented in the CASA pipeline and will be validated against the scripted pipeline by end Q4.

Pipeline Reprocessing Interface (RPI): Version 2 of the RPI will be completed in Q2 FY2016 with SUS coordinating user testing and validation.

New NRAO Archive: Version 2 of NRAO archive data archive tool will be completed in Q2 FY2016 with SUS coordinating user testing and validation.

Integrated NRAO/ALMA Science Portal: The integrated science portal will be deployed in Q3 FY2016. User testing will be coordinated by SUS.

Table 8.5.2: PMD FY2016 Major Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
HEADQUARTERS					
Deliverables	Quarter Status Updates	1	1	1	1
	Program Operating Plan				2
	Long Range Plan				3
	Annual Progress Summary				4
NEW MEXICO					
NM and DMS PM/SE Training	Finalize NM Ops and DMS Training Plan (2nd Phase)		5		
	PM/SE Implementation Training			6	
DMS Support	DMS Group Practices Assessment	7			
	Implementation of DMS Reporting Tools				8
	PM/SE Learning Sessions	9	10	11	12
CDL/ALMA					
	Provide tailored PM/SE Training	13	14	15	16
	Facilitate Concept feasibility gate 1: Synchronize parallel data streams with an unformatted serial link			17	
	Facilitate Concept feasibility gate 2: Best approach to calibrating a DOMT				18
	Facilitate Concept feasibility gate for 2015 Experiment 2.1: Reliably de-interleave multiple sources of data on an unformatted serial link	19			
GREEN BANK					
GB PM/SE Training	Finalize Training Evaluation Criteria			20	
	Evaluate and Report on Training Results				21
	PM/SE Learning Sessions	22	23	24	25

Milestones:	Deliverables:
1. Quarterly Status Updates	[1] Quarterly Reports
2. Program Operating Plan (if required)	[2] Report
3. Long Range Plan (if required)	[3] Report
4 .Annual Progress Summary	[4] Report
5. Finalize NM Ops and DMS Training Plan (2nd Phase)	[5] NM Ops and DMS Training Plan (2nd Phase)
6. PM/SE Implementation Training	[6] On-site training session for NM Ops and DMS Staff
7. DMS Group Practices Assessment	[7] DMS Group Practices Assessment Report
8. Implementation of DMS Reporting Tools	[8] 1st Group Reports to DMS AD and Deputy AD
9-12. Host learning session	[9-12] Completed number, and outcomes of learning sessions
13-16. PM/SE Training development	[13-16] PM/SE Training
17. Facilitate gate review	[17] Decision Point
18. Facilitate gate review	[18] Decision Point
19. Facilitate gate review	[19] Decision Point
20. Finalize Training Evaluation Criteria	[20] Training Evaluation Criteria
21. Evaluate and Report on Training Results	[21] Assessment Report
22-25. Host learning session	[22-25] Completed number, and outcomes of learning sessions

6 SCIENCE SUPPORT & RESEARCH

The NRAO Science Support and Research (SSR) department coordinates, aligns, and manages the collective efforts of the three NRAO sites — Charlottesville, Virginia; Socorro, New Mexico; and Green Bank, West Virginia — to support science users of NRAO facilities, to broaden the Observatory's impact through education and visitor programs, and to oversee the research and performance of the scientific staff. It does so through two groups:

- Telescope Time Allocation (TTA) manages the process and tools by which users prepare and submit proposals for use of NRAO telescopes, as well as the proposal evaluation and time allocation process.
- Science User Support (SUS) is responsible for providing the scientific community with the support necessary to execute successful scientific programs with NRAO facilities including the GBT, VLA, VLBA and ALMA.

In addition, SSR provides two observatory-wide services: 1) *NRAO reference* comprises the NRAO Library and the Historical Archives; 2) *Statistics and metrics* aggregates data for internal used and to report various metrics to the NSF, to AUI, to external review committees.

SSR also oversees the research activities of the NRAO scientific staff, staff performance review, staff development activities, the Jansky Fellowship program and postdocs, and various other scientific activities such as the Jansky Lecture, scientific meetings, colloquia, and seminars.

6.1 Telescope Time Allocation

The TTA group is responsible for overseeing the process, and for providing the tools, by which proposals for the use of NRAO NA telescopes—the VLA, the VLBA, and the GBT—are prepared, submitted, and peer reviewed; and by which time allocation recommendations are made to the NRAO Director and then communicated to proposers and suitably publicized to the community. As an international project, ALMA proposals are managed separately by the JAO. However, as part of the POP activities described herein, an increased degree of coordination and alignment between the NRAO time allocation process and the JAO ALMA time allocation process will be sought.

The NRAO NA proposal process is common to all three telescopes. It is semester-based with nominal proposal deadlines of February 1 and August 1 annually, or the nearest Monday to these dates should they fall on a weekend. All proposals are evaluated on the basis of scientific merit by eight Science Review Panels (SRPs), each covering a different category of scientific inquiry. SRP members are recruited from the scientific community for typical term of four semesters, or two years. All proposals are also reviewed for technical feasibility by members of the NRAO scientific staff. Scientific and technical reviews are forwarded to the Time Allocation Committee (TAC). The TAC consists of the chairs of the SRPs and is charged with recommending time allocations to the NRAO Director. After consideration of TAC recommendations by the Directors Review, disposition letters are sent to proposers and the approved science program is posted online.

TTA is also responsible for gathering the requirements for the software tool suite used in support of this process, conveying those requirements to DMS department for implementation, and testing and validating new releases of these tools by DMS. The tools include the PST, used for proposal preparation and submission, and for management of the science and technical review process; and the Proposal Handling Tool (PHT) and the Green Bank Session Editor (GBSE), used in support of the TAC meeting, as well as

analyzed for their potential impact to radio astronomy observing by performing propagation simulations and mapping terrain profiles, calculating the expected power flux density at the array antenna, and comparing the results to internationally recognized detrimental interference thresholds.

2. Informing external spectrum users at the U.S. Space Command (GPS-L3), the tethered aerostat radar system (TARS) sites, and other military and commercial shared-spectrum users of NRAO and NAIC planned spectrum usage each month.
3. Monitoring VLA and VLBA site spectrum conditions using array observations and external monitoring equipment, and reviewing the resulting spectral plots to detect new, unknown RF emissions.
4. Performing RF emissions tests on incoming commercial or NRAO-designed equipment and reviewing the results in order to determine interference potential.

FY2016

As for FY2015

16.3 WV Spectrum Management

Activities at the Green Bank site, including links to resources for NRAO users and recent RFI monitoring of the local electromagnetic environment around Green Bank can be found at https://science.nrao.edu/facilities/gbt/interference-protection/ipg

The National Radio Quiet Zone (NRQZ) and resources for applicants wishing transmitter approval are described at https://www.nrao.edu/facilities/gbt/interference-protection/nrqz

Radio Quiet Zone Management

Cosmic radio signals are easily masked or confused by man-made interference: a cellular telephone on Mars would produce a signal on Earth stronger than most astronomical sources studied with the GBT. The NRAO Green Bank facility is located within two RFI protection zones—the federal NRQZ and the West Virginia Radio Astronomy Zone (WVRAZ). Together these provide protection against sources of terrestrial interference, which is administered by staff at the Green Bank site. The NRQZ was established in 1958 to minimize possible harmful interference to NRAO's Green Bank Observatory and the radio receiving facilities at the Navy Information Operations Command in Sugar Grove, WV. The NRQZ encloses a land area of approximately 13,000 square miles around the state border between Virginia and West Virginia and protects both sites from all Federal Communications Commission (FCC) and NTIA licensed fixed radio transmitters. The WVRAZ is a 10 mile radius region around the GBT within which the telescopes are protected from harmful man-made radio transmissions. Together these provide the GBT and other site telescopes with an invaluable and increasingly rare view into the radio spectrum.

FY2015

Working with colleagues from the federal Sugar Grove, WV facility, NRAO will continue to administer all FCC applications within the NRQZ. In managing the WVRAZ, NRAO will continue looking for potentially harmful interference and working with the community to find solutions for their needs which do not impinge upon GBT observers.

Employee Climate Survey: FY2016 is the year for re-engaging our employees in providing feedback to the Observatory through the Employee Climate survey. A key component of this vehicle is identifying areas where the Observatory can enable and implement change. Design and deliver the employee climate survey in partnership with Mercer. Summarize the feedback and create an action plan to address areas of concern/improvement and communicate such to employees.

Table 5.3.2: CDL FY2016 Major Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Repair, Maintenance, Production, Support	Band 6 Spare Mixer Production				1
	Deliver 140 Band 1 amplifiers to ASIAA				2
Research and Development	High quality Nb/AlN/NbTiN SIS junction				3
	Cryogenically test BAE stock MMIC design			4	
	Develop and test 385 – 500 GHz polarizer				5
	Synchronize parallel data streams with an unformatted serial link			6	
	Tapered waveguide calibration of DOMT				7
	L-Band Cryogenic Receiver			8	
	System testing of PAF				9

Milestones:

1. Complete repair of eight spare Band 6 SIS mixers
2. Pending contract with ASIAA: deliver 140 Band 1 amplifiers (will continue into FY2017)
3. Demonstrate high quality Nb/AlN/NbTiN SIS junctions suitable for THz operation.
4. Cryogenically test BAE stock MMIC design
5. Develop and test 385 – 500 GHz polarizer
6. Synchronize parallel data streams on an unformatted serial link using FIFO buffering.
7. Tapered waveguide calibration of DOMT.
8. Improvement to the L-Band Cryogenic Receiver.
9. System testing of PAF with digital backend.

Deliverables:

[1] Repaired and tested eight spare Band 6 SIS mixers
[2] Delivery of contract (to be negotiated between NRAO and ASIAA) specified Qty. of MIC based Band 1 LNAs to ASIAA
[3] Test data for Nb/AlN/NbTiN SIS junctions
[4] Test data for BAE stock MMIC LNA
[5] Test data for 385 – 500 GHz polarizer
[6] Experiment results
[7] Experiment results
[8] Report on upgrade and test results
[9] Test result

- Investigate issues with locking, fringing, output power, and general communication dropouts.
- Perform routine power supply and battery maintenance.
- Retrofit upgrades or additions to enhance equipment safety.
- Perform bench work on modules for repair or assembly.
- Monitor modules responsible for array timing, adjusting as needed.
- Perform maintenance on ACUs and Focus Rotation Mount (FRM) controllers.
- Replace ~10 Silicon Controlled Rectifier (SCR) driver cards in the VLA antenna servo cabinet per year.
- Monitor for local radio frequency interference (RFI) at the VLA site.
- Swap out and calibrate the site weather station twice yearly for preventive maintenance.

Site Maintenance and Renewal

Antennas: VLA antennas are routinely cycled through the Antenna Assembly Building for checkout and overhaul throughout the year. Under normal maintenance circumstances, up to eight antennas per year could be cycled through the assembly building. If an antenna is upgraded with new control circuitry Antenna Control Unit (ACU) it requires roughly double the period of time for a regular overhaul, which impacts the number of overhauls that can be carried out per year. In addition to the mechanical work associated with an ACU upgrade, the overhaul process includes (1) structural inspections that may reveal existing and potential problems; (2) the installation of upgrades to mechanical parts, electrical systems, and electronic equipment; (3) addressing maintenance issues that require the Antenna Assembly Building resources, such as azimuth gear and bearing replacement; (4) inspecting and changing oil in gear boxes; (5) carrying out touch-up painting on the structure; and (6) repairing and replacing parts as needed. One antenna azimuth bearing per year will be replaced in FY2015 and FY2016.

Preventive maintenance is conducted in the field to inspect, clean, and lubricate each antenna's FRM and azimuth and elevation bearings. During these inspections antenna mechanics routinely check grease for metal chips on all antennas in the field so as to be alerted for potential failure of moving parts. This is especially important for the sustainability of the azimuth gears. The antenna mechanics will continue to respond to mechanical/structural problems that occur regularly, such as inoperative motors, water leaks into the antenna, equipment rooms, broken anemometers located on the dish lip, realigning misaligned FRMs, and addressing other antenna issues brought to their attention. The two transporters used to move the antennas during reconfigurations undergo maintenance and repair between move periods. Maintenance on the almost forty year old transporters includes servicing the motors, checking the generators that keep critical power to the antenna during a move, lubricating the moving parts, checking on the twenty-four wheel axles and wheels and maintaining electrical and hydraulic systems. Antenna mechanics also inspect the 72 concrete antenna pads to ensure their structural integrity and to measure for signs of shifting. If the tripod legs of the pad were to shift too far apart, the antenna would not be able to be bolted to the pad.

Track: During FY2015 and FY2016, inspection of the VLA railroad tracks will continue, checking for problems that could compromise the safety of the transporters that carry the antennas during array reconfigurations and other antenna moves. These inspections also guard against problems that could jeopardize the safety of the maintenance rail vehicles that are used by technicians to service the antennas.

Maintaining track integrity requires specialized railroad repair vehicles and equipment, as well as cross-ties, ballast, rails, and other miscellaneous components. In late 2013 NRAO contracted a Gauge Restraint Measurement Survey (GRMS) for the VLA track. NRAO document PMD00040, *2013 VLA Holland Track Survey, Results and Recommendations*, recommends a need to increase the level of

Following are examples of programs being pursued over the coming two years. These are critical to many of the high priority science goals delineated in NWNH, and span the broad categories of Discovery, Origins, Cosmic Order, and Frontiers of Knowledge.

Cosmology: The NRAO facilities play an important role in the modern age of precision cosmology. The continued development of 90GHz bolometer cameras at the GBT will lead to the most detailed studies of the Sunyaev–Zel'dovich (SZ) effect to date, imaging the substructure in galaxy clusters on tens of kiloparsecs (kpc) scales. The water megamaser program with the GBT and VLBA has discovered new water masers in distant Active Galactic Nuclei (AGN). In the next two years, a few percent measurement of the local Universal expansion rate will be attained, providing a key prior in the Cosmic Microwave Background (CMB) analysis of cosmic acceleration and dark energy. The first microJansky (μJy), wide surveys with the VLA will also provide a unique test platform to study weak cosmic lensing in radio surveys with sub-arcsecond resolution.

Galaxy Formation: Centimeter through submillimeter wavelength observations play crucial roles in the studies of the molecular lines that arise in the fuel for star formation in forming galaxies; the atomic fine structure lines that are the principal coolants for the interstellar medium gas; the thermal dust continuum emission that is a key star formation rate estimator; and the radio synchrotron emission that measures star formation and signals the presence of relativistic jets. Through imaging at sub-arcsecond angular resolution the VLA and ALMA have revealed dramatic structure in the molecular gas in the first galaxies. In parallel, the GBT has performed valuable surveys for molecular line emission from galaxies in the distant Universe, and obtained 'blind' redshifts for dust-obscured galaxies using molecular lines. With these new capabilities, the next two years will see the fulfillment of the evolution of studies of molecular gas in distant galaxies from mere detection, to detailed characterization of the gas distribution and dynamics, and multi-species studies of the physics and chemistry of the interstellar medium (ISM) in the earliest galaxies.

An area that has seen an explosion of interest through the new capabilities of ALMA is the study of atomic fine structure line emission from early galaxies. Studies include using the [CII] 158μm line as a means to obtain redshifts for dust-obscured galaxies, and as the most effective method to determine gas dynamics in forming galaxies at sub-kpc resolution. The coming years will see the use of atomic fine structure lines as a key diagnostic on the energetics (heating and cooling) of the ISM in forming galaxies.

These centimeter through submillimeter observations of the cool gas in early galaxies are an essential complement to the near-infrared (IR) observations that probe the stars and ionized gas, and the X-ray observations that reveal the AGN. Together, observatories operating from centimeter to X-ray wavelengths in the coming decade are providing the requisite panchromatic view of the processes involved in cosmic reionization and the formation of the first generation of galaxies and Supermassive Black Holes (SMBHs). Indeed, in the coming years studies of galaxy formation will rely heavily on observations of the cool atomic and molecular gas, dust, and star formation, at cm through submillimeter (submm) wavelengths using NRAO facilities.

Baryon cycle and the cosmic web: It has become clear in recent years that galaxies at both low and high redshift cannot sustain their rate of star formation without a continued supply of gas from the intergalactic medium. This issue of the 'baryon cycle' for galaxies has been called out in NWNH as one of the paramount questions in studies of galaxy formation. The NRAO facilities are playing a major role in understanding this cycle. The GBT is leading the field in the study of low column density, low mass gas clouds surrounding galaxies and in the IGM. Numerous recent observations with the GBT point to the

Table 3.4.2: New Mexico Operations FY2016 Major Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
VLA Science Operations	Define capabilities to be offered for GO and SRO	1		2	
	Scientific support for Call for Proposals		3		4
	Support array reconfigurations	5	6	7	8
VLA Array Operations	Reconfigure array	9	10	11	12
	Release Operations GSA vehicle(s)	13			
VLA Antenna Maintenance	Antenna overhauls				14
	Replace azimuth bearing				15
	PM on transporters	16		17	18
VLA Track Maintenance	Replace 5000 cross-ties				19
	Replace 5 antenna pad intersections				20
VLA Site Infrastructure Maintenance	PM on VLA site hatch gear	21			
	PM on VLA site transformers				22
VLA Technical Upgrades and Enhancements	Solar upgrade, L-Band		23		
	Solar upgrade, X-Band				24
	Solar upgrade, Ku-Band			25	26
	Solar upgrade, S-Band				27
	Front End card cage upgrades		28		
	Thermal gap retrofits, C-Band			29	
	Thermal gap retrofits, L-Band				30
	Noise diode installation				31
	F318 installation				32
VLA Observing Capability Enhancements	P-Band available through Obs Prep Tool			33	
	Pulsar observing available through Obs Prep Tool			34	
VLA Operational Enhancements	Reference pointing				35
	Tipping scans		36		
	Pipeline heuristics		37		
	VLA Sky Survey support		38		
VLBA Science Operations	Define capabilities to be offered for GO and SRO	39		40	
	Scientific support for Call for Proposals		41		42
VLBA Antenna Maintenance	Major maintenance campaigns			43	44
VLBA Technical Upgrades and Enhancements	Replace some VME functionality		45		
VLBA Observing Capability Enhancements	DDC-4 on Arecibo				46
Site Operations	Renew lease	47			

Milestones:

1. Define VLA capabilities to be offered for semester 2016B.
2. Define VLA capabilities to be offered for semester 2017A.
3. Update VLA documentation to support 2016B Call for Proposals, perform proposal technical reviews.
4. Update VLA documentation to support 2017A Call for Proposals, perform proposal technical reviews.
5. Determine baselines and pointing for antennas moving into their D configuration locations.
6. Determine baselines and pointing for antennas moving into their DnC and C configuration locations.
7. Determine baselines and pointing for antennas moving into their CnB and B configuration locations.
8. Determine baselines and pointing for antennas moving into their BnA and A configuration locations.
9. Complete reconfiguring array to D configuration.
10. Reconfigure array to DnC, then C configuration.
11. Reconfigure array to CnB, then B configuration.
12. Reconfigure array to BnA, then A configuration.
13. Release Operations GSA vehicle(s).
14. Perform 8 antenna overhauls during the course of the year.

Deliverables:

[1-2] Software requirements and documentation.
[3-4] Documentation and reviews.
[5-8] Operational functionality.
[9-12] Array reconfigured and antennas operational.
[13] Vehicle released.
[14-15] Antennas overhauled and returned to array.
[16-18] Preventive maintenance.
[19-20] Track maintenance.
[21-22] Preventive maintenance.
[23-27] Upgraded receivers.
[28] Upgraded card cages.
[29-30] Upgraded receivers.
[31-32] Hardware installed.
[33-34] Commissioning and documentation.
[35-36] Commissioning and documentation.
[37] Software requirements and documentation.
[38] Commissioning and documentation.
[39-40] Software requirements and documentation.
[41-42] Documentation and reviews.
[43-44] Antennas overhauled and returned to array.

Table 6.5.2: SSR FY2016 Major Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
Telescope Time Allocation (TTA)	Call for proposals		1		2
	Science and technical review		3		4
	TAC meeting	5		6	
	Software requirements & testing	7	8	9	10
	Documentation		11		12
Science User Support (SUS)	Education, training, & outreach			13, 14	
	Science meetings & conferences	15			
	Software requirements & testing		16		17
	Broadening impact		18,19	20	21,22
	Documentation	23	24	25	
SSR services	Library & Archives		26		

Milestones:

1. CfP for semester 2016B
2. CfP for semester 2017A
3. SRP and tech review process, semester 2016B
4. SRP and tech review process, semester 2017A
5. TAC meeting for semester 2016A
6. TAC meeting for semester 2016B
7. Update SW tools requirements for TAC support 2016A
8. Update SW tools requirements for PST 2016B
9. Update SW tools requirements for TAC support 2016B
10. Update SW requirements tools for PST 2017A
11. Update documentation for CfP and tools 2016B
12. Update documentation for CfP and tools 2017A
13. 15th Synthesis Imaging summer school
14. ALMA cycle 4 CDE planning
15. NAASC sponsored science workshop
16. Testing of version 2 of RPI and NRAO archive
17. Testing/validation of CASA pipeline
18. Summer student selection
19. Summer student offers
20. Summer student program begins
21. Summer student program complete
22. SOS selection begins
23. Update CASAGUIDES
24. Review ALMA user documents
25. Update CASAGUIDES
26. Library contracts negotiated

Deliverables:

[1] eNews announcement
[2] eNews announcement
[3] Science and technical reviews
[4] Science and technical reviews
[5] TAC meeting
[6] TAC meeting
[7] Requirements for PHT and GBSE
[8] Requirements for PST
[9] Requirements for PHT and GBSE
[10] Requirements for PST
[10] User documentation
[12] User documentation
[13] Summer school
[14] CDE plan
[15] Science meeting
[16] Testing and validation
[17] Testing and validation
[18] Summer student selection
[19] Summer student offers
[20] Summer student program begins
[21] Summer student program ends
[22] SOS selection begins
[23] User documentation
[24] User documentation
[25] User documentation
[26] Library service

Table 10.3.2: EPO FY2016 Major Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
STEM Education	Skynet Jr. Scholars	1, 2, 3	3	3	4,5
	New VLA Visitor/Education Center				6,7
	VLA Visitor Center Operations	8	9	10	
	STEM Role Models	11	12		13
	Space Public Outreach Team (SPOT)	14	15		16
News and Public Information	Public Website Upgrades			17	
	Public Website Content	18			19
	Smartphone/Tablet Apps	20, 21	22	23	

Milestones:

1. Translation of SJS curriculum to 4H project books complete
2. SJS instructional videos complete
3. Final round of SJS professional development meetings for educators
4. Skynet 2.0 for SJS complete
5. Afterglow 2.0 for SJS complete
6. VLA Visitor/Education Center Education and Interpretive Plan completed (subject to available funding)
7. VLA Visitor/Education Center architectural schematic design completed
8. VLA Visitor Center volunteer tour guide recruitment begins
9. VLA Visitor Center volunteer tour guide applicants selected
10. VLA Visitor Center volunteer tour guide applicants on-site
11. STEM Career Day at Dominion Virginia Electric
12. 10th Grade STEM Day at Piedmont Virginia Community College (if invited)
13. STEM Career Focus videos
14. Recruit additional SPOT undergraduate ambassadors
15. Additional training for SPOT ambassadors
16. Seek additional SPOT funding
17. Joomla 3-enabled indexing and searching for public website
18. Orion Explorer specification and scripts completed
19. Orion Explorer debuts on public.nrao.edu
20. Beta version of Android edition of "RadioSky" app ready for testing
21. Specification and design for "Zombie Stars" interactive pulsar app completed
22. "RadioSky" app ready for distribution
23. "Zombie Stars" iOS app ready for alpha testing

Deliverables:

[1] Curriculum materials ready for national 4H review
[2] SJS instructional videos
[3] Educator meetings in October, January, March, April
[4] Web-based telescope interface for Skynet Jr. Scholars complete
[5] Online Skynet data processing application available
[6] Education and Interpretive Plan document
[7] Schematic design drawings
[8] Advertisements placed in publications/websites frequented by amateur astronomers
[9] Volunteers notified
[10] Volunteers trained and ready to give tours
[11] NRAO representation at STEM Career Day
[12] NRAO representation at PVCC 10th Grade Career Day
[13] 12 Career Focus videos complete and posted to NRAO public website
[14] Additional ambassadors recruited and trained
[15] SPOT training weekend completed
[16] Meeting with NASA partners to pursue continued support
[17] Indexing and searching capabilities enabled on public.nrao.edu
[18] Document enabling production of Orion Explorer web feature to commence
[19] Orion Explorer feature completed, up and running
[20] All graphics locked; beta testing for functionality only
[21] Script document sufficient for production to commence
[22] "RadioSky" app posted to iTunes and Google Play
[23] Internal test version ready for staff testing

determining the proper replacement for the now aged active surface electronics on the GBT. However, due to budgetary restrictions, there will be no new work in the radio cameras development program, a program which could improve the GBT's scientific output by a factor of 100 or more. Only those instruments started in FY2013 (ARGUS and MUSTANG 1.5) will be completed. Additionally, projects to improve the GBT's performance at high frequencies, improve the receivers system temperature and band pass at low frequencies, greatly improve the RFI environment on site, and plans to digitize the signal at the receiver (to improve the overall band pass shape) have also been put on hold pending improvements in the site budget.

