United States Gemini Program

Quarterly Review

of

The Gemini Near Infrared Spectrograph

(GNIRS)

Held

September 3, 2002

at

Tucson, Arizona

Distribution

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USGP Report of the Quarterly Review for GNIRS

September, 2002

1. Meeting Background

A USGP Quarterly Review (QR) of GNIRS was held on September 3, 2002. The meeting was attended by Jeremy Mould (Director, NOAO), Taft Armandroff (US Project Scientist, acting) and Mark Trueblood (Work Package Manager) from the USGP, Mark Hunten (Gemini observer), Larry Daggert (NOAO Engineering and Technical Services Manager) and members of the GNIRS team including Neil Gaughan (GNIRS Project Manager), Jay Elias (Instrument Scientist), and Dan Eklund (GNIRS Project Assistant). Bernadette Rodgers (Gemini GNIRS Instrument Scientist) attended by videocon. The previous QR was held May 1, 2002.

The goal of the QR's is to evaluate each instrument project's overall status with respect to the entire project lifetime and to review and assess recent progress in a number of different areas on a periodic basis, with emphasis on management and high-level concerns. Specifically, the USGP uses a formal mechanism to determine whether a project is on track with respect to budget and schedule, and to identify potential problems before they significantly impact progress.

2. Major Findings

All individual mechanism testing, both warm and cold, is complete. The project is now in the system integration phase, in which subassemblies are assembled into a complete instrument and tested as a whole.

At the September 2002 QR, the Project Manager was candid in revealing both successes (the completion of mechanism testing mentioned above) and setbacks. The latter included the following during this quarter:

- discovery that one of the short red camera lenses made of BaF_2 had a crack along an edge; this lens was returned to the vendor for rework, and is expected in September
- the slit-slide assembly, a large, major subassembly that had previously failed its third cold test, required a multi-week effort to diagnose the problem (improper bearing preparation), find an alternate vendor for bearings, procure new bearings, and install them; this is now complete, and the assembly passed its cold test and is now integrated with the main bench
- dewar wiring took longer than anticipated, in large part because of underestimation of the job, shield interference with wire routes, and problems in scheduling the work around other GNIRS tasks
- considerable rework of the radiation shields was required that had not been planned
- several smaller tasks cropped up during system integration that had not been anticipated by the team and factored into the schedule from the start.

It is normal that some unanticipated problems would be discovered at this stage, in which many tasks are sequential and most of the effort lies on the Critical Path. But for this very reason, discovering these problems at this late stage is both time-consuming and costly, and better planning on the part of both the technical staff and project management could have avoided many of them.

The Work Package Manager (WPM) now believes that it is unlikely that the instrument will be ready to be shipped from Tucson before June 2003, due to the following reasons (mostly based on project history):

- since the Project Restart, there has been a major unanticipated problem with the project every few months or so that set the project back (main bench design, bulkhead design, collimator design, radiation shields design, BaF_2 procurement, OIWFS delivery, mechanism testing); every time each major problem was solved, USGP was assured the rest of the project would proceed according to plan, yet it did not
- recent history at previous QR's has shown that about two-thirds of the milestones for a particular QR have been achieved, with about one-third outstanding; using only a rough guide of leaving a month's work to go every three months, between September and the end of March, the WPM predicts there will be over two months' additional work, pushing the Pre-Ship A/T into May if no major problems occur
- there is still considerable uncertainty in major risk areas, especially electronic noise and flexure, and to a lesser extent with light leaks. Although the bench design is more robust than other Gemini instruments, which will go a long way towards meeting the rigorous Gemini flexure requirements, until test results are in hand, there is substantial risk that additional time now not in the schedule will be required to address flexure. This is based on experience with other Gemini instruments.
- the collimator is designed to compensate for much of the residual flexure, but requires precise adjustment; although lab experiments are under way to calibrate the optical figure changes versus counterweight placement on the collimator lever arms, the WPM predicts that more iterations of counterweight placement than currently scheduled will be needed to bring the flexure within specification
- recent experience with the short red camera lens and the two gratings made incorrectly indicate that a few NOAO design/specification/inspection processes need improved "down-the-line" communication; given this, these same processes may have produced other, as yet undetected problems
- the current schedule shows four cool-down cycles; although the GNIRS team is performing a great deal of cold testing on individual mechanisms in the test dewar, the NIRI instrument amply demonstrated that this alone will not preclude the occurrence of other problems, and all other Gemini instruments have shown that four cold cycles is not enough to integrate and test an instrument of this size and complexity.

