Consolidated Monthly Reports on GBT Project Coordination: March 1998-March 2001

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Contents

I. Introduction

The Green Bank Telescope (GBT) construction project was largely comprised of two parts: the contract to build the antenna structure, and the work undertaken by NRAO to build all the hardware and software systems that make the structure a working radio telescope. Monthly status reports were written to document the progress on NRAO's part of the work from March 1998 through March 2001. Within this timeframe, the telescope was accepted from the contractor, recorded its "first light", formally dedicated, outfitted with hardware and software systems, commissioned, and brought into science operations, all while the antenna contract was in dispute through binding arbitration. The reports document the variety and magnitude of problems encountered and overcome by a dedicated Green Bank staff during the project. The reports were distributed to a local archive, some members of NRAO management, and occasionally the NSF, but they have yet to be cataloged in NRAO's permanent historical record (e.g. as part of a memo series). The purpose of this memorandum is to consolidate the reports into a single document for NRAO archiving.

The monthly reports do not cite two important dates in the GBT construction project, which are important to note for context:

- COMSAT became a subsidiary of Lockheed Martin on August 2, 2000. Prior to this date, the monthly reports refer to the antenna contractor as COMSAT. After that date, the reports refer to the contractor as Lockheed Martin (LM).

- On February 12, 2001, an arbitrator reached a decision in the dispute between LM and AUI regarding additional costs on the contract to design and construct the GBT. The decision called for AUI to pay LM approximately $4 million over the contract amount, in contrast to the $29 million that LM originally sought.

Monthly reports were not written in September and October 1998 because an intensive program to measure radio frequency interference (RFI) from the Iridium satellites with the 140-Foot Telescope was conducted at the time.

In January 2001, the title of the monthly reports changed from *GBT Monthly Systems Report on Project Coordination* to *GBT Monthly Report* in recognition that construction of the antenna was largely complete and that NRAO controlled activities at the telescope by that time.

Two monthly reports are particularly noteworthy. The August 2000 report documents the telescope's first light observation and its formal dedication only three days later. The March 2001 report highlights the GBT's first science observation, yet only to announce that the science program was suspended due to problems with the telescope's azimuth track.

II. 1998

A. GBT Monthly Systems Report on Project Coordination for March 1998

A draft of the GBT commissioning plan was written. More detailed plans and schedules for commissioning will be developed from this general plan.

Fisher, Maddalena, Braatz, and McKinnon reviewed Condon's ideas on the detailed astronomical observations required for commissioning. Essentially all of these observations are of the same type ("self-correcting" cross-scans of radio sources) and therefore require similar data analysis procedures. Condon emphasized the importance of collimating and focusing the telescope before conducting general pointing observations. He also emphasized the need to completely understand the expected performance of the telescope before its commissioning. Srikanth can provide much of the RF performance information. The Spectral Processor may be needed for total power measurements during commissioning for polarimetry and RFI rejection.

Chuck Beverage agreed to maintain schedules for outfitting and commissioning the GBT. He will start his scheduling work by updating Norrod's initial outfitting schedule.

A budget was prepared for items required at the GBT site for the telescope's commissioning and initial operation. The budget total is $1.2M. Items in the budget were prioritized. $178K was requested for items this year. Of this amount, it appears Green Bank will receive only $70K, and that is for optical fiber cable.

Other NRAO sites were asked to provide technician labor to help terminate cables on surface panel actuators. Tucson may be able to provide two technicians for two months provided the cables are terminated during the summer shutdown of the NRAO 12-meter Telescope. Socorro volunteered one man-month to the effort.

The uncertainty in the contractor's schedule makes it difficult to plan a specific date for cable termination. This activity needs to be coordinated with the contractor so that NRAO staff can work in a level actuator room.

The scientific staff in Green Bank discussed the fate of the 140-Foot Telescope. The current plan is to cease general user observations on the 140-Foot at the end of 1998. At that time, telescope operator positions can be transferred to the GBT provided that no other users can pay for operating the 140-Foot.

Priorities were suggested for items in the 1998 Green Bank Research Equipment (RE) plan. The top two priorities were the GBT Q-band receiver and new receiver calibration devices. A topic of particular interest in the RE meeting was the 26-40 GHz receiver. It may be possible to produce a single receiver to cover the entire band in linear polarization. Two receivers, one at 26-33 GHz and another at 33-40 GHz, are required if circular polarization is required. RF engineers are evaluating the trade-off in system noise for the single broad-band receiver. Condon solicited input from the NRAO scientific staff on the relative importance of the 26-33 GHz and the 33-40 GHz bands. The staff stated that 26-33 GHz is the scientifically more important band.

Norrod, Hunt, Maddalena, Clark, Ford, Brandt, and McKinnon discussed software support for the mockup because mockup testing had been stalled due to apparent software problems. Many problems occurred because mockup tests and software development tests were not coordinated. A "sign-up" board has been installed near the mockup to avoid future problems in the scheduling of tests. As a result of this discussion, a "generic" device in the form of a VME computer was assembled for Maddalena so that he could test his operator/engineer interfaces independently of specific devices.

Gary Anderson inquired if solar observations would be made with the GBT prime focus receiver (PF Rx). His inquiry was forwarded to Tim Bastian (NRAO-AOC), who doesn't "expect any requests to point the GBT at the Sun in the near term". However, future observations of the Sun with a high-frequency multi-feed array may be desirable.

Applications for the mechanical engineering position were reviewed, and a short list of potential candidates was made. One candidate has been interviewed, and others will be interviewed in April.

B. GBT Monthly Systems Report on Project Coordination for April 1998

Comments were received on the preliminary general plan for commissioning the GBT. Detailed commissioning plans and schedules will be developed over the next few months.

Interviews were scheduled for three potential candidates for the mechanical engineer's position.

Extensive measurements of RFI from GBT electronics have been made in the anechoic chamber. These electrical devices must be modified if the RFI generated by them exceeds a certain level. In shielding the devices, one would like to know how much shielding is provided by the GBT Receiver Room. Investigations have begun to determine what is required for measuring the shielding effectiveness of the Receiver Room.

C. GBT Monthly Systems Report on Project Coordination for May 1998

Fisher, Condon, and McKinnon started to develop detailed commissioning plans and schedules.

Three potential candidates for the mechanical engineer's position were interviewed.

Condon and McKinnon developed an agenda for the GBT Science Workshop and reminded potential participants of the registration deadline (June 1). Braatz will assist in the local organization of the workshop.

Fisher and Norrod are developing plans for RFI testing of the GBT Receiver Room.

Lockman formed a working group on GBT operational modes. The general charge to the group is to help NRAO-GB produce a summary document that defines the observational modes expected for the GBT and their priority.

Pedtke and McKinnon derived the objectives and specifications for the Q-band tertiary reflector from GBT Memorandum 141. The objectives and specifications were forwarded to Condon for scientific evaluation/approval.

D. GBT Monthly Systems Report on Project Coordination for June 1998

Schiebel, Wells, Payne, and McKinnon are pinpointing the locations of the elements of the quadrant detector. King is forwarding the dimensions of the telescope structure needed to locate and size the small hole in the primary reflector that is required for the detector.

Condon developed scientific requirements for GBT metrology. The requirements and their implications were discussed in a meeting of scientists, metrologists, and software engineers. Action items were assigned to converge upon an appropriate strategy for integrating laser metrology into the monitor and control (M&C) system for Phase III operations of the telescope.

A GBT Coordination meeting was held on June 16, 1998. Issues raised at the User's Committee Meeting were discussed. The Users wanted to keep the 140-Foot Telescope open through mid-1999. They also wanted to see the results of mockup testing posted in a public forum. RFI tests of the GBT Receiver Room were discussed. NRAO will perform much of the work required to prepare the room for the tests. Concern was expressed that the contractor has not purchased an RFI door for the room, but NRAO may be able to fabricate a temporary door for the tests. The agenda for the upcoming GBT Science Workshop was briefly reviewed. It has been difficult to record accelerometer data at the GBT. Lawrence was given the responsibility of coordinating data recording sessions in the future to avoid or minimize problems with the accelerometers.

Fisher and Norrod developed plans for RFI testing of the GBT Receiver Room.

The objectives and specifications of the Q-band tertiary reflector summarized in GBT Memorandum 141 were reviewed and endorsed by Condon. McKinnon will summarize the objectives and specifications in a memo to the GBT archive.

E. GBT Monthly Systems Report on Project Coordination for July 1998

A GBT Coordination meeting was held on July 16, 1998. Given recent personnel changes, Ford clarified some areas of responsibility in the Electronics Division. Amy Shelton is working on the GBT active surface. Tim Weadon is responsible for the panel setting tool and the moving of the timing center to the Electronics Room. J. D. Nelson is transferring from telescope operations to the digital group. Dan Pedtke is developing the fiber optic E-stop. Many people in Electronics are routing actuator cables at the GBT now. Ford also suggested that we postpone the routing of cryogenic lines at the GBT. Manpower shortages in Electronics and site-wide problems in cryogenics have slowed the routing of the lines at the GBT. Although Steve Reeves has developed plans for cable routing at the elevation cable wrap, an overall plan has not been developed. Electronics will develop this plan. Jerry Lawrence will determine if postponing the cryogenic line work will affect COMSAT's plans. McKinnon reviewed the results from the recent meeting on the scientific requirements for metrology. The requirements are discussed in a memorandum to Jay Lockman from Jim Condon. Dana Balser recorded the minutes of the meeting in a memorandum to the GBT archive. Condon will revise his memorandum so that it can be included in the GBT memo series. McKinnon reviewed the agenda for the upcoming GBT

Science Workshop. Integrated testing and programming of the Spectrometer were briefly discussed.

Over 50 people attended the GBT Science Workshop on July 27-29. Capabilities of the GBT were discussed by the Green Bank staff on the first day of the workshop, and science with the GBT was discussed by potential users on the second day. GBT commissioning issues were discussed on the final day of the workshop. Workshop participants made specific recommendations on priorities for commissioning and Spectrometer observing modes, integrated software and hardware testing, and the development of future hardware.

Dennis Egan was hired as the mechanical engineer. He will report to work on August 24.

F. GBT Monthly Systems Report on Project Coordination for August 1998

Jim Ruff, a mechanical engineer from the VLA, spent the summer in Green Bank to work on GBT mechanical issues. Most of his time was devoted to developing a detailed design of an access platform for the PF Rx in addition to a powered cart for the receiver. Among many other things, he also prototyped a watch spring-type wrap for the optical fiber cable, designed a convenient access to a feed arm laser, developed a concept to increase the torque on the Receiver Room turret drive, made recommendations for convenient access to the elevation bearing retroreflector, and investigated the installation of the pintle bearing seal.

Gary Anderson, George Behrens, and Jim Ruff noted that the limited real estate in the prime focus area, as well as in the GBT elevators and walkways, will limit the size of receiver boxes and feeds to a maximum diameter of about six feet. This means that future low frequency receivers may have to incorporate deployable feeds or other unconventional feed designs to overcome the space limitations.

Rudy Latasa, the cryogenics supervisor from the VLA, made an evaluation of Green Bank cryogenics on August 25-27. He made a number of recommendations on cryogenic-related issues around the site. The majority of his recommendations will be implemented. Rudy thought the GBT cryogenic lines were being properly routed. He recommended that all the installed cryogenic lines be leak-checked, tightened, and helium-pressurized. He stated that the ends of cut tubing should be reamed so that the cuttings will not cause sealing problems for valves in the cryogenics system. Weld slag (from the contractor’s welding on the GBT structure) has stained the cryogenics lines, and Rudy suggested that these lines be cleaned and insulated to minimize their deterioration.

Roger Norrod, Bob Simon, and others have been preparing the GBT Receiver Room for RFI testing. A temporary RFI door is being built, openings in the building walls are being sealed with metal plates, the conductive turret seal is being installed, conductive paint has been applied where needed, and cables that penetrate the building walls have been removed.

Bob Hall was concerned that the geometry of the surface panel gaps (e.g. trapezoid versus rectangle) might affect the RF performance of the antenna. Rick Fisher reported that the geometry doesn't really deteriorate the performance as long as the total area of the gaps does not exceed the specifications for the reflector surface.