The total amount of science on the GBT in FY2015 is expected to remain at roughly 6,500 hours. Of these hours, roughly 700 will be provided to a number of universities through private contracts, while the remaining hours will be available under NRAO's "open skies" policy to all qualified astronomers. Of the open skies time, typically 10% will be spent as part of the VLBI array, 30% on pulsar science, 5% doing continuum studies, and the remaining time on spectral line projects.

A complete list of supported GBT receivers and backends is given below. Observer supplied backends also exist on site and are open for use with agreement of the instrument PI.

- Prime Focus: The prime focus receiver is mounted in a focus rotation mount on a retractable boom. The boom is moved to the prime focus position when prime focus receiver is in use, and retracted when Gregorian receivers are required.
    - *Prime Focus 1 (PF1):* The PF1 receiver is divided into 4 frequency bands within the same receiver box. The frequency ranges are 290 - 395 MHz, 385 - 520 MHz, 510 - 690 MHz and 680 - 920 MHz. The receivers are cooled High electron mobility Field Effect Transistor (HFET) amplifiers. The feeds for the first three bands are short-back re dipoles. The feed for the fourth is a corrugated feed horn with an OMT polarization splitter.
    - *Prime Focus 2 (PF2)* (0.910 - 1.23 GHz): PF2 uses cooled FETs and a corrugated feed horn with an OMT.

- Gregorian Receivers: The receiver room located at the Gregorian Focus contains a rotating turret in which the Gregorian receivers are mounted. There are 8 portals for receiver boxes in the turret. All eight receivers can be kept cold and active at all times. The Gregorian subreflector can be used for slow chopping. Unless otherwise stated, each of the Gregorian receivers is a cooled HFET amplifier and every feed/beam has a corrugated horn wave-guide. All calibration for the Gregorian receivers is done via injection of a signal from a noise diode.
    - *L-Band* (1.15 - 1.73 GHz): This receiver has one beam on the sky, with dual polarizations. The feed has a cooled OMT producing linear polarization, but a circular hybrid can be chosen.
    - *S-Band* (1.73 - 2.60 GHz): This receiver has one beam with dual polarizations. The feed has a cooled OMT producing linear polarization, but a circular hybrid can be chosen.
    - *C-Band* (3.95 - 8 GHz): This receiver has one beam, with dual polarizations. The feed has a cooled OMT producing linear polarization, but a circular hybrid can be chosen.
    - *X-Band* (8.0 - 10.0 GHz): This receiver has one beam, with dual circular polarizations. The feed has a cooled polarizer producing circular polarizations.
    - *Ku-Band* (12.0 - 15.4 GHz): This receiver has two beams on the sky, each with dual circular polarization.

3 NEW MEXICO OPERATIONS

3.1 Very Large Array

3.1.1. Science

In FY2015 and FY2016 NRAO will continue to offer a suite of robust and scientifically powerful observational capabilities on the VLA, designed and tailored to address the highest priority scientific needs of the general community as outlined in Section 1.1. These key science themes also drive the planning of expanded VLA capabilities and improvements.

FY2015

In FY2015 we plan a number of improvements Atmospheric Phase Interferometer (API), 3-bit samplers, frequency averaging to enhance the science return on topics as varied as astro-chemistry, star formation, protoplanetary/protostellar disks, and the molecular phase of galaxy formation in the early Universe. The new focus on wide and deep continuum surveys will be enhanced with the offering of an on-the-fly mosaicing mode and the beginning of the two-year science operations of the VLA Low Band Ionospheric and Transient Experiment (VLITE) on behalf of the Naval Research Laboratory (NRL). VLITE is a commensal system, built and tested in FY14, that is capable of observing with the prime focus feeds at 330 MHz simultaneously but independently of the TAC-approved science pointings carried out with the Cassegrain feeds and WIDAR correlator. Deep, narrow continuum and neutral hydrogen (HI) surveys will continue to explore galaxy evolution while the community preparations for the VLA Sky Survey (VLASS) proposal are completed.

FY2016

For FY2016 we describe improvements designed to enhance the exploration of time-domain science. These include new pulsar observing modes, the ability to do fast data dumps, and autonomous observing in response to an external trigger. With the existing capabilities we expect the time-domain community to continue to use the VLA to prepare for LSST and the search for electromagnetic (EM) counterparts to gravitational waves from Advanced LIGO. The VLITE experiment, now in its second year, will have the capability to search for both slow and fast radio transients. Likewise FY2016 will see a significant improvement in the ability to study the temporal evolution of the Sun and the corona as we complete the building of solar-capable receivers. High frequency science (astro-chemistry, star formation, protoplanetary/protostellar disks, and molecular galaxy formation) will see new gains from the introduction of tipping scans and improved reference pointing. Improvements in continuum sensitivity will result through the completion of the C- and L-Band receiver retrofit of a new thermal gap design, and switched power will be used for improved calibration. Observing for the VLASS, if approved, will begin in FY2016, and is expected to have a major impact on science (and operations).

3.1.2. Operations

Science Operations

Observing Programs: The VLA will continue to offer three types of observing programs to users in FY2015 and FY2016: General Observing (GO), Shared Risk Observing (SRO) and Resident Shared Risk Observing (RSRO). Observing capabilities are first offered to the community through the RSRO program, which enables the community to express their scientific interest in potential capabilities

FY2016

Core NIO activities to continue managing and further expanding the partnerships to sustain the scientific operations and unique technical capabilities of the VLBA and GBT are expected to continue through FY2016.

9.1 New Initiatives Office Major Milestones

There are no milestones associated with NIO activities during FY2015 and FY2016 as the work for this department is preliminary opportunist and reactive, and based on the evolving strategy of the NRAO.

The Data Management and Software (DMS) department plans for FY2015-2016 plans are detailed in Section 7, including scientific information services, system software, and software development.

Section 8 provides the FY2015-2016 plans for the Program Management Department (PMD), which ensures best practices in the management of projects, performs project management and systems engineering, develops program and grant documentation, facilitates proposal development, and provides analytics for executive decisions.

The FY2015-2016 plans for the New Initiatives Office (NIO) that pursues, develops, and manages strategic partnerships and collaborations with academic, government, and non-profit organizations are provided in Section 9.

The EPO department plans for FY2015-2016 are given in Section 10, including Science, Technology, Engineering, and Mathematics (STEM) Education, and News and Public Information.

Section 11 describes the FY2015-2016 plans for the Computing and Information Services (CIS) team to provide Observatory-wide support, site specific facilities infrastructure, and maintenance and renewal. Section 12 provides the FY2015-2016 plan that to improve diversity and build a vibrant STEM pipeline with national and international partners. The NRAO Human Resources Department and Communications Office plans for FY2015-2016 are detailed in Section 13 and 14, respectively.

Section 15 details the FY2015-2016 Administration Department plans for NRAO business services, contracts and procurement, environmental safety and security, management information systems, and technology transfer. The Observatory's FY2015-2016 plans for spectrum management are described in Section 16. The Director's Office plans for FY2015-2016 are in Section 17.

Eight appendices provide additional support information. Appendix A is the high-level Financial Plan for FY2015 and FY2016. Appendix B summarizes the FY2015-2016 funding by NRAO department and object. Appendix C lists all CSA-1 expenditures for FY2015 and FY2016. Appendix D lists FY2015 Funding by Instrument, including development funding. Appendix E describes all FY2015 Common Cost Expenses by Location. Appendix F is a dictionary for the Observatory WBS. Appendix G summarizes the major NRAO FY2015-2016 milestones. Appendix H defines each acronym that appears in this POP.

Each section of the plan contains three budget tables, an FY2015 table by WBS code, a pie chart showing FY2015 expenditures by object, and an FY2016 table by WBS code. A summary of expenditures by department can be found in Appendix B. Note that the numerical WBS code corresponds to a more expansive definition of the element in the WBS dictionary.

11 COMPUTING & INFORMATION SERVICES

Computing and Information Services (CIS) support staff is matrixed into the DMS Department. This ensures transparent sharing of highly skilled Information Services resources to be available for both telescope supporting science responsibilities (tracked under DMS), as well as general staff IT support duties (CIS).

CIS is responsible for:

- Staff Helpdesk (tracking Service and Change Requests as well as Outages)
- Full Service Catalog (https://inside.nrao.edu/computing)
- Support for Desktop platforms (Windows, Mac, and Unix)
- Client services: e-mail, browser, 3rd party productivity/engineering applications
- Standard core services such as e-mail/printing/file sharing/backups
- Commodity data networks (Intranet, Internet, secure VPN)
- NRAO hosted Phone/voicemail systems
- Video-conference systems (room and desktop)
- Meeting room and NRAO science event support (registration/audio/visual)
- Mobile, satellite and smartphone services
- Licensing, maintenance, and support for commercial software
- Maintenance contracts for computer/communication hardware
- Web platform provisioning to support content and software development
- Collaboration solutions (wiki, Instant Messaging, WebEx)
- Document/content Management system (Sharepoint/Plone)
- Monitoring and alerting of key services and data center environmentals
- Coordinating add/move/change requests for staff and visitors
- Staff/Observer login and account management directory services
- Staff training (onboarding, documentation and annual security training)
- IT Audit compliance (in conjunction with MIS for key control systems)

CIS is focused on supporting Observatory operations by leveraging the structure of the Common Computing Environment (CCE) to ensure that all standard NRAO computers have a common system image and that the expertise available for supporting servers is also leveraged for desktops and laptops to ensure a consistent end-point security model and user experience. This consistency of oversight extends from hardware to software and on to supported applications and training.

This oversight includes planning, policy, standards (for software, hardware, and system administration), computer security, allocation of the CIS budget, computer staff training, inter-site computing-related travel, procurements, and ongoing maintenance contracts. CIS also manages the telecommunications infrastructure (voice, video, data and mobile communications) within the observatory. In addition, CIS covers the cost of upgrading computing infrastructure for desktop and servers as well as printers and the storage systems.

The following sections outline the activities and milestones coordinated by CIS, to ensure an optimum computing, storage, and communications environment for staff and users of NRAO telescopes as well as providing agile service support for an active research and development program.

1 OVERVIEW

This National Radio Astronomy Observatory (NRAO) Program Operating Plan (POP) describes the planned allocation of the Observatory's Fiscal Year (FY) 2015 and 2016 funding from the National Science Foundation Division of Astronomical Sciences (NSF-AST) in support of its mission to enable forefront research into the Universe at radio wavelengths.

1.1 Science Overview

In the coming year, the Atacama Large Millimeter Array (ALMA), and the Karl G. Jansky Very Large Array (VLA), will both be in routine operation with full scientific capabilities, thereby achieving an order of magnitude leap in observational power from 1 GHz to 1 THz over previous facilities. In parallel, the Robert C. Byrd Green Bank Telescope (GBT) and Very Long Baseline Array (VLBA) will continue their improvements in frequency coverage, sensitivity, wide-field imaging, and increased flexibility with the High Sensitivity Array (HSA). Operating synergistically with the next generation of optical, infrared, and X-ray telescopes, the NRAO facilities will enable discovery over a remarkably broad range of key problems in modern astrophysics, as identified in New World New Horizons (NWNH).

Using the Observatory facilities, the community will carry out precision cosmological measurements, test fundamental physics, and study astrophysics and chemistry from our Galaxy to the first galaxies in the Universe. These programs will probe deep into the earliest, most intense, and optically obscured phases of planet, star, galaxy, and black hole formation; reveal the cool dense gas from which stars form; and provide essential tools for studying magnetic fields and high energy cosmic phenomena. Line and continuum ultra-deep field surveys will become routine, exploring the evolution of galaxies at unprecedented distances and resolution.

Even with a limited number of antennas, ALMA has already demonstrated its revolutionary impact in submillimeter astronomy, with its dramatic images of planet, star, and galaxy formation. These results will accelerate as the full array becomes operational, and with the longer baselines it will achieve an angular resolution of tens of milliarcsec. Likewise, the broadband VLA has ushered in a new era in centimeter astronomy, with ground-braking results published in areas ranging from Galactic protostellar clouds to images of the molecular gas in the earliest galaxies. The VLBA represents the world's pre-eminent facility for microarcsecond astrometric studies, and sub-milliarcsecond imaging, at frequencies up to 90GHz. Similarly, the GBT continues to be the most versatile single-dish radio telescope in the world, pioneering measurements of extremely low surface-brightness phenomena from centimeter (cm) to millimeter (mm) wavelengths, and leading fundamental studies of pulsars and gravity.

These facilities are tools for the entire scientific community, as clearly demonstrated by the impressive demand for ALMA – the latest proposal deadline resulted in the most proposals ever for an astronomical facility! The VLA continues its dominance of centimeter astronomy, with a steady high demand from a broad community. Demand for the GBT is just as great. In 2015 the GBT will conduct routine operations with a seven element, 22 GHz receiver for sensitive, wide field imaging, as well as perform the first science observations with new multi-pixel systems in the 3mm band. The VLBA will also continue to improve its capabilities within the context of the HSA, which should provide fundamental science returns at the ultimate in precision astrometry and imaging. The record number of proposals received for NRAO instruments in semester 2014A was a testament to these improvements. The NRAO facilities in 2015 will pursue a community-driven, broad-ranging scientific program with the VLA and ALMA in full operation, and with the continually improving capabilities of the GBT and VLBA.

learning sessions will be hosted by the site PMD POC for anyone interested in the topic. Standard PM and SE topics will be covered over the course of the fiscal year, driven in part by identified gaps in knowledge, as well as specific topic requests from the site.

FY2016

PMD Headquarters

PMD HQ will continue to evolve the PMD processes to ensure the optimal performance for the Observatory. Education and training will be provided to all staff upon request.

PMD will organize and lead production of NSF deliverables, including an FY2017 POP and other documents as requested.

PMD New Mexico

FY2016 training will build on the knowledge base established in FY2015, with the goal of effecting implementation of project management and systems engineering practices in typical site activities such as internal development and maintenance projects. Informal learning sessions will continue to be hosted throughout FY2016.

DMS support will include an assessment of the differing methodologies, processes and practices used across the DMS groups, with recommendations for implementing the most effective practices across all software development groups. Regular status reporting tools will be harmonized to provide the DMS department management a recurring assessment of department progress and issues.

PMD CDL and ALMA

PMD will continue to play a large role in the research and development of Phased Array Feeds and Integrated Receiver Development by providing systems engineering and project management leadership, mentorship, and training and providing tools and templates. PMD will facilitate the decision gates for these initiatives and work with the principal investigators on the design of experiments for the future depending on the decision gate outcomes.

The CDL is involved it the following ALMA Development projects with PMD support in 2016; Prototype Band 2 Cartridge with project completion scheduled Q2 FY2016; and Expansion of the ALMA Central LO Article to 5 Sub-arrays with project completion scheduled Q1 FY2016.

Continue training as needed or requested to build on the buy-in and knowledge base established in FY2015. Informal learning sessions will continue to be hosted throughout FY2016.

The next Call for ALMA Development Project Proposals will be in April 2016 for projects to begin in FY2017. This will allow enough time for the currently in progress ALMA Development projects to complete. NRAO proposals will be vetted through the PMD process prior to submittal to the ALMA Development selection process.

17.1 Director's Office Major Milestones

Table 17.1.1: Director's Office FY2015 Major Milestones

		FY2015			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
ALMA	ALMA Board	1	1	1	1
	ALMA Director's Council	2	2	2	2
	ALMA Completion Review		3		
Corporate Meetings	AUI Board of Trustee meeting	4	4	4	
	AUI Executive Committee meeting	5		5	5
Science Community	Appoint new Users Committee members	6			
	Users Committee Meeting			7	
Management Review	NSF Annual Program Review	8			
	All Hands meeting	9		9	
Report	New Strategic Plan			10	

Milestones:	Deliverables:
1. ALMA Board Meeting	1. Presentations & Report
2. ALMA Director's Council	2. Presentations & Report (monthly)
3. ALMA Completion Review	3. Presentations & Report
4. AUI Board of Trustees meetings	4. Presentations & Report
5. AUI Executive Committee meetings	5. Presentations & Report
6. Appoint new Users Committee members	6. UC Meeting and Presentations
7. Users Committee meeting	7. Select new committee members
8. NSF Annual Program Review	8. Presentations & Reports
9. All Hands presentation	9. Presentation
10. Develop new Strategic Plan	10. Report

Table 17.1.2: Director's Office FY2016 Major Milestones

		FY2016			
Program	**Project**	**Q1**	**Q2**	**Q3**	**Q4**
ALMA	ALMA Board	1	1	1	1
	ALMA Director's Council	2	2	2	2
Corporate Meetings	AUI Board of Trustee meeting	3	3	3	
	AUI Executive Committee meeting	4		4	4
	AUI Visiting Committee meeting			5	
Science Community	Appoint new Users Committee members	6			
	Users Committee Meeting			7	
Management Review	NSF Annual Program Review	8			
	All Hands meetings	9		9	

Milestones:	Deliverables:
1. ALMA Board Meeting	1. Presentations & Report
2. ALMA Director's Council	2. Presentations & Report (monthly)
3. AUI Board of Trustees meetings	3. Presentations & Report
4. AUI Executive Committee meetings	4. Presentations & Report
5. AUI Visiting Committee Meeting	5. VC Meeting and Presentation
6. Appoint new Users Committee members	6. UC Meeting and Presentations
7. Users Committee Meeting	7. Select new committee members
8. NSF Annual Program Review	8. Presentations & Reports
9. All Hands presentations	9. Presentations

experts will be assigned to the EOC long baseline campaign in Q1 FY2015; further campaigns are not yet defined by EOC but we anticipate a similar level of support in FY2016). The NAASC Telescope Support Group Lead coordinates with the EOC Lead to identify additional areas of need where NRAO experience can be leveraged. This support is balanced against the workload needed to support the NA community (see following sub-section).

In addition to these EOC support missions, the NAASC provides 14 Astronomer on Duty (AoD) shifts or "turnos" each year. These are fulfilled via seven ~three week deployments of NAASC and National Research Council (NRC) scientists to the ALMA Operations Support Facility, where they help plan weekly observing sessions, select projects for observing, and update observing logs and session summaries. During these trips they also interact closely with their counterparts at the JAO and visiting AoDs from the other ARCs.

Additional support of JAO operations is by participation in bi-annual software acceptance tests of all ALMA operations software subsystems, and by providing subsystem scientists and regional Cognizant Leads for each software subsystem and each international ALMA working group. Subsystem scientists provide expert scientific advice to the software developers on new requirements and desired capabilities, help plan and organize software tests and write test reports, and report to the rest of the project on software issues. Cognizant Leads provide regional input to the subsystem scientist and arrange local participation in tests and input on operations procedures and policies. The NAASC provides three subsystem scientists (CASA, ALMA Science Portal, and helpdesk) and ten Cognizant Leads. Some of these experts participate in the bi-annual "Obsmode" meetings comprised of experts from EOC and across ALMA operations, and charged with defining which capabilities are offered each observing cycle, and providing scientific input to the software developers for developing those capabilities.

Finally, the NAASC supports the JAO in the international review process by providing technical assessors to help review all proposals, and technical secretaries to support the panel meetings. The NA ARC Manager arranges for NA participation in ALMA core documentation review, software testing, and panel review support. He is a member of the Science Operations Integrated Product Team (IPT) to define and track ALMA operations procedures, policies and software priorities, and to produce ALMA status updates and observing session summaries for the Board and ALMA users. Frequent trips to JAO and the other ARCs are required.

NA ALMA User Support

The NAASC leads those aspects of NA ALMA user support that are exclusive to ALMA, whereas those tasks that benefit from a pan-NRAO approach are led by the Observatory-wide SUS group. NAASC staff support both efforts. User support responsibilities centered at the NAASC include preparation and review of materials for each observing cycle, helpdesk support, generation and review of scheduling blocks, data reduction, visitor support for data reduction, and contact scientist (CS) responsibilities.

NAASC staff will be involved in many aspects of user outreach and training, observation preparation support, and data reduction for ALMA observing cycles. The NAASC provides a CS for each Principle Investigator (PI) project. The duties of CSs include assisting PI projects with the review of their scheduling blocks (SBs), assisting with data reduction and analysis for visiting PI teams, and supporting remote requests for pipeline re-processing.

A primary NAASC support activity is manual data reduction, including imaging, data packaging and delivery to PIs. Additionally, SUS will organize and NAASC staff will support one to two day data

5. Increase bandwidth to sites	5. VLBA site bandwidth enhancement (e.g. North Liberty)
6. Increase bandwidth to sites	6. VLBA site bandwidth enhancement (e.g. Kitt Peak)
7. Increase bandwidth to sites	7. Enhance service in CV and NM
8. XSEDE access	8. Successful allocation request to XSEDE
9. Federated identity management evaluation	9. Evaluate federated trust between user directory services
10. PSC access	10. Leverage Slash2 and Blacklight resources
11. Amazon cloud for CASA	11. Price/performance analysis of commercial cloud options
12. Multi-core development testbed installed	12. Provide access to Cuda and Intel MIC architecture
13. Unified approach to Lustre backup	13. Test installation of a Lustre backup solution
14. ALMA Fall 2014 Release	14. ALMA System Software released
15. ALMA Spring 2015 Release	15. ALMA System Software released
16. ALMA Phasing Project	16. APP complete, all software delivered
17. Deploy software to support Semester 2014B observing.	17. Semester 2014B observing software
18. Deploy software to support Semester 2015A commissioning.	18. Semester 2015A commissioning software
19. Deploy software to support Semester 2015A observing.	19. Semester 2015A observing software
20. Deploy software to support Semester 2015B commissioning.	20. Semester 2015B commissioning software
21. Integrate VLITE Operations	21. Software and documentation
22. Deliver Frequency Averaging	22. Software updated for frequency averaging
23. Write Pointing Table	23. Software updated
24. VME replacement	24. Software support, initial design
25. Modify Astrid to Use Streaming	25. Software and documentation for Astrid modifications and commissioning.
26. Operations software update	26. Project start
27. Vegas Pulsar Modes	27. Project start
28. NRQZ software	28. Project start
29. M&C release	29. Software update
30. CLEO Update	30. Device Explorer software update
31. Parallelize Pipeline	31. Software modifications to pipeline.
32. Pipeline improvements	32. Software and documentation
33. Test Pipeline with PSC – evaluate candidates	33. List of candidate use cases
34. Operationalize the new NRAO Archive and RPI	34. New Archive Tool and RPI in production
35. Implement CASA calibration pipeline in production for the VLA	35. CASA software and pipeline heuristic implementation
36. Release CASA version 4.3	36. CASA Package 4.3
37. Release CASA version 4.4	37. CASA Package 4.4
38. Implement PST updates for Semester 2015B Call for Proposals	38. PST software updates for Semester 2015B Call for Proposals
39. Implement PST updates for Semester 2016A Call for Proposals	39. PST software updates for Semester 2016A Call for Proposals
40. Implement PHT updates for Semester 2015B TAC Meeting	40. PHT software updates for Semester 2015B TAC Meeting
41. Implement PHT updates for Semester 2016A TAC Meeting	41. PHT software updates for Semester 2016A TAC Meeting
42. Implement OPT updates for Semester 2015A VLA Observing	42. OPT software updates for Semester 2015A VLA Observing
43. Implement OPT updates for Semester 2015B VLA Observing	43. OPT software updates for Semester 2015B VLA Observing
44. Create Architecture for Observatory Tools	44. Observatory Tools Architecture delivered
45. Expand CASA Test Scope	45. Additional platforms and branches automatically tested.
46. Hand over ALMA Testing to Chile	46. Testing software and documentation handed over to Chile IRM

apartments, townhouses and 3-4 bedroom homes, is available for use both by Green Bank staff and all site visitors, including primary school students, college students, summer visitors, etc. The site cafeteria is open only to local staff (for lunch) and official site visitors. The NRAO Science Center, part of NRAO's Center for Education which is described in Section 10, is also housed on site and contains both the exhibit hall, auditorium, classrooms, and gift shop and also the Starlight Café which is open to the general public.

Due to budget shortfalls, a number of high priority tasks will not be implemented in FY2015 (or FY2016). These include:

- replacing aging test equipment for the GBT;
- purchasing a permanent, fixed, automatic (auto-start) generator for the Science Center to both provide backup-up to the NRAO's Management Information Services (MIS) disaster recovery systems and to provide safety in case of emergency when school age and other visitors and staff are on site;
- remodeling of the GBT warehouse - built for the GBT's construction and lacks any RFI shielding for the telescope. Currently it is the largest source of site-based interference for the GBT.

Site Infrastructure: The Green Bank (GB) site buildings and grounds will continue to undergo routine annual inspection and maintenance in FY2015. This includes annual road repair and winter plowing; roof repairs; heating and cooling systems maintenance; pest and weed control; servicing of sewer systems, water supply, backup generator power, HVAC systems, electrical lines and related systems.

Road repair, maintenance, and plowing (as needed): The GB site owns and maintains all roads within its boundary, and is therefore responsible to repair all damage and keep the roads clear for proper use and, most importantly, for the passage of emergency vehicles when necessary. To that end, the maintenance group is responsible to repair all road damage caused by accident or extreme weather, and plow the roads of snow in the winter. Proper maintenance of the roads has kept them in outstanding shape over the course of the last 50 years with minimal outlay of funds for replacement. These activities are required to ensure the GB site and the GBT remain in a current state of repair. In FY2015 we will be repairing and replacing parts of the culvert in the interferometry area on site, which is in the processes of washing out.

Vehicle Support: The GB site continues to operate more than 65 vehicles and heavy equipment items, such as loaders, dozers, backhoes, trenchers, tractors, mowers, fleet vehicles, and buses. All of these are used daily and will continue to be routinely serviced and repaired to remain in safe, efficient working condition through FY2015 and onward.

Fixed Rate with Carry Forward Provision

The fixed rate is a permanent rate established for a future prospective period of time. The rate is based on an accurate estimate of costs for the fiscal year as to avoid unduly large carry-forward adjustments. Actual costs are determined by NRAO's accounting system. The difference between the estimated costs used to establish the fixed rate and the actual costs of the period covered by the rate is "carried forward" as an adjustment to the rate computation of the second fiscal year subsequent to the fiscal year covered by the plan (e.g., an over-recovery in FY2014 would impact the FY2016 rate).

AUI IDC and Management Fee: The AUI IDC rate is a federal rate compliant with A-122. This recovery pays AUI corporate costs, including Fiscal Operations, associated with the management of the NRAO. For FY2015 and FY2016 the AUI IDC rate is 5.9% of MTDC.

The NRAO budget includes the management fee. An estimate for that as yet to be determined amount is included in WBS level 5811.

Funding Sources

NSF Allocations: Annual President's Request Level (PRL) budgets provided by NSF.

Carry-Over: Funds which have been allocated by NSF in prior years but have not been spent.
The ALMA carryover amounts include a $1.8M fuel reserve as well as development funds which have not been awarded.

Canadian ALMA Contribution: Canadian contribution to ALMA operations and development.

Sale of Telescope Time: NRAO has multiple contracts to provide guaranteed telescope time to certain domestic and international partners. Revenue from telescope time is generally accounted for as program income. The USNO contract of approximately $1M/year for VLBA services is an exception and a portion of VLBA operations is charged to that external contract. The Observatory annually determines a menu of rates for use of the GBT and VLBA (at this time, telescope time on the VLA and ALMA is only available through the TAC process.) These rates vary from cost-reimbursement level rates offered to domestic Institutions of Higher Education (IHE) and other federal entities to amounts that include a capital cost and premium component for commercial and international entities.

External Common Cost Recovery: NRAO applies its ICC rate to external grants and WFO contracts.

ALMA Development Awards: CSA-2 contains funding for an ALMA development program. NRAO's staff and programs must compete for these funds. When awarded, for CSA accounting purposes, these are considered to be "external" awards and are tracked outside of the ALMA budget. Plainly put, these awards are shown in the budget twice - once as an expenditure made in CSA-2 (the award) and once as a development expense in the development fund source.

WFO Proceeds: NRAO participates in WFO projects. When doing work for non-educational or non-federal organizations, NRAO must charge a 'market rate.' The difference between cost reimbursement and the market rate is used to fund additional mission-related activities. Usually these are technology development programs which could not be pursued within the budgetary confines of the CSA. In FY2015 and FY2016, NRAO expects to generate and spend $970K and $1.3M respectively from these sources.

Table C.2: FY2016 ALL CSA-1 Expenditures (Part 1 of 2)

	NRAO Ops, CSA-1											
	GBT		VLA		VLBA		Other		NON-TELESCOPE		GRAND TOTAL	
Work Breakdown Structure	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's	TOTAL	FTE's
⊟1000 Telescope Operations												
⊟1100 Maintenance												
⊟1110 Corrective												
1111 Unscheduled			1,760,827	20.0	1,309,554	14.6					3,070,380	34.5
1112 Scheduled	60,741	0.6	1,008,508	11.1	584,251	6.6	1,000	0.0			1,654,500	18.3
1114 Software					200	0.0					200	0.0
⊟1120 Preventive												
1121 Scheduled	246,879	3.2	1,386,412	18.5	60,873	0.3	8,476	0.1			1,702,640	22.0
1122 Painting	203,171	3.0					1,000	0.0			204,171	3.0
1123 Inspections	175,000	0.0									175,000	0.0
1125 Telescope Structure	63,968	0.8									63,968	0.8
⊟1200 Operations												
⊞1210 Scheduling	39,195	0.3	55,979	0.4	67,729	0.6			3,997	0.0	166,901	1.4
⊟1220 Operating												
1221 Observing	346,564	5.7	345,121	6.0	824,131	10.3	500	0.0			1,516,316	22.0
1222 Recording & Media Distribution			13,368	0.2	93,755	0.8					107,123	1.0
⊟1230 Support & Testing												
1231 Calibration	134,171	1.4	2,175	0.0	61,460	1.0					197,806	2.4
1232 Antenna Moves/Repositioning			72,195	1.1							72,195	1.1
1235 Systems Hardware Support	2,055,332	20.1									2,055,332	20.1
1236 Scientific Support	175,639	2.6	1,035,991	7.1	84,967	0.6					1,296,598	10.3
⊞1240 M&C Software	308,162	2.9	26,752	0.3	43,610	0.4					378,523	3.5
⊟1300 Spectrum Management												
⊞1310 Interference Suppression			1,400	0.0	600	0.0			89,886	0.9	91,886	0.9
⊞1320 NRQZ Management									156,232	1.9	156,232	1.9
⊞1330 Anechoic Chambers									21,870	0.2	21,870	0.2
⊟1400 Infrastructure Mods & Upgrades												
⊞1410 Small Scale R&D					202,829	1.5					202,829	1.5
⊞1420 Modifications	448,875	3.1	659,656	5.6	54,104	0.5					1,162,635	9.2
⊟1500 Management												
⊞1510 Telescope operations Mgmt	251,541	2.0	79,002	0.8	124,046	0.8			84,004	0.5	538,593	4.1
⊞1520 Science Support Mgmt	189,812	1.0	166,636	1.0	106,425	0.6					462,873	2.6
⊞1530 Mechanical Engineering Mgmt	86,732	0.5	608,277	4.2	31,273	0.2					726,281	4.9
⊞1540 Electronics Mgmt	256,417	2.0	307,003	2.0	175,074	1.4					738,495	5.4
⊞1550 Software Mgmt	97,078	0.8	1,103,621	8.9	103,291	0.9					1,303,990	10.5
1000 Telescope Operations Total	5,139,278	49.9	8,632,922	87.1	3,928,172	41.0	10,976	0.1	355,989	3.5	18,067,337	181.5
⊟2000 Development Programs												
⊟2200 Technology Development												
⊟2210 Enabling Technologies												
2211 Low Noise Amplifiers									293,110	3.0	293,110	3.0
2214 Receivers									362,235	2.6	362,235	2.6
2217 Phased Array Feeds									113,314	1.5	113,314	1.5
⊟2220 Production												
2221 Low Noise Amplifiers									379,658	3.7	379,658	3.7
2222 MM/SubMM Detectors									246,084	1.2	246,084	1.2
2223 Optics & EM Components									250,697	1.8	250,697	1.8
⊟2230 Next Generation Facilities												
2231 PAPER/HERA									194,572	1.4	194,572	1.4
⊟2300 R&D Support												
⊞2310 Machining									314,175	3.7	314,175	3.7
⊞2320 Chemistry Lab									112,244	0.8	112,244	0.8
⊞2400 Software Development									299,784	2.3	299,784	2.3
⊞2500 Management									187,800	0.0	187,800	0.0
2000 Development Programs Total									2,753,673	21.9	2,753,673	21.9

*All CSA-2 Expenditures are shown in Tables 2.7.1-2.7.3.

APPENDIX D: FUNDING BY INSTRUMENT

Table D.1: FY2015 Funding by Instrument (Part 1 of 2)
(Includes Development Funding)

	ALMA		GBT		VLA		VLBA		Other		NON-TELESCOPE		GRAND TOTAL	
	Total	FTE's	Total	FTE's	Total	FTE's	Total	FTE's	Total	FTE's	Total	FTE's	Total	FTE's
⊟1100 Maintenance														
⊟1110 Corrective														
1111 Unscheduled					1,762,113	20.0	1,311,483	14.6					3,073,597	34.6
1112 Scheduled			60,741	0.6	1,010,438	11.1	585,538	6.6	1,000	0.0			1,657,717	18.3
1113 Hardware (Config)	2,342,396	14.1											2,342,396	14.1
1114 Software							200	0.0					200	0.0
⊟1120 Preventive														
1121 Scheduled			246,879	3.2	1,386,412	18.5	60,873	0.3	8,476	0.1			1,702,641	22.0
1122 Painting			203,171	3.0					1,000	0.0			204,171	3.0
1123 Inspections			175,000	0.0									175,000	0.0
1125 Telescope Structure			63,968	0.8									63,968	0.8
⊟1200 Operations														
⊟1210 Scheduling														
1211 Telescope Status & Scheduling			39,195	0.3	55,979	0.4	67,729	0.6			3,997	0.0	166,901	1.4
⊟1220 Operating														
1221 Observing			346,564	5.7	345,121	6.0	821,976	10.2	500	0.0			1,514,161	21.9
1222 Recording & Media Distribution					13,368	0.2	93,755	0.8					107,123	1.0
⊟1230 Support & Testing														
1231 Calibration			134,171	1.4	2,175	0.0	61,460	1.0					197,806	2.4
1232 Antenna Moves/Repositioning					72,195	1.1							72,195	1.1
1235 Systems Hardware Support			1,850,646	18.4									1,850,646	18.4
1236 Scientific Support	822,180	3.5	160,848	2.4	1,035,991	7.1	84,967	0.6					2,103,986	13.6
⊞1240 M&C Software	1,160,648	10.5	312,695	3.0	26,752	0.3	43,610	0.4					1,543,705	14.1
⊟1300 Spectrum Management														
⊞1310 Interference Suppression					1,400	0.0	600	0.0			89,886	0.9	91,886	0.9
⊞1320 NRQZ Management											156,232	1.9	156,232	1.9
⊞1330 Anechoic Chambers											21,870	0.2	21,870	0.2
⊞1340 International Spectrum Management											68,419	0.3	68,419	0.3
⊟1400 Infrastructure Mods & Upgrades														
⊞1410 Small Scale R&D							202,829	1.5					202,829	1.5
⊞1420 Modifications	2,400,000	0.0	650,824	4.8	659,656	5.6	54,104	0.5			0	0.0	3,764,584	10.8
⊟1500 Management														
⊞1510 Telescope operations Mgmt	16,792,018	0.0	251,541	2.0	79,002	0.8	123,756	0.8			84,004	0.5	17,330,320	4.1
⊞1520 Science Support Mgmt			189,812	1.0	166,636	1.0	106,425	0.6					462,873	2.6
⊞1530 Mechanical Engineering Mgmt			75,149	0.5	608,277	4.2	31,273	0.2					714,699	4.9
⊞1540 Electronics Mgmt			175,269	1.5	307,003	2.0	175,074	1.4					657,347	4.8
⊞1550 Software Mgmt	89,795	0.5	97,078	0.8	1,103,621	8.9	103,291	0.9					1,393,785	11.0
1000 Telescope Operations Total	23,607,037	28.6	5,033,553	49.0	8,636,138	87.2	3,928,944	40.9	10,976	0.1	424,408	3.9	41,641,057	209.6
⊟2000 Development Programs														
⊟2100 Business Development														
⊞2110 Partnerships											392,775	1.8	392,775	1.8
⊞2120 Commercialization											156,000	1.0	156,000	1.0
⊟2200 Technology Development														
⊟2210 Enabling Technologies														
2211 Low Noise Amplifiers											293,110	3.0	293,110	3.0
2214 Receivers	1,250,000		204,000	1.3							362,235	2.6	1,816,235	3.9
2215 Digital Signal Processing	629,000												629,000	
2217 Phased Array Feeds											598,314	5.3	598,314	5.3
2218 Unallocated Projects	5,359,202	0.0											5,359,202	0.0
⊟2220 Production														
2221 Low Noise Amplifiers											379,658	3.7	379,658	3.7
2222 MM/SubMM Detectors											246,084	1.2	246,084	1.2
2223 Optics & EM Components											250,697	1.8	250,697	1.8
2224 Receivers	1,056,063												1,056,063	
⊟2230 Next Generation Facilities														
2231 PAPER/HERA											194,572	1.4	194,572	1.4
⊟2300 R&D Support														
⊞2310 Machining											314,175	3.7	314,175	3.7
⊞2320 Chemistry Lab											112,244	0.8	112,244	0.8
⊞2400 Software Development											299,784	2.3	299,784	2.3
⊞2500 Management	266,799	1.0	32,882	0.3							418,169	1.0	717,850	2.3
2000 Development Programs Total	8,561,064	1.0	236,882	1.5							4,017,817	29.4	12,815,763	32.0

