MERLAB, PC **David R. Smith, Ph.D., PE**
Mechanical Engineering Research Laboratory David_Smith@merlab.com
357 S. Candler St. (404)378-2138
Decatur, GA 30030-3746 June 17, 2011

Dr. Michael Nolan
National Astronomy and Ionosphere Center (NAIC)
HC03 Box 53995
Arecibo, PR 00612

Dear Dr. Nolan:

Please find attached a proposal to provide the design, fabrication, and testing of an automatic shutter mechanism for the Arecibo ALFA receiver. Since the most expensive component is the shutter itself, it is listed separately in the contract.

This proposal is offered with a firm, fixed price that includes engineering calculations, design drawings, test procedures, fabrication, assembly, shop testing, and site testing in a laboratory at Arecibo Observatory. The level of effort included in the quotation is clearly stated for each task; any activities requested beyond the quoted scope of work will require a separate contract.

I understand that time is of the essence for the observatory for this contract. As a result, the proposal is structured to make long lead purchases very early in the program, rather than waiting for the completion of the design.

If you have any questions, please do not hesitate to contact me.

Sincerely,

David R. Smith, President

Design, Fabrication, and Testing of an Automatic Shutter Mechanism for the ALFA Receiver at Arecibo Observatory
June 17, 2011

MERLAB, P.C.
357 S. Candler St.
Decatur, GA 30030-3746
(404)378-2138
FAX: (404)378-0822

Contact: David R. Smith, Principal and President
E-mail: David_Smith@merlab.com

Table of Contents

1.0 Introduction

The ALFA receiver at the Arecibo Observatory is a seven pixel, L-band instrument. It is the principal receiver used for the large survey projects on the telescope, so its availability must be maximized. However, for its own protection, it must be covered during radar observations. Currently, the cover consists of a 1.2 m diameter aluminum disk that matches the dimensions of the receiver ground plane. This disk must be installed manually at the platform before radar operations begin. Later, when the radar observations are complete, the cover must be removed. This installation and removal process requires multiple workers to go up to the platform, and the time lost is significant.

To address this problem, the observatory has requested the design of an automatic shutter system (filename ALFAShutterMech06152011.pdf, included here by reference). Such a system should still protect the receiver during radar operations, but must be operable from the control room. This will allow more rapid switching between ALFA observations and radar and will also eliminate the need to send a work team to the platform.

The design of the electromagnetic features of the shutter has been established by the observatory. The design effort outlined in this proposal will add additional mechanical features so that the shutter can be connected to the mechanism. The result will be an automatic system that will enable remote opening and closing of the shutter.

MERLAB's anticipated role in this project will be to design, fabricate, and test the shutter mechanism. Additionally, the effort will include the design of a support fixture to enable shop testing. In this capacity, MERLAB will perform the mechanical design and analysis, procure and supervise the fabrication of the components, and assemble and test the system. Additionally, MERLAB will repeat the assembly and lab testing at the observatory. The specific scope of work for the design phase is given in section 2.0.

2.0 Scope of Work

The scope of work for this proposal includes tasks described below. These must be performed while meeting the performance specifications, and they end in a series of deliverable items, resulting ultimately in an operational system.

2.1 Tasks

The tasks for the scope of work fall into five (5) principal categories. These are design, fabrication, assembly, shipping, and site testing.

2.1.1 Design Tasks

SOW 2.1.1.1: *MERLAB will complete the mechanical design of the shutter.*

Beginning with the electromagnetic design of the shutter provided by NAIC, MERLAB will design additional mechanical features (*e.g.*, mounting holes and flanges) necessary to connect the shutter to the rest of the system. The deflection of the system will be checked to ensure compliance with the specifications. This task is complete when the design drawings and calculations have been approved by NAIC or when design is released for fabrication and procurement.

SOW 2.1.1.2: *MERLAB will design the shutter mechanism mechanical system.*

Using the top-level specifications provided in this proposal (section 2.3), MERLAB will design or select all of the mechanical components of the shutter mechanism. It is anticipated that these components will include a support structure, guide rails, connection bracketry to the shutter, and a safety tether. Additionally, MERLAB will select drive elements (*e.g.*, a linear actuator, motor, and any necessary gearing) sufficient to achieve the desired motion. For all designed or selected mechanical components, hand calculations will be provided demonstrating sufficient strength, stiffness, and/or life as appropriate. In addition to the shutter mechanism, the design will also include an assembly procedure and the design of a test fixture sufficient to allow operation of the system on the ground. This will enable shop verification of the system and also laboratory testing at the Arecibo Observatory prior to installation on the receiver cabin rotating platform. The design of each component is complete when the design drawings and calculations have been approved by NAIC or when design is released for fabrication and procurement.

SOW 2.1.1.3: *MERLAB will design the shutter mechanism electrical system.*

Using the top-level specifications provided in this proposal (section 2.3), MERLAB will design an RFI/EMI shielded drive cabinet to provide control of the actuator selected in section 2.1.1.2. This cabinet will include RFI/EMI shielding for any cable feedthroughs or ventilation openings. This task is complete when the design drawings and calculations have been approved by NAIC or when design is released for fabrication and procurement.

SOW 2.1.1.4: *MERLAB will submit design review documentation to NAIC.*

The limited time available to this effort will not permit a single design review for the whole system prior to starting any fabrication or procurement. However, as indicated in tasks 2.1.1.1–2.1.1.3, prior to releasing any component for fabrication or procurement, MERLAB will provide the drawings or design documentation to NAIC. Completion of this task is included in the sections 2.1.1.1–2.1.1.3.

2.1.2 Fabrication Tasks

SOW 2.1.2.1: *MERLAB will subcontract and supervise the fabrication of the shutter.*

MERLAB will contract with an appropriate machine shop to fabricate the shutter designed in section 2.1.1.1. Additionally, MERLAB will contract for the fabrication of a simple, flat plate of the same outer dimensions, edge thickness, and hole pattern for use in the test fixture. Alternatively, MERLAB will supervise the shutter and test plate fabrication at a vendor selected and paid by NAIC. This task is complete when the shutter and test plate are ready for shipment from the fabrication subcontractor.

SOW 2.1.2.2: *MERLAB will procure or subcontract the components of the shutter mechanism mechanical system.*

MERLAB will contract with appropriate machine shops or vendors for the fabrication and procurement of all components of the mechanism and the test fixture. This task is complete when all of the components have arrived at MERLAB.

SOW 2.1.2.3: *MERLAB will procure or subcontract the components of the drive system and cabinet.*

MERLAB will contract with appropriate machine shops or vendors for the fabrication and procurement of all components of the drive cabinet, including actuators, sensors, and cables. This task is complete when all of the components have arrived at MERLAB.

2.1.3 Assembly Tasks

SOW 2.1.3.1: *MERLAB will perform or subcontract the assembly of the shutter mechanical system.*

MERLAB will, either internally or via subcontract, assemble the shutter mechanical system and test fixture. This task is complete when the system is assembled on the test fixture, including either the actual shutter or the shutter test plate.

SOW 2.1.3.2: *MERLAB will perform or subcontract the assembly of the drive cabinet.*

MERLAB will, either internally or via subcontract, assemble the drive cabinet, including all cabling. This task is complete when the drive cabinet is assembled and connected to the mechanism and when the system is ready for acceptance testing.

SOW 2.1.3.3: *MERLAB will perