

# **The NRAO Annual Progress Summary**

**FY 2010**



*November 2010*



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## FY 2010 Annual Progress Summary

This summary gives a brief description of the activities that have been reported in the Quarterly Status Updates (QSU) for FY 2010 Quarter 1 (Q1), Quarter 2 (Q2), Quarter 3 (Q3), and Quarter 4 (Q4) spanning October 1, 2009 through September 30, 2010. For detailed descriptions of the activities, please consult the individual Quarterly Status Update briefings submitted as Interim Reports to the National Science Foundation (NSF). This document is meant to report all activity done on behalf of the Program Operating Plan FY 2010 and is provided to the NSF in lieu of a Q4 annotated briefing.

### I. Science Highlights

Numerous significant and exciting scientific results were obtained in FY 2010 by observers using the NRAO telescopes and research facilities, as described below.

#### **Expanded Very Large Array (EVLA) & Very Large Array (VLA)**

**EVLA Reveals a Colossal Galactic Nursery:** Using the new Ka-Band receivers, Ivison et al imaged a huge molecular gas cloud associated with a massive star-forming galaxy in the early Universe ( $z \sim 2.8$ ). The cloud is larger than 25 kpc and contains sufficient molecular gas to create the stellar population of a large elliptical galaxy.

*Investigators: R. J. Ivison (UK-ATC, Edinburgh), Ian Smail (Durham), P. P. Papadopoulos (Argelander-Institut für Astronomie), I. Wold (Wisconsin) J. Richard (Durham), A.M. Swinbank (Durham), J.-P. Kneib (Laboratoire d'Astrophysique de Marseille) and F.N. Owen (NRAO). 2010 MNRAS, 404, 198.*

**EVLA Images Magnetic Fields in a Massive Star-forming Region:** The new EVLA Ka-Band receiver system enabled astronomers to observe and analyze the Zeeman effect in methanol masers in a massive star-forming region, M8E, revealing structure on scales  $\sim 1000$  AU, and dynamically strong fields.

*Investigators: A.P. Sarma (DePaul) and E. Momjian (NRAO). 2010 ApJ 705, L176.*

**A Massive Molecular Gas Reservoir in the Most Distant Sub-mm Galaxy:** The new capabilities of the EVLA and the Plateau de Bure interferometer have enabled the detection of CO emission from an enormous molecular gas reservoir in AzTec-3, the most distant submillimeter-luminous galaxy, which is located in a massive  $z = 5.3$  protocluster structure in the COSMOS field. This discovery enhances our understanding of early galaxy formation, pushing back to a cosmic epoch where the Universe was less than 1/12 its present age.

*Investigators: Dominik Riechers, Peter Capak, Nick Scoville, and Lin Yan (Caltech); Chris Carilli (NRAO); Pierre Cox and Roberto Neri (IRAM); Eva Schinner (MPIA); and Frank Bertoldi (Univ. Bonn). 2010 ApJ, 720, L131.*

**EVLA Performs Broadband, High-Resolution 22 GHz Imaging:** Numerous key molecular transitions have been detected via new broadband, high-resolution 22 GHz EVLA imaging of the Orion molecular hot core, a massive star-forming region.

*Investigators: R. Perley (NRAO) et al., in preparation.*

**VLA Pinpoints Super Star Cluster Formation Sites:** Brogan et al studied the Galactic-type water masers in the Antennae interacting galaxies at 80 mas (9 pc) resolution, highlighting H<sub>2</sub>O maser potential to pinpoint sites of highly obscured, young super star cluster formation.

*Investigators: Crystal Brogan (NRAO), Kelsey Johnson (Virginia/NRAO), and Jeremy Darling (Colorado). 2010 ApJ, 716, L51.*

**Cold Molecular Gas in Star-forming Disk Galaxies:** The VLA imaged the cold molecular gas in normal star-forming galaxies at  $z \sim 1.5$ , confirming the low excitation conditions typical of Milky Way gas. These systems have large gas masses ( $>10^{10}$  solar masses) and sizes ( $> 10$  kpc). The gas masses are larger than the stellar masses, suggesting an early evolutionary stage for these galaxies.

*Investigators: M. Aravena (NRAO), C. Carilli (NRAO), E. Daddi (CEA Saclay), J. Wagg (ESO), F. Walter (MPIfA), D. Riechers (Caltech), H. Dannerbauer (CEA Saclay), G.E. Morrison (IfA/CFHT), D. Stern (JPL), and M. Krips (IRAM). 2010 ApJ, 718, 177.*

### **Very Long Baseline Array (VLBA)**

**Giant Magnetic Loop Sweeps Through Space Between Stellar Pair:** Peterson et al employed the High Sensitivity Array (HSA) to make the most detailed image of a magnetic field around any star other than the Sun. The research team discovered and studied at sub-AU scales a large magnetic loop that connects the stars in the Algol binary star system.

*Investigators: W.M. Peterson (Iowa), R.L. Mutel (Iowa), M. Güdel (ETH-Zurich), W.M. Goss (NRAO). 2010 Nature, 463, 207.*

**Massive Star Formation: The Movie.** A VLBA ‘movie’ has provided the most detailed view of the dynamics of gas within 20 AU of a young massive star. Mathews et al. imaged the SiO masers in an YSO in Orion over a 21-month period with the VLBA down to 0.2 AU resolution. The 19-epoch movie created from these data reveal a bipolar outflow from the accretion disk, likely magnetically confined, and provide the most detailed view to date of the dynamics and temporal evolution of molecular material within  $\sim 20 - 100$  AU of a massive YSO.

*Investigators: L.D. Mathews (CfA/MIT Haystack), L.J. Greenhill (CfA), C. Goddi (CfA), C.J. Chandler (NRAO), E.M.L. Humphreys (CfA), M. Kunz (NRAO/Illinois). 2010 ApJ, 708, 80.*

**The First Black Hole Direct Distance Measurement:** Using astrometric VLBI observations, Miller-Jones et al have determined the parallax of the black hole X-ray binary V404 Cyg to be  $0.418 \pm 0.024$  mas, corresponding to a distance of  $2.39 \pm 0.14$  kpc, significantly lower than previously accepted. This model-independent estimate is the most accurate distance to a Galactic stellar-mass black hole measured to date and confirms that the source was not super-Eddington during its 1989 outburst.

*Investigators: J.C.A. Miller-Jones (NRAO), P.G. Jonker (SRON/CfA), V. Dhawan (NRAO), W. Brisken (NRAO), M. P. Rupen (NRAO), G. Nelemans (Nijmegen), E. Gallo (MIT). 2009 ApJ, 706, L230.*

**Imaging Neutral Atomic Gas Near a Massive Black Hole:** The VLBA has imaged the atomic hydrogen on sub-parsec scales near the active nucleus of Centaurus A. The HI absorption lines are seen against the radio loud nucleus and jet. The broadest HI components are located within 1 pc of the

nucleus, as opposed to being intervening clouds further out in the disk, indicating that dissociation of H<sub>2</sub> near the nucleus is efficient, and may foster the fueling process of the supermassive black hole.

*Investigators: D. Espada (ASIAA, Harvard-Smithsonian CfA, Instituto de Astrofísica de Andalucía), A. B. Peck (JAO, Harvard-Smithsonian SMA, NRAO), S. Matsushita (ASIAA, JAO), K. Sakamoto (ASIAA), C. Henkel (MPIfR), D. Iono (Nobeyama Radio Observatory), F. P. Israel (Sterrewacht Leiden), S. Muller (Onsala Space Observatory), G. Petitpas (Harvard-Smithsonian SMA), Y. Pihlström (UNM, NRAO), G. B. Taylor (UNM, NRAO), and D. V. Trung (Vietnam Academy of Science and Technology, ASIAA). 2010, ApJ, 720, 666.*

**A Supernova Remnant Puzzle:** New global very long baseline interferometry images of the supernova remnant SN 1986J have led investigators to a puzzle: Is the central bright spot a compact stellar remnant or the localization of impact of the expanding SN shell with a dense condensation in the circumstellar medium? The small proper motion suggests the former, but the optically thin spectral index favors the latter.

*Investigators: M.F. Bietenholz (Hartebeesthoek/York), N. Bartel (York), M.P. Rupen (NRAO). 2010 ApJ, 712, 1057.*

**The Distance to the Youngest YSO:** The precision astrometry capability of the VLBA has determined the distance to the proto-Herbig-Haro object EC95 in Serpens. A trigonometric parallax of  $415 \pm 5$  pc to the Serpens core is derived using non-thermal emission, almost a factor two larger than previous determinations.

*Investigators: Sergio Dzib (CRyA-UNAM), Laurent Loinard (CRyA-UNAM), Amy J. Mioduszewski (NRAO), Andrew F. Boden (CalTech), Luis F. Rodriguez (CRyA-UNAM), Rosa M. Torres (Univ. Bonn). 2010 ApJ, 718, 610.*

**Precision Astrometry with the VLBA:** Sato et al used H<sub>2</sub>O masers to measure an trigonometric parallax for the massive star-forming region, W51:  $0.185 \pm 0.010$  mas. This parallax implies a distance of 5.41 (+0.31/-0.28) kpc. Combining parallaxes and proper motions, the team obtained the full-space W51 motion. The H<sub>2</sub>O masers trace powerful bipolar outflows, some associated with dusty molecular hot cores and/or compact HII regions.

*Investigators: M. Sato (Tokyo/CfA/VERA), M.J. Reid (CfA), A. Brunthaler (MPIfR), and K.M. Menten (MPIFR). 2010 ApJ, in press.*

### **Green Bank Telescope (GBT)**

**A Unique Image of the Magellanic Stream:** Nidever et al. imaged the HI in the Magellanic Stream, an enormous gas stream enveloping the Galaxy. The gas is continuous over tens of kpc scales, connects our nearest two companion dwarf galaxies, and likely originated as outflow from these galaxies driven by active star formation.

*Investigators: David L. Nidever (Virginia), Steve R. Majewski (Virginia), W. Butler Burton (Leiden/NRAO), and Lou Nigra (Wisconsin). 2010 ApJ, in press.*

**Imaging the Sunyaev-Zel'dovich Effect in a Distant Cluster:** Mason et al. used the 90 GHz MUSTANG array with the GBT to create the highest resolution Sunyaev-Zel'dovich effect map and detect the hot gas from a major merger event in a  $z \sim 0.5$  cluster.

*Investigators: B.S. Mason (NRAO); S.R. Dicker, P.M. Korngut, and M.J. Devlin (Pennsylvania); W.D. Cotton (NRAO); P.M. Koch and S.M. Molnar (Academia Sinica); J. Sievers (CITA); J.E. Aguirre (Pennsylvania); D. Benford (NASA-Goddard); J.G. Staguhn (NASA-Goddard/Johns Hopkins); H. Moseley (NASA-Goddard), K.D. Irwin (NIST), and P. Ade (Cardiff). 2010 ApJ, 716, 736.*

**Dense Cores Show Sub-sonic Gas:** GBT imaging of NH<sub>3</sub> emission from dense gas in star forming cores has revealed non-thermal, subsonic motions, indicating a sharp transition from turbulent outer clouds to more quiescent inner cores.