A GBT Coordination meeting was held on August 11, 1998. Jody Bolyard, the new site safety officer, was introduced. Jody's help will be much appreciated as Green Bank staff spend more time at the GBT site. It was emphasized that Dan Pedtke is responsible for the overall design of the tertiary reflector for the Q-band receiver. Bob Hall is concerned about protecting the tertiary from falling ice and other environmental effects. The GBT Science Workshop, integrated testing, and Spectrometer operation were also discussed at the meeting. Most people at the meeting felt that good progress has been made in developing individual pieces of hardware and software, but more effort needs to be devoted to integrated testing. Some suggested that single dish users should be solicited for help in end-to-end testing of GBT electronics and software. User documentation is needed for the Spectrometer and for spectral line data reduction in AIPS++. A more concentrated effort needs to be devoted to on-line data analysis for quick feedback during commissioning and initial observations. AIPS++ personnel are focusing their efforts on the Measurement Set so that data fillers can work faster.

III. 1999

A. GBT Monthly Systems Report on Project Coordination for November 1998 to January 1999

Issues affecting metrology integration and pointing are identified, addressed, and sometimes resolved at weekly meetings. Goldman, Balser, and Wells developed analytical methods to convert laser rangefinder measurements to telescope pointing coefficients. Sandell proposed an optical guide telescope for the GBT. The proposal was well received, and the guide telescope should be particularly helpful in measuring tracking stability of the GBT. Jewell has indicated that a turnkey guide telescope may be available from NRAO-Tucson. Multipose photogrammetry has not accurately calibrated the lengths of the actuators on the subreflector, and the pointing group is exploring alternative calibration methods. For example, one experiment has begun to record inclinometer data at various orientations of the subreflector. Brandt arranged for the recording of the data, and Wells has been analyzing it. Wells has mentioned that errors in the subreflector surface can potentially be corrected with the active surface of the primary reflector. Members of the group also noted that the GBT holography system operates at prime focus and, therefore, does not measure surface irregularities in the subreflector.

A number of items required for the GBT site have been purchased for GBT operations. All of the items were identified in a GBT site list in March 1998, and include safety equipment, radio communications equipment, an operations vehicle, a manlift, components for remote E-stops, and furniture for the GBT control room.

Arrangements were made to hire junior technicians for continuous testing of the GBT subreflector servos. The tests were run 24 hours per day for approximately 30 days in November 1998. No servo failures occurred during the tests. Wells and Brandt are investigating glitches in positions of the subreflector actuators that were found in data recorded during the tests. Servo tests at prime focus should occur in February 1999.

Maddalena identified resources required to test the GBT holography system on the 140-Foot Telescope. His proposal will be reviewed to reassess the test objectives, refine the scope of work, and formally schedule the tests.

RF engineers have not been able to combine all five PF Rxs into a single box. The combined design also requires swapping dewars in the box for certain frequency changes. In order to expedite the completion of the PF Rxs and to avoid the operational headaches inherent to a dual-dewar design, McKinnon decided to construct two separate prime focus boxes. The existing PF Rx 1 will be completed with GBT project funds. PF Rx 2 will be completed with RE money: $25K from 1998 RE and $25K from 1999 RE.

Anderson, Stennes, Ford and McKinnon developed a formal schedule to complete the S-band and prime focus #1 receivers by mid-May 1999. The schedule also helped establish priorities in the machine shop.

B. GBT Monthly Systems Report on Project Coordination for February 1999

A detailed review of the GBT Project was held with Phil Jewell, Paul Vanden Bout, and Bob Hall on February 3, 1999. All group leaders reported on the status of their work. A number of problem areas were identified at the meeting, including manpower shortages in both M&C and Green Bank cryogenics, the need for information on how to accommodate VLBI observations on the GBT, the need for a "Friend of the GBT Spectrometer", and the continual struggle with the contractor's problems on servos. The primary action item generated in the meeting was to produce schedules that show how NRAO completes its work before the end of 1999. Draft and formal schedules are to be complete in three and six weeks, respectively. McKinnon circulated scheduling guidelines to ensure uniformity and consistency in group schedules. The group leaders have completed their draft schedules.

Goeran Sandell is developing detailed plans and schedules for telescope commissioning that are based upon McKinnon's general commissioning plan. Initial drafts of the detailed plans will be available in early April 1999.

Amplifier delivery dates were discussed with Bradley and Thacker at the Central Development Laboratory (CDL). The 800 MHz amplifiers were delivered to Green Bank on February 16. About ten Q-band amplifiers are produced at the CDL each month, and delivery to NRAO operational sites is made on an as needed basis. Some confusion exists as to whether additional S-band amplifiers will be produced by the CDL for the GBT. No additional amplifiers are needed if the performance of the on-hand S-band amplifiers is found to be satisfactory.

The general plan for tests of the GBT holography system on the 140-Foot Telescope were finalized and scheduled. Hardware will be tested during a one day session in April 1999. A contingency test session has also been set aside for mid-May. The actual holography observing runs (observations of satellites and astronomical sources) are scheduled for a two day session in mid-June. The holography tests are being designed to have essentially no impact upon the GBT M&C group.

Group leaders estimated the cost to complete NRAO systems for the GBT and made specific recommendations to senior management on how to complete major portions of the project within the project's budgetary constraints.

C. GBT Monthly Systems Report on Project Coordination for March 1999

The position of the GBT subreflector needs to be measured with the laser rangefinders to (1) align the foci of the primary and secondary reflectors and (2) verify the motion of the subreflector for proper operation and calibration. Two methods, which place mutually exclusive requirements upon the orientation of the retroreflectors within their mounts on the subreflector, had been proposed to achieve these objectives. One method required that the limited opening angle of the retroreflectors be aligned with the feed arm lasers, and the other method required an alignment that is optimized to the ground lasers. It was decided that the ability to range on the subreflector retroreflectors from the feed arm lasers would provide more flexibility in measuring subreflector motions, particularly during the commissioning of the telescope, and that the retroreflectors should be installed accordingly.

Priorities for the 1999 RE budget were proposed. The proposed priorities are, in order, Q-band receiver, PF Rx 2, interference monitoring station, L-band array feed prototype, and Ka-band receiver. A meeting will be held to discuss these priorities, as well as other projects requiring RE funds.

In late February and early March, group leaders prepared schedules to complete the work on NRAO systems for the GBT. These schedules are being consolidated into an overall project schedule.

At the request of upper management, specific project milestones were identified as potential topics for formal press releases when the milestones are achieved. Some examples are point-to-point measurements with the ground laser rangefinders, complete the integration of the Spectrometer into the GBT M&C system, first pointing observations, first laser rangefinder measurements of the primary reflector, and completion of the Q-band receiver.

Cecilia Barnbaum will be visiting Green Bank for six weeks this summer to write user documentation for the Green Bank site and various aspects of the GBT.

D. GBT Monthly Systems Report on Project Coordination for April 1999

The project budget and a consolidated schedule to complete NRAO systems on the GBT were reviewed at a GBT Coordination meeting on April 27. Much of the schedule is keyed to the shutdown of the 140-Foot Telescope on July 26. Toward the end of July, GBT receivers will be moved from the 140-Foot to the Jansky Laboratory for refurbishing, and other equipment, such as the SAO maser, Spectral Processor, and VLBA Data Acquisition Rack, will be moved to their permanent locations in the Electronics Room. The control of the Spectral Processor will then be integrated into the most recent version of the GBT M&C software. It was agreed that a temporary local control facility (besides the COMSAT warehouse) was not needed; the telescope can be temporarily controlled from the alidade Servo Room. Efforts are underway to complete operator, engineer, and astronomer interfaces to the GBT by the end of July so that general tests of the mockup and evaluations of the graphical user interfaces (GUIs) can be made. Those attending the meeting provided valuable input to make the schedule as realistic as possible.

The proposed list of priorities for 1999 RE funds was endorsed in a meeting on April 27. The final list of priorities is (1) complete the Q-band receiver, (2) complete PF Rx 2, (3) complete the interference monitoring station, (4) complete the prototype for an L-band focal plane array, (5) the GBT Ka-band receiver, (6) outfit the anechoic chamber with test equipment suitable for operation through 3mm, and (7) a machine to build/repair surface-mount PC boards.

Maddalena, Braatz, White, and Granados made engineering tests of the GBT holography system with the 140-Foot Telescope on April 20 and 21. The RMS noise in the phase measurements was much smaller than expected; therefore, Maddalena concluded that the instrumental contribution to the overall phase RMS will be insignificant. Problems with hardware nonlinearities, software, and satellite positions that were identified during the tests are being addressed. Astronomical tests of the holography system will be made later this summer.

A meeting on pointing/metrology integration was held on April 28. Parker and Creager reviewed the Metrology Group's recent point-to-point measurements of the ground laser rangefinders. Preparing for these automated tests revealed hardware and software problems that were quickly solved. Data recorded during the tests showed the strong effects of varying atmospheric refraction. Additional tests using more rangefinders need to be made so that a regression analysis can be performed with the rangefinder data. Brandt finalized the protocol for pointing synchronization messages in the GBT M&C software. It is possible that the VLA/VLBA can loan us inclinometers for measurements of the GBT structure. The effects of recent revisions to the project budget upon metrology and pointing were briefly reviewed.

E. GBT Monthly Systems Report on Project Coordination for May 1999

Funds were received from the Observatory's 1999 RE budget to complete a dual beam, dual polarization Q-band receiver. Outstanding issues regarding the receiver design were resolved at a detailed design review on May 18. The procurement of remaining receiver components has begun. Additional work is needed to define specific requirements for the receiver's tertiary mirror so that the detailed design and costing of the mirror can proceed.

Priorities for operational items needed at the GBT site were reviewed, and money from the GBT site account was allocated to items such as safety equipment, substation power monitor, cryogenics, front end (FE) carts, and dummy FE loads.

After a review of the NRAO-internal project schedule, the software development group investigated methods to accelerate the integration of the Spectrometer into the M&C software. Specific areas of responsibility for the development of Spectrometer code were redefined. Glen Langston is providing much needed help with the Spectrometer's data handling software.

The VLA/VLBA loaned inclinometers to Green Bank for measurements of the GBT structure.

The machine shop completed the feed transition and dewar for the S-band receiver. The S-band feed is nearly complete. Additional shop work needed to complete the entire S-band receiver includes the amplifier cold plates and the receiver rack. The shop also completed an access platform for a feed arm laser.

F. GBT Monthly Systems Report on Project Coordination for June 1999

Efforts to schedule the work for completing NRAO systems on the GBT appear to be producing results. For example, the machine shop completed the feed and amplifier cold plate for the S-band receiver. Srikanth, Stennes, and Dunbrack made preliminary tests of the feed and OMT; the initial test results are encouraging. The shop also completed the retroreflector mounts for the GBT subreflector. Amy Shelton completed both the software for the slave status monitor on the surface actuators and an actuator test box. The GBT K-band and C-band receivers were removed from the 140-Foot Telescope for refurbishing.

The Metrology Group repeated point-to-point measurements with nine ground laser rangefinders on the evening of June 23. The data recorded with the measurements can be used to solve for parameters such as rangefinder locations, air refractive index, and retroreflector calibration terms with a least squares analysis. The measurements included impressive displays of automatic target acquisition and laser servo performance.

The GBT holography receiver has been designed for installation at prime focus. The receiver will be able to directly measure the deformations in the surface of the primary reflector from this location. However, positioning errors and surface deformations of the subreflector can degrade telescope performance, and corrections to the primary reflector surface must also compensate for these imperfections in the subreflector. Therefore, holography also needs to be done from the Gregorian Receiver Room. The feed from the existing Ku-band receiver could be used with the holography receiver to make holography measurements at the Gregorian focus. (Note: The reference horn for the holography receiver will be permanently mounted on the telescope feed arm).

At the GBT Science Workshop last summer, a high priority was placed on a GBT Spectrometer observing mode that uses 16 IF inputs. However, the scientific motivation and the IF configuration for this mode were not discussed at the meeting. Many IF configurations are possible on the GBT, so the user community was polled to determine which configuration is most desirable. The preferred RF/IF configuration for the 16 IFs to the Spectrometer is two polarizations in a single telescope beam at eight different sky frequencies. There are just enough frequency synthesizers to support this mode, but splitters will need to be added in the IF at the telescope Receiver Room if an astronomer wants to use this observing mode.