3. Project Summary

3.1 Project Overview and Key Accomplishments

The key accomplishments since the last QR have been:

- Completed diagnosis of the slit/slide mechanism failure mode, ordered and tested bearings from various vendors, then ordered production lots of bearings and installed a qualified lot of bearings into the instrument. After the new bearings were installed, the slit/slide mechanism passed its warm and cold tests.
- Diagnosed a problem with slit/slide track wear, hard anodized the tracks, tested the solution, and found it to be acceptable
- Completed replacement of lens 4 of the Short Red Camera with the correct material (see write-up below under Systems Engineering)
- Received correct replicated rulings for the gratings
- Performed a fit check of the bench, radiation shields, and dewar shell; detected some minor interferences that were corrected, permitting the instrument to be properly assembled.

3.2 Project Status and Plans

The GNIRS project is on schedule according to the recently revised schedule. Note that this is the fourth time in as many QR's that the schedule has been revised to accommodate schedule slips due to design and fabrication delays. This is confusing to those performing project oversight, and gives the misleading impression that the project is on schedule when in fact there are issues that require (and are) being addressed. In the future, USGP requests that the schedule be rebaselined no more than twice in any calendar year.

Despite being on schedule now, the WPM believes the instrument will be delivered (will pass the Pre-Ship A/T) about 8 months later than the date predicted at the Restart Review (June 2003) for the reasons given in Section 2 above. If major problems with flexure are not detected until system integration is well under way (drawing a parallel with NIRI, T-ReCS, and other Gemini instruments), the integration and testing phase could be drawn out significantly longer than currently planned.

The following goals for this September 2002 QR that were met are (some of these are from previous QR's):

- *Electrical wiring and cabling (external to the dewar).* Internal dewar wiring is still in progress, and is expected to be completed during September 2002.
- *Mechanism testing.*
- *Parts cleaning.*
- *Manual outlines.* The complete Software Maintenance Manual was delivered ahead of schedule.

- *Draft manuals.* (Please note that a "draft" as defined in the SOW has only a section or two filled in to indicate the level of detail, while a final version for Gemini review is the first time Gemini sees the complete manual.)
- *Shipping container design.*
- *Shipping container in fabrication.*
- *Grating replacement.*
- *CaF_2 lens replacement.*
- *Test Components Controller Software with electronics.*

The following goals from previous QR's that were **not** met are (**goals have been combined for clarity**):

- *Flexure testing.* This will be performed as part of the second cooldown late this autumn.
- *Complete two cold test cycles.* This is now a goal for the next QR.
- *Deliver design documentation.* As-built drawings are nearly complete, and are expected to be delivered late this autumn.

By the next review, nominally scheduled for December 2002, the Project Manager plans to:

- Complete flexure testing
- Complete two cold test cycles
- Complete manual outlines
- Complete final manuals and deliver them to Gemini for review
- Deliver design documentation
- Complete fabrication or procurement of the shipping container

In addition to these items, the USGP would add the following goals for the next QR:

- Complete all mechanical parts rework
- Receive, test, and install the short red camera BaF_2 lens, and verify it meets the image quality goals that Gemini accepted
- Verify vacuum integrity of the dewar and demonstrate it can reach acceptable vacuum levels in a reasonable time
- Verify cooldown time of the assembled instrument and demonstrate that it can reach acceptable temperature levels within a reasonable variance of the estimates provided at the design reviews
- Verify thermal stability of the optical bench and demonstrate that it can keep temperature variations within design limits
- Verify performance of the collimator mechanical flexure compensation system, and demonstrate that it can correct for flexure within design limits

The project is 92% complete from the Restart Review to the completion of the Pre-Ship Acceptance Test, now scheduled for March 2003, compared to 91% at the QR held May 1, 2002.

3.3 Project Problems and Concerns

At the September 2002 QR, the Project Manager noted the following problems and concerns:

- *Schedule:* As project staff proceeds through the last of the assembly steps to get to the point where the dewar can be closed and the first cooldown test begun, the technicians continually discover additional work. This has resulted in a week-by-week slip due to a myriad of small mechanical interference details that needed to be addressed before other tasks, such as internal dewar wiring, could be completed. The Project Manager decided to finish the basic mechanical and electrical tasks necessary to go cold with an intact instrument, without the cameras and engineering array. This means correcting mechanical non-conformances that are encountered as they proceed through the final assembly.