*Investigators: Jaime E. Pineda (CfA), Alyssa A. Goodman (CfA), Hector G. Arce (Yale), Paola Caselli (Leeds), Jonathan B. Foster (CfA/Boston), Philip C. Myers (CfA), and Erik W. Rosolowsky (UBC-Okanagan). 2010 ApJ, 712, L116.*

**Diffuse Gas in Hickson Groups:** The GBT and VLA have revealed the presence of diffuse neutral hydrogen in Hickson groups of galaxies. This gas represents an intermediate stage in the evolution of tidal debris, and ~1/3 of the HI in these groups is in this form.

*Investigators: Sanchayeeta Borthakur (Massachusetts), Min Su Yun (Massachusetts), Lourdes Verdes-Montenegro Instituto de Astrofísica de Andalucía). 2010 ApJ, 710, 385.*

**Anomalous Dust Emission in a Nearby Galaxy:** Murphy et al measured star-forming regions in the nearby galaxy NGC 6946, detecting excess 28-38 GHz emission. The excess emission indicates spinning dust and that this anomalous component is detectable in extragalactic sources. These results suggest that external galaxies might show appreciable anomalous dust emission.

*Investigators: E.J. Murphy (Spitzer), G. Helou (Caltech), J.J. Condon (NRAO), E. Schinnerer (MPIfA), J.L. Turner (UCLA), R.Beck (MPIFR), B.S. Mason (NRAO), R.-R. Chary (Spitzer), and L. Armus (Spitzer). 2010 ApJ, 709, L108.*

**A New Population of Galactic HII Regions:** Bania et al have used the GBT to discover a large population of previously unknown Galactic H II regions via their hydrogen radio recombination line emission. In the first quadrant of the Galaxy, 602 discrete recombination line components were detected, more than doubling the known H II regions there. The longitude-velocity distribution of H II regions gives unambiguous evidence for Galactic structure, including the kinematic signatures of the radial peaks in the spatial distribution, a concentration of nebulae at the end of the Galactic Bar, and nebulae located on the kinematic locus of the 3 kpc arm.

*Investigators: T.M. Bania (Boston), L.D. Anderson (Boston/Laboratoire d'Astrophysique de Marseille), Dana S. Balser (NRAO), and R.T. Rood (Virginia). 2010 ApJ, 718, L106.*

**GBT demonstrates new technique for studying Dark Energy:** Using the intensity mapping technique, the GBT has made the first detection of HI 21cm emission at substantial redshift ( $z \sim 1$ ). This technique uses low spatial and spectral resolution imaging to detect the aggregate 21cm signal from thousands of galaxies at high  $z$ . Cross correlation with optical redshift surveys reveals a robust detection of the mean HI signal. This technique has promise for mapping large-scale structure at high redshift and for determining the nature of Dark Energy.

*Investigators: T.C. Chang (ASIAA, Univ. Toronto), Ue-Li Pen (Univ. Toronto), Kevin Bandura and Jeffrey B. Peterson (Carnegie Mellon). 2010 Nature, 466, 463.*

## 2. Observatory Science Operations

**Organization:** The definition of site-specific versus Observatory Science Operations (OSO) roles, and the interfaces to other NRAO divisions and telescope sites is complete. The implementation plan includes a detailed Work Breakdown Structure (WBS) with initial staffing and cost projections. The OSO Steering Committee has defined the tasks and path needed to go-live in FY 2011. Interviews are underway for the OSO Head position.

**User Access and Support:** A new NRAO science Internet presence debuted December 31. The NRAO Helpdesk was launched with the required active departments. The science web now provides a consolidated meeting list across the NRAO. There has been significant progress on the User Access & Support functions, including successful participation in two rounds of Atacama Large Millimeter/submillimeter Array (ALMA) integrated testing. Planning for the NRAO User Portal included a test installation of the *Plone* open-source content management system and procedures for a mass migration of existing web content into a *Plone* web development environment.

**Observation Preparation Tool (OPT):** WIDAR correlator setups were incorporated, and the OPT was released to EVLA Open Shared Risk Observing (OSRO) observers January 15. All EVLA users employ the OPT.

**The Proposal Submission Tool (PST):** The PST was modified to support Shared Risk Observing programs for EVLA Early Science and was integrated into the science web site. The ALMA Project Data Model has been adopted into the ALMA Observing Tool. As planned, the proposal and user databases were separated to facilitate mirroring of the user databases across NRAO sites and enable single sign-on for users of the NRAO web-based applications.

**Data Processing and Analysis:** Common Astronomy Software Application (CASA) version 3.0 was released for ALMA and EVLA. A dynamic CASA wiki tutorial went live for ALMA. CASA was adopted for KAT7 and MeerKAT commissioning and operations. The NRAO began hosting the Science Data Archive for EVLA on NGAS servers. Planning was completed for the first state installation of the NA ALMA Mirror Archive. EVLA data access is via an Archive Access Tool.

**Observatory Statistics and Metrics:** Logging of metrics data is now in place.

**Archive and VAO:** The NRAO Archive Strategy is being executed, leveraging the Next Generation Archive System (NGAS) servers and the successful grant of 200 TB archive storage from TeraGrid for GBT Pulsar survey data. Scalable storage systems are on-line for EVLA, VLBA, ALMA and GBT data, although work remains on user access tools with focus on survey data for GBT. A backup archive system from Socorro to Charlottesville is on-hold pending router upgrade in November 2011. Resources at the National Center for Supercomputing Applications (NCSA) and the Texas Advanced Computing Center (TACC) have been committed for code development and data analysis with data made available through the TeraGrid network as needed.

## 3. Atacama Large Millimeter/submillimeter Array (ALMA)

**Management:** The ALMA External Review held November 16-19 concluded that the management team works well and that the schedule is primarily threatened by two major deliverables: antennas from Europe, and front-end components from North America. An extensive cost-to-complete exercise assessed remaining costs and initiated parametric cuts to restore contingency. Adrian Russell departed

July 1; Mark McKinnon became the ALMA NA Project Manager March 15 and NA Project Director June 28, 2010.

**Site:** An Infrastructure Implementation Review in June evaluated the infrastructure deliverables status. The NSF approved the Array Operations Site (AOS) roads and utilities contracts to install power and fiber optic cables to AOS antenna stations and work was initiated. The fiber optic cables were delivered to Chile on schedule. Power and fiber optics was delivered to 22 ALMA Compact Array (ACA) antenna stations. Delivery of the electrical transformers was completed. Switchgear delivery will be completed on schedule in FY 2010. The ALMA Camp Extension was completed. The road surfacing work was added to the road construction contract. The contract for the road aggregate was awarded to the same vendor building the Operations Support Facility (OSF) to AOS roads for the European executive. The AOS utilities contract experienced major delays and was terminated June 30. A new bid is proceeding with a work restart in November. The risk posed by this delay is that the antenna stations in the “central cluster” may not have the fiber optic and electrical connections for first science observations. Risk mitigation includes inviting contractors more familiar with the work and site to bid. The delivery of switchgears continued and will be completed on schedule during October 2010. AOS road construction is ongoing, it is 58% complete, and will restart in October after the winter break.

**Antenna:** Nutator Unit #1 acceptance was delayed; a change in responsibility for design and implementation of the servo control system was made. Significant progress was made identifying and resolving problems with the mechanical system stiffness and natural frequencies. An interim nutator system design review was held in May. The control system design advances were significant, and the nutator was demonstrated to be near achieving most critical performance requirements. Additional structural modifications of the nutator were required as a result of the nutator analysis and testing done in Q3. Single pitch carbon fiber reinforced plastic (CFRP) was required to increase the overall stiffness of the subreflector and Invar counterweights were required to avoid surface deformation due to the mismatch in the coefficient of thermal expansion between the stainless steel counterweights and the CFRP mounts. This material had to be imported to Taiwan. All structural changes have been completed for units 1 & 2. The tuning of the nutator’s servo control system continues to be a challenge. To speed completion of the tuning, one nutator system will be shipped to Green Bank where the Electronics Division will work in parallel and collaboratively with the engineers at ASIAA who will retain and work with nutator #2. The risk posed by the delayed delivery of the nutator is a delay in the ability of the Melco antennas to provide the total power measurements required by some science projects. The risk is being mitigated with a contingency plan that implements a fast scanning technique on the Melco antennas.

The first Production Optical Pointing Telescope (POPT) was successfully integrated into the ALMA software, but image positions drifted with temperature. The risk posed by a delayed POPT delivery is a delay in the all-sky pointing acceptance tests for ALMA antennas. To mitigate this risk, a consultant assisted the vendor with the optical-mechanical design. The POPT Unit #1 was successfully used to perform acceptance testing on Vertex Antenna #10. The all-sky and offset pointing measurements were consistent with earlier testing with prototype OPT. Unit #1 was transferred along with Antenna #10 to Assembly Integration and Verification (AIV) for their use and Unit #2 was used by AIPT for testing on Antenna #11 and on. A new objective lens design and construction was completed by HIA using a lens-mounting technique first developed for the Gemini Multiobject Spectrographs (GMOS) instrument on the Gemini Telescope. This lens was tested and reduced the amount of temperature dependency by ~ 50%, but did not eliminate the drift. The remaining contributor has been found to be the CFRP optic tube. The existing tube is manufactured using a 45° crosshatch pattern of multiple layers of fabric. A new CFRP tube is going to be manufactured using unidirectional CFRP pre-pregated material.

Vertex antennas 6-10 were accepted into ALMA, and acceptance documentation for the 10<sup>th</sup> antenna is being finalized. Thus, the planned acceptance rate of 3 antennas per quarter was achieved. The acceptance of DV10 was delayed ~ 2 months due to the refurbishment of #1, the additional inspections of #1 to uncover root cause of surface degradation, and commissioning of POPT for use in acceptance testing.

A significant Q4 event was the investigation and resolution of the root cause of the surface degradation first discovered on DV02 and later confirmed on DV01. The root cause was damaged panel adjusters that were over-torqued during installation. The over-torquing resulted in plastic deformation to the anchor nut of the adjuster and allowed the adjuster rod to move due to thermal expansion over many months. Vertex inspected 100% of the panels that had moved since the time the surface was initially set and found 21 of 50 adjusters were overstressed and had to be replaced. The correlation between degraded panels and damaged adjusters was 1:1. A major effort to resolve a frequent communication problem between the ALMA computer and the antenna controller was undertaken at the OSF by a team comprised of a Vertex software engineer and an ALMA computing engineer. The root cause was found to be in the CAN BUS driver used in the Vertex antenna. This driver software was rewritten and the problem has not reappeared.

**Front End (FE):** The NA Front End Integration Center (FEIC) leadership transitioned to new leadership, responsible for technical and programmatic aspects. The FE components team has priority access to the staff needed to expedite FE components deliveries. The FE components, is now off the critical path.

One integrated NA FE underwent testing in Q4, but will be held in Charlottesville to be used for design verification tests. Three more front ends are in process of assembly and test in parallel with the design verification, with delivery of two scheduled for Q1 FY 2011. The delay in shipping will reduce the cost risk of any design modifications but may cause an overload of the AIV process as a large number of FEs will be delivered in rapid succession.

A total of 35 Band 3 cartridges have been delivered to date. The FY 2010 goal was to deliver 24 Band 3 cartridges; 28 Band 3 cartridges were actually delivered in FY 2010. A total of 32 Band 6 cartridges have been delivered to date. The FY 2010 goal was to deliver 24 Band 6 cartridges; 28 Band 6 cartridges were actually delivered in FY 2010.