G. GBT Monthly Systems Report on Project Coordination for July 1999

The proposal for setting GBT surface panels states that the panel corners will be set to an accuracy of 0.002 inch and that most actuator assemblies will be positioned to an accuracy of 0.25 inch. Since the maximum deflection which can be measured with holography is a quarter wavelength, or 0.25 inch at 12 GHz, a consequence of this proposal is that the GBT holography receiver will not be able to accurately measure the large deformations in the surface as originally set. The large deformations will need to be removed with the active surface, using photogrammetry data or laser rangefinder measurements, before holography measurements can be made. Detailed commissioning plans may need to be revised to account for current surface setting plans.

The setting of panels and checking of actuator cables will place large demands upon the NRAO staff, particularly in the Electronics Division. The full impact of these activities will not be completely understood until COMSAT begins laying panels, at which time it may be necessary to readjust project priorities.

Scheduled activities completed over the month of July include the fabrication of laser access platforms for installation on the GBT, the gold-plating of the S-band amplifier cold plate, and the moving of the GBT X-band receiver and VLBA Data Acquisition Rack from the 140-Foot Telescope to the Jansky Laboratory. A potential location for the new site radios was identified.

The Metrology Group measured ranges to a retroreflector on the GBT feedarm. Measurement accuracies were on the order of 10 microns; a factor of 10 less than anticipated.

The GBT holography receiver was tested on the 140-Foot Telescope on July 20-22. Maddalena reported that the large bandwidth accepted by the receiver limits its dynamic range and may affect its system temperature. White is considering the installation of a tunable narrow band filter to overcome the dynamic range problem. The receiver is also being modified so that it can be operated at the GBT Gregorian focus in addition to prime focus.

H. GBT Monthly Systems Report on Project Coordination for August 1999

Scheduled activities completed over the month of August include the completion of the S-band receiver, the installation of an emergency motor generator set for the GBT Electronics and Control Rooms, and the installation of the optical fiber cable between the Jansky Laboratory and the GBT. The machine shop completed the fabrication of parts for the azimuth track cover, the IF rack thermal plates, and the RFI enclosures for the IF rack. An optical guide telescope (an 8-inch Meade) for the GBT was received, and a frame grabber was purchased for it.

The Digital Electronics Group reviewed the outfitting of the Actuator Control Room (ACR) on August 26. The major tasks required to outfit the ACR include testing the actuator cables, installing the actuator control panels, installing the ground plane plates between panels, wiring the panels, installing the transnet (the communication bus between all of the control modules), connecting the transnet and motor power, securing the panels to the ground grid, installing transnet power supplies, installing the actuator control computer, installing motor power supplies, and terminating the monitor cables. Although the group discussed possible methods for expediting the completion of these tasks, it is clear that the duration of control room outfitting will be long because of the amount of work required and the limited amount of space available to perform the work.

The entire process of measuring the GBT surface with the laser rangefinders, fitting the resulting data, and correcting surface deformations with the active surface was reviewed at a pointing and metrology integration meeting on August 11. Specific areas of responsibility were identified and assigned during the discussion. Most of this work is either done or well underway; however, large amounts of detailed software work still remain.

Building cryogenics systems for the GBT while maintaining other cryogenics systems on site have been challenging tasks for the NRAO-GB cryogenics technician. Unfortunately, and for reasons unrelated to the work to be done, the technician recently resigned. To bolster cryogenics support for all telescopes on the Green Bank site, the technician was replaced and the responsibilities of an RF technician were altered to include cryogenics tasks (i.e. there are now effectively two cryogenics technicians instead of one). A possible consequence of this redistribution of tasks is the ability of the Electronics Division to maintain existing receivers and develop future RF systems may be curtailed.

Problems were encountered with the L-band array feed receiver during test observations on the 140-Foot Telescope. The observations will be repeated later this year. Since the SAO maser and Spectral Processor are needed at the 140-Foot for these observations, moving them to the Jansky Laboratory will be postponed.

GBT telescope operators provided valuable assistance to the M&C Group by generating the text input which describes the GBT device circuitry. The M&C IF Manager uses the text to describe what the RF/IF circuitry does, to calculate sky frequency, and to provide general feedback to telescope users.

Norrod completed the purchase of major components for the dual beam, dual polarization Q-band receiver. He is now investigating the detailed design of the Q-band tertiary reflector.

Weadon started to develop a cable routing plan for the GBT.

Maddalena made a Beta release of the Control Library for Engineers and Operators (CLEO), the operator and engineer GUIs for the GBT. He described CLEO to project personnel in a presentation on August 24.

I. GBT Monthly Systems Report on Project Coordination for September 1999

COMSAT announced that it would begin testing surface actuator cables after the S70 derrick has been disassembled. COMSAT personnel who disassemble the derrick will also test the cables. COMSAT estimates that the disassembly of the derrick will be complete in late October or early November. NRAO originally planned to test the cables in September. These cable testing plans will be postponed, and NRAO-internal priorities will be adjusted accordingly.

The Spectral Processor was moved from the 140-Foot Telescope to the GBT Electronics Room. The SAO maser at the 140-Foot supplied a 5 MHz reference signal to the Interferometer Control Building. Mike Stennes changed the source of the reference signal to the Sigma Tau maser so that the SAO maser can be moved to the Electronics Room. Once the SAO maser is moved, all GBT equipment installed at the 140-Foot, with the exception of a computer, will have been removed.

John Shelton and Jody Bolyard developed a laser safety training program that complies with ANSI standards. Different levels of safety training will be given to Green Bank personnel, depending upon the degree of their interaction with the lasers. General laser safety at the GBT site was also briefly reviewed by Bolyard, Shelton, Parker, and McKinnon. A fence will be installed around the entire perimeter of the GBT (at about 10m outside the ground laser rangefinders) to limit access to the lasers and the telescope. Backstops will also be installed behind the lasers so that an inadvertent and unlikely stray laser beam cannot propagate beyond the new fence.

On September 8, Don Wells showed how a servo-shaping technique called "Posicast" could be used to effectively eliminate the oscillations which occur in the GBT feedarm when the telescope is abruptly moved in azimuth. The technique employs two impulses which are properly timed such that the oscillations induced by each impulse add in antiphase and, therefore, cancel one another. Posicast appears to be much more effective than other servo control methods (e.g. CPP-B) in removing feedarm oscillations. Wells is publishing his results in a GBT memorandum entitled "Jerk-Minimizing Trajectory Generator in C".

Tim Weadon completed the GBT cable routing plan.

Simon Radford at NRAO-Tucson is developing a two-element, 12 GHz interferometer to monitor atmospheric phase stability near the GBT. Radford's preliminary estimates indicate that the interferometer may be ready for installation by the first of next year.

A relatively simple and stand-alone enhancement to the GBT Spectrometer can be made to bypass the long term accumulators so that raw Spectrometer lags can be sent directly to disk or tape. This Spectrometer observing mode is particularly useful for pulsar searches. Jim Cordes (Cornell) expressed an interest in implementing the mode and is recruiting an electrical engineering graduate student (Steve Kuebler) to do the work. Cordes and Kuebler will decide if they can undertake the project after a review of relevant Spectrometer engineering documents.

J. GBT Monthly Systems Report on Project Coordination for October 1999

COMSAT is still disassembling the S70 derrick. Since COMSAT personnel who disassemble the derrick will also test actuator cables, cable testing and outfitting of the ACR will be further delayed.

The SAO maser was moved from the 140-Foot Telescope to the GBT Electronics Room. All GBT equipment that was installed at the 140-Foot has now been moved to the Jansky lab.

With good engineering and a bit of luck in purchasing, Norrod was able to complete purchases of components for the Q-band receiver well within budget. The savings will be used to complete the 4-beam receiver that was originally planned (i.e. not just a 2-beam system) and, hopefully, to build a simple tertiary reflector.

Group leaders reevaluated the cost to complete the GBT in view of extending the project through the first quarter of 2000. A decision to not rework the surface retroreflectors resulted in a cost savings of $22K.

A budget account was established for spare GBT equipment. The budget allocation for spares is $200K, and $114K has been committed to spare servo boards, surface panels, and gear reducer.

Other high priority spare components will be purchased with the remaining $86K. The spares budget is insufficient to cover all components identified as single point failures.

Discussions of spare components brought up the issue of warehouse storage space for the spares. The warehouse is already overcrowded with material waiting to be installed on the GBT. Some warehouse space can be made available with a little house cleaning.

The 100 MHz reference signal for the lasers will be routed on coaxial cable instead of optical fiber. The phase noise of the signal on optical fiber prevents the phase lock loops on the lasers from working properly. Shielded cable and low pass filters will be used to minimize the RFI caused by the 100 MHz signal and its harmonics.

K. GBT Monthly Systems Report on Project Coordination for November 1999

COMSAT is still disassembling the S70 derrick. Since COMSAT personnel who disassemble the derrick will also test actuator cables, cable testing and outfitting of the ACR will be further delayed, again.

The need for the walkways on the GBT backup structure was reviewed again. The walkways are believed to be inherently safe, but will require routine inspection and proper maintenance. Having the walkways on the telescope will help NRAO maintenance staff replace actuators, inspect the structure, and inspect/replace actuator cables.

Repeater antennas for the new GBT radio communications system were installed on November 5. The repeaters comply with NRQZ power density limits. The radio system became operational on November 11. Operations and maintenance personnel are evaluating the system to see if it provides the radio coverage they need.

A pointing/metrology integration meeting was held on November 10. Rangefinder measurements of the GBT feedarm on October 15 revealed two modes of oscillation. The modes occurred at the frequencies (0.7 and 0.9 Hz) and in the directions predicted by structural analysis. The frequencies of the oscillations were also verified by an independent measurement with accelerometers. The rangefinder data showed RMS residuals of 10 microns, about an order of magnitude better than anticipated. The "phase-closure" experiment (point-to-point measurements) with the ground rangefinders was reviewed. The data fit the two dimensional geometry of the rangefinders at about the noise level of the data, thereby proving phase closure. The experiment is scheduled to be repeated in December 1999 using 12, instead of nine, rangefinders.

A GBT Coordination meeting was held on November 16. The purchase of prioritized spare parts is well underway. Revisions to the GBT Site drawing were reviewed. The revisions include the relocation of the site road, the addition of a dirt road and fence around the perimeter of the ground laser rangefinders, the removal of the local control building, and the addition of a variety of cables, including optical fiber, 4160V power lines, and telephone lines. The drawing should be further modified to show parking lots, truck turn-around points, and septic lines (There is a concern for settling of the rangefinder monuments).

An end-to-end test of GBT software was scheduled for December 1. The software that will be evaluated during the test includes the M&C software, the operator/engineer interface, the observer's interface, and the commissioning tools in AIPS++. During the test, an all sky pointing observation will be simulated with an antenna simulator. The hardware that will be used during the test includes the Ku-band receiver, IF electronics, and the Digital Continuum Receiver (DCR).

Dennis Egan designed a feed support/seal for the C-band receiver. The feed support is being fabricated in the shop.

At the request of COMSAT, Tim Weadon is proceeding with a two week trial period of setting panel corners with the corner setting tool.

L. GBT Monthly Systems Report on Project Coordination for December 1999

An end-to-end test of GBT software was successfully carried out by Dana Balser on December 1. During the test, an all sky pointing observation was simulated with an antenna simulator. The software evaluated during the test included the M&C software, the operator/engineer GUI, the observer's GUI, and the commissioning tools in AIPS++. The hardware used during the test included the Ku-band receiver, IF electronics, and the DCR. A few minor problems, such as memory leaks and inadequate disk space, were identified during the test. Staff astronomers and telescope operators will continue to run these tests to familiarize themselves with the software and to identify additional problems.

The budget for GBT spares will support the purchase of approximately 92 items identified as critical spare parts. However, not all items identified as critical spares can be purchased with the budget. Quotations have been received for 66 of the 92 items, and purchase orders have been issued for 26 of them. Rich Lacasse and Jerry Lawrence are leading the effort to acquire GBT spare components.