APPENDIX F: WBS DICTIONARY

Observatory Work Breakdown Structure (WBS) Dictionary

WBS Number					Observatory Telescope Operations
1	Observatory Telescope Operations				
1.1		Maintenance			Work done to maintain and repair the telescopes.
1.1.1			Corrective		Maintenance done in response to an identified problem with the telescope operation.
1.1.1.1				Unscheduled	Forced Emergency repairs done to return the telescope to operation. Cost of bringing repair/technical crew to the telescope for repair purposes outside of scheduled working hours.
1.1.1.2				Scheduled	Scheduled telescope down time for corrective maintenance repairs
1.1.1.3				Hardware (Config)	Corrective Action on Physical Components of the Telescope like Servo Systems, Receivers, Backends, Frontends, Computing Hardware and etc. Work done to correct system hardware for latent defects, modify the system to incorporate new requirements, enhance the existing system to add capability, and alter the hardware to increase performance.
1.1.1.4				Software	Correction Action on Software Programming of the Telescope Systems. Work done to correct system software for latent defects, modify the system to incorporate new requirements, enhance the existing system to add capability, and alter it to increase performance.
1.1.2			Preventive		Routine Scheduled Maintenance
1.1.2.1				Scheduled	Routine Maintenance in accordance with Component or Manufacturers Recommendations Oil Changes, Chiller Work, Elevator Maintenance, Greasing, Actuators and etc.
1.1.2.2				Painting	Cleaning, preparing and recoating structural elements
1.1.2.3				Inspections	Inspecting structural elements
1.1.2.5				Telescope Structure	Structural Repairs
1.2		Operations			Work done scheduling, operating and support and testing of the telescopes
1.2.1			Scheduling		Work done scheduling telescope observations
1.2.1.1				Telescope Status & Scheduling	Work done to plan and schedule telescope observing time
1.2.2			Operating		Work done operating the telescope
1.2.2.1				Observing	Work done operating the telescope while observing.
1.2.2.2				Recording & Media Distribution	Science data storage equipment
1.2.3			Support & Testing		Work done supporting and testing the telescope.
1.2.3.1				Calibration	Work done to calibrate the telescope with known standards.
1.2.3.2				Antenna Moves/Repositioning	Work done relocating antennas to different array pads.
1.2.3.3				Data Transmission	Work done transferring data (a digital bit stream) over a point-to-point or point-to-multipoint communication channel; such channels are optical fibers, wireless communication channels, and storage media.
1.2.3.6				Scientific Support	Science staff present during observing and receiver changes.
1.2.4			Monitor & Control Software		
1.2.4.1				M&C Software	Maintenance & development of the M&C software systems & capabilities
1.3		Spectrum Management			Management of the Radio Frequency Spectrum for the benefit of Telescope Operations and Data Collection.
1.3			Spectrum Management		see above
1.3.1.1				Interference Suppression	Activities to monitor and decrease interference within the immediate area of the NRAO telescopes.
1.3.2.1				NRQZ Management	Work done to manage the National Radio Quiet Zone (NRQZ)
1.3.3.1				Anechoic Chambers	Operation and maintenance of the anechoic chamber.
1.3.4.1				International Spectrum Management	Work done to address spectrum management issues internationally
1.4		Infrastructure Modifications & Upgrades			Work associated with the modification, **retrofit** and upgrade of the telescope.
1.4.1			Small Scale R&D		Small R&D projects, <$25K
1.4.1.1				Projects	BU's added as projects are defined
1.4.2			Modifications		Modifications, retrofits and upgrades of the telescope amounting to greater than or equal to $25k
1.4.2.1				Projects	BU's added as projects are defined
1.4.3			Small Scale Modifications		Modifications, retrofits and upgrades of the telescope amounting to less than $25k
1.4.3.1				Projects	BU's added as projects are defined
1.5		Management			Supervisory & Management Costs for OTO
1.5			Management		Expenses such as Travel and Conferences for OTO Management and Supervisors, Software, Manuals, Books and other incidentals.
1.5.1.1				Telescope Operations Mgmt	Telescope operations Management
1.5.2.1				Science Support Mgmt	Science Support Management
1.5.3.1				Mechanical Engineering Mgmt	Mechanical Engineering Management
1.5.4.1				Electronics Mgmt	Electronics Management

Observatory Work Breakdown Structure (WBS) Dictionary

WBS Number					Observatory Science Operations
3	Observatory Science Operations				
3.1		Observatory Time Allocation			Tools and support for the allocation of telescope time.
3.1.1.1			Tools & Documentation		Software engineering support of the PST/PHT/Ph1M, and ancillary tools], Scientific oversight and testing for the PST/PHT/Ph1M, and ancillary tools; PETA Documentation.
		Reference			
3.1.2.1			Proposal Review & Time Allocation		Process by which telescope proposals are vetted, scored, and telescope time is allocated. Panelist support and External TAC member support, Internal support for review, e.g. Technical Assessment, Technical Secretary.
3.2		Reference			Production and maintenance of and facilitating access to NRAO and related scientific materials.
3.2.1.1			Library		Maintenance of and access to technical literature and information resources, including collection development, electronic subscriptions, NRAOPapers , cataloging, page charge support.
3.2.2.1			Historical Archives		Processing and development of historical archives
3.2.3.1			Metrics/Statistics		Compilation/analysis of observing hours/statistics
3.3		Broader Impacts			Programs that provide outreach and assistance to the user community.
3.3.1			Student Programs		Programs that provide outreach and assistance to students.
3.3.1.1				Undergraduate	Includes REU, Co-ops , NRAO summer students, and NRAO interns.
3.3.1.2				Graduate	Includes Reber Fellows, NRAO summer students, and NRAO interns.
3.3.1.3				Student Observing Support	Provides travel and other support to students using the NRAO telescopes.
3.3.1.4				High School	Includes High School educational programs
3.3.2.1			Visitor Support		Includes Sabbatical visitors, Data reduction visits, and Colloquia.
3.4		Scientific Staff			Research and Related activities by the NRAO scientific Staff
3.4.1			Staff Research		Research and Related activities by the NRAO scientific Staff
3.4.1.1				NRAO Staff	Research and related activities, student & postdoc supervision and mentoring.
3.4.1.2				Jansky Fellows	Research and related activities - Jansky Fellows participants
3.4.1.3				NRAO Postdocs	Research and related activities - NRAO Postdocs
3.5		Management			Supervisory & Management Costs for OSO
3.5.1			Management		Includes AD, Deputy AD, Manager - management, coordinating, reporting and planning; including broader impacts management and coordination. Expenses such as travel and conferences for OSO management and supervisors.
3.5.1.1				Management	OSO Management
3.6		Scientific User Services			
3.6.1			Community Support		Education and support for telescope users.
3.6.1.1				User Assistance	Includes Helpdesk, F2F visit support, contact scientist, and data delivery.
3.6.1.2				Education & Training	Includes CDEs, tutorials, schools, training workshops; user documentation & web material (e.g. casaguides), and online training material.
3.6.1.3				Workshops & Conf.	Science workshops and conferences
3.6.2			Science Data Processing		
3.6.2.1				Data Processing Ops	Pipeline operations/staff data reduction and QA2 of user produced products; Special/Large/Key Projects. Data capture and preprocessing/scrubbing/compression prior to delivery to a user.
3.6.2.2				Data Analysis Tools	Enhanced Science Software Tools (e.g. analysis_utils.py, visualization applets, pipeline scripts)
3.6.3			Science Software		Includes maintenance, testing, validation, implementation and upgrade of scientific software
3.6.3.1				Post-Processing Software	Software engineering and implementation for data reduction software, including pipelines (e.g. [CASA], [AIPS], [GBTIDL]).
3.6.3.2				Obsprep Software	Software engineering and implementation for observing & proposal preparation software (e.g. [OPT], [OT]).
3.6.3.3				Archive Software	Software engineering and implementation for science data archive infrastructure and access, including VAO methods (e.g. [AAT], [ASA]).
3.6.3.4				Misc. Software	Software engineering support for applications/tools for science and operations users (e.g. Helpdesk, user portal, PLONE, Splatalogue, user DB/registry).
3.6.3.5				Software Evaluation	Scientific oversight, validation, requirements tracking, subsystem scientist work for science software (e.g. data reduction, pipeline, ObsPrep, applications, archive queries, VAO protocols).

Observatory Work Breakdown Structure (WBS) Dictionary

WBS Number	Observatory Admin Services
4	**Observatory Facilities & Administration**
4.1	Business Services — Business functions of the Observatory including budgeting, fiscal, computing, HR, management information systems, safety and purchasing.
4.1.1	Business Office — Activities related directly to the support of the Site and Science activities, including tasks such as Budgeting, Administrative and Management functions, and regulatory issues.
4.1.1.1	Business Office — Performing administrative, professional and managerial support of site operations and auxiliaries; includes budgeting of all site activity, oversight of the staffing, physical, fiscal, and communications infrastructures and liaison with external groups.
4.1.1.2	Visitor Support — Activities that support the safety, comfort, and logistical needs of visitors.
4.1.2	CIS — Maintenance and upgrades of the Observatory servers, computers, commercial software, websites, data storage, network connections and cyber security.
4.1.2.1	CIS — (duplicate of above)
4.1.3	CAP — Manage the flow and negotiation of proposals and contracts for new and existing projects and vendors and maintain requisitions/PO's for supplies and services.
4.1.3.1	CAP — (duplicate of above)
4.1.4	MIS — Manage the AUI/NRAO Enterprise Resource Planning (ERP) software/hardware systems needed to collect and organize the information on the performance and operation of corporate AUI and various funding sources.
4.1.4.1	MIS — (duplicate of above)
4.1.5	ESS — Manage the physical safety and security of the employees and facilities of the Observatory, as well as environmental issues.
4.1.5.1	ESS — (duplicate of above)
4.1.6	HR — Manage the training and development of new and existing employees, conduct employee orientation, maintain employee files/records, manage benefits programs, analyze compensation, direct recruitment, and mediate employee issues.
4.1.6.1	HR — (duplicate of above)
4.1.7	Fiscal — Manage cash balances, payment of vendors, payroll processing, recording and tracking assets and inventory, financial statement preparation, and financial reporting.
4.1.7.1	Fiscal — (duplicate of above)
4.2	Facilities — Operations and maintenance of services required to assure the facility performs the functions for which it was designed and constructed, including both long-term and day-to-day activities.
4.2.1	Plant Maintenance — Upkeep and preservation of facility assets to consistently and reliably perform services and operational capacity
4.2.1.1	Plant Maintenance — see above
4.2.2	Communication — Ongoing costs related to services for information or data transmission, television services, and telephone communications.
4.2.2.1	Communication — see above
4.2.3	Utilities — Large scale services or commodities provided by a third party, such as electric power utilities, fuel oil services, and diesel fuel, necessary for normal operations.
4.2.3.1	Utilities — see above
4.2.4	Leases — Agreements related to use or occupancy of a property.
4.2.4.1	Leases — see above
4.2.5	Infrastructure — Permanent installations and upgrades necessary for operations and function of a facility, such as water, wastewater, electrical distribution, roads, parking areas, and grounds.
4.2.5.1	Infrastructure — see above
4.2.6	Vehicles — Automobiles, heavy and light equipment, and generators owned and/or maintained for official business use
4.2.6.1	Vehicles — see above
4.2.7	Central Instrument Shop — A facility to provide machining, welding and fabrication of components for mission related activities including but not limited to Radio Telescopes and Radio Astronomy Instruments.
4.2.7.1	Central Instrument Shop — see above
4.3	Auxiliaries — Self-supporting entities that furnish "non-core" goods and services to visitors and staff by charging fees directly related to these services.
4.3.1	Visitor Center — Facility to provide information, education, and house exhibits related to each location
4.3.1.1	Visitor Center — see above
4.3.2	Housing — Facilities to provide short- and long-term lodging for employees and visitors.
4.3.2.1	Dorms — Short-term group housing in larger bunkhouse or hostel style.
4.3.2.2	Residence Hall — Single room "hotel and apartment style" housing for short term visitors.
4.3.2.3	Houses — Long term housing rentals for NRAO employees and visitors, and short-term rentals for Residence Hall overages/conferences.
4.3.3	Food Handling — Purchasing, preparing, transporting, and serving foods directly to consumers, with all required appurtenances.
4.3.3.1	Cafeteria — Dining facility with pre-prepared and al a carte menu in which customers are normally served at a counter and carry their meals on trays to tables in a large dining room.
4.3.3.2	Café — Dining facility with small service area, limited menu, and operating hours.
4.3.4	Gift Shops — Retail store that sells miscellaneous merchandise and small items appropriate for giving as gifts.
4.3.4.1	Gift Shops — see above
4.3.5	Management — Supervisory & Management Costs for Auxiliary activities
4.3.5.1	Management — Expenses such as Travel and Conferences for OAS Management and Supervisors, Software, Manuals, Books and other incidentals.
4.3.6	Promotional Fees — Fees and Royalties charged to outside entities for access to NRAO facilities
4.3.6.1	Promotional Fees — see above