The final batch of ten FE support structures (FESS) were accepted in September, closing out the FESS task.

Local Oscillator (LO) Warm Cartridge Assemblies (WCA) were delivered throughout FY 2010. Band 6 production resumed testing after determination that the cross-polarization measurements are not understood but the project can live with the present performance level. NRAO will deliver 24 Band 6 cartridges in FY 2010. A change request was submitted to modify Band 6 from 6-10 GHz to 5-10 GHz. Band 3 cartridges were delayed by discovery of a SIS mixer fabrication problem that has been solved. Twenty-four Band 3 cartridges were delivered in FY 2010.

The FE Critical Design Review (CDR) was passed in February 2010. The NA FE Integrated Production Team (IPT) organization transitioned after CDR, reflecting the evolution from engineering to manufacturing. Three FE have been shipped to Chile; three more are in process with delivery of two scheduled for Q4. Late FE delivery risks delaying the outfitting of antennas with receivers, limiting Early Science. The delay is caused primarily by late FE component deliveries. The risk is being mitigated by

management changes, working closely with vendors, requesting sensible waivers to component specifications, and optimizing the project schedule.

FE LO and test source production, which compete for resources, are critical and are just keeping up with project needs. Technical problems with Band 7 WCAs have been solved, and we are in full production mode for all four primary bands. Band 6 Cold Cartridge Assembly (CCA) is in full production with the formal approval of the cross polarization specification change. The remaining FE purchase contracts were placed. Owing to the sluggish U.S. economy, many electronics parts suppliers have scaled back production, creating some parts shortages and rationing.

**Back End (BE):** Antenna Articles (AAs) have been integrated in North America according to the schedule but held up to increase shipment sizes to the Operations Support Facility (OSF). Immediately prior to the scheduled December 2009 shipment of AAs 12-20, the need for a firmware revision was discovered. A revision was successfully implemented and shipment occurred in January 2010.

A successful CDR was held November 2009 for the AAs and Data Receiver Articles (DRXA). A Central LO Article #1 (CLOA1) Provisional Acceptance on-Site (PAS) review occurred October 2009. CLOA1 is now in active use at the AOS and supporting ALMA commissioning. A successful CDR for the CLOA and LO Photonic Receiver Article (LPRA) was held in March 2010. BE IPT leader departed ALMA to be EVLA Project Manager and was replaced May 21, 2010.

Antenna Articles (AAs) have continued to be integrated in North America according to schedule with AAs 31-40 crated for shipment in August 2010. The next batch of 10 will be finished and ready for shipment in December 2010. These 20 AAs will be stored in the VLA warehouse until early 2011 to maintain warehouse space at the OSF and to minimize costs of any unanticipated modifications to the deliverables. The remaining 16 AAs will ship mid-2011. Line Length Corrector (LLC) and Sub Array Switch (SAS) LRUs, 16 each, were delivered and installed in June and July 2010 at the AOS. This installation completes the outfitting of the Central LO Article 1, and brings it to its full capability of supporting reference timing for 16 antennas. Looking ahead, the first article units for the Photonic Reference Distribution LRUs arrive in late Q1 FY 2011 and are undergoing acceptance testing. These items are of interest in that they represent the last new components integrated into the Central LO Article 2 (CLOA2) which is the final photonics deliverable scheduled for installation in Q2/Q3 FY 2011. All other components in CLOA2 are add-ons to those in CLOA1 and represent a lower risk.

**Correlator:** To meet the need for operating two correlator quadrants simultaneously by April 2010, quadrant-2 was delivered early so that engineering tests with quadrants-2 and -3 could verify the two-quadrant operation while quadrant-1 was used for Assembly, Integration, and Verification/Commissioning and Science Verification (AIV/CSV) activities. Quadrant-4 construction was completed so that a software test bed was available in Charlottesville, Virginia. Quadrant 3 was shipped to the AOS Technical Building, reassembled, and passed PAS review. All correlator modes have been verified.

**Computing:** ALMA software v7.0 was released in December 2009, as scheduled. Deployment testing and fixes continued through early January. While the deployment was more difficult than expected, it did not delay the CSV start date. CASA 3.0 was the first non-beta release, and become available approximately three weeks later than scheduled due to regression test failures that required resolution. CASA prepared a patch on the previous 3.0 release that was released in April. CASA released a patch (3.0.2) in June that was used during the NRAO Synthesis Summer School, where CASA was the primary

data reduction package used in the tutorials for the first time. CASA release 3.1 was developed and is scheduled for October 2010 release, after integration and test.

ALMA Software version R7.1 was released in June. A patch to the deployed ALMA release (R7.1.1) was installed in Chile in Q4. More problems than anticipated were discovered in this patch, although they were quickly resolved. The lesson learned was that the testing must include critical CSV developed scripts, including data analysis of the observed data. These will be identified and tested for subsequent releases, including R8.

**Science:** The Science IPT scientifically tested the calibration and interferometric software tools implemented on the production ALMA system during commissioning at the AOS. ALMA Commissioning started January 22. Closure amplitude was achieved with four antennas May 20; data were obtained with five antennas during June. Commissioning includes understanding instrument performance, including ensuring that its performance meets specifications. Measurement of the antenna surfaces through the use of planets allowed a range of frequencies and elevations to be used to explore antenna behavior. The accuracy of the surface images informed our understanding of antenna thermal and gravitational behavior. Surface errors are well within the 25-micron specification. Data were acquired and analyzed to understand and probe antenna performance, including small-scale surface errors, pointing and tracking and focus stability.

A test image of the active spiral galaxy NGC 253 was produced from six antennas at the AOS in August. ALMA imaging ability, which goes as the square of the number of antennas, grew through the period as the AOS array increased to eight antennas on September 30, and test data acquisition followed soon thereafter. The 28 baselines available via eight antennas offer a substantial leap in ALMA's ability to accurately represent emission from the sky.

**Science Operations:** A major proposal for FY 2012-2015 ALMA Operations was completed and submitted to NSF. An external review was conducted in Chile in July. Effort continued on the ALMA Operations Plan update, led by the Joint ALMA Observatory (JAO), and in preparation for the ALMA Board in April. North American ALMA Science Center (NAASC) staff rotations to Chile continued; staff on turno at the OSF participated in multiple CSV activities, including phase stability, sun-moon scans, astro-holography and correlator-mode verification.

Many new functions were added to CASA, which was released in first non-beta form. NAASC developed and deployed the casaguides wiki with use cases and scripts and participated in a Santiago workshop. Development and testing of user software included finalization of the technical review forms for the proposal process and Observing Tool (OT) testing, integration of Splatologue into CASA, import of Australian Telescope Compact Array (ATCA) and Combined Array for Research in Millimeter astronomy (CARMA) data in CASA, and improvements to the CASA viewer, Gaussian fitting user interface, and single dish tasks. An access protocol client was developed for Splatologue, and offline versions of Splatologue were generated for use with CASA and the OT. The NRAO Helpdesk was deployed with an ALMA department.

The first NA ALMA mirror archive racks and Oracle database servers were installed and improvements to the archive room cooling system were completed. An instance of the ALMA helpdesk was deployed in preparation for integrated testing of the observation planning software. Integrated tests of the observation planning software, from Helpdesk questions through to technical assessments and mock proposal review meetings were performed with the JAO and other ALMA Regional Centers (ARC).

New science user web pages were developed, extensively reviewed, and deployed in December 2009 according to schedule and in readiness for the January 2010 American Astronomical Society (AAS) meeting. A Special Session, "Preparing for ALMA", was held at the May AAS meeting and a Special Session on "Observing with ALMA" was proposed and accepted for the January 2011 AAS meeting in Seattle. Data reduction and Simdata guides were developed for CASAguides in preparation for the NRAO Synthesis Imaging School. CASA and Simdata tutorials and OT and Splatologue walkthroughs were given at the NRAO Synthesis Imaging School, and an ALMA Townhall was held. Planning began with Herzberg Institute of Astrophysics (HIA) for the 5<sup>th</sup> NAASC science workshop, to be held January 2011 in Victoria, British Columbia.

**Japan Partnership:** NRAO received all LO Photonic Receiver Articles for test and delivery to the Front End Integration Centers (FEICs). CLOAI already had eight each of the units, but required an additional eight each for full functionality. Shipment and installation of these remaining units occurred Q3. The first pre-production Band 4 and Band 8 CCAs were integrated and tested in NA FE#3. It was determined that Band 4 will need magnets added to the SIS mixer blocks to suppress Josephson current and that Band 8 will need filtered connectors on the cold Intermediate Frequency (IF) amplifiers. The change control board rejected waivers for these two defects, and these cartridges will be replaced at some point in the future.

Development of an LO driver/frequency multiplier combination for Band 10 with the new designs continued and is presently in fabrication. The prototype that was delivered last quarter failed and was repaired and returned. A new design power amplifier chip for Band 10 that was scheduled for fabrication in Q4 will not be ready for tests until Q2 FY 2011. Frequency multipliers and WCA LO drivers were delivered to cold cartridge manufacturers for use with all bands. A Band 4 and 8 LO CDR was held and designs were released for production. Components for assembling Front Ends, including Band 6 cold cartridges, were delivered to all integration centers. The NA FEIC assisted the other integration centers with assembly and test of Front Ends. Support was provided for integrating Front End assemblies into antennas. Components for assembling the EA FEIC FE assemblies were delivered.

**The AUI/NRAO Office in Chile:** The Associated Universities, Inc. (AUI)/NRAO Office in Chile provided extensive legal and institutional support for ALMA contracts and procurements including the AOS roads construction contract, AOS utilities – electrical and fiber optic (FO) cables installation contract, fiber optic cable supply and contractors' camp expansion. Monthly reports were issued to the Comision Nacional del Medio Ambiente (CONAMA) related to flora/fauna and archaeological follow-ups. The termination of the AOS utilities – electrical and FO cables installation contract involved additional activities required to legally close the contract.

As of the end of FY 2010, the number of employees for which the AUI/NRAO Office in Chile provides ALMA with legal, payroll and travel support is 225 local staff; 25 of these employees are assigned exclusively for AUI/NRAO activities. Although in May 2010 a new AUI/NRAO Office in Chile office space was found, subsequent visits to it revealed flaws in the design and restrictions in building and electrical installations that led to cancelling this as a viable option. A new office building was found in the area, and negotiations are under way. Outfitting will occur in Q1/Q2 FY 2011. The decision for the AUI/NRAO Office in Chile to lease and move into an independent building was approved by the NSF.

The AUI/NRAO Office in Chile was heavily involved in the union negotiations, which it carried out on behalf of the JAO and the other Executives; they were successfully completed in August and the union signed a three-year contract.

In addition, AUI's employment of local staff was reviewed in August, as per agreement with ESO, to evaluate compliance with Chilean legal matters, operations cost efficiency, and programmatic requirements responsiveness. This review was conducted September 1-3, 2010 and concluded "... overall that AUI has met the legal requirements for employing staff in Chile under the law that governs international observatories; established an effective, professional HR organization in Chile; hired over 80 local staff members; complied with existing management agreements among AUI, ESO, NAOJ, and the JAO; and successfully negotiated a three-year collective bargaining agreement with the newly formed employees' union. The committee compliments AUI on these successes." The committee identified several issues that remain to be resolved and other issues that ALMA will face as it continues to grow and transitions from construction to operations. The committee presented 20 recommendations for follow-up action.