Roger Norrod arranged for the purchase of all major components for the 4-beam, dual polarization Q-band receiver in October. The pacing items for the completion of the receiver are the low noise amplifiers that are produced at the CDL. The receiver dewar was fabricated in the machine shop, and the dewar end plates are nearly complete. Norrod and Dennis Egan have designed the tertiary reflector that will be used with the receiver.

The NRAO-GB Safety Officer, Jody Bolyard, produced a draft document on inspection requirements for the walkways and safety cables beneath the surface backup structure. Inspection involves tightening bolts, inspecting components for rust and damage, and tagging components as safe to use. Currently, COMSAT devotes about 10 man-days per quarter to inspecting the walkways and lines. If these items are to remain on the structure and assuming

NRAO adopts COMSAT's inspection guidelines, this equipment inspection will place large demands upon the NRAO maintenance staff. Bolyard's document investigates how time spent on maintenance may be reduced while maintaining a safe work environment.

A GBT Coordination meeting was held on December 20 to discuss GBT spares, results of the software tests, the Q-band receiver and tertiary, and the draft inspection requirements for walkways on the surface backup structure.

The feed support for the C-band receiver was completed in the machine shop on December 16. All GBT receiver feeds require supports with the exception of the feeds for the L-band, S-band, and PF Rxs, which are self-supporting. The feed supports resemble inverted cans and also serve as RFI and weather seals. All feed supports have now been fabricated.

The 800 MHz feed for the PF Rx is being chromated in the paint shop in preparation for the installation of fiberglass reinforcement.

NRAO staff led by Tim Weadon completed the two week trial period of setting surface panel corners with the corner setting tool. Additional corner setting will not take place until COMSAT agrees to use the tool.

Pointing/metrology integration meetings were held on December 9 and 20. The primary purpose of the meetings was to optimize the locations of the spherical retroreflectors that have large viewing angles. A total of 18 retroreflectors are on hand, but there are 42 bench marks on the GBT structure and as many as 10 triplet assemblies on the rim of the primary reflector that could be reasonable locations for the retroreflectors. Don Wells made a recommendation for the retrosphere locations based upon astronomical requirements. His recommendation will be reviewed by the GBT Project Office to ensure that the proposed locations are also beneficial for monitoring the integrity of the GBT structure.

Point-to-point measurements of 12 ground rangefinders were postponed to support alignments at the GBT elevation bearings. The measurements were rescheduled for mid-January 2000.

In a technical presentation on December 10, the GBT operations staff demonstrated the maintenance software they propose to use for the GBT.

Phil Jewell and Mark McKinnon presented a development program for 3mm observations with the GBT to an NRAO advisory committee in Charlottesville, Virginia on December 3. The program discussed plans for developing atmospheric monitoring, metrology systems, 3mm instrumentation, and dynamic scheduling.

IV. 2000

A. GBT Monthly Systems Report on Project Coordination for January 2000

In late December, COMSAT revealed preliminary plans for completing the GBT this year. A rough schedule of its general activities and NRAO's major tasks on the telescope is

- Preliminary servo testing (COMSAT/NRAO) 01/10/00 - 03/01/00
- Actuator cable testing (COMSAT/NRAO) 01/18/00 - 04/01/00
- Panel corner setting (COMSAT/NRAO) 04/01/00 - 06/01/00
- Actuator room outfitting (NRAO) 04/01/00 - 06/01/00
- Begin final servo/acceptance test (COMSAT/NRAO) 06/01/00

Since COMSAT indicated that the GBT would not be complete before June 1, the NRAO GBT budget was extended through the second quarter of 2000.

Testing of actuator cables began on January 18. Despite the bad weather, about 28 cables were tested over five hours on the first day of testing. The cable testing rate of about one every 10 minutes is roughly what was expected. However, the duration of cable testing is being stretched out because of bad weather and ice in the cable connectors. Special thanks are due to Tom Bailey, Brian Ellison, Mike Fowler, Rich Lacasse, J. D. Nelson, Dwayne Schiebel (who is leading the NRAO cable testing effort), Amy Shelton, and Jerry Turner for enduring the bone-chilling cold to complete this important task for the project.

Galen Watts is installing a two-element, 100-meter baseline, 12 GHz interferometer near the laser lab to measure atmospheric phase stability. The measurements will provide an indication of the severity of anomalous refraction, which adversely affects telescope pointing at high frequencies, at the Green Bank site. The interferometer is being built by George Weiland and Simon Radford of NRAO-Tucson and should be delivered to Green Bank during the week of February 14. Radford and Weiland will commission the interferometer during the week of March 6. The device should be in routine operation by mid-March.

Jim Condon and Qi Feng Yin developed a list of 1071 pointing calibrators for the GBT. The calibrators have flux densities of over 1 Jy at 1.4 GHz and cover the sky fairly uniformly at declinations above -40 degrees. The list contains position, position error, and flux densities at 1.4 GHz and 4.85 GHz for each calibrator. Position errors can be as small as one arcsecond. The calibrator list will be published in an upcoming GBT memorandum.

Jim Cordes and Steve Kuebler of Cornell University are planning on implementing the "raw-lag dump mode" of the GBT Spectrometer for pulsar searches. They visited Green Bank on January 17 to discuss the technical details of the Spectrometer with Rich Lacasse and Ray Escoffier. They will build a custom data tap card, similar to one that has already been built, that bypasses the Spectrometer's long term accumulator and sends the machine's correlations directly to a highcapacity data storage medium. Discussions are underway to determine if the GBT disk array and tape drives could be used in this data recording mode.

Dana Balser repeated end-to-end tests of GBT software in the mockup on January 27. The tests were similar to those carried out in December with the exception that the Spectral Processor was used as the telescope backend instead of the DCR. Problems in the M&C software prevented the use of the AIPS++ DISH software to analyze the recorded data. The tests will be repeated soon, after the M&C problems are fixed.

Dave Parker developed a calibration procedure for the surface retroreflectors. The mount that supports a retroreflector actually suspends the retroreflector below the telescope surface. The calibration procedure is needed to determine the normal distance between the telescope surface (the face of the mount) and the retroreflector's reflecting point. These normal distances must be subtracted from the rangefinders' measurements of the surface to give the true distance to the surface. A test jig that Parker designed for the calibration procedure will be manufactured in the machine shop in February. GBT telescope operators will calibrate the 2209 retroreflectors so that they can be installed on the telescope sometime after May 1.

Point-to-point measurements of 12 ground rangefinders were postponed so that the retroreflector calibration procedure could be developed. Bad weather and illnesses in the Metrology Group have also hampered efforts to carry out metrology experiments.

The production schedule for the Q-band receiver was briefly reviewed with Gerry Petencin at the CDL to ensure that the low noise amplifiers would be delivered on schedule. Two amplifiers are in Green Bank, two were shipped from the CDL to Green Bank on February 3, and the remaining four amplifiers should be shipped by the end of February. If the amplifiers are delivered as scheduled, the assembly of the receiver should be complete by May 1.

The machine shop is installing the fiberglass reinforcement on the GBT receiver feeds. The fiberglass "foam" has been installed on all the feeds (S-band, 800 MHz, and 1070 MHz) and has been shaped and sanded on the S-band feed. The fiberglass installation should be complete in late February after the application of epoxy/resin and paint.

B. GBT Monthly Systems Report on Project Coordination for February 2000

RSI completed the fabrication, measurement, and painting of all GBT surface panels. As of February 27, all panels have been delivered to the GBT site, and 1753 of the 2004 panels have been installed on the telescope. If the weather continues to be good, panel installation should be complete by the first of April, at which time panel corner setting will resume.

The GBT was tipped to five degrees elevation for the first time on February 28. This implies that the elevation gear segments have been rough aligned.

Over 700 surface actuator cables have been tested since testing began on January 18. At the current rate of testing, this first round of cable testing should be complete by the end of April. This will delay the outfitting of the ACR by at least a month. Water or ice has been found in the connectors of over a third of the tested cables. These cables always fail the insulation resistance test that is made during the testing procedure. Cables with wet connectors are hung out to dry after they are tested instead of being permanently attached to an actuator. Personnel in the digital lab have developed a method to dry the connectors using alcohol and compressed air. The drying method cannot be used effectively until the ambient air temperature is consistently above freezing. The wet cables will need to be retested to ensure that their insulation resistance is acceptable.

A metrology integration meeting was held on February 23 to schedule the activities required to measure the GBT structure with the ground rangefinders. The schedule is keyed to the installation of the GBT azimuth and elevation encoders. Coupled with a structural model of the telescope, the encoder readings allow the rangefinders to automatically point to a target location. Target acquisition in the past has been done manually. Other subtasks that need to be addressed before the measurements can be made include a test of the telescope's commanded track that is generated by M&C, the final calibration and installation of all 12 ground rangefinders, and the testing of the structural model.

Tim Weadon completed the servo monitor. It should be installed soon when servo tests begin.

The machine shop and Metrology Group have essentially completed the test jig for the calibration of surface retroreflectors. Dave Parker designed the jig and developed the calibration procedure. Telescope operators will start calibrating the 2209 retroreflectors the week of March 6.

Progress on completing the Q-band receiver has been good. The two remaining feed horns are being built in the machine shop. The CDL delivered two low noise amplifiers on February 23. The two remaining amplifiers should be delivered any day.

The machine shop completed the installation of the fiberglass reinforcement on the feeds for the S-band and 800 MHz receivers. The fiberglass installation on the 1070 MHz feed (PF Rx 2) is complete except for painting.

Mike Fowler and Ed Childers installed connectors on one end of the 48 multimode fibers that are contained in the optical fiber cable between the GBT and Jansky lab. Connectors will be installed on the other end of the fibers when the telescope is outfitted. The 60 single mode fibers in the cable will be spliced as needed during outfitting.

The date for the dedication of the GBT was set for August 25, 2000.

C. GBT Monthly Systems Report on Project Coordination for March 2000

The assembly of the four-beam, dual polarization Q-band receiver is nearly complete. The Green Bank machine shop fabricated the receiver's four feed horns, and the CDL delivered the receiver's eight low noise amplifiers. The initial cool-down and testing of the receiver will begin in April.

At the end of March, 1985 of the 2004 panels had been installed on the telescope. Approximately 1770 of the 2209 actuator cables have been tested.

A metrology integration meeting was held on March 22 to review the schedule of activities required to measure the GBT structure with the ground rangefinders. Brandt made the telescope commanded track available to the metrology system, and Creager verified that the track provided the proper information. COMSAT installed the azimuth and elevation encoders; however, additional work is needed to finalize the encoder installation. In order to synchronize data collection, the same IRIG time stamp was made available to M&C, the rangefinders, and the accelerometers. The servo monitor built by NRAO was installed at the telescope. The calibration procedure for the surface retroreflectors was developed, and 1437 of the 2209 retroreflectors have been calibrated. These retroreflectors are placed at a 45 degree angle within their mounts. The enhancements to the test jig needed for the 25 and 35 degree-mounted retroreflectors are being made in the machine shop.

The NRAO staff reviewed and returned comments on COMSAT's Servo Site Test Procedure, Operations and Maintenance Manual, Site Restoration Plan, Optics Alignment Procedure, and Final Testing and Acceptance Plan.

The two-element, 100-meter baseline, 12 GHz interferometer was placed into operation the week of March 6. The interferometer is a replica of the device used for ALMA site monitoring. This project was a cooperative effort between NRAO Tucson and Green Bank.

The project budget was revised to reflect the extension of the project through the third quarter of 2000. Overruns caused by the project extension were covered by diverting funds from the project's M&C budget. The resulting shortfall in the M&C budget was covered by a $75K supplement from the Observatory's RE budget. An additional $80K for data analysis computers is expected from a Sun Microsystems grant. The Observatory's RE budget also supported allocations for the Q-band tertiary mirror ($10K) and PF Rx 2 ($20K).

As part of a laser safety measure, four engineers and technicians completed "baseline" eye examinations. If these personnel incur any eye damage as a result of their exposure to the lasers, the damage should be apparent by comparing the baseline examination with the results of future examinations.