APPENDIX G: MAJOR MILESTONES SUMMARY

FY2015 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
2.6		**Atacama Large Millimeter/submillimeter Array (ALMA)**	
		Operations	
	1	Carry out AoD shifts at the OSF	12/31/2014
			03/31/2015
			06/30/2015
			09/30/2015
	2	Hire two data analysts and two scientists	12/31/2014
	3	Cycle 2 Status Update	12/31/2014
	4	Support Long Baseline Campaign	12/31/2014
	5	Eliminate Backlog in Cycle 2 Data Reduction	12/31/2014
	6	Participate in Cycle 3 Obsmode go / no-go meeting	12/31/2014
	7	Participate in ALMA Intl Science Conference and Postdoc Symposium	12/31/2014
	8	Participate in ALMA Operations Readiness Review	03/31/2015
	9	Offer Data Processing Workshop in Charlottesville	03/31/2015
	10	Cycle 3 Prep: S/W tests, Documentation Prep, Call for Proposals	03/31/2015
	11	Cycle 3 Prep: Community Day Events, User Support for Deadlines	06/30/2015
	12	Cycle 3: Technical Assessments, Tech Secretary Support	06/30/2015
	13	Cycle 4: Capabilities Planning	06/30/2015
	14	Cycle 3: P2G and CS Assignments	09/30/2015
	15	Cycle 3: First batch of SBs validated	09/30/2015
	16	Offer Data Processing Workshop in Charlottesville	09/30/2015
	17	Pipeline Heuristics: Input on Reference Imaging	12/31/2014
	18	Pipeline Heuristics: Input on Improved Calibration heuristics	03/31/2015
		Development	
	19	NA ALMA Development Studies initiated in FY2014 will be completed	03/31/2015
	20	NA ALMA Development Studies Call for Proposals date – next round (preliminary date)*	03/31/2015
	21	NA ALMA Ongoing Development Projects initiated in FY12 will be completed	12/31/2014
		Maintenance and Renewal	
	22	Commission the FE test cryostat at the NTC.	03/31/2015
	23	Install and test one FETIM module in an antenna receiver cabin.	06/30/2015
	24	Execute on-site (re) training.	09/30/2015
		NRAO-Chile Office	
	25	Hire NRAO-Chile Chief of Staff	12/31/2014
	26	Support ALMA HR Department	12/31/2014
			03/31/2015
			06/30/2015
	27	Prepare for Upcoming Union Negotiations	06/30/2015
			09/30/2015
	28	Study Alternative Office Locations	12/31/2014

FY2015 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
		VLBA Technical Upgrades and Enhancements	
	58	Install production M450 in a VLBA antenna for testing	06/30/2015
		VLBA Observing Capability Enhacements	
	59	Commission and document DDC-8 on Effelsberg for 2016B	09/30/2015
	60	Commission and document PFB on LMT for 2016B	09/30/2015
		Site Operations	
	61	Complete electronic door access for the DSOC	12/31/2014
	62	Renew leases for OV and SC	12/31/2014
4.4		**West Virginia Operations**	
		GBT Development	
	1	Commissioning of MUSTANG1.5	12/31/2014
	2	Commissioning of ARGUS receiver	03/31/2015
		GBT Maintenance	
	3	Beginning of summer painting	06/30/2015
	4	End of summer painting	09/30/2015
	5	GBT track inspection will take place, any needed repairs completed	09/30/2015
	6	Beginning of structural inspections	06/30/2015
	7	End of structural inspections	09/30/2015
	8	Begin replacement of GBT active surface electronics	09/30/2015
		Site Operations	
	9	Repair culvert by interferometer	09/30/2015
5.3		**Central Development Laboratory**	
		Repair, Maintenance, Production, Support	
	1	Complete repair of eight spare Band 6 SIS mixers	09/30/2015
	2	Design, build and test Qty. 4 MIC LNAs	12/31/2014
	3	Build and test Band 1 amplifiers	03/31/2015
	4	Design ALMA Band 2 optical system	12/31/2014
	5	Test Band 2 optical system	12/31/2014
	6	Deliver Band 2 optical system	12/31/2014
	7	Complete ALMA Phasing System hardware and firmware acceptance tests.	12/31/2014
	8	Fabricate, evaluate, and deliver spare components to the PAPER-128 site.	09/30/2015
		Research and Development	
	9	Demonstrate balanced low-noise 4-12 GHz amplifier with superconducting hybrids	09/30/2015
	10	Cryogenically test MMIC amplifier modules using NGC 35nm PHEMT process	06/30/2015
	11	Cryogenically test MMIC amplifier module using BAE 50nm MHEMT process	06/30/2015
	12	Develop a new feed for the 14 meter diameter paraboloidal reflector antenna. This will be based on the PAPER dipole. The work will include electromagnetic design and analysis.	09/30/2015
	13	Mentor pre-doctoral student to measure the beam pattern of a new HERA prototype antenna using satellite downlink signals.	09/30/2015
	14	Develop the DARE radiometer proof-of-concept and calibration procedure.	09/30/2015

FY2015 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
	15	Mentor Reber pre-doctoral graduate student to examine the influence of the ionosphere on the measurement of Dark Ages hydrogen	09/30/2015
	16	Implement a six-channel "IRD Backend" using a Kintex-7 FPGA processor.	06/30/2015
	17	Demonstrate de-interleaving of multiple data sources on a shared fiber-optic link using a CPLD keyed to gain mismatch.	09/30/2015
	18	Implement advanced topologies and miniaturized packaging of reflectionless filters.	09/30/2015
	19	Prototype and evaluate redesigned low noise amplifiers.	06/30/2015
	20	Integrate and test the digital downconverter with PAF front end	06/30/2015
	21	Digital receiver development: Prototype photoreceiver PC board and test with Roach 2 firmware	09/30/2015
	22	Improve PAF electromagnetic and beamforming model	03/31/2015
	23	Feasibility study for improved PAF receiver	09/30/2015
6.5		**Science Support & Research**	
		Telescope Time Allocation (TTA)	
	1	CfP for semester 2015B	03/31/2015
	2	CfP for semester 2016A	09/30/2015
	3	SRP and tech review process, semester 2015B	03/31/2015
	4	SRP and tech review process, semester 2016A	09/30/2015
	5	TAC meeting for semester 2015A	12/31/2014
	6	TAC meeting for semester 2015B	06/30/2015
	7	Update SW tools requirements for TAC support 2015A	12/31/2014
	8	Update SW tools requirements for PST 2015B	03/31/2015
	9	Update SW tools requirements for TAC support 2015B	06/30/2015
	10	Update SW requirements tools for PST 2016A	09/30/2015
	11	Update documentation for CfP and tools 2015B	03/31/2015
	12	Update documentation for CfP and tools 2016A	09/30/2015
		Science User Support (SUS)	
	13	4th VLA data reduction tutorial	12/31/2014
	14	SPF I CDE	03/31/2015
	15	ALMA cycle 3 CDE planning	06/30/2015
	16	Filaments workshop	12/31/2014
	17	Revolution in Astronomy	12/31/2014
	18	AAAS session on Galaxy Assembly	03/31/2015
	19	SPF I meeting	03/31/2015
	20	Integrated HD requirements	12/31/2014
	21	RPI and NRAO archive user testing	12/31/2014
	22	Integrated science portal requirements	06/30/2015
	23	Summer student selection	03/31/2015
	24	Summer student offers	03/31/2015
	25	Summer student program begins	06/30/2015
	26	Summer student program complete	09/30/2015
	27	SOS selection begins	09/30/2015
	28	Update CASAGUIDES	12/31/2014
	29	Review ALMA user documents	03/31/2015
	30	Update CASAGUIDES	06/30/2015

FY2015 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
		SSR Services	
	31	Library contracts negotiated	03/31/2015
	32	Metrics web interface requirements	03/31/2015
7.4		**Data Management & Software**	
		Scientific Information Services	
	1	SSO aligned for MyNRAO and ALMA accounts	12/31/2014
	2	Merger of helpdesk	03/31/2015
	3	PI Access to NAASC cluster	06/30/2015
	4	Increase bandwidth to sites	12/31/2014
	5	Increase bandwidth to sites	03/31/2015
	6	Increase bandwidth to sites	06/30/2015
	7	Increase bandwidth to sites	09/30/2015
	8	XSEDE access	03/31/2015
	9	Federated identity management evaluation	03/31/2015
	10	PSC access	06/30/2015
	11	Amazon cloud for CASA	09/30/2015
	12	Multi-core development testbed installed	12/31/2014
	13	Unified approach to Lustre backup	06/30/2015
		ALMA System Software	
	14	ALMA Fall 2014 Release	12/31/2014
	15	ALMA Spring 2015 Release	06/30/2015
	16	ALMA Phasing Project	06/30/2015
		VLA/VLBA System Software	
	17	Deploy software to support Semester 2014B observing.	03/31/2015
	18	Deploy software to support Semester 2015A commissioning.	03/31/2015
	19	Deploy software to support Semester 2015A observing.	09/30/2015
	20	Deploy software to support Semester 2015B commissioning.	09/30/2015
	21	Integrate VLITE Operations	03/31/2015
	22	Deliver Frequency Averaging	12/31/2014
	23	Write Pointing Table	03/31/2015
	24	VME replacement	09/30/2015
		GBT System Software	
	25	Modify Astrid to Use Streaming	12/31/2014
	26	Operations software update	12/31/2014
	27	Vegas Pulsar Modes	12/31/2014
	28	NRQZ software	03/31/2015
	29	M&C release	09/30/2015
	30	CLEO Update	06/30/2015
	31	Parallelize Pipeline	12/31/2014
	32	Pipeline improvements	09/30/2015
	33	Test Pipeline with PSC – evaluate candidates	03/31/2015
		Software Development	
	34	Operationalize the new NRAO Archive and RPI	03/31/2015
	35	Implement CASA calibration pipeline in production for the VLA	06/30/2015
	36	Release CASA version 4.3	12/31/2014
	37	Release CASA version 4.4	06/30/2015
	38	Implement PST updates for Semester 2015B Call for Proposals	12/31/2014

FY2015 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
		National/Domestic Outreach	
	4	Undergraduate Intern Program for SOC Electronics Division	03/31/2015
	5	LSAMP, NAC, SOC Summer Youth Employment Program, PING, African American Teaching Fellows coordination	06/31/2015
	6	Partnership with Native American point of contact and designate representative from CV and SOC	06/31/2015
		International Outreach	
	7	NINE- NRAO Staff to South Africa – teaching and recruitment	03/31/2015
	8	UVA/NRAO Chilean PhD Sponsorship	03/31/2015
		Improve Workplace Culture	
	9	Diversity and Cultural Awareness Training #1	06/31/2015
	10	Diversity and Cultural Awareness Training #2	09/30/2015
13.7		**Human Resources**	
		Policy	
	1	Complete the final revisions, formatting and refinement of the combined Supervisor's Manual and Employee Handbook and ensure posting readiness to NRAO internal website. Obtain appropriate legal review and final review/ approval from NRAO and AUI	12/31/2014
		Training	
	2	Deliver 4 newly designed Mgmt/Supervisory courses Courses are: 1) Time off/Attendance/FML, 2) Harassment/ Bullying/Discrimination, 3) The Electronic PEP Process, and 4) Effective Planning and Goal Setting	03/31/2015
	3	Design two new Mgmt/Supervisory courses	06/30/2015
		Compensation	
	4	Ensure all reconfiguration changes/improvements are complete in order to launch the electronic PEP process for the FY2014 performance period	12/31/2014
	5	All preparations complete and salary review worksheets are open to pay decision managers for final merit review decisions	03/31/2015
	6	Participate in all credible/scheduled salary survey sources and conduct analysis of benchmark jobs	09/30/2015
	7	Job Description Builder module added to Halogen System. HR Staff will be trained on how to be administrators/users	06/30/2015
		Benefits	
	8	HR prepares and distributes all open enrollment materials to employees and makes enrollment changes into JDE and with vendors	12/31/2014
	9	Create and deliver targeted wellness program and processes to address high frequency/high cost illness/injury areas to employees and the Observatory. Proactively identify others trending towards high frequency/high cost	06/30/2015
	10	NRAO HR partners with AUI to review and identify health plan design changes for the next calendar year	09/30/2015
		Employment	
	11	Update WFM and Staffing Plans	03/31/2015
		Human Resources	
	12	Implement Phase I Succession Planning	06/30/2015