In February, the fifth largest earthquake ever recorded, along with a major tsunami, struck central Chile. The ensuing damage was extensive and substantial loss of human life occurred, especially near the coast. No ALMA employees or their immediate families were injured, although some suffered major material losses. The ALMA site in north Chile was unaffected. Santiago was severely shaken, but no serious damage to the ALMA offices was recorded. Non-vital activities at the site were frozen for nearly a week, and employees were allowed to travel home and be with their families. A relief fund to help employees and their families was created, and counseling was provided to help them overcome the psychological impact of this violent event.

#### **4. Expanded Very Large Array (EVLA)**

**Antenna:** The conversion of antennas to EVLA design and all mechanical overhauls were completed ahead of schedule. Fabrication of X-Band (8-12 GHz) feed horns completed on schedule in January. Fabrication of S-Band (2-4 GHz) feed horns completed in April, outpacing receiver production. X-Band (8-12 GHz) feed horns fabrication was complete before receiver production began; installation of these feed horns started in March. Ku-Band (12-18 GHz) feed horn fabrication is ongoing.

**Front End:** The X-Band orthomode transducer (OMT) final design was to be selected early FY 2010, with full production of the X- and Ku-Band receivers commencing Q1. However, the time required to select the OMT design for the X-Band receiver delayed its deployment start to August. Receiver production and installation are expected to be completed with no expected project impact. Production and installation of K-Band (18-22 GHz) receivers was completed in June; Q-Band (40-50 GHz) receivers are on track for completion by August. The installation of the last two Ka-Band (26-40 GHz) receivers will be completed Q1 FY 2011. The impact of the late Ka-Band receivers should be slight since only 27 antennas/receivers can be used simultaneously. The production and installation of the fully EVLA-compliant L-Band (1-2 GHz), S-Band (2-4 GHz), and C-Band (4-8 GHz) receivers continues per plan.

**LO/IF:** The assembly of all local oscillator and intermediate (LO/IF) frequency modules was completed early. Compliant updates to specific modules are on track for completion by Q2 FY 2011. EVLA central LO racks were updated following the correlator swap. Modules for the digital transmission system, formatter, and de-formatter met the antenna conversion schedule per plan.

**Fiber Optic:** An external review of the de-multiplexer on the 3-bit, 4Gbps sampler board was held to evaluate alternative designs and the design was finalized October 2009. Evaluation of 3-bit, 4Gbps sampler prototype on four antennas began Q3 2010. The late deployment of the 3-bit, 4Gbps samplers has delayed the availability of 8 GHz observing capability, but will not delay EVLA project completion. The first tests have been successful and the first production board deliveries with routine installation of

antennas expected beginning January 2011. Deployment is expected on schedule. The Data Transmission System test rack was completed, allowing for simultaneous testing of 4 transmitter–receiver module pairs, and is on schedule for Q1 FY 2011 completion.

**Correlator:** The start of general user observing with the new WIDAR correlator in March marked the beginning of EVLA operations. Delivery of the final four WIDAR baseline boards was completed in September (These boards are not needed for Early Science). A draft correlator hardware Acceptance Plan was sent to Dominion Radio Astrophysical Observatory (DRAO) and will be finalized in Q2 FY 2011. General user observations with WIDAR resumed in March in parallel with testing and commissioning, as well as for expansion of capabilities.

**Science Support Systems:** In FY 2011, the OPT was used for OSRO. Extended use of the tool will commence with RSRO. The Observation Scheduling Tool (OST) is being used to dynamically schedule selected observing. And in FY 2010, the Archive Access Tool (AAT) was modified to function with EVLA data.

**Shared Risk Observing:** Access to the EVLA Early Science is provided by two shared risk observing programs for the user community, the OSRO program and the Resident Shared Risk Observing (RSRO) program, and one for EVLA Commissioning Staff Observing (ECSO). These programs were advertised to the community for the October 1, 2009 proposal deadline, and the response was excellent. Following the VLA correlator shutdown in January, hardware was transferred to the new EVLA correlator. The first astronomical observation with all available stations connected to the EVLA correlator took place in March via the OSRO program. Subsequently, the fraction of time being used for astronomical observations rather than system integration is steadily increasing. Initial observations focused on OSRO projects. Provisional scheduling of RSRO and ECSO projects, which have access to wider correlator bandwidths, began in April, and began to produce science in. Participation in this program will likely remain at approximately 6-7 visitors in Socorro for the next two years. The user community was advised that the projects most “at risk” during EVLA commissioning would be rapid response science, but in fact target of opportunity and small exploratory projects have comprised more than 10% of the observing time.

To date, OSRO projects have comprised the majority of EVLA observing time. RSRO observations with 16 correlator sub-bands began in July. The D-configuration was extended to accommodate wideband science. The move to the DnC hybrid configuration took place in September. The EVLA is currently in C-configuration.

**Data Access:** Dataset sizes obtained through the OSRO program are up to an order of magnitude larger than any obtained previously by the VLA. These are currently being made available to the user community through an Archive Access Tool and ftp, via a fast 1 Gbps link from the Domenici Science Operations Center to the Internet-2 hub in Albuquerque. Further improvements in the way archive queries are handled have increased the speed of data access during Q4. While in theory the 1 Gbps link will have the bandwidth to support ftp downloads of future wideband data—data rates will increase by another order of magnitude in mid-2011—in practice the speed with which users can download data will probably be limited by general network traffic and the link speed at the recipient’s end. We have thus begun planning an alternative model for the dissemination of large datasets, involving the shipping of hard drives to users upon request. This model will be tested with RSRO data during FY 2011.

**Observation Preparations:** WIDAR correlator setups were incorporated in the OPT in anticipation of a revised release for the OSRO. OPT testing was completed, and its first public release supported Early Science users preparing their observations.

**Science Operations:** The first public CASA release occurred, which was patched with updates and released as version 3.0.2 to support the data reduction tutorials for the 12<sup>th</sup> Synthesis Imaging Workshop (June 8-15) with 150 students attending. At this year's workshop 130 students learned to reduce EVLA data in CASA; 20 students worked on VLBA data in Astronomical Image Processing System (AIPS).

**EVLA Commissioning and Science Verification:** The commissioning effort following the shutdown of the VLA correlator focused on system integration of the new EVLA correlator, and bringing up the observing modes needed for OSRO observations. CSV effort focused on: (1) enabling remaining OSRO observing modes, such as switching between correlator set-ups and narrow bandwidth observing; (2) improving overall system stability; and (3) commissioning wideband observing modes in preparation for RSRO and ECSO science observing; and (4) testing the performance of the VLA 74 MHz dipoles with the wideband EVLA electronics in preparation for the September 15 Call for Proposals. The OPT was expanded to incorporate RSRO observing modes.

**Panel to Advise on Science and EVLA Operations (PASEO):** The PASEO held its meeting in mid-July to provide advice on EVLA construction, commissioning, and science operations. The recommendations of this committee will be taken under advisement and implemented as appropriate.

**Engineering Services:** The replacement of 5000 ties along the 44 miles of array track and the installation of new azimuth gearboxes on antennas-6 and -7 were completed. The planned azimuth bearing change on antenna-25 was performed on antenna-6 instead, to coordinate with the repair of its azimuth gearbox; antenna-25 will have its azimuth bearing changed at a later date. The reconfigurations into C- and B-configuration were moved to FY 2011.

**American Recovery and Reinvestment Act (ARRA):** There is activity on all ARRA-funded projects. These funds are being used to purchase track repair material, a tamper and tie puller, azimuth bearings, a transformer, and a spare dry-type transformer. The decision to demolish the Visiting Scientists Quarters (VSQ) was agreed to with the National Science Foundation (NSF).

## 5. Green Bank Telescope

**Camera Development K-Band Focal Plane Array (KFPA):** A 7-pixel 18-26 GHz array of traditional heterodyne receivers was completed and commissioned. Commissioning observations verified hardware functionality, monitor & control (M&C) functionality, and quantified spectral purity. Analysis of KFPA via the data pipeline verified the instrument calibration. The KFPA receiver cryogenics were modified between commissioning runs to reduce the amplifier physical temperature so the system temperatures for the receiver are comparable to the EVLA K-band receivers and below the 35 K maximum specified system temperatures. All observing modes were tested and each of the seven beam calibrated. Integration into the GBT observing systems prepares the receiver for the shared risk observing call for Q1 FY 2011. Testing and documentation of the KFPA Python data reduction pipeline nears completion and position switched data reduction has been completely tested from observation planning, observation and automatic data reduction by multiple test observers.

**Camera Development MUSTANG:** The MUSTANG 64-pixel bolometer array is in regular scientific use on the GBT. The University of Pennsylvania group responsible for the development of the MUSTANG receiver has proposed to build a new horn-based array which will meet the theoretical limit threshold in noise. An ATI proposal to build this instrument was submitted in Q3. Though the proposal received many favorable reviews it was not funded.

The MUSTANG 64-pixel array will be replaced with a 100-pixel array produced by the National Institute of Standards and Technology (NIST). NIST completed a 100-pixel detector array, using results from the University Penn witness pixel measurements, earlier in the summer, and installed it in the array package. A wire-bonding issue, now being addressed, compromised the first test run. With the 90 GHz observing season imminent and a heavy GBT proposal load, the original 64 pixel array was reinstalled and 100 pixel retesting will occur later in the season.

**Camera Development W-Band Focal Plane Array (FPA):** Work continued toward a conceptual W-Band FPA receiver design. Oversight of the R&D aspects of this work will be transferred in Q1 FY 2011 from Green Bank Development into the Coordinated Design Laboratory in Charlottesville.

**Digital Signal Processing - Green Bank Ultimate Pulsar Processing Instrument (GUPPI):** The CICADA GUPPI instrument was completed in FY10, including full release of all de-dispersion modes. Science with the new modes began in this period. NRAO has agreed to build a version of its GUPPI pulsar backend for the Arecibo telescope in Puerto Rico. The Arecibo Observatory will be able to leverage the significant work by NRAO and the Berkeley CASPER group for an affordable world-class backend to use in science related to timing microsecond pulsars and NANOGrav experiments.

**Spectrometer:** The GB spectrometer ATI grant through UC-Berkeley has been funded. A project kickoff meeting was held September 2, establishing milestones, and action plan for the project, and initial specifications. NRAO and UC-Berkeley are in ongoing dialog to refine the specifications in accordance with the design phase as described in the ATI proposal.

**Precision Telescope Control Systems - Surface Holography (PTCS):** The goal of 35% GBT aperture efficiency at 90 GHz (20% at 115 GHz) was met during FY10. Work continued on the memo re surface panel deformations, comparing manufacturer predictions with holography measurements under different environmental conditions. The PTCS group has begun assisting the Sardinia Radio Telescope (SRT) group in commissioning their holography system. Using effort provided by the SRT and a University Maryland graduate student (funded by AUI), additional "out-of-focus" (OOF) holography data processing improvements were initiated.

**Dynamic Scheduling System (DSS):** The new DSS was released. The scheduler's tools were improved in functionality and ease of use throughout FY 2010, work which continues. The scheduling algorithm is being expanded to include hooks for climate models, historical weather data, and improved receiver temperature modeling. The scheduling algorithm infrastructure was augmented to include hooks for climate models, usage of historical weather data, and more realistic modeling of receiver temperatures. These expanded capabilities will be released early in Q1 FY 2011, immediately benefiting high-frequency observers. A sensitivity calculator, which will assist astronomers in determining observation durations based upon science objectives, was developed and will be available to astronomers as part of the proposal creation and submission process.