D. GBT Monthly Systems Report on Project Coordination for April 2000

The assembly of the four-beam, dual polarization Q-band receiver was finished the week of April 3. The receiver was cooled down, and initial tests indicate that the receiver temperatures in each of its eight channels averages about 40-45 K, in close agreement with what was predicted.

All but two of the surface panels were installed on the GBT by April 24.

The first round of actuator cable testing was completed on April 12. The 680 cables that failed their insulation resistance test due to wet connectors will be retested by COMSAT as soon as the connectors dry.

The setting of the corners on the GBT surface panels was started on April 11. Approximately half of the corners were set by the end of April. The corner setting is being done by COMSAT personnel and NRAO telescope operators. The project is supervised by Tim Weadon.

The calibration of the zero point offsets on the laser rangefinders was completed, and all 12 ground rangefinders with control panels were installed by April 10. The point-to-point measurements using all 12 ground rangefinders were repeated on April 28. Data recorded during the experiment are being analyzed. Don Wells delivered a structural model of the telescope to Ray Creager so that automatic laser pointing routines could be developed. Joe Brandt completed the M&C software that was needed for the RPC interface between M&C and laser metrology. The calibration of the surface retroreflectors that are oriented at 25 and 35 degrees within their mounts was completed by telescope operators on April 6.

The design of the cryogenic compressor packages was enhanced to optimize the separation of lubricating oil. One of the six compressors has been modified to incorporate the new enhancements and is currently being tested. Modifications to the other five packages are underway.

The feed for PF Rx 2 was painted.

Major components in the RF section of PF Rx 2 were assembled to test the ability of a Model 1020 refrigerator to cool down the receiver dewar.

Gary Anderson measured the phase centers of PF Rx 1 at five different frequencies near 800 MHz.

A Description of Current Instrumentation and Facilities and the Commissioning Plan were written for the GBT Comprehensive Management and Operations Plan. Updated copies of the GBT Outfitting Schedule and the GBT Commissioning Schedule were included in the plans.

E. GBT Monthly Systems Report on Project Coordination for May 2000

Tim Weadon and GBT telescope operators completed the setting of the corners on the GBT surface panels on May 18.

Detailed plans for installing the four laser rangefinders on the feed arm of the GBT were developed. The plans begin with reinforcing the ladder that provides access to one of the lower lasers. The ladder reinforcements are being fabricated in the machine shop. A fall protection device will be installed after the ladder is reinforced. The laser mounts will also be fabricated in the machine shop. The lasers should be installed in early August.

On May 22, Joe Brandt and Ray Creager successfully tested the M&C interface to the metrology system by controlling a laser rangefinder. This achievement is a significant milestone in integrating the metrology system into telescope M&C.

Detailed plans were developed for installing the optical fiber cable that carries signals between the GBT and the control room in the new Jansky lab. The azimuth cable wrap will be installed in mid-June before the cable is installed in mid-July. Terminating the fibers in the cable will follow cable installation.

Plans were also made to reroute the road around the GBT. The new road will prevent vehicles from passing through the path of ground laser rangefinders. The road will be covered with gravel initially. The road will be paved with asphalt as future funds allow.

Plans were also made to test the quality of commercial and conditioned AC power in the new Jansky lab. Apparently, RFI filters in the shielded rooms corrupt the AC power, causing UPS systems to switch on and off.

The machine shop completed the fabrication of the track covers and the 340 MHz feed for the PF Rx. Components for the triplet assembly are being fabricated. Materials for the prime focus box handler were ordered.

Major components in the RF section of PF Rx 2 were assembled to test the ability of a Model 1020 refrigerator to cool down the receiver dewar. Initial test results indicate that the 1020 may be a suitable refrigerator for the receiver.

Preparations are being made to move weather station number 2 from the 140-Foot Telescope to its permanent location on the north side of the GBT.

Steve White's paper on the "Implementation of a photonic automatic gain control system for correcting gain variations in the Green Bank Telescope fiber optic system" was accepted for publication in Review of Scientific Instruments.

S. Srikanth and G. Anderson measured the frequency-dependent phase centers of the feed horn for the S-band receiver.

In a meeting on May 17, Richard Prestage discussed detailed plans for installing an optical guide telescope on the GBT. Initially, the guide telescope will not be integrated into the GBT M&C system. Possible locations for the guide telescope were discussed at the meeting.

Don Wells analyzed data recorded with the 12 ground rangefinders during the April 28th experiment. Discrepancies identified in the data are being investigated by the Metrology Group.

F. GBT Monthly Systems Report on Project Coordination for June 2000

COMSAT completed photogrammetry of the GBT primary reflector surface on June 6. Preliminary photogrammetry results indicate that only a small percentage (about 1%) of surface actuators need to be adjusted.

The routing of panel gaps is essentially complete. A 7.5 HP motor was installed on the prime focus boom, and electrical work continues near the feed Receiver Room. Significant effort has been devoted to determine what causes a pinging noise in the azimuth wheels.

The antenna Central Control Unit (CCU) was connected to the GBT M&C system on June 14. The connection allows the M&C software to monitor readings from the azimuth and elevation encoders. The encoder readings can be used by the laser metrology system for automatic pointing, as opposed to manual pointing, of the lasers for measurements of targets on the GBT structure.

The NRAO azimuth cable wrap was installed in the pintle bearing room. The optical fiber cable that carries IF and computer signals between the telescope and the Electronics Room was pulled from the base of the telescope to the Receiver Room on June 26. (The cable was pulled between the base of the telescope and the Electronics Room in the Jansky lab some time ago.) The cable was routed through the azimuth cable wrap and the Servo Room before being taken up the alidade and vertical feed arm. Many of the optical fibers will be separated from the cable and terminated in the Servo Room.

Ed Childers made measurements of the commercial and conditioned AC power in the new Jansky lab. The quality of the power was suspect because recently purchased UPS units were switching on and off. The tests were made on commercial and conditioned power before and after the RFI filters in the Electronics Room. The dominant structures in the spectra of commercial and conditioned power are the odd harmonics of 60 Hz. For either power source, commercial or conditioned, spectra of AC power are similar before and after the RFI filter, but the amplitudes of the harmonics in the post-filter measurements are about 5 dB higher than the pre-filter measurements. The spectra change with power source. The strongest harmonic in a spectrum of commercial power is the 5th harmonic (300 Hz) of 60 Hz, and is about 37 dB below the 60 Hz peak in a pre-filter spectrum. The strongest harmonic in a spectrum of conditioned power is the 11th harmonic (660 Hz), and is about 28 dB below the peak in a pre-filter spectrum. The 11th harmonic is visible in an oscilloscope trace. It was concluded that the RFI filter and power conditioner operate properly. Tests were also made with UPS units connected to and disconnected from the AC power. The UPS units appeared to have little or no effect upon power quality. Some of the UPS units had problems regardless of the AC power source. Upon the recommendation of the UPS manufacturer, the UPS units are being replaced with more robust units. The quality of the AC power does not appear to affect the operation of other equipment in the Electronics Room.

COMSAT and NRAO-GB completed the GBT Site Closeout Agreement on June 14. As a result of the agreement, the COMSAT warehouse and BUS walkways will remain after COMSAT leaves the site. In exchange for these items, NRAO agreed to install surface retroreflectors, take a more active role in testing and connecting actuator cables, and forego repairs on the damaged asphalt road.

Major components in the RF section of PF Rx 2 were assembled to test the ability of a Model 1020 refrigerator to cool down the receiver dewar. The test results show that the 1020 will be a suitable refrigerator for the receiver.

The road to the GBT is being rerouted around the GBT site. The road will be complete in early July after it is covered with gravel.

The machine shop fabricated the reinforcements for the laser ladder.

The COMSAT board of directors visited the GBT site on June 15. Phil Jewell gave a presentation to the board on the importance of the GBT to radio astronomy.

G. GBT Monthly Systems Report on Project Coordination for July 2000

COMSAT completed the alignment of the Receiver Room. The room is being welded in place. Approximately 290 welded joints on the structure have been identified as high stress points. The welds at splice plates in these joints are being re-ground to produce a more "stress-friendly" shape in the weld. Ray Wright, the servo technician with PCD, has been on site to initiate the servo checkout. Servo work has started on the subreflector drive cabinet and the setting of drive limits on subreflector actuators.

COMSAT and NRAO investigated the cause of a pinging noise that occurs at the azimuth wheels when the telescope is rotated in azimuth. The noise seems to originate in the wheel bearings. An inspection of the bearings in wheel number 9 revealed a significant amount of rust on the bearing rollers. The rust is attributed to water leaking through the bearing seal and mixing with a molybdenum disulfide additive in the grease to produce sulfuric acid, which initiates the rust. COMSAT will likely inspect all bearings to determine the extent of the rust problem. The pinging noise and rust are thought to be unrelated. Currently, there is no consensus on what causes the noise.

The optical fiber cable that carries various signals between the GBT Receiver Room and the Jansky lab was installed in late June. A large fraction of the optical fibers in this cable will be terminated in the Servo Room. The installation of connectors on the multimode fibers in the Servo Room was completed on July 18. The single mode fibers in the room still need to be spliced. Connectors are now being installed on the multimode fibers in the Receiver Room. A separate cable services the prime focus area, and connectors have been installed on the multimode fibers in it.

Telescope operators started the installation of the surface retroreflectors on July 26. They are also removing the old photogrammetry targets from the surface panels as they install the retroreflectors.

The reinforcement of the ladder that services one of the lower feed arm lasers was completed on July 28. Fall protection was also installed on the ladder. The ladder reinforcement will also support the conduit and cable tray that are routed to the laser. COMSAT will install the conduit and cable tray, and NRAO will install the appropriate wiring as part of telescope outfitting.

The machine shop fabricated the mounts for the triplet assemblies. The mounts are now being painted. The plates which support the retroreflectors within the triplet assemblies are being fabricated. The mechanical assembly of the triplets should be complete in mid-August. A trial fit of the prototype triplet assembly will be made on the telescope in early August. A prototype mount for the feed arm lasers was also fabricated in the shop.

On July 25, telescope mechanics installed the actuator control panels in one of the four bays in the ACR. Each bay supports 13 panels. Connecting actuator cables to the panels will begin in mid-August when manpower becomes available.

Approximately 61 of the 680 actuators cables that failed an insulation resistance test due to wet connectors are still not dry. There is some evidence that water in the connector has wicked into the cable. NRAO made a recommendation to COMSAT that the connectors on these cables be replaced. "Pigtails" consisting of a connector and about 15 feet of actuator cable can be made in the lab. A pigtail would then be spliced into the appropriate cable on the structure.

The molds and tooling that were used to fabricate the GBT surface panels were shipped from Sterling, Virginia to Green Bank. The molds and tooling are stored in one of the "cable barns" near the 85-2 telescope.

The rerouting of the road around the GBT site was completed during the first week of July.

H. GBT Monthly Systems Report on Project Coordination for August 2000

First light with the Green Bank Telescope was detected on August 22, 2000 at approximately 7:00pm. The telescope was used to observe a continuum source, 1140+223, and a pulsar, PSR B1133+16, at a frequency of 403 MHz. An observation of another pulsar, PSR B0329+54, was made during the GBT dedication ceremony on August 25.

COMSAT welded the Receiver Room in place after it was aligned. The re-grinding of 290 welded joints that were identified as high stress points was completed. COMSAT began the disassembly of two large cranes (the 4100 and the 9299) during the week of August 21. Ray Wright and Bobby Schroeder from PCD, with assistance from Rich Lacasse, Tim Weadon, and Joe Brandt, completed initial rigorous tests of the GBT servo system. Additional servo tests will follow. There is some indication from the servo tests that the elevation gear segments are slipping.

On August 22, COMSAT and NRAO agreed to the modified final acceptance of the GBT. One of the main purposes of modified final acceptance is to describe how the problems with the azimuth wheel bearings can be addressed so that COMSAT can complete the project and NRAO can begin the outfitting and commissioning of the telescope this year. The terms of the acceptance agreement describe how a plan for the inspection and repair of the azimuth wheel bearings will be developed, how "punch list" items will be addressed in the acceptance of the telescope, and how the retainage for the project will be distributed at acceptance. The anticipated date for acceptance is September 30, 2000.