- *Camera:* The SRC lens has been delayed in coating at the vendor (Janos). The projected delivery keeps slipping week by week, from early September to late September. Even if this schedule is met, the processing the lens must undergo when finally received will delay installation into the camera until early October. It will take a week to install the lens and test the SRC before the camera barrel can be installed into the Camera Assembly Mechanism. This delay has created a situation where the first cold cycle will be without the Camera Barrels installed, and flexure testing will now not occur until the second cold test.

  The Project Manager decided to proceed with the first cooldown cycle with the Camera Mechanism spindle installed so the mechanism can be functionally and electrically checked out while cold. The cooldown cycle will be productive from a diagnostic viewpoint due to the large number of functional checks that can be done even though the optical path is not complete. Also, there is a good chance that the lost time may be absorbed by parallel activities already planned for in the test sequence after the first cold cycle. This is the lowest risk approach with respect to functional checkout and schedule.

- *Flexure testing:* This is a major milestone that will not be faced until the second cooldown cycle. There is therefore an increased risk of discovering a flexure problem later in the schedule that may require some backtracking to repair.

As noted above, the WPM believes that, despite the current "on-schedule" status depicted by the latest MS Project schedule update on the recently revised schedule, the project is now 9 months behind the Restart Review schedule (showing delivery in July 2002) in a way that cannot be recovered, and that this will result in late delivery of the instrument by that amount. This conclusion is supported by the fact that the Project Manager stated at the September 2002 QR that there remained no "contingency" in the schedule.

In the previous QR report, the USGP recommended that the Project Manager closely monitor the integration phase because "it will require the constant attention, involvement, and vigilance of the Project Manager on a daily basis to keep it on track and moving forward at a reasonable pace. Early recognition of problems and willingness to take action will be critical to success during

this phase of the project." Unfortunately, it now appears that the Project Manager is a step removed from the minor, day-to-day problems that impede progress, and that sum to major schedule delays. The USGP recommends that the Project Manager implement a different oversight structure for completing the remaining integration tasks, so that he is made aware of progress and problems on a frequent, if not daily, basis.

In the previous two QR reports, the WPM recommended that the Project Manager review the schedule from the standpoint of what is most likely to occur based on the experience of other Gemini instrument teams, identify possible corrective actions to mitigate problems, and put into place contingency plans to minimize the impact of possible problems. The goal of such an exercise is to move problems from the category of being "unanticipated" to being "unscheduled, but manageable". The WPM renews this recommendation.

3.4 Project Schedule

The summary-level project schedule is available on the GNIRS Web site (a copy is attached to this report). An analysis of the schedule performance of each major engineering discipline appears below. Now that the project is in the System Integration phase, the Critical Path is occupied by a limited number of sequential tasks performed by a very limited number of people, increasing the need for the Project Manager's close scrutiny and active involvement in problem identification and solution.

3.5 Project Milestones, Cost, and Manpower Charts

A summary-level Microsoft Project schedule is attached as an appendix. This reporting category is not repeated for each work area below, since all work areas are represented in the project schedule and manpower charts. The manpower charts were presented in the handouts and will not be repeated in this report, except at a summary level.

3.6 Project Budget and Expenditures to Date

The estimated cost (from January 1999 forward) increased for the third straight QR, this time by about $57k from the May 2002 QR value. The estimated cost of the project from January 1999 forward is now just over $4.5 million.

The cost of the entire project is now estimated to be over $6.9M, including the $2.4M spent between the project start in October, 1995 and December 31, 1998 when new management took over. However, this estimate has already been exceeded. As of the end of August 2002, the project had spent a total of $6,926,714 against a planned value of $6,833,426 yielding an overrun of $93,288. Overruns in labor reflect the need to retain engineering staff longer than anticipated to design the radiation shields and for other tasks. At previous QR's, the Project Manager forecasted a substantial overrun in capital, the budget for which includes contract labor for drafting staff that had to be retained longer than expected due to delays in designing and drafting various assemblies over the life of the project. This forecast proved accurate, in part due to an accounting change that moved soft money NOAO labor into capital.