**Science Projects:** A core team of scientists and engineers presented the design concepts for the 4mm Two-pixel receiver to a joint meeting of Green Bank and Central Development Lab (CDL) staff. The

conceptual designs were validated with the primary unresolved issue being the need for a cold isolator. To mitigate the risk of this unresolved element, the team devised a plan to build a single pixel RF thread in the production dewar and perform baseline stability and polarization purity measurements to determine if the planned design requires the additional components.

New hybrids were installed in the Ka correlation receiver and the receiver was reinstalled on the GBT in Q4 for Zspectrometer, Spectrometer, and Continuum backend characterizations. Initial results show baseline improvements since the rehabilitation. Once final characterization with the various backends is complete, Ka observers will be notified of the new performance limits and be invited to reinstate their projects.

Rehabilitation of the GB 20m telescope and two receivers (L- and X-Band) began. The frequency coverage of the L-Band receiver will be expanded to match the SkyNet science requirements and NRAO will place the X-Band components in a new dewar for the better long-term cryogenic performance required of the SkyNet project.

Work continued on the GBT Very Long Baseline Interferometry (VLBI) Upgrade with as much of the first round coding that could be started without the recorder complete and ready for testing. The Roach Digital Bank End is being returned to Socorro for reprogramming and will require some interface adjustments when it is returned. Two Green Bank staff will travel to Socorro in early Q1FY11 for implementation meetings

Work continues on data reduction and mining software to streamline publication of GBT data and science results.

**Broadband Initiative:** West Virginia (WV) Commerce Secretary Goes traveled to Green Bank with representatives of WV Homeland Security and the other state representatives to meet with NRAO and Frontier Communications Corporation on the carrier's plans for a dedicated high speed broadband from Green Bank to West Virginia University (WVU), ultimately linking to LambdaRail and Internet2 via the Pittsburgh, Pennsylvania supercomputing center. A working group was established to refine the specifications and recommend a design. Frontier Communications has proposed to the State of WV and NRAO a path for a broadband connection to WVU. Technical capabilities will be reviewed with the stakeholders in Q1 FY 2011. Direct contact has also been made by NRAO with a second provider to evaluate alternative service options as a competitive and risk-reducing strategy.

**Operations:** With additional painters contracted and good weather, a larger than usual portion of the GBT was painted in FY 2010. This is part of a multi-year increase in painting effort to bring the GBT into compliance with outside engineering consultant's recommendations for maintenance. Several surface panels were painted and then re-measured to verify that they remained within surface thickness specifications.

In February, a military helicopter crashed near the Observatory during a training mission. The NRAO facility was opened to the Army as a forward command post and Observatory staff assisted on-site and in the field. The NRAO received commendations from the Army and National Guard for its cooperation and assistance. Painting work on the GBT was continued, with one of the most productive seasons yet for the telescope.

**American Recovery and Reinvestment Act (ARRA):** In accordance with the rules for expenditures of stimulus funds, all parts and materials were purchased in Q4 for all projects funded by the ARRA. Four projects are complete and materials purchased for all others.

## 6. Very Long Baseline Array (VLBA)

**Sensitivity Enhancement Program:** The Distributed FX (DiFX) correlator achieved full operational readiness ahead of schedule and full-time data reduction using DiFX correlator is in effect. All Digital Backend (DBE) support hardware design and development is complete. Installation of trial DBE at Los Alamos was also completed. The initial electronic connections to the Pie Town and Mauna Kea VLBA antennas planned for Q4 were delayed by the delayed signing of the NRAO-United States Naval Observatory (USNO) Memorandum of Understanding (MoU), which is funding for the upgrade; the MoU was signed in Q4. The design and production of all DBE support hardware was completed. The project is still on track for initiating the installation of DBE/Mark 5C recorder systems at all ten VLBA sites, demonstrating 2 Gbps recording capability in FY 2011. By the end of FY 2010, four antennas were outfitted with the new recorder systems and recording at 2 Gbps has been demonstrated. The purchase of 8 TB disk packs via the MRI-R2 NSF proposal grant will enable 512 Mbps sustained operations by mid-FY 2011 and triple the achievable VLBA sensitivity. Some problems have been experienced with the 8 TB modules to date, but the vendor is addressing the problem.

**New Receiver Systems:** The new Major Research Instrumentation (MRI) proposal submitted to the NSF for the installation of full coverage C-Band (4-8 GHz) VLBA receivers was rejected in Q4. Since the NSF-USNO MoU has been signed, the 6-8 GHz receivers will be built using reallocated ARRA funds, pending NSF approval.

ARRA funds were intended to be used to design and build 33 GHz receivers for the VLBA, pending signing of MoU with NASA and USNO. Both agencies committed to the MoU development, but found they did not have committed funding when it was time to sign. It is unlikely this MoU will be signed, and we await approval to use these funds to build the 4-8 GHz receivers instead, as above.

**Partnerships:** As of the end of FY 2010, NASA had not signed the MoU to provide operating funds for the VLBA. The USNO has signed a MoU, effective for 5 years beginning Q1 FY 2012 (NSF signature still pending). USNO and NRAO have signed an agreement to fund the installation of fiber links to Pie Town and Mauna Kea that will enable the USNO to compute UT1-UTC with much reduced latency.

**Engineering Service:** Four VLBA stations received major maintenance visits by the VLBA Tiger Team: Mauna Kea [Q1]; Hancock [Q2]; Fort Davis [Q3]; and Brewster [Q4]. An engineering and painting visit to St. Croix was completed Q3. A major Pie Town antenna track failure was quickly repaired. Security system improvements were installed at six stations.

## 7. Central Development Lab (CDL)

**Precision Array to Probe the Epoch of Reionization (PAPER):** The 32-element correlator was delivered, and 32 element arrays were deployed in South Africa and Green Bank. Laboratory-based receiver modeling focused on determining the temperature coefficients for gain and noise temperature. Laboratory-based receiver modeling focused on determining the temperature coefficients for gain and noise temperature. Calibration of the 32 element Green Bank and South African arrays was completed. The second data run was completed with the South African 32-element array. The Green Bank 32-element array completed a 12-day data run for each polarization. Several engineering experiments—

antenna rotation, receiver modeling, and study of ionospheric effects—are continuing as graduate student projects.

**Broadband Active Feed:** Pattern measurements for the 1-3 GHz sinuous feed were conducted at Lincoln Lab. Mechanical modifications improved the assembly of the cryogenic version of this feed. The ambient temperature 300-3000 MHz feed is completed. Work continues on refinements of the cryogenic version.

**Lunar University Node for Astrophysics Research (LUNAR):** The grant from the NASA Lunar Science Institute is to develop instrumentation for lunar-based research. Activities centered on the development of a helical antenna for the Self-Tending Array Node and Communications Element (STANCE). Research focused on improving the electromagnetic performance of the helical antenna along with developing a system for accurately measuring the beam pattern of the antenna while it is in place.

**Phased Array Feed Development:** Dewar drawings were completed. The Green Bank machine shop has nearly completed the parts fabrication for the Cryostat, dual low noise amplifier (LNA), and thermal transitions. The LNAs are commercial Monolithic Microwave Integrated Circuits (MMIC's) from Caltech. The compact sideband separating mixer with integrated analog to digital converters was tested successfully. A twelve and a half minute integration (limited by hard drive storage) revealed no evidence of self-generated radio frequency interference (RFI) from the L-Band receiver, though a 33.3 MHz and 66.6 MHz PXI bus clocks from the test equipment and the 125 kHz plus odd-numbered harmonic transmissions from the access card readers outside the lab were detected.

The uncooled 19-element prototype array was taken to Arecibo for tests on that telescope at Gregorian focus. These measurements will be of value in assessing the modified dipole for better noise match in the presence of mutual coupling. Our next measurement campaign on the 20-meter will include tests of both the uncooled array dipoles with better noise match and our first array with cooled LNAs. NRAO's new 40-channel data acquisition system with up to 5 Msa/s data streaming to disk will be used in these measurements.

**Amplifier Production, Repair, & Development:** The major EVLA amplifier production remained on schedule. The deliveries of 18-26 GHz, 26-36 GHz and 38-50 GHz amplifiers in support of MPI Receiver Group and Combined Array for Research in Millimeter Astronomy (CARMA) are on schedule. The deliveries of 38-50 GHz amplifiers for Korean VLBI network and 18-26 GHz amplifiers for Jet Propulsion Laboratory's (JPL) Deep Space Network (DSN) were completed. Research on general noise properties of three terminal active devices and noise properties of heterostructure bipolar transistors (HBTs) and CMOS MOSFET continued. Design of 230-470 MHz amplifier for EVLA P-Band receiver continued; the goal is to provide significantly better noise performance at room temperature than commercial low-noise amplifiers. Three prototypes of the P-Band 230-470 MHz amplifier have been evaluated and tested. The mechanical design of the amplifier body of two production versions of the amplifier is under way. New amplifier production milestones included four 1-2 GHz, four 2-4 GHz amplifiers, four 8-18 GHz, and four 26-40 GHz amplifiers. Repair, upgrade, and retesting of amplifiers included one 1-2 GHz, two 8-18 GHz, four 18-26 GHz, one 26-40 GHz and four 38-50 GHz amplifiers. In total, 28 amplifiers were shipped. The EVLA amplifier production is slightly ahead of schedule. The deliveries of 18-26 GHz and 38-50 GHz amplifiers in support of MPI Receiver Group are on schedule.

Using the THz SIS mixer test dewar, the noise temperature improvement of the W-Band 35nm MMIC LNA at lower ambient temperature was measured. Improvement of 4-6K in noise temperature was seen going from 17.5K to 8.5K ambient temperature, in agreement with theory.

**Advanced Receiver Development:** The first prototype 3-probe and 4-probe versions of the Digital OMT have been tested successfully. This not only proves the concept for the 3-probe version whose feasibility was not intuitively obvious, but shows excellent initial results with better than 40 dB linear polarization isolation. The prototype Digital Sideband-Separating Mixer (DSSM) with integrated analog-to-digital converters is complete and awaits testing.

NRAO partnered with the Keck Institute on their proposal for these 35nm InP MMIC wafer runs and will be receiving modest funds to support the design effort. This is the first of three planned wafer runs. The NRAO designs are for 68-90 GHz, 84-116 GHz, and 68-116 GHz, the possible frequency ranges for a GBT W-Band focal plane array. Continued the design concepts and performance parameters studies for a GBT W-Band (68-116 GHz) focal plane array.

The first cryogenic Digital Orthomode Transducer (DOMT) is being designed for S-Band (1.7-2.6 GHz) and will include a common-mode coaxial input for field-calibration. It is hoped that eliminating the cal coupler and injecting the calibration signal instead into an orthogonal mode, as well as minimizing the path length from the feed to the cryogenic amplifiers, will lead to a small but nonetheless beneficial reduction in noise temperature over our best current systems.

A provisional patent application, "Statistical Word Boundary Detection in Serialized Data Streams," has been filed concerning the techniques we have developed to implement low-overhead digital photonic links between receiver arrays in the field and backend signal processing facilities. The first hardware demonstration of this concept will be done using low-cost PCB's, for which the schematics are nearly complete and the layouts are in progress.