The conditions for the acceptance of the GBT were outlined in the GBT Final Acceptance Test Procedure. At meetings held on August 3 and 17, COMSAT and NRAO formally agreed that approximately half of the items listed in the procedure have been satisfactorily completed. The items include the proper installation and alignment of the pintle bearing and azimuth wheels, the proper installation of the azimuth track, the proper alignment of the primary reflector RF axis, the proper alignment of the surface actuators, the proper manufacture of the surface panels, and the proper alignment of the azimuth and elevation encoders. The satisfactory completion of most of the remaining items in the procedure depends upon the outcome of the servo tests.

The status of RE projects in Green Bank was reviewed. Purchase orders totaling $30K will be issued in the next few months for the DSP hardware and software that will be used in the array feed and RFI monitoring projects. The $20K that was allocated to complete PF Rx 2 will be retained to purchase electronic components for the receiver's hybrid phase-shift network and for the electro-polishing of the receiver's dewar. Other commitments in Green Bank have prevented progress on the Q-band tertiary mirror, and it is unlikely that the $10K allocated for this project will be spent before year's end.

A great deal of activity over the past month has concentrated on outfitting the telescope. The L and S-band feed horns were installed in the turret of the Receiver Room on August 9. A compressor for feed horn pressurization was also installed in the Receiver Room. A test prime focus box was installed on August 7 for tests of the prime focus servo. The test box was replaced with an actual receiver on August 22 in preparation for a demonstration observation during the GBT dedication ceremony. The prime focus box handler, which was designed by Dennis Egan, greatly simplified the installation of the receiver. All cabling that services the prime focus area was installed. Essentially all connectors have been installed on the multimode optical fibers in the Servo Room and Receiver Room. The replacement of the connectors on the 61 wet actuator cables was started. The termination of the actuator cables in the ACR began on August 21. The control panels for the two lower feed arm lasers were installed. All of the mounts for the triplet assemblies, the passive optical devices that will be used to tie the measurements from the feed arm and ground-based lasers, were installed by August 24. To date, telescope operators have installed approximately 1900 retroreflectors on the telescope surface. A number of telephones and optical fiber junction boxes have been installed on the telescope structure.

I. GBT Monthly Systems Report on Project Coordination for September 2000

NRAO and LM completed the terms of modified final acceptance of the GBT on September 28. Any items that were considered potential acceptance issues have been identified in a punch list. NRAO has retained sufficient funds to ensure that LM completes the items on the punch list. Starting October 2, NRAO will have control of the telescope. The GBT will be placed in the access position for the month of October so that NRAO can complete its outfitting chores. In the evening, LM will continue with the alignment of the elevation bull gear. Any liability issues connected with LM’s use of the telescope will be covered by their insurance. The one year warranty on the telescope will start on November 1.

The inspection of the azimuth wheel bearings was completed in late September. After the bearing retainer plates were removed and the grease cleaned from the bearings, the bearings were graded on a scale of 1 to 5. A grade of 1 indicated that the bearing was good, a 2 meant that discoloration was visible on the bearing, a 3 indicated that slight indentations could be felt on the bearing, a 4 was given to bearings with obvious pitting, and a 5 was assigned to bearings in poor condition. A bearing was considered bad if it received a grade of 3 or higher. Using these criteria, 9 of the 32 bearings failed the inspection (there are 2 bearings in each of 16 azimuth wheels). LM and NRAO graded the bearings independently, and the grading results of the two parties generally agreed. LM will submit a plan for bearing replacement in the next few weeks. After the bearings were inspected, the retainer plates were reinstalled and the entire bearing cavity was filled with a new type of grease.

Tests of the elevation encoder by Tim Weadon showed that apparent errors in encoder readings were caused by thermal expansion of the encoder mount. At sunrise with the encoder mount exposed to sunlight, the encoder reading changed by 20 arcseconds although the telescope elevation was fixed. This apparent error exceeded the 14 arcsecond pointing error budget that was specified for the antenna. After shading the encoder, the apparent error was reduced to a 7 arcsecond variation that was anti-correlated with ambient temperature. The fact that there was no time delay between the encoder reading and temperature suggested that what was causing the error had a small thermal mass (i.e. the encoder mount). LM has agreed to build a more massive mount for the encoder and to enclose it with a small shelter. Work is underway to determine why the azimuth encoder readings also show a dependence upon ambient temperature.

Progress in outfitting the active surface system has been very good. All control panels have been installed in the ACR, and all 2209 actuator cables have been terminated at the panels. All 61 of the wet connectors on the actuator cables have been replaced. LM has delivered 70 of the 80 replacement connectors for NRAO's spare stock.

Motion of the elevation gear segments was discovered during servo testing. The elevation bullgear is now being realigned. To avoid motion of the segments in the future, the keys between segments are being trimmed, and the segments are being pressed closer together. The segments will be held in place by stops welded at either end of the bullgear. It is possible that a metal grout may need to be installed along the gear segments to secure them in place.

Grease was installed on the azimuth track as a protective coating during construction. The grease will be removed prior to telescope operation to ensure better wheel traction and to provide better electrical contact for the telescope's lightning protection system. It is thought that rust will not accumulate on the track because of the continuous operation of the telescope. Most wheel and track antennas (e.g. VLBA and Bonn) run on the bare metal of the azimuth track. NRAO may apply some type of protective coating at the edges of the track where there is no wear by the azimuth wheels.

The servo test procedure calls for a "hard stop" of the antenna at an elevation of 5 degrees. LM has been reluctant to conduct this test because of potential damage to the structure. Hard stops have already occurred at other elevation angles and are certain to occur again upon the failure of commercial power. Recognizing that hard stops are not good for the long term operation of the antenna, NRAO and LM have agreed to implement a "soft stop" for the antenna. The details of how this will be done are being investigated.

Initial tests of the turret drive motor in the Receiver Room indicated that the current drawn by the motor exceeded its rated value. Additional tests showed this was not the case. The current was essentially the same when the turret guide rollers were tight or loose, suggesting that most of the friction in the turret occurs at the turret weather/RFI seal.

Requests for quotation on the installation of a fence around the GBT site were submitted on September 7. Bids are due October 16, and the installation of the fence should begin in mid-November. The fence should be installed by the end of the year.

The installation of surface retroreflectors is complete with the exception of 50 retroreflectors at the antenna vertex.

LM delivered three sets of GBT operation and maintenance manuals. Data for the final alignment of the GBT subreflector was also submitted for NRAO's approval.

J. GBT Monthly Systems Report on Project Coordination for October 2000

The major activity at the GBT during the month of October was the outfitting of the telescope with NRAO equipment. All electronics racks (prime focus, motor, LO, IF, and fiber interface) and the L, S, C, X, and Ku-band receivers along with their power supplies were installed in the Receiver Room. Interconnecting coaxial cables were routed between the racks and receivers. A feed pressurization manifold was also installed in the Receiver Room. MCB cables were connected to equipment in the Receiver Room so that the equipment could be monitored with M&C software. Connectors were installed and splices were made on the optical fibers that run between the Receiver Room and Servo Room. Servo racks and the servo UPS were installed in the Servo Room. Transnet power supplies were installed in the ACR. All six sets of cryogenic lines were pressure tested, and two sets of lines were evacuated and cold-trapped. The L-band receiver was cooled down. Portions of the asphalt road leading to the GBT site warehouse were removed in preparation for the installation of a fence around the GBT.

LM and NRAO finalized plans for the replacement of the nine rusty bearings on the azimuth wheels. Seven of the bearings will be replaced by a LM subcontractor during the month of May 2001. The subcontractor, FEMCO, is a subdivision of Manitowoc and was recommended by the bearing manufacturer. NRAO determined that the two remaining bearings can still be used and will replace them at a future date if necessary. NRAO will also implement an aggressive grease inspection program to ensure that all bearings remain in good condition. Since the wheel trucks will be elevated on hydraulic jacks, the telescope cannot be moved during bearing replacement. As the bearings are removed, the bearing inner race needs to be inspected for rust and pitting because it was inaccessible during the initial inspection when the bearings were mounted on the wheels. Once the rusty bearings are removed, they will remain the property of NRAO. It is possible that some of these bearings may be reconditioned for use as spares. Four pancake jacks that will be purchased and used by FEMCO to level the telescope corner weldment during the truck jacking process will become the property of NRAO. LM will purchase the nine new bearings from SKF. These bearings are identical to the originals manufactured by FAG. It is possible that LM will construct a ramp to the azimuth track to facilitate bearing replacement.

NRAO asked LM to secure the azimuth track wear strips in the final punchlist for the GBT. In doing this, LM found that the caps or heads of the bolts which secure the wear strips to the track base plates had come off about 25 percent of the 672 bolts in the track. (There are 48 wear strips with 14 bolts in each strip). Upon further inspection, it was found that the wrong bolts had been installed in the track. The track design called for high strength, SAE grade 8 bolts, but the bolts installed in the track were low strength, SAE grade 5. All bolts will be replaced by LM.

During the negotiations for modified final acceptance of the GBT, LM agreed to investigate the implementation of a "soft-stop" for the telescope. The soft-stop is considered to be preferable to the hard-stop test that is required by the telescope's servo acceptance procedure. After reviewing what would be required for a soft-stop, LM determined that is was too costly and recommended that we proceed with hard-stop testing. NRAO will implement the soft-stop in the near future.

LM completed its optical alignment of the subreflector, Receiver Room, and prime focus boom. The Kollmorgen motors that position the subreflector and prime focus boom were then returned to the manufacturer for repairs.

The finite element model of the GBT showed that two structural members in the box structure can become overstressed in one of the more severe design loads for the telescope (ice on the structure). LM proposed a modification to the members that halves the effective length of the members, and thereby increases their allowable stress by a factor of two. The proposed modification is under review.

K. GBT Monthly Systems Report on Project Coordination for November 2000

LM fabricated and installed a new mount for the elevation encoder. The new mount is more massive than the old one; therefore, variations in encoder readings due to thermally-induced motions of the mount should be much smaller than those previously recorded. The new mount also allows for independent alignment of the encoder and the torque-tube support bearing. LM also installed a permanent enclosure for the mount to shield the encoder from direct sunlight.

The Kollmorgen motors that position the subreflector and PF Rx were repaired by the manufacturer. The motors were reinstalled on November 14.

After the bolts in the azimuth track wear strips were replaced, the wear strips moved circumferentially as the telescope was rotated in azimuth. The strips continued to move despite increasing the torque on the bolts from 550 ft-lbs to 800 ft-lbs. LM is consulting design engineers at Loral to determine the cause of this problem. It may be partially due to an anti-fretting compound (a rust inhibitor) that was applied between the wear strips and the azimuth track base plates. The compound may have the undesirable property of reducing the coefficient of friction between the strips and base plates.

LM is revising the elevation cable wrap to allow for a larger bend radius on the cables in that location. The large glycol hoses at the cable wrap have been shortened to avoid tangling with other cables. The glycol hoses have also shown premature deterioration, and they will be replaced with hoses made from an "anti-ozone" material.

Most of the month of November was dedicated to the alignment of the elevation bullgear. To ensure that the gear teeth were perpendicular to the drive pinions, the gear segments had to be aligned in the same arc, the gap between segments could not slope, and the twist of an individual gear segment had to be minimized. The gap between segments also had to be set to a tight tolerance. Once the difficult chore of aligning the bullgear was completed, Kirksite, a metal alloy of low melting point and low thermal expansion that is used similarly to grout, was installed at the joints of the gear segments to secure them in place. The Kirksite occupies the space between the alignment bolts on consecutive segments (a block that is roughly two inches high by nine inches long and five inches wide). Metal stops were welded on either end of the assembled gear to press the individual segments together. The keys between consecutive segments will also be tack-welded in place.