3.7 Organization

The project appears to be staffed with a sufficient number of competent staff. A change from the previous QR is that Mr. Hileman has been released from the project, and is used only as an occasional consultant.

4. Project Management

4.1 Project Management Overview and Key Accomplishments

The Project Manager continues to exert management control over the project. Since the previous QR, the major accomplishment in project management was the diagnosis and repair of the slit/slide assembly, using an "investigative team" approach of staff other than those directly involved in the original design of the mechanism to determine the cause of the failure and to recommend a course of action to correct the defect. This approach corrected the problem in about a month, while other Gemini instruments have had problems drag on for several months using the original designers to diagnose their own problems.

4.2 Project Management Status and Plans

In the past, despite several technical difficulties leading to schedule slips, the project was more or less effectively managed. The fact that the projected delivery date and Estimated Cost At Completion have increased substantially over that last three QR's after not changing significantly for almost three years since the current Project Manager was assigned to the project reflects a series of problems that have eluded the normally careful scrutiny of the Project Manager. In the last four months since the previous QR, the GNIRS Team's estimated delivery date has slipped four months from November 2002 to March 2003. There have been a few technical setbacks, such as the slit/slide assembly's failing the cold testing and requiring new bearings, and the cracking of the Short Red Camera lens that are not the direct fault of the Project Manager. However, delays in dewar wiring, radiation shield fitting, and other problems could have been recognized and addressed sooner, rather than allowing them to continue while addressing the technical setbacks. This would have permitted the first cooldown to have occurred before the September QR, in the WPM's estimation.

As in the May 2002 QR report, the USGP recommends that the Project Manager become personally involved in monitoring the integration effort on a near-daily basis so that he understands the progress, the status, the setbacks, and the flow of effort at each moment of the integration effort. At this critical stage, although the Instrument Scientist must lead the technical aspects of the system integration, the Project Manager must be careful to maintain active management control of his project.

4.3 Project Management Problems and Concerns

As at the previous two QR's, the major issue now facing the Project Manager is keeping the system integration effort on track. This will require daily oversight, attention, involvement, and

vigilance by the Project Manager to keep the system integration moving ahead at the pace needed to keep it on schedule.

The USGP once again reminds the Project Manager of the huge documentation task that lies ahead, and of the resources and time required to address this task. Although some personnel have been assigned to begin writing manuals, the enormity of the undertaking should not be underestimated. The USGP recommends that the Project Manager direct a fair portion of his energy and time to reviewing this task now and determining whether the plan now in place is adequate and fits well with the current schedule and staffing plan. In particular, documents have been delivered to the USGP in what was represented by the Project Manager as being in "final" form that were clearly in an early draft form. The WPM recommends in the future that the Project Manager spend adequate time reviewing a document before forwarding it to the USGP, to ensure that a product is in the state he thinks it is before recommending it for delivery to Gemini. Only with proper review and involvement of the Project Manager and the Project Scientist will the documentation effort be successful.

4.4 Project Management Schedule

The Project Manager usually delivers reports on schedule and meets his other schedule obligations. Project Management is a level of effort activity that is 88% complete.

4.5 Project Management Budget and Expenditures to Date

The GNIRS Statement of Work does not require this WBS element to be reported separately to the USGP.

4.6 Project Management Organization

The GNIRS Project Management organization consists of Neil Gaughan (Project Manager), Dan Eklund (assigned half time as Project Assistant), and Melissa Bowersock (Administrative Assistant to the Project Manager).

5. Systems Engineering

Systems engineering is complete. All further systems engineering work is in the area of optical alignment, subsystem integration, system integration, and testing.

Since the previous QR report, the Instrument Scientist, acting as the Systems Engineer, oversaw the testing of the remade Short Red Camera lens 4, and found the new lens did not quite meet specification. In the mode that most tests its performance, the Systems Engineer predicts a 1% degradation on image quality with respect to the requirements, with nearly imperceptible, if any, impact on the science. Gemini was advised of this failure to meet the requirement, and was offered the cost-free (but with an impact to the schedule) option of having the lens remade, and chose to proceed with the lens already in hand.

6. Optics Design

The optics design is complete. All further optical work is in the area of procurement, installation, alignment, and integration.

7. Optics Fabrication

All optics fabrication is being performed by outside contractors. Previously, all GNIRS instrument optics were in hand and ready for installation. The rework for the Short Red Camera (SRC) lens (see Section 5 above) and the gratings identified in the May 2002 QR report is complete, and the optics for the flexure rig telescope simulator are in hand.