The 35nm MMIC LNAs are in fabrication at Northrop Grumman. Delivery of chips for testing is expected in early FY 2011.

**Electromagnetic Support:** Measured an X-Band phase shifter for the EVLA project to validate simulated performance. Measured and tuned Ortho-Mode Transducer OMTs for the 38-50 GHz band. Completed designs of power divider, circular-to-square transition and test transitions for the 38-50 GHz band. These components are developed for future wide band receivers for the GBT. This receiver will yield better performance on the EVLA in the 38-40 GHz range compared to the Ka-Band receiver in the same band. The GBT subreflector is translated to track the focus as the telescope is moved in elevation. A study to analyze the cross-polarization performance as a function of elevation is underway. A total of 2 EVLA X-Band (8-12 GHz) and 19 EVLA Ku-Band (12-18 GHz) phase shifters were measured and evaluated. A S/X dichroic reflector for VLBA was measured and evaluated.

**Millimeter & Submillimeter-Wave Receiver Development (mm/sub-mm):** Precise on wafer measurement of London penetration depth of Nb and NbTiN films using cryogenic probe station progressed. The new hot deposition system is the key equipment needed for the Submillimeter-Wave SIS mixer development. It allows the deposition of superconducting films with lower radio frequency (RF) loss than can be obtained with these materials deposited at room temperature. Construction of the test set to characterize the 700  $\mu\text{m}$  and 350  $\mu\text{m}$  (850 GHz) SIS mixers and development of software to allow for semi-automated testing continued.

The initial set of 700 $\mu$ m SIS circuits had too thin AlN barriers, and therefore too high current densities. We therefore have stepped back to optimize the processing parameters, specifically the nitridation growth time, to accurately produce junctions with the correct current density. Three test wafers with different nitridation times are in the final steps of fabrication. Progress has been made in direct sputtering of the AlN barrier. This is expected to give more repeatable current densities and is a necessary step in producing the NbTiN/AlN/NbTiN junctions, needed for quantum-limited SIS mixers up to 1.4 THz. The loss of the 400-500 GHz superconducting Nb hybrid did not go away upon cooling as expected. The resistivity of the substrate is the suspected culprit. The hybrid is being refabricated on high-resistivity silicon. In the continuing design of a 790-950 GHz SIS mixer, a Matlab program was developed to calculate the surface impedance of a normal metal in the extreme anomalous limits and calculated surface impedance values for 787-950 GHz for Nb, NbTiN and Al.

## **8. NRAO SKA Program Office (NSPO)**

The NRAO is developing an “industrial commissioning” model with the South African team building the KAT-7 and MeerKAT telescopes. Industrial commissioning requires capabilities such as automated procedures and testing antennas/components in batches, executable by operations personnel rather than expert scientists. The goal is to develop and test this process on the 80 antenna MeerKAT, which envisions a peak commissioning rate of more than one antenna per week. The NRAO CASA package has been adopted for KAT7 and MeerKAT commissioning and operations; CASA is also being used for ALMA and EVLA data reduction.

We have in principle agreed to manage the Dish Verification Program, DVA-I, as a 3-part project: (1) producing a design for a SKA Prototype Antenna as a deliverable of the Technical Development Plan (TDP) to South African SKA Program Development Office (SPDO), culminating in a Conceptual Design Review (CDR); (2) a costed preliminary design and plan for construction and testing of a DVA-I antenna likely at the EVLA site; (3) assuming resources are identified, actual construction and testing of DVA-I. There are milestones between each step, with opportunity for re-assessment. The DVA-I CDR is scheduled for January 2011 in Socorro, NM. The outcome of this review of TDP deliverables will determine whether we move forward to prototype construction under TDP funding.

## **9. Spectrum Management**

**IUCAF:** NRAO participates on the Scientific Committee on Frequency Allocations for Radio Astronomy and Space Science (IUCAF) and began drafting the IUCAF overall strategy-planning document for the World Radiocommunications Conference in 2012 (WRC 12). In FY 2010, NRAO participated in two weeks of International Telecommunication Union-Radio Communications Section (ITU-R) meetings finalizing preliminary draft of the WRC12 treaty text. WRC12 will be in Geneva and be preceded by a February 2011 meeting to finalize the draft input treaty text. The 3<sup>rd</sup> IUCAF Summer School was held in Mitaka, Japan in June. Geneva meetings in finalized draft WRC input text regarding footnote protection of frequencies above 275 GHz. The IUCAF vice-chair authored a White Paper regarding preferred WRC actions for items of interest to radio astronomy. NRAO drafted a revision of the ITU-R Recommendation re the importance of preserving the radio quiet environment of the L2 Sun-Earth Lagrange point.

**Chile:** NRAO met with SUBTEL in Chile while working at ALMA in May to discuss ALMA Radio Quiet Zone operations. Chile recently allocated 71 –76 GHz and 81 – 86 GHz spectrum for fixed microwave links in advance of the U.S., but extended Quiet Zone protections to these bands and made provision to exclude such links from the vicinity of ALMA.

**Continental U.S.:** The NRAO Spectrum Manager, along with the Kitt Peak National Observatory Director and an Office of the State auditor of New Mexico representative, discussed the effect of the electric US-Mexico border fence project on astronomy in Arizona. Toyota has requested that the allowed power for 76-77 GHz vehicular radars be greatly increased and requirements on radar operation be relaxed. The NRAO was the only body that responded with timely comments to the FCC. Hughes belatedly responded, favorably, to the NRAO letter of 2009 October noting FCC requirement to coordinate with NRAO regarding installation of home earth stations within the National Radio Quiet Zone (NRQZ).

**Quiet Zone Administration:** 100s of requests were processed for different frequency assignments at a variety of geographic sites within the NRQZ. Met with the FSS, City of Lewisburg, and numerous other organizations to find solutions to their needs within the NRQZ restrictions. Developing a much-needed database management tools for monitoring frequency assignments, along with a web-based front-end for frequency assignment application.

**GB Interference Protection Group (GBIPG):** In addition to the Quiet Zone work, the GB IPG replaced the 2-18 GHz amplifiers in the test chamber and gave several outreach talks and demos of its use for RFI protection. The group also worked to replace a number of radio-loud pieces of equipment on the GBT and to test all new equipment slated for deployed on NRAO Green Bank grounds. Continued survey and maintenance of regions subject to the West Virginia Radio Astronomy Zoning Act.

**EVLA site RFI Mitigation:** New wide-band EVLA receivers demand a new level of quiet from on-site operating equipment. Tested RF emissions from new copiers and office devices, converted commercial LCD monitors into ultra-low emissions devices (below EVLA protection thresholds), tested the shielding effectiveness of Long Wavelength Array (LWA) electronics container, and analyzed data.

**Wind Farms:** Six wind farm proposals for eastern New Mexico were reviewed. Field tests of ultra-high frequency (UHF) RFI generated by high voltage power transmission lines and power distribution substations were conducted.

## **10. Education and Public Outreach (EPO)**

**Media Studio:** A new Media Studio took shape in 2010 within EPO, staffed by specialists in public science communication and equipped with the technologies to produce visually rich web pages, YouTube videos, and more. This team is developing new public offerings, including media-rich public website content, virtual site tours of NRAO facilities, illustrated expositions of key radio astronomy science topics, and more. New technical capabilities are being developed to support this effort including high-definition video production and high-resolution astronomy visualization.

**Social Networking:** Social Networking efforts are generating increasing external participation. The NRAO Facebook fan numbers increased by 27% in Q4 to 2300. NRAO “tweets” have been “re-tweeted” (by recipients) 97 times in Q4, reaching ~ 33,000 people plus the many thousands of people following the #astronomy, #seti, #space, and #womeinscience hashtags. One tweet that “went viral” with re-tweets entailed our pointing to a nice ALMA EPO resource posted on the ESO website; this also demonstrates NRAO commitment to fostering success of the international ALMA EPO effort.

**Science News Releases:** More than a dozen science press releases were issued by the NRAO. A well-attended Science Writer's Conference was organized in Washington, DC in June in collaboration with NSF-OLPA and the Thirty Meter Telescope media team.

**ALMA Explorer:** The EPO team created and deployed an extensive ALMA "virtual tour" accessible via web browser.

**EVLA Demonstration Images:** A Demonstration Images project was initiated in FY 2010 that will use the new EVLA capabilities to acquire visually compelling astronomical images. Image data will be acquired at each array configuration.

**STEM Education:** Funded for three years (2008-2010) by the NSF-Innovative Technology Experiences for Students (ITEST) program, the Pulsar Search Collaboratory (PSC) partners the NRAO with West Virginia University to provide high school students with opportunities to learn 21<sup>st</sup> century skills while conducting world-class research in pulsar astronomy. The Governor's School for Math and Science – a two-week residential program for 60 rising 8<sup>th</sup> graders – was held in Green Bank for the 6<sup>th</sup> consecutive summer. The School instills a strong appreciation for mathematics and the sciences before these students make key decisions that will guide their academic and professional careers. The NRAO initiated May Term Astronomy Institutes, inviting students from minority serving-institutions to Green Bank and Charlottesville for intensive "immersion" experience into the world of science.

**SKYNET:** The NRAO was awarded \$300K by the NSF-ITEST program in FY 2010 to renovate the 20-meter radio telescope in Green Bank and provide radio-wavelength capability to SKYNET, a distributed network of robotic telescopes operated by students and faculty at the University of North Carolina - Chapel Hill.

**ViewSpace:** A multi-media program was created in FY 2010 in cooperation with the University of Virginia Center for Chemistry of the Universe. This program is delivered to the 220+ informal science education venues that subscribe to *ViewSpace*, a self-updating multi-media astronomy display produced by the Space Telescope Science Institute.

**Science Centers:** The NRAO operates a wide range of short and long-duration, formal and informal education visitor programs in Green Bank and at the Very Large Array, including scientist-involvement-rich, hands-on-with-real-gear education programs that have become our hallmark. More than 42,000 people visited the Green Bank Science Center in 2010; and 20,000+ persons visited the EVLA Visitor Center.

**SETI Workshop and Webcast:** An educational, multidisciplinary workshop—"From Project Ozma to the Starship Enterprise, a Conversation about the Next 50 Years of SETI"—was held in Green Bank in September, in commemoration of the 50<sup>th</sup> anniversary of Project Ozma. Fifty-three invited participants, including scientists, scholars, and communicators attended. EPO staff broke new ground during the conference by increasing public participation in novel ways.

## **II. Communications (COM)**

**Science Internet:** After an extensive review of the design, structure, navigation, and content of science websites at comparable observatories, the NRAO science web site was completely re-designed. The new site debuted in December COM and Computing & Information Services (CIS) are working to select

an appropriate content management system that will enable more straightforward and effective science web site content management across the Observatory.