Although access to the tipping structure was very limited due to the alignment of the elevation bullgear, some outfitting activities on the GBT were completed in November. All twenty power supplies for the surface actuator motors were installed in the ACR, so the outfitting of the ACR is essentially complete. IRIG and Ethernet signals were connected to the ACR, and the LVDT readings from all 2209 actuators were recorded in preparation for an additional setting of the reflector surface. The K-band receiver was installed in the Receiver Room. The pulsar receiver that was used during the GBT dedication was removed and PF Rx 1 was installed in its place. Weather station 2 was installed at its permanent location on the north side of the telescope. A total of six servo warning lights were installed at the telescope; one at each azimuth truck and one on either side of the elevation bullgear. The machine shop fabricated three RFI door latches. LM has installed the latches on the doors of the Receiver Room, Servo Room, and ACR. An RFI enclosure for the GBT telephone PBX was fabricated in the machine shop and was installed in the Servo Room. Telephone wires are being routed to the Servo Room. The local telephone company will install the PBX in the RFI enclosure and terminate telephone wires beginning the first week of December. A transport cart for PF Rx 1 was also fabricated in the machine shop.

With most of the cabling in the Receiver Room complete and electrical power provided to the racks and receivers, the simulated pointing observations that were conducted in the mockup with the M&C software were resumed on November 10.

L. GBT Monthly Systems Report on Project Coordination for December 2000

LM completed the alignment and reinforcement of the elevation bullgear in November. Two tests were conducted in December to check the gear's integrity and alignment. In the first test, a force was applied to one segment of the bullgear with hydraulic jacks, and the motion of the segment relative to the elevation wheel was measured. The segment did not move when a small force was applied, but it moved by approximately 0.005 inches under the maximum design load of 212,000 pounds (the conditions for the maximum design load occur for an emergency stop at an elevation rate of 20 degrees per minute with a 50 mph wind in the direction of telescope motion). The segment did not return to its original position when the large force was removed. The motion and hysteresis of the gear segment suggest that additional reinforcement of the segments is necessary. LM is investigating possible solutions to this problem. The second test replicated an earlier servo test where the structure was repeatedly tipped in elevation between 5 and 95 degrees at a rate of 10 degrees per minute. Readings from the tachometers on the elevation drive motors were recorded during the experiment. In the original servo test, large spikes occurred in the tachometer data when the gaps between gear segments passed over the drive pinions, indicating that the gaps were expanding. The spikes were not present in the most recent data set, suggesting that the gaps are more secure. However, tachometer data recorded at some gear segment locations appeared noisier than at others, suggesting that the alignment of some segments could be improved. Upon further investigation, it was found that the noise in the data has a 4.2 Hz sinusoidal structure. The structure in the noise is thought to be the natural frequency of the elevation motor mounts. NRAO needs to determine if these sinusoidal oscillations adversely affect telescope pointing.

Additional tests were also made of the azimuth track. The tests show that the track wear strips and baseplates move in the direction of telescope motion. A single wear strip can move by as much as one-eighth of an inch after the four wheels in an azimuth wheel truck pass over it. There was little if any additional motion of the strip as additional wheels passed, suggesting that the "play" in the bolts was taken up by the initial motion of the strip. LM will attempt to prevent the motion of the track by attaching as many as four consecutive sections of the track. Tests of the azimuth track will be repeated at that time. It is also possible that the telescope can be routinely moved in azimuth after the sections are attached.

Recognizing that problems with the bullgear and azimuth track will delay GBT pointing observations, a number of tasks were identified and scheduled to allow the commissioning of the telescope to proceed. These tasks do not require the telescope to point, and include RFI surveys, frequency checks, tests of IF amplitude stability, and spectral baseline checks.

The finite element model of the GBT showed that two structural members in the box structure can become over-stressed in one of the more severe design loads for the telescope (ice on the structure). LM proposed, and NRAO agreed to, a modification to the members that halves their effective length, and thereby increases their allowable stress by a factor of two.

The servo and optical alignment sections of the GBT Final Acceptance Test Procedure were completed and accepted on November 29. The sections in the test procedure that remain to be completed are HVAC, hoists and manlifts, electrical, and the primary reflector structure, which includes the elevation bullgear.

The GBT project budget was effectively closed in December. The last major purchase in the project was made on December 20 for a data handling workstation and an array of data storage disks. All project consulting agreements have been closed. The major outstanding item for the project budget is an invoice for LM's installation of the conduit and cable tray to the lasers on the lower feedarm. LM will submit the invoice in early January 2001. No additional charges will be made to the project.

LM delivered four compact disks containing all but about 20 of the as-built drawings for the GBT. LM also submitted a technical memorandum (TM-43) on the analysis of the elevation rotating structure.

After the feed pressurization manifold was installed in the Receiver Room, it was discovered that the airflow to the L-band and S-band feed horns was insufficient to maintain adequate air pressure within these large horns. Airflow to the horns, and thus the pressure within them, was increased by drilling small holes in the transition sections of the horns and routing additional air lines to the holes. The holes will not affect the RF performance of the horns.

Construction of PF Rx 2 progressed during the month of December. A trial fit of the receiver dewar was made to the receiver box. The dewar was then sent to a shop in Alexandria, Virginia for electro-polishing. Phase-shifters for the receiver hybrid network and IF attenuators were purchased.

The feed horns of the X-band and Ku-band receivers were temporarily removed from the Receiver Room so that their phase centers could be measured at the antenna test range. The phase centers of the feed horns on all Gregorian receivers have now been measured with the exception of K-band.

Additional tasks at the GBT have been completed or are ongoing. The local telephone company installed the PBX within an RFI enclosure located in the Servo Room. LM completed the installation of the new elevation cable wrap. LM electricians are installing the conduit and cable trays for the lower feedarm lasers. The HVAC subcontractor was on site in early December to balance fluid flows in the HVAC system again. A serviceman inspected, repaired, tested, and certified the two manlifts on the GBT. However, operational problems continue for the upper manlift.

In early 2000, scientists and engineers at Cornell University expressed an interest in building a "spigot card" and data handling system that will enable the GBT Spectrometer to record pulsar search data. Although the project was started at Cornell, progress has been much slower than expected. Consequently, interested parties at Cornell, Caltech, and NRAO-GB entered a preliminary agreement to provide this important functionality for the Spectrometer. NRAO's involvement in the project will be to design and build the spigot card and to maintain the system on a long term basis. Ray Escoffier at the CDL has already developed a preliminary design for the spigot card. Caltech will provide an EDT data transfer card, a data handling computer, a computer disk for a modest amount of data storage, and data analysis software. Additional discussions are needed to determine a suitable data storage medium. System integration specifications also need to be developed.

V. 2001

A. GBT Monthly Report for January 2001

The first attempt at a real pointing observation with the GBT was successfully made on January 12, 2001. The observation was made with PF Rx 1 at a frequency of 800 MHz. The received signal was transmitted over optical fiber to the Electronics Room in the Jansky Laboratory and recorded with the DCR. The antenna and all NRAO electronics were controlled by version 3.2 of the GBT M&C software. The telescope's observer interface, GO, was used to execute the pointing scans, and the operator's interface, CLEO, was used to monitor the observations.

The first release of M&C version 3.2 was made on January 7, with an updated version (3.2.1) released on the 18th. Version 3.2 contains support for PF Rx 1 through the IF Manager, generation of receiver calibration FITS files via the Measurements Manager, and generation of a FITS file directly by the Antenna Manager. It also incorporates more robust data collection in the Spectral Processor, together with a number of more minor enhancements and bug fixes.

A number of commissioning tests that did not require telescope motion were completed in January. The tests included frequency checks, reflectometry from the Gregorian Receiver Room, RFI surveys, IF checks, IF stability tests, baseline checks, and the measurement of clock delays. The results obtained from some of these tests are described below.

- The tuning and frequency stability of the GBT RF/IF/LO system were evaluated by injecting a test tone in the telescope's receivers and recording spectra with the Spectral Processor. The frequency resolution of the Spectral Processor was 78 Hz. For test tone frequencies near 1420 and 4500 MHz, the test tone appeared in the proper frequency channel of the Spectral Processor. The frequency of the test tone was also varied in 7 Hz increments, and the recorded spectra were consistent with the changes in test tone frequency. The results of these tests indicate that the tuning and frequency stability of the GBT RF/IF/LO system are very good.

- Time domain reflectometry was used to search for standing waves caused by components of the GBT structure. Reflections corresponding to the distance between the top of the Receiver Room and the subreflector (15 meters) were detected. The reflections will manifest themselves as a 10 MHz standing wave in GBT spectral line observations. The strength of these reflections is about 20 dB below those initially recorded on the 140-Foot Telescope. Reflections from the GBT primary surface were not detected.

- An RFI survey conducted with the Spectral Processor and the L-band receiver showed, among other things, an unusually broad spectral feature near 1400 MHz. Further investigations suggested that the source of this signal is internal to the receiver dewar. The receiver will be removed from the telescope next month to determine the source of the RFI. The RFI survey also indicates that considerable RFI is generated by the GBT servo system.

- The GBT IF system was systematically checked for spurious spectral features by recording spectra at different combinations of LO and IF frequencies. The initial results from these IF checks are encouraging.

- The stability of GBT IF transmissions over optical fiber was tested. The tests showed that the stability is good. Excessive loss in two of the fibers was found to be caused by pinched fibers.

Outfitting activities continue on the telescope. Operational telephones were installed in the Receiver Room, Servo Room, and ACR. The S-band receiver was cooled down. Computer workstations were installed in the Servo Room so that commissioning activities could be conducted from there. The spillover shield was installed below the subreflector. However, the shield will need additional modifications because it lies within the volume of space delimited by the software limits of the subreflector. The reference horn for the holography receiver and one of the feed arm lasers will be installed in February.

The first end-to-end test of the software components in the GBT Spectrometer system was successfully completed. All Glish scripts that control the Spectrometer in its basic modes (those identified at the 1998 GBT Science Workshop) are now working.

Tests of the actuators in the active surface system have shown that some actuator motors malfunction because water has seeped into the motor housings. The extent of this problem will be determined when the tests are completed.

To prevent the motion of the azimuth track baseplates, LM welded four consecutive baseplates to the splice plates that are secured in the concrete foundation. Measurements of the track showed that the welded baseplates moved 0.003 inches relative to the foundation, whereas unwelded baseplates moved 0.055 inches. With these encouraging results, LM proceeded to secure the remaining baseplates by welding six consecutive baseplates into one super-segment. Since the azimuth track consists of 48 baseplates, the track will contain eight super-segments. The gaps between super-segments are large enough to accommodate thermal expansion of the track. LM will attempt to secure the wear strips to the baseplates by installing two, one-inch dowels on each end of a wear strip. Tests of a single wear strip will be conducted in early February to determine if the dowels secure the strip.

LM reinforced one segment of the elevation bullgear by installing Kirksite at two additional locations between the segment and the gear wheel. As in a previous test, the segment was subjected to its maximum design load of 212,000 pounds, and the resulting motion of the segment relative to the wheel was measured. The segment motion of 0.005 inches was comparable to what was measured prior to the reinforcement. A different method of reinforcing the gear may be necessary to permanently secure the segment to the wheel.

LM also completed a number of miscellaneous activities at the GBT site in January. The temporary extension to the deck at the elevation bullgear was removed. Two surface panels were reinstalled near the center of the telescope's primary reflector. One of the more severe design cases on the GBT showed that two structural members in the telescope box structure can be overstressed. LM reinforced these members so that they could accommodate the design stress.

The velocity and acceleration of the azimuth and elevation drives were reduced by a factor of two to reduce forces on the azimuth track and elevation bullgear. These modifications to the telescope servo are temporary, and the original design velocities and accelerations will be restored when the problems with the azimuth track and bullgear are resolved. A number of servo tests have also been conducted to set and check azimuth and elevation limit switches, to check subreflector motion with "cube tests", and to test the servo subcontractor's software.

B. GBT Monthly Report for February 2001

GBT commissioning observations began on the evening of February 5 by pointing and focusing the telescope with the PF Rx at a frequency of 800 MHz. By February 23, the GBT commissioning team had completed most of its prime focus work, and turned its attention to commissioning observations with the subreflector and S-band receiver at 2 GHz.