However, while assembling the new SRC lens into the camera barrel, it was noticed that the front BaF_2 lens had developed a crack along one edge. This lens was returned to the vendor (Janos) to have the crack removed by stoning. Janos had previously lost a lens to an edge crack during final processing when attempting to fill this order, and this lens will be taken off the shelf and will have its crack removed by stoning as well, to serve as a backup. Janos has had problems with its coating facility, so the estimated date for receiving the SRC lens #1 has slipped twice from late August to mid-September. This will soon cause delays in assembling the SRC in time for the first cooldown, so it appears that the camera spindle will be left on the bench unpopulated with optics barrels for the first cooldown. This will permit testing the mechanism, but without optics.

8. Mechanical Design

8.1 Mechanical Design Overview and Key Accomplishments

The shipping container design was completed. This completes all mechanical design activity.

8.2 Mechanical Design Status and Plans

Mechanical design and fabrication (which are reported together) are 96% complete overall with benches 100% complete, mechanisms 100%, and fixed assemblies 93%. All design activity is complete, and fabrication activity is complete except for the shipping container, and some minor items that are considered to be part of the integration activity, such as elongating holes in the radiation shields.

8.3 Mechanical Design Problems and Concerns

None

8.4 Mechanical Design Schedule

Mechanical design is on schedule.

8.5 Mechanical Design Budget and Expenditures to Date

The GNIRS Statement of Work does not require this WBS element to be reported separately to the USGP.

8.6 Mechanical Design Organization

The GNIRS mechanical engineering group consists of Gary Muller. The mechanical designer assigned to GNIRS is John Andrew. Dave Rosin was released from the project for reassignment in August.

9. Mechanical Fabrication

9.1 Mechanical Fabrication Overview and Key Accomplishments

Fabrication is complete except for the shipping container, which is on schedule.

9.2 Mechanical Fabrication Status and Plans

Fabrication status is not reported separately from design (see above). By the next QR, the shipping container should be complete, and all fabrication should be done.

9.3 Mechanical Fabrication Problems and Concerns

None

9.4 Mechanical Fabrication Schedule

Mechanical fabrication is complete, except for the shipping container.

9.5 Mechanical Fabrication Budget and Expenditures to Date

The GNIRS Statement of Work does not require this WBS element to be reported separately to the USGP.

9.6 Mechanical Fabrication Organization

Mechanical parts fabrication is performed by a combination of outside machine shops and the NOAO instrument shop. NOAO instrument makers assemble and check out each subassembly. The NOAO instrument maker assigned to GNIRS is John Stein. Ron Harris was released from the project in August for reassignment to another project.

10. Electronics Design

Electronics design is complete.

11. Electronics Fabrication

11.1 Electronics Fabrication Overview and Key Accomplishments

Electronics fabrication is complete, except for dewar wiring.

11.2 Electronics Fabrication Status and Plans

The overall electronics effort for design and fabrication stands at 87% complete. The only remaining electronics fabrication work is:

- approximately 30 internal dewar ribbon cables
- supporting software testing

By the next QR, fabrication and harnessing will be complete, and software testing will have begun using the integrated electronics and wired dewar. The activities listed above are now considered to be part of system integration.

11.3 Electronics Fabrication Problems and Concerns

Dewar wiring is on the Critical Path and is not progressing according to schedule or technician estimates.

11.4 Electronics Fabrication Schedule

Electronics fabrication is on the revised schedule, but the schedule has been revised in each of the three previous QR's, and dewar wiring is now on the Critical Path and seems to be not only the pacing item, but is not progressing according to schedule or technician estimates.

11.5 Electronics Fabrication Budget and Expenditures to Date

The GNIRS Statement of Work does not require this WBS element to be reported separately to the USGP.

11.6 Electronics Fabrication Organization

The GNIRS electrical engineer is Jerry Penegor, assisted by electronics technician Ron George.

12. Software Design

The software design is complete.

13. Software Fabrication

Software fabrication is complete.

14. Subsystem Integration

14.1 Subsystem Integration Overview and Key Accomplishments

Mechanism testing was completed when the problems with the slit/slide assembly were diagnosed and the bearings were replaced with commercially-prepared bearings.