**Science Community Meetings:** The NRAO broadly participated in the January (Washington, D.C.) and June (Miami, FL) AAS meetings. The NRAO exhibit set and space was re-designed to create a more open, welcoming, and visually interesting space to interact with the community. New support materials were created to convey NRAO science, projects and capabilities to the community, including an extensive video. A successful NRAO Town Hall was organized for the winter AAS meeting and was attended by 400 scientists. A well-attended “*Preparing for ALMA*” Special Session was proposed and organized at the summer AAS meeting. The NRAO electronic newsletter for the professional science community, NRAO eNews, has 5,200+ subscribers. COM and CIS jointly designed and organized an NRAO exhibition for the International Conference for High Performance Computing, Networking, and Storage & Analysis (SC09) in November (Portland, OR). A proposal for a VLBA-themed science symposium at the 2011 Annual Meeting of the American Association for the Advancement of Science was peer-reviewed and accepted.

**External Stakeholders:** The NRAO accepted an AAS invitation to exhibit and represent the community and the AAS at the April Coalition for National Science Funding (CNSF) exhibition for lawmakers and staffers on Capitol Hill. NRAO scientific staff visited the offices of Congressional representatives from West Virginia, New Mexico, and Virginia in conjunction with the CNSF event. Initial design and text for a FY 2010 NRAO Annual Report was completed. The Report’s target audience includes funding agencies (NSF-AST et al), AUI, the AUI Board, NRAO external committees, Observatory Libraries and Directors around the world. A copy will also be provided to every NRAO/AUI employee.

**Internal Communication:** A comprehensive internal communications plan was created and briefed to the management team 30 Sep. COM organized all-hands meetings around the Observatory and supporting multimedia content. Work began on a new NRAO Intranet site design that will transform the site into an effective internal communication tool.

## **12. Science and Academic Affairs (SAA)**

**Proposal Management:** The NRAO conducted three Calls for Proposals in FY 2010, with proposal submission deadlines of 1 October 2009, 1 February and 1 June 2010. The community submitted 249, 207, and 209 proposals in response to the October, February, and June Calls for Proposals; another 235 proposals were submitted in September for the October 2010 deadline.

**Meetings:** These FY 2010 conferences and workshops were funded either partially or in full by SAA: the 2010 Postdoctoral Symposium (Green Bank) in April; the Cometary Radio Astronomy Workshop (Green Bank) in May; the Twelfth Synthesis Imaging Workshop (Socorro) in June; and *From Project Ozma to the Starship Enterprise: A Conversation About the Next 50 Years of SETI* (Green Bank), a workshop in September.

**Scientific Staff:** Scott Ransom was awarded the 2010 Helen B. Warner Prize for Astronomy by the AAS. Dale Frail was awarded a prestigious Guggenheim Fellowship. Jim Ulvestad accepted an appointment as NSF-Astronomical Sciences Division Director. The NAASC hired scientists Adam Leroy (Asst. Astronomer/Tenure Track) and Scott Schnee (Asst. Scientist). NAASC postdoc hires were Amy Kimball (U. WA); Robin Pulliam (U. AZ); and Nuria Marcelino (Lab for Molecular Astrophysics). Jansky Fellows Glenn Jones and Nirupam Roy began their appointments in October; Ran Wang began her

appointment in April. The 2010 Jansky Fellows are Laura Chomiuk (U. Wisconsin) and Gregory Halinan (U. Ireland). NAASC scientist hires included Adam Leroy (Assistant Astronomer, Tenure Track), Scott Schnee (Assistant Scientist/A), and Stuart Corder. NAASC postdocs include Amy Kimball (U. Washington), Robin Pulliam (U. Arizona), and Nuria Marcelino (Lab for Molecular Astrophysics, Madrid).

**Grant funds** were awarded to NRAO scientific staff:

- \$38,000 from NASA to Dale Frail for “NRA/ Research Opportunities in Space and Earth Sciences” (April 2010–April 2011)
- \$135,215 from NSF to Tim Bastian, for “Imaging Spectroscopy of Coherent Radio Bursts on the Sun: a New Probe of Magnetic Energy Release” (June 2010–May 2013)
- \$507,258 from NSF to R. Craig Walker for “MRI-R2 VLBA Sensitivity” (April 2010–March 2011)
- \$61,983 from University Virginia to Rich Bradley for PAPER #2 (March–December 2010)
- \$21,402 from JPL/Spitzer to Carol Lonsdale for “IRS Observation of Four Exceptionally Red 24 Micron Sources” (March 2010–September 2011).
- \$10,000 from NSF to Karen O’Neil for the Project Ozma workshop
- \$176,800 to Scot Ransom from a PIRE grant
- \$43,000 to Rich Bradley from Cornell

**Jansky Lecture:** The 2010 Jansky Lecture will be presented in Charlottesville and Socorro by Reinhard Genzel, Director of the Max Planck Institute for Extraterrestrial Physics and Professor at the University of California - Berkeley.

**Summer Student Program:** The 2010 application deadline was February 1; offers were made March 1. Thirty students participated in the 2010 summer student program; 19 of these students attended the 12th Synthesis Imaging Workshop in Socorro; and 19 students will present their summer research results at the January 2011 American Astronomical Society meeting.

**Pre-Docs:** Rohit Gawande (UVA) worked on ultra-wide-band feeds for radio astronomy and won first place at the 2009 IEEE International Microwave Symposium low noise amplifier design competition. Paul Ries (UVA) worked with Todd Hunter on PTCS. Katie Chynoweth completed her work under the supervision of Glenn Langston (NRAO-GB) and Kelly Holley-Bockelmann (Vanderbilt) on HI observations of interacting galaxies at the GBT and VLA. Cheng-Yu Kuo (UVA) continued working with Jim Braatz on VLBI observations of H<sub>2</sub>O maser emission from galactic nuclei. Urvashi Rao-Venkata (NM Tech) worked with Frazer Owen on wide-band imaging algorithms and techniques. She completed her PhD and returned as scientific staff. Josh Marvil completed his graduate internship and began an appointment as a Pre-Doc, working with Frazer Owen.

**Student and Visiting Scientist Programs:** Visiting Astronomers included Jake Hartman and Miriam Krauss-Hartman, who were Visiting Assistant Scientists in Socorro. Jack Gallimore and Michelle Thornley (Bucknell) visited the NAASC. Robert Sault (Univ. Melbourne) visited Socorro. Sheila Kannappan came to Charlottesville in January for a five month sabbatical from UNC. Jake Hartman, Miriam Krauss-Hartman and Sarah Spolaor (Swinburne Univ.) visited Socorro. Jacqueline van Gorkom took sabbatical leave from Columbia in Socorro. Carl Melis (UC-San Diego) visited Socorro in May to work on a VLBA proposal that was subsequently designated a Key Science Project.

Graduate interns worked on a wide range of research topics at the NRAO. Abhirup Datta (NM Tech) worked on simulations of reionization and low frequency data processing. Joshua Marvil (NM Tech) worked on an EVLA study of local star-forming galaxies. Amanda Moffett (UNC-Chapel Hill) collaborated with Visiting Assistant Scientist Sheila Kannappan on the GALEX mission's discovery of

extended ultraviolet-bright disks representing very young stars around seemingly ordinary disk galaxies. Nimish Sane (U. Maryland) continued a graduate internship with John Ford on digital processing for radio spectroscopy. Charles Romero (UVA) worked with Brian Mason on the Sunyaev-Zel'dovitch Effect at high-resolution. Timothy Pennucci (UVA) worked with Scott Ransom on the NANOGrav project; and Sergio Dzib (UNAM) worked with Amy Mioduszewski on the distance of young stars as part of his PhD thesis. Leon Harding (NUI Galway) is working with Greg Hallinan on broadband periodic dynamic spectra of ultracool dwarf pulsars.

Five University of Virginia graduate students—three in astronomy, two in electrical engineering—continued work under the supervision of NRAO staff members in Charlottesville. Bin Chen (UVA) continued to work with Tim Bastian, funded by an NSF/AGS grant; Paul Ries (UVA) continued to work with Todd Hunter, funded via the NRAO Student Observing Support program; Nicole Gugliucci (UVA) continued to work with Rich Bradley, funded via PAPER; Rohit Gawande and Chatili Parashare (UVA) also continued to work with Rich Bradley.

Nine New Mexico Tech undergraduates continued undergraduate internships working in the Electronics Division in Socorro, working on the EVLA: Dana Sills, Cameron Welch, Aaron Cunningham, Deepak Rai, Sara Waters, James Durand, Jordan Leak, Scott Scott Davidson, and Matt Tibbetts. Emily Jones (WVU) built an encoder test fixture in Green Bank.

Kenneth Johnson completed a four-month co-op program appointment in Socorro in December.

**Student Observing Support (SOS):** Six Trimester 2010A student proposals were awarded funding that totaled \$99,784; six Trimester 2010B student proposals were awarded funding that totaled \$158,400; and four Trimester 2010C student proposals were awarded funding that totaled \$106,500.

**Library and Historical Archives:** The NRAO Library completed full-text scanning of the GBT and EDIR memo series that are now available electronically. This project will continue until all NRAO Memo Series and reports are available digitally. The Library scanned three NRAO workshop title and made them available electronically. Historical Archives received materials to be digitized and catalogued, including papers of Ronald N. Bracewell, David S. Heeschen, Woodruff T. Sullivan III, and materials from the NRAO Director's Office. Web pages were created the IAU Historic Radio Astronomy Working Group.

### **13. Computing & Information Services**

**Common Computing Environments (CCE):** Successfully completed second ALMA User Portal and Helpdesk integration test. The Plone Content Management System, version 4, has been installed and is being populated. Plone installed and configured to replicate the style and structure of NRAO science web site, which will allow for workflow control over online document and content publication. ALMA/NRAO High Availability servers are now in place running the Helpdesk and Plone web-based Content Management System and User Portal including user authentication to JAO user database. Improved security on passwords and digital signatures was put in place.

**Networking and Telecommunications:** Transitioned long distance, international, calling cards and voice/web conferencing to the new Networx contract. Only the Brewster WA VLBA site remains from WAN upgraded in October. Substantial progress has made in the on-going commitment to upgrade all major sites to 1Gigabit/sec to facilitate data access. The Internet bandwidth upgrade was completed in Charlottesville and Socorro. The WV State awarded \$8M million in economic stimulus funds to deliver

10 Gbit/sec from Green Bank to WVU and on to the North American Research Networks, which will be complete Q4 FY 2011. A contract has been finalized with AURA for 1 Gigabit/Second link from ALMA SCO to NA-ASC with connectivity in Q1 FY11. ARRA funds have been used to successfully replace the PBX and Voicemail system used throughout the Green Bank WV site.

**Digital Infrastructure:** ALMA archive servers, User Portal and Oracle Database are now running in Charlottesville with initial test data on-line. The Next Generation Science Data Archive System (NGDAS) servers are now storing and replicating production EVLA data in Socorro, leveraging high speed Lustre file system for staging data for CASA. Access to 200 TeraBytes of Archive storage and 100,000 hours of computer time is being leveraged from NSF TeraGrid to support the re-use of the 350MHz GBT pulsar survey data.

**Security:** An IT Risk Assessment review was successfully completed with Cherry, Bekaert & Holland, L.L.P., who were engaged by AUI; a HIPAA review was completed with Mercer. Recommendations from both reviews will continue to be executed throughout FY 2011.