FY2016 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
		VLBA Science Operations	
	39	Define VLBA capabilities to be offered for semester 2016B	12/31/2015
	40	Define VLBA capabilities to be offered for semester 2017A	06/30/2016
	41	Update VLBA documentation to support 2016B Call for Proposals, perform proposal technical reviews	03/31/2016
	42	Update VLBA documentation to support 2017A Call for Proposals, perform proposal technical reviews	09/30/2016
		VLBA Antenna Maintenance	
	43	Tiger Team maintenance campaign to KP	06/30/2016
	44	Tiger Team maintenance campaign to MK	09/30/2016
		VLBA Technical Upgrades and Enhancements	
	45	Replicate monitor data stream to the station control computer	03/31/2016
		VLBA Observing Capability Enhancements	
	46	Offer DDC-4 observing with Arecibo on HSA under RSRO program for 2016B	09/30/2016
		Site Operations	
	47	Renew lease for PT	12/31/2015
4.4		**West Virginia Operations**	
		GBT Maintenance	
	1	Beginning of summer painting	06/30/2016
	2	End of summer painting	09/30/2016
	3	GBT track inspection will take place, any needed repairs completed	09/30/2016
	4	2015 structural inspections report complete	06/30/2016
	5	Begin active surface electronics replacement	09/30/2016
5.3		**Central Development Laboratory**	
		Repair, Maintenance, Production, Support	
	1	Complete repair of eight spare Band 6 SIS mixers	09/30/2016
	2	Pending contract with ASIAA: deliver 140 Band 1 amplifiers (will continue into FY2017)	09/30/2016
		Research and Development	
	3	Demonstrate high quality Nb/AlN/NbTiN SIS junctions suitable for THz operation	09/30/2016
	4	Cryogenically test BAE stock MMIC design	06/30/2016
	5	Develop and test 385 – 500 GHz polarizer	09/30/2016
	6	Synchronize parallel data streams on an unformatted serial link using FIFO buffering	06/30/2016
	7	Tapered waveguide calibration of DOMT	09/30/2016
	8	Improvement to the L-Band Cryogenic Receiver	06/30/2016
	9	System testing of PAF with digital backend	09/30/2016
6.5		**Science Support & Research**	
		Telescope Time Allocation (TTA)	
	1	CfP for semester 2016B	03/31/2016
	2	CfP for semester 2017A	09/30/2016
	3	SRP and tech review process, semester 2016B	03/31/2016
	4	SRP and tech review process, semester 2017A	09/30/2016
	5	TAC meeting for semester 2016A	12/31/2015
	6	TAC meeting for semester 2016B	06/30/2016

FY2016 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
	7	Update SW tools requirements for TAC support 2016A	12/31/2015
	8	Update SW tools requirements for PST 2016B	03/31/2016
	9	Update SW tools requirements for TAC support 2016B	06/30/2016
	10	Update SW requirements tools for PST 2017A	09/30/2016
	11	Update documentation for CfP and tools 2016B	03/31/2016
	12	Update documentation for CfP and tools 2017A	09/30/2016
		Science User Support (SUS)	
	13	15th Synthesis Imaging summer school	06/30/2016
	14	ALMA cycle 4 CDE planning	06/30/2016
	15	NAASC sponsored science workshop	12/31/2015
	16	Testing of version 2 of RPI and NRAO archive	03/31/2016
	17	Testing/validation of CASA pipeline	09/30/2016
	18	Summer student selection	03/31/2016
	19	Summer student offers	03/31/2016
	20	Summer student program begins	06/30/2016
	21	Summer student program complete	09/30/2016
	22	SOS selection begins	09/30/2016
	23	Update CASAGUIDES	12/31/2015
	24	Review ALMA user documents	03/31/2016
	25	Update CASAGUIDES	06/30/2016
		SSR Support	
	26	Library contracts negotiated	03/31/2016
7.4		**Data Management & Software**	
		Scientific Information Services	
	1	XSEDE access	09/30/2016
	2	Align version of NGAS	12/31/2015
	3	Leverage NGAS for Green Bank data archive	06/30/2016
	4	Recommendation of multi-core co-processor systems	03/31/2016
	5	User Portal Redesign	06/30/2016
		ALMA System Software	
	6	ALMA Fall 2015 Release	12/31/2015
	7	ALMA Spring 2016 Release	06/30/2016
		VLA/VLBA System Software	
	8	Deploy software to support Semester 2015B observing.	03/31/2016
	9	Deploy software to support Semester 2016A commissioning.	03/31/2016
	10	Deploy software to support Semester 2016A observing.	09/30/2016
	11	Deploy software to support Semester 2016B commissioning.	09/30/2016
	12	VME Replacement	09/30/2016
		GBT System Software	
	13	Operations Software Update	09/30/2016
	14	Vegas Pulsar Modes	03/31/2016
	15	NRQZ Software	09/30/2016
	16	M&C Release	09/30/2016
	17	CLEO Port	09/30/2016
	18	GBT Pipeline Improvements	09/30/2016
	19	Test with PSC	06/30/2016

FY2016 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
		Software Development	
	20	New NRAO Archive	03/31/2016
	21	ALMA Cycle 3 Pipeline Release	12/31/2015
	22	Pipeline Reference Imaging	09/30/2016
	23	Release CASA version 4.5	12/31/2015
	24	Release CASA version 4.6	06/30/2016
	25	Implement PST updates for Semester 2016B Call for Proposals	12/31/2015
	26	Implement PST updates for Semester 2017A Call for Proposals	06/30/2016
	27	Implement PHT updates for Semester 2016B TAC Meeting	03/31/2016
	28	Implement PHT updates for Semester 2017A TAC Meeting	09/30/2016
	29	Implement OPT updates for Semester 2016A VLA Observing	12/31/2015
	30	Implement OPT updates for Semester 2016B VLA Observing	06/30/2016
	31	Integrate ALMA and NRAO RPI	03/31/2016
	32	Deliver Phase I of the Observatory Tools Update	12/31/2015
	33	Deliver iOS App for Public Outreach	03/31/2016
	34	Expand CASA Test Scope	06/30/2016
8.5		**Program Management Department**	
		Headquarters	
	1	Quarterly Status Updates	12/31/2015
			03/31/2016
			06/30/2016
			09/30/2016
	2	Program Operating Plan (if required)	09/30/2016
	3	Long Range Plan (if required)	09/30/2016
	4	Annual Progress Summary	09/30/2016
		New Mexico	
	5	Finalize NM Ops and DMS Training Plan (2nd Phase)	03/31/2016
	6	PM/SE Implementation Training	06/30/2016
	7	DMS Group Practices Assessment	12/31/2015
	8	Implementation of DMS Reporting Tools	09/30/2016
	9	Host learning session	12/31/2015
	10	Host learning session	03/31/2016
	11	Host learning session	06/30/2016
	12	Host learning session	09/30/2016
		CDL/ALMA	
	13	PM/SE Training development	12/31/2015
	14	PM/SE Training development	03/31/2016
	15	PM/SE Training development	06/30/2016
	16	PM/SE Training development	09/30/2016
	17	Facilitate gate review	06/30/2016
	18	Facilitate gate review	09/30/2016
	19	Facilitate gate review	12/31/2015
		Green Bank	
	20	Finalize Training Evaluation Criteria	06/30/2016
	21	Evaluate and Report on Training Results	09/30/2016
	22	Host learning session	12/31/2015
	23	Host learning session	03/31/2016

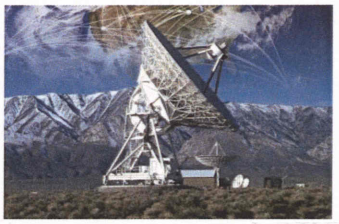
FY2016 Major Milestones			
POP Section Number	**POP Milestone**	**Task Name**	**Completion Date**
		MIS	
	9	Load and testing of new Chart of Accounts	09/30/2016
	10	Prepare list of possible improvements, upgrades and additions Calculate effort, cost, and benefit of each change.	03/31/2016
		TTO	
	11	Identify from IP Asset Register, review choices through selection committee, begin commercialization efforts.	09/30/2016
	12	Prepare follow-up program based on prior year agenda	06/30/2016
16.5		**Spectrum Management**	
		Spectrum Management	
	1	ITU-RWRC-15	12/31/2015
		WV Radio Quiet Zone	
	2	WV Radio Quiet Zones	03/31/2016
17.1		**Director's Office**	
		ALMA	
	1	ALMA Board Meeting	12/31/2015
			03/30/2016
			06/30/2016
			09/30/2016
	2	ALMA Director's Council	12/31/2015
			03/30/2016
			06/30/2016
			09/30/2016
		Corporate Meetings	
	3	AUI Board of Trustees meetings	12/31/2015
			03/30/2016
			06/30/2016
	4	AUI Executive Committee meetings	12/31/2016
			06/30/2016
			09/30/2016
	5	AUI Visiting Committee meeting	06/30/2016
		Science Community	
	6	Appoint new Users Committee members	12/31/2016
	7	Users Committee meeting	06/30/2016
		Management Review	
	8	NSF Annual Program Review	12/31/2016
	9	All Hands presentation	12/31/2015
			06/30/2016

APPENDIX H: ACRONYMS

Acronym	Definition
AA	Antenna Articles
AAAS	American Association for the Advancement of Science
AAS	American Astronomical Society
AAT	Archive Access Tool
AATF	African American Teaching Fellows
ACEAP	Astronomy in Chile Educator Ambassadors Program
ACU	Antenna Control Unit
AD	Assistant Director
ADC	Analog to digital converter
ADMIN	Administration
ADSC	ALMA Development Steering Committee
AGN	Active Galactic Nuclei
AIPC 1	Antenna Inspection Point Chile of antenna number 1
ALMA	Atacama Large Millimeter/submillimeter Array
AMG	Antenna Maintenance Group
AoD	Astronomer on Duty
AOS	Array Operations Site (ALMA, Chile)
API	Atmospheric Phase Interferometer
APP	ALMA Phasing Project
ARC	ALMA Regional Center
ARDG	Algorithm research and development group
ARO	Arizona Radio Observatory
ASA	ALMA Science Archive
ASAC	ALMA Science Advisory Committee
ASDM	ALMA Science Data Model
ASIAA	Academia Sinica Institute for Astronomy and Astrophysics
ASKAP	Australian SKA Pathfinder
ATI	Advance Technologies and Instrumentation
AU	Astronomical Unit
AUI	Associated Universities, Incorporated
BAE	British Aerospace
BBC	Base Band Converter
BE	Back End
BeSSel	Bar and Spiral Structure Legacy Survey
CAP	Contracts and Procurement
CARMA	Combined Array for Research in Millimeter-wave Astronomy
CASA	Common Astronomy Software Applications
CBE	Correlator Back-End
CBI	Cosmic Background Imager
CCA	Cold Cartridge Assembly
CCB	Caltech Continuum Backend
CCE	Common Computing Environment
CDE	Community Day Events
CDL	Central Development Laboratory

Acronym	Definition
FCC	Federal Communications Commission
FE	Front End
FEMC	Front End Monitor and Control
FETIM	FE Thermal Interlock Modules
FICA	Federal Insurance Contributions Act
FIFO	First In, First Out
FRB	Fast Radio Burst
FPGA	Field-programmable Gate Array
FRM	Focus Rotation Mount
FTE	Full-Time Equivalent
FY	Fiscal Year (1 October through 30 September)
GB	Green Bank, WV
Gbps	Giga-bits per second
GBSC	GB Science Center
GBSE	Green Bank Session Editor
GBT	Green Bank Telescope
GHz	Gigahertz
GO	General Observing
GPS	Global Positioning System
GPU	Graphics Processing Unit
GSA	General Services Administration
GUI	Graphical User Interface
GUPPI	Green Bank Ultimate Pulsar Processing Instrument
HERA	Hydrogen Epoch of Reionization Array
HFET	Heterojunction Field-Effect Transistor
HPC	High Performance Computing
HR	Human Resources
HRIS	Human Resource Information System
HSA	High Sensitivity Array
HSI	Hispanic Serving Institutions
HVAC	Heating, ventilation, and air conditioning
HST	Hubble Space Telescope
Hz	Hertz
IAU	International Astronomical Union
ICR	Indirect Cost Recovery
ICT	Integrated Computing Team
IDC	Indirect Cost
IDP	Individual Development Plan
IET	Integrated Engineering Team
IF	Intermediate Frequency
IHE	Institutions of Higher Education
InP	Indium Phosphide
IPT	Integrated Product Team
IR	Infrared
IRD	Integrated Receiver Development
ISM	Interstellar medium



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