14.2 Subsystem Integration Status and Plans

Subsystem integration is now complete.

14.3 Subsystem Integration Problems and Concerns

None.

14.4 Subsystem Integration Schedule

Subsystem integration is complete.

14.5 Subsystem Integration Budget and Expenditures to Date

The GNIRS Statement of Work does not require this WBS element to be reported separately to the USGP.

14.6 Subsystem Integration Organization

Bill Ditsler and Ken Don clean parts and reassemble mechanisms. Dick Joyce and Jay Elias perform mechanism testing, optical alignment, and integration. Ron George wires the dewar and performs other integration tasks.

15. System Integration

15.1 System Integration Overview and Key Accomplishments

System integration is well behind schedule, according to the payment milestone schedule. However, the GNIRS team has been looking ahead to the day when the array controller will need to be integrated, making certain it will run with the ALADDIN 3 arrays in a test dewar, and ensuring that the GNIRS controller is in good working condition years after its acceptance test and delivery to the project from Gemini.

15.2 System Integration Status and Plans

System integration is more or less on schedule according to the recently-revised schedule, but since the schedule has been revised several times in the past year, this activity is about 7-9 months late according to the Restart Review schedule.

15.3 System Integration Problems and Concerns

Other Gemini instruments have endured protracted integration periods that have delayed instrument delivery, despite mechanism cold testing and other precautions. Although the GNIRS team has endeavored to avoid the mistakes of other teams to date, and has scheduled several months for system integration, the compacted schedule and the elimination of schedule contingency have made it unlikely that the instrument will be delivered on schedule. It remains to be seen if the GNIRS team will fare better than others in terms of problems they encounter during the system integration and test and checkout phases of the project, especially after the first cold test. A well-planned and coordinated approach to system integration is essential to maintaining control of the schedule.

15.4 System Integration Schedule

The recently-revised schedule shows alignment and integration tasks to be 57% complete, as follows:

Dewar and structure	31%
Mechanism integration	94%
Warm tests	0%
Cold tests	0%

15.5 System Integration Budget and Expenditures to Date

The GNIRS Statement of Work does not require this WBS element to be reported separately to the USGP.

15.6 System Integration Organization

Various engineers and technicians perform system integration, depending on the subsystem being integrated into the instrument. The primary personnel performing system integration are Jay Elias and Dick Joyce.

16. Test and Checkout

These tasks are reported as part of System Integration.

17. Documentation and Training

17.1 Documentation and Training Overview and Key Accomplishments

A draft version of the software manual and outlines for the other two manuals were delivered for Gemini review.

17.2 Documentation and Training Status and Plans

Documentation is on schedule according to the current schedule, but is seriously behind schedule as measured by meeting Work Scope payment milestones.

17.3 Documentation and Training Problems and Concerns

Although work on manuals has begun, it has been the experience of USGP that other Gemini instrument teams have found it easier to let this important area lag while trying to finish the instrument. In particular, USGP notes the lack of a senior individual leading the documentation effort with the ability to command the team and to obtain the cooperation of its members to meet writing deadlines and to generate the materials needed to produce the manuals. Another important role of the document leader is quality control, ensuring adherence to Gemini requirements and proper responsiveness to Gemini comments. The WPM predicts that this lack of leadership will make itself evident in the months to come as the documentation effort slips its milestones even further.

In addition, the Team must allow time to iterate with Gemini on the draft manuals.

17.4 Documentation and Training Schedule

The documentation task completion status is:

- electronics -- 95% complete
- test plans – 99%
- manuals – 22% (9% in May 2002)
- as-built fabrication drawings – 0%.

Although the percent complete claimed for as-built fabrication drawings is 0%, the process for drawing update and release, and parts fabrication is to update the drawings first before parts are fabricated, instead of redlining drawings on the instrument makers desk. This should speed up the task of generating and delivering as-built fabrication drawings.

17.5 Documentation and Training Budget and Expenditures to Date

The GNIRS Statement of Work does not require this WBS element to be reported separately to the USGP.

17.6 Documentation and Training Organization

For electronics documentation, the responsible parties are the GNIRS electrical engineer, Jerry Penegor, assisted by electronics technician Ron George. Jay Elias is writing the Test Plans. Manual text is being prepared by Jay Elias, Peter Ruckle, and Al Davis.

18. Other Activities

No tasks for other activities were scheduled to begin before the Quarterly Review.