#### **14. Observatory Management Services**

**Human Resources:** Observatory management focused on recruitment efforts associated with diversity. An independent diversity consultant was engaged to facilitate the process. An action plan that builds a diversity support network across the Observatory was created. The NRAO implemented a Diversity Advocate model and incorporated broader impact/diversity goals into the annual employee evaluation process. Recognition of the NRAO initiatives in Diversity Careers magazine resulted in a noticeable increase in diversity among NRAO employment applications. An initiative to assist Howard University in further developing its astronomy program was completed. NRAO scientists are collaborating with Howard University faculty and students, and appropriate internship opportunities have been created in Green Bank. A thorough review of NRAO compensation process was completed. Human Resources completed an assessment of Observatory critical skills in preparation of completing the Observatory Staffing Plan required for the Long Range Plan. An evaluation of the effectiveness of NRAO recruitment efforts was also completed.

**Fiscal:** The Fiscal Division assisted throughout FY 2010 with the design and implementation of the Other Direct Cost (ODC) allocation pool. Management Information Services (MIS) stabilized and enhanced data mining for the NRAO Electronic Time Keeping (ETK) systems. Planning continued for a major J. D. Edwards software upgrade to the latest EnterpriseOne version. Three unplanned activities required significant resources: an investigation of AUI Recommended Cost Pools, an AUI IT Risk Assessment, and a NSF DCAA Audit. Contracts and Procurement shifted resources and workload to place a high priority on ARRA projects. The major OMB A-133 audit was completed February 4; preparation for the audit began June. Fiscal Division supported an audit and review of FY 2010 ARRA expenditures by the IG/DCAA, as requested by the NSF. An entrance conference with NSF, DCAA, AUI, and NRAO was held March 3. Audit fieldwork was conducted in Socorro in late June, and will be conducted at Green Bank and Charlottesville in Septemeber. Fiscal completed site visits to possible electronic archiving systems vendors and is working with MIS to determine the hardware requirements to implement each system.

**Contracts and Procurement:** The Observatory-wide contractor procurement system review (CPSR) report was finalized by CBH, internal auditors and actions continue to be taken to address recommendations. The Buyers completed FY 2011 having issued 6,077 purchase orders for ~ \$29.850M. Significant time and energy used to support the increasing number of audits. A procurement review was

conducted in Chile for Q1 FY10 activity; a procurement review for Q2 through Q4 is scheduled for December 2010. Import/export activities increased 74% from FY 2009 to FY 2010, with 650+ transactions. ARRA expenditures were major focus in FY 2010, and we have been working with NSF in Q4 to re-align remaining ARRA funds to new projects. BDO Seidman, the external auditor, will conduct an audit of ARRA awards in FY 2011. The CAP manuals have been escalated to a higher priority level.

**Environmental Safety & Security (ES&S):** Coordinated safety/security issues and requirements with key NM Tech personnel. Working with the NM Tech Emergency Coordinator, ES&S surveyed campus flood hazards and their mitigation as they affect NRAO employees and discussed various security issues including earthquake and “active shooter” awareness. We discussed security concerns with NM Tech Police Department Chief and advised him of DSOC employee schedules to enable his department to provide additional security. EVLA site security issues were discussed and reviewed with the Socorro County Sheriff. ES&S conducted safety walk-through to educate staff. ES&S developed and implemented a process to distribute the Weekly Safety Topics to all NRAO facilities via an on-line Safety Blog. A PowerPoint safety overview was developed for visiting scientists and a new DSOC-based employee safety orientation was created.

EVLA Site support by ES&S included training sessions in Lockout/Tagout and Cranes, Hoist & Slings and Slip, Trip and Fall awareness, as well as Understanding Safety at work; plus new employee safety orientations. The Safety Office attended weekly coordination meetings, monthly safety committee meetings and ES&S coordination meeting. ES&S supported environmental/green initiatives in NM, transporting ~ 120 lbs. of used batteries to the EVLA holding facility and ~ 15 gallons of used isopropyl alcohol to the used oil facility. Additional green initiatives included 2,960 lbs of Lead-acid Batteries with Wise Recycling, 2,161 gallons of dyed diesel and oil with Mesa Environmental, 350 gallons of antifreeze, 300 gallons of heavy grease, and 200 gallons of machining oil. ES&S assisted the Datil Fire Department with required NFPA hoses testing. The Safety Officer assisted Magdalena Fire and EMS with ambulance and fire truck inspection and responded under mutual aid agreement. Regular monthly and quarterly inspection and testing were conducted for fire extinguishers in buildings and at the antennas.

Green Bank facilities recycling efforts continued with 500 gallons of used oil recycled Q4. Site sewer water treatment system continued within limits performance for the third successive year. An annual site OSHA inspection was conducted at GB in July found no major issues to report. Training was conducted in the area of Respiratory Protection refresher and new employee safety orientations.

All VLBA sites were updated with first aid kits and/or supplies.

ES&S travelled to the Operations Support Facility site in northern Chile in Q4 to actively participate in an ALMA Executive Safety meeting that was refocused to support the accident investigation and determine safety rules and procedure changes. ES&S also supported the ALMA Front End Service Vehicle Design Review in Taiwan.

OSHA-mandated training for the NTC was completed. The NTC now has an internally operated Fire Extinguisher management program, and a volunteer Safety Coordinator to ensure that we take full advantage of internal resources before we use outside resources. All Building Maintenance and Fire Extinguisher Inspections were completed.

## Acronyms

Acronym	Definition
AAS	American Astronomical Society
AA	Antenna Article
AAT	Archive Access Tool
ACA	ALMA Compact Array
AIPS	Astronomical Image Processing System
AIV	Assembly Integration and Verification (AIV)
ALMA	Atacama Large Millimeter/submillimeter Array
AOS	Array Operations Site (ALMA, Chile)
ARRA	American Recovery and Reinvestment Act of 2009
ARC	ALMA Regional Center
ATCA	Australian Telescope Compact Array
AUI	Associated Universities, Incorporated
BE	Back End
CARMA	Combined Array for Research in Millimeter Astronomy
CASA	Common Astronomy Software Application
CCA	Cold Cartridge Assembly
CDL	Central Development Laboratory
CDR	Critical Design Review
CfA	Center for Astrophysics
CFRP	Single pitch carbon fiber reinforced plastic
CICADA	Configurable Instrument Collaboration for Agile Data Acquisition
CIS	Computing and Information Services
CLOA	Central LO article
CNSF	Coalition for National Science Funding
CONAMA	Comision Nacional del Medio Ambiente
CPSR	Contractor procurement system review
CSV	Commissioning and Science Verification (ALMA)
DBE	Digital Backend
DiFX	Distributed FX correlator
DOMT-X	Digital Ortho-Mode Transducers
DRAO	Dominion Radio Astrophysical Observatory
DRXA	Data Receiver Articles
DSN	Defense Switched Network
DSS	Dynamic Scheduling System
DSSM	Digital Sideband Separating Mixer
DVA-I	SKA Dish Verification Program
ECSO	EVLA Commissioning Staff Observing
EPO	Education and Public Outreach
ES&S	Environmental Safety & Security
ESO	European Organisation for Astronomical Research in the Southern Hemisphere
ETK	Employee Timekeeping System
EVLA	Expanded Very Large Array
FCC	Federal Communications Commission
FE	Front End
FEIC	Front End Integration Center
FESS	Front End Support Structures
FO	Fiber Optic
FPA	Focal-Plane Array
FY	Fiscal Year (October 1 through September 30)
GB	Green Bank, WV

<b>Acronym</b>	<b>Definition</b>
GBIPG	GB Interference Protection Group
Gbps	Giga-bits per second
GBT	Green Bank Telescope
GHz	Gigahertz
GMOS	Gemini Multiobject Spectrographs
GSPS	Giga-Samples Per Second
GUPPI	Green Bank Ultimate Pulsar Processing Instrument
HBT	Heterostructure bipolar transistors
HIA	Herzberg Institute of Astrophysics
HR	Human Resources
IAU GA	International Astronomical Union (IAU) General Assembly (GA)
IEEE	Institute of Electrical and Electronics Engineers
IF	Intermediate Frequency
IPT	Integrated Product Team
IRAM	Institut de Radioastronomie Millemétric
ITEST	NSF-Innovative Technology Experiences for Students program
ITU-R	International Telecommunication Union-Radio communications Sector
IUCAF	Scientific Committee on Frequency Allocations for Radio Astronomy and Space Science
JAO	Joint ALMA Office
JPL	Jet Propulsion Laboratory
KFPA	K-Band Focal Plan Array
LLC	Line Length Correctors
LNA	Low noise amplifier
LO	Local Oscillator
LO/IF	Local Oscillator/Interim Frequency Systems
LPR	LO Photonic Receivers
LRU	Line Replaceable Unit
LUNAR	Lunar University Node for Astrophysics Research
LWA	Long Wavelength Array
M&C	Monitor and Control
Mbps	Mega-bits per second
MHz	Megahertz
MIS	Management Information Services
mm	millimeter
MMIC	Monolithic Millimeter-wave Integrated Circuit
MOU	Memorandum of Understanding
MPI	Message Passing Interface
MPIfR	Max Planck Institut für Radioastronomie
MRI	Major Research Instrumentation
μas	Micro-arcsecond
μJy	microJansky
MUSTANG	Multiplexed SQUID/TES Array for Ninety Gigahertz
NA	North American
NAASC	North American ALMA Science Center
NA-FEIC	NA Front End Integration Center
NAOJ	National Astronomical Observatory of Japan
NASA	National Aeronautics and Space Administration
NCSA	National Center for Supercomputing Applicatons
NGAS	Next Generation Archive System
NIST	National Institute of Standards and Technology
NRAO	National Radio Astronomy Observatory

<b>Acronym</b>	<b>Definition</b>
NRQZ	National Radio Quiet Zone
NSF	National Science Foundation
NTC	NRAO Technology Center (Charlottesville, VA)
OMT	OrthoMode Transducer
OOF	out-of-focus
OPT	Observation Preparation Tool
OSF	Operations Support Facility (ALMA, Chile)
OSHA	Occupational Safety and Health Administration
OSO	Observatory Science Operations
OSRO	Open Shared Risk Observing
OT	Observing Tool
PAPER	Precision Array to Probe the Epoch of Reionization
PAS	Bands for passive systems
PASEO	Panel to Advise on Science and EVLA Operations
POPT	Production Optical Pointing Telescope
PSC	Pulsar Search Collaboratory
PST	Proposal Submission Tool
PTCS	Precision Telescope Control System
Q	Fiscal Quarter
QSU	Quarterly Status Update
R&D	Research and Development
RF	Radio Frequency
RFI	Radio-Frequency Interference
RSRO	Resident Shared Risk Observing
SAA	Science & Academic Affairs
SIS	Superconductor–Insulator–Superconductor
SKA	Square Kilometre Array
SNR	SuperNova Remnant
SPDO	South African SKA Program Development Office
SRO	Shared risk observing
SRT	Sardinia Radio Telescope
STANCE	Self-Tending Array Node and Communications Element
SAS	Sub-Array Switch
TACC	Texas Advanced Computing Center
TDP	Technical Development Plan
UNAM	Universidad Nacional Autonoma de Mexico
UHF	Ultra-High Frequency
USNO	United States Naval Observatory
UVa	University of Virginia
VAO	Virtual Astronomical Observatory
VLA	Very Large Array
VLBA	Very Long Baseline Array
VLBI	Very Long Baseline Interferometry
WIDAR	Wideband Interferometric Digital Architecture
WBS	Work Breakdown Structure
WCA	Warm Cartridge Assemblies
WRC	World Radiocommunication Conference
WV	West Virginia
WVU	West Virginia University