The preliminary results from the commissioning observations indicate that the performance of the GBT is as good as might be expected. Local pointing corrections at both 800 MHz and 2 GHz do not vary by more than +/- two arcminutes over the range of azimuths and elevations where observations have been made. The results from the prime focus observations show that the pointing curves are smooth, predictable, and repeatable, and that the residual pointing errors may be no larger than eight arcseconds RMS in each of azimuth and elevation. The first observations with the S-band receiver showed that the aperture efficiency of the telescope is approximately 70 percent, the system temperature is about 20 K, and the first sidelobes are about 30 dB down from the main beam. The focusing parameters for the subreflector and prime focus box have been determined to an accuracy that maintains aperture efficiency to within five percent of its optimum value. These encouraging results indicate that the optical alignment of the telescope is very good. The commissioning observations have also demonstrated that the software written for tracking, pointing, focusing, and mapping observations is working very well.

A number of software modifications and enhancements have aided the commissioning observations. Antenna trajectories have been refined for smoother transitions between antenna positions. The processing of observational data has been streamlined within AIPS++ to match observing techniques so that results can be produced quickly. A timing offset between the antenna and DCR was found to be a major contributing factor to the apparent hysteresis shown by telescope cross scans in pointing observations. Security checks have been added to the Antenna Manager so that telescope operators can control access to the telescope control system.

RFI surveys and commissioning observations with the GBT have revealed a number of sources of RFI. An unusually broad spectral feature at 1400 MHz was caused by a resonance within the dewar of the L-band receiver. After the resonance was removed by installing absorber material and a resistive card in the dewar, the L-band receiver was reinstalled in the GBT Receiver Room on February 20. Defective switches in the electrical heaters in local construction buildings produced broadband RFI that severely hampered initial observations at prime focus. The electrical power to these temporary heaters is turned off when observations are in progress. Initial observations with the S-band receiver were saturated by the 2310-2335 MHz transmissions from the Sirius satellite. This satellite was placed in operation last November and provides digital radio broadcasts for automobiles in the continental United States. The effects of the Sirius transmissions were temporarily suppressed by using an 80 MHz wide IF filter. Unfortunately, the use of the filter also suppresses the IF power to a level that is marginally useful for commissioning observations. The servo system for the prime focus boom and subreflector produce broadband RFI. Personnel in the Electronics Division are in the process of identifying the precise sources of this interference and rectifying them.

Tests of the azimuth track in late January showed that welding consecutive baseplates together could effectively reduce baseplate motion as the telescope was rotated in azimuth. The welding of the remaining baseplates in the track began on February 5, and is approximately 50 percent complete.

LM attempted to secure the azimuth track wear strips to the track baseplates by installing two, one-inch diameter dowels on each end of a wear strip. As a test on February 8 showed, this modification to one of the wear strips did not constrain the motion of the wear strip. Apparently, the force that causes the wear strip to move caused the soft baseplate material at the dowels to yield. As the holes containing the dowels became elongated due to the yielding baseplate material, the dowels began to bend and ultimately broke. The fact that the dowels broke at two or three locations is consistent with the bending hypothesis. Had the dowels failed in shear, they would have broken in one place at the interface between wear strip and baseplate. This means that the force which caused the failure does not exceed the shear strength of the dowels. LM and NRAO are investigating the use of larger dowels and shims to solve this problem.

Nine of the GBT azimuth bearings will be replaced in May. The new bearings were shipped from the SKF manufacturing facility in Sweden during the week of February 20, and should arrive at an SKF receiving facility in Tennessee by the end of March.

LM delivered CDs and a zip disk that contain as-built drawings for the GBT. The CDs contain structural and mechanical drawings, as well as the structural and mechanical portion of the GBT O&M manual. The zip disk contains the electrical drawings. LM's servo contractor, PCD, submitted its final version of the GBT Site Acceptance Test Procedure that documents the results of GBT servo tests. LM also submitted invoices for the installation of conduit and cable tray for the lower feed arm lasers and for the completion of the structural analysis of the telescope. The laser invoice has been approved for payment, and the structural analysis invoice will be approved once the analysis has been reviewed for completeness and accuracy.

The inability of the GBT HVAC system to adequately cool the Receiver Room on warm days has been attributed to air in the coolant lines. The small bleeder valve on the coolant lines was replaced with a large, 2-inch valve to aid in the removal of air from the system. The larger valve has already allowed for the addition of over 40 gallons of coolant into the HVAC system. A number of small bleeder valves will be installed at other locations in the system where air is likely to accumulate. LM is also providing a portable pump for charging the system with coolant from level one of the alidade so that air can be forced from the system.

Tests of the active surface system revealed that 25 of the 2209 actuator motors had seized because of water seeping into the motor housings. These motors will be repaired, and all actuator motors need to be resealed.

Experiments were made to test the ability of the ground laser rangefinders to automatically acquire targets on the structure at different orientations of the telescope. The rangefinders used the structural model of the telescope and readings from the telescope azimuth and elevation encoders to perform the experiment. When the telescope was stationary, the structural model was able to predict target locations to within two arcminutes of the laser pointing, which is sufficiently accurate for the lasers to acquire their targets. The lasers were also able to acquire and track targets as the telescope was tipped in elevation from 5 to 95 degrees.

Outfitting activities completed over the past month include the installation of the reference horn for the holography receiver and the installation of conduit and cable tray for the lower feed arm lasers. Cables are currently being routed to the locations of these lasers. The spillover shield was removed so that it can be modified for subreflector clearance problems. The installation of a fence around the entire GBT site was started during the week of February 26. The PF Rx was reinstalled on the telescope on February 5 after a problem with its cryogenics system was repaired.

C. GBT Monthly Report for March 2001

The first three weeks of March were dedicated to GBT commissioning observations at 2 GHz. The initial S-band observations concentrated on accurately positioning the GBT subreflector. Although the subreflector positioning system has six degrees of freedom, the primary motion of the GBT focal point occurs along the subreflector X and Y axes, which are elevation dependent primarily because of the gravitational flexure of the telescope feed arm. Observations were made to empirically determine the elevation dependent focal point, and the resulting focus tracking model was incorporated into the telescope M&C software.

The first all-sky pointing observation of the GBT using automatic focus tracking and refraction correction was made on March 9-10. After fitting the pointing data to a traditional pointing model that consists of eight physical terms, the all-sky residual pointing error of the telescope was found to be 8.5 arcseconds RMS. The pointing model is now incorporated into the telescope's M&C system for automatic pointing corrections.

The first scientific observations for the GBT were successfully conducted on March 24-26. The observations used bi-static S-band radar to image regions of Venus and a close-passing asteroid (2001 EC 16). The observations were made in conjunction with the Arecibo Observatory. The observations demonstrated the ability of the telescope's M&C software to accurately track a solar system object.

The Venus observations required accurate estimates of the GBT's location and the signal time delay between the telescope and the Jansky Laboratory. Measurements made by Dave Parker and a coordinate conversion made by Frank Ghigo show that the geocentric location of the intersection of the GBT elevation and azimuth axes is X = 882590.171m, Y = -4924873.510m, and Z = 3943729.225m. These coordinates will be useful for initial VLBI observations with the GBT. Roger Norrod found the time delay between the S-band receiver cal control switch and the converter rack in the Electronics Room to be 14,230ns +/- 100ns.

The ability of all 12 ground laser rangefinders to measure ranges to all spherical retroreflectors on the structure was successfully verified on March 14. The target ranges acquired during this experiment will be used to determine the Cartesian coordinates of the retroreflectors. The resulting coordinates can be used to refine the structural model of the telescope.

The azimuth encoder failed on the evening of March 7 and was replaced with a spare encoder the following day. This is the second encoder failure since August 2000. The encoder will be returned to BEI for repairs. An apparent failure of the elevation encoder occurred on March 26. This problem was caused by a temperature switch on the encoder power supply that protects the unit from excessively low temperatures. The power supply was cold because a LM painter had left the door open on the encoder shelter.

Miscellaneous outfitting activities continue on the telescope. Welders from the Green Bank machine shop are making a number of safety enhancements to the telescope. The C-band receiver was cooled down. A suspected vacuum leak has prevented efforts to cool down the X-band receiver. A new 5 HP cryogenic compressor was completed and tested in the cryogenics laboratory. The routing of cables to the lower feed arm lasers is now essentially complete. The lasers will be installed after these cables are terminated. The spillover shield was modified to accommodate a clearance problem with the subreflector. The installation of the fence around the GBT site is over 50 percent complete.

The welding of the azimuth track baseplates was completed the week of March 12. Two large dowels (1.5 inch diameter x 4 inches long) were then installed in either end of an azimuth track wear strip, and the motion of the wear strip relative to the baseplate was measured when the telescope was rotated in azimuth. The dowels initially constrained the wear strip motion to about 0.020 inches, but subsequent tests revealed additional motion, suggesting that the baseplate material was yielding as in a previous test. An inspection of the baseplate showed that the dowel holes were elongated in the direction of telescope motion as suspected. But unlike the previous test, the large dowels did not break, probably because of a combination of their larger size, their softer material, and their location in the track. On March 15, an attempt by LM to minimize wear strip motion by installing shims in the gaps between strips also failed. With the failure of these attempts to secure the wear strips and given the fact that additional wear strip hold-down bolts were breaking, LM recommended that motion of the telescope in azimuth should be suspended until a solution for the track problem could be found. NRAO-GB has approached consulting engineers for recommendations on how to solve this problem. In the meantime, other commissioning tasks and systems tests that do not require azimuth motion are being undertaken.

Nine new bearings that will be used to replace substandard azimuth wheel bearings on the telescope arrived at the GBT site on March 29. FEMCO, the subcontractor who will replace the bearings, will begin its work on April 30.

The installation of additional air bleeder valves on the coolant lines of the GBT HVAC system is complete. A portable charge pump was used to add additional coolant and force any remaining air out of the lines. The lines should now be completely charged with coolant, and the HVAC system should be able to adequately cool the Receiver Room.

Two items on the GBT punch list require that paint and insulation deficiencies be identified and rectified. A list of painting and insulation concerns was developed by NRAO and forwarded to LM for review.

To satisfy a requirement of its insurance company, LM used a special machine to physically verify that all main circuit breakers in the telescope electrical system trip at the appropriate current.

VI. Acronyms

AC ……………… Alternating Current

ACR ……………. Actuator Control Room

AIPS++ ……….. Astronomical Image Processor System (++)

ANSI …………… American National Standards Institute

AOC …………… Array Operations Center

AUI …………….. Associated Universities, Incorporated

BEI

BUS ……………. Back-Up Structure

CCU ……………. Central Control Unit

CPP-B ………… Command Pre-Preprocessor - B

CD ……………… Compact Disk

CDL …………….. Central Development Laboratory

CLEO …………… Control Library for Engineers and Operators

dB ………………. decibels

DCR ……………. Digital Continuum Receiver

DSP …………….. Digital Signal Processing

EDT …………….. Electronic Data Transfer

FAG …………….. Fischers Aktien-Gesellschaft

FE ………………. Front End

FEMCO

FITS …………….. Flexible Image Transport System

GBT ……………. Green Bank Telescope

GHz ……………. Giga-Hertz

GUI …………….. Graphical User Interface

HP ………………. Horse Power

HVAC …………. Heating, Ventilation, and Air Conditioning

Hz ………………. Hertz

IF ……………….. Intermediate Frequency

IRIG ……………..Inter-Range Instrumentation Group (time code)

LM ……………… Lockheed Martin

LO ………………. Local Oscillator

LVDT …………… Linear Variable Differential Transformer

M&C ………….. Monitor and Control

MCB …………… Monitor and Control Bus

MHz …………… Mega-Hertz

NRAO …………. National Radio Astronomy Observatory

NRQZ …………. National Radio Quiet Zone

NSF …………….. National Science Foundation

O&M ………….. Operations and Maintenance

OMT …………… Orthomode Transducer

PCD ……………. Precision Control Division

PBX ……………. Private Branch Exchange

PF Rx …………. Prime Focus Receiver

RE ………………. Research Equipment

RF ………………. Radio Frequency

RFI ……………… Radio Frequency Interference

RMS ……………. Root Mean Square

RPC …………….. Remote Procedure Call

RSI …………….. Radiation Systems, Incorporated

SAO …………….. Smithsonian Astrophysical Observatory

SKF……………… Svenska Kullagerfabriken

UPS ……………. Uninterruptible Power Supply

VLA …………….. Very Large Array

VLBA …………… Very Long Baseline Array

VLBI ……………. Very Long Baseline Interferometry

VME …………… Versa Module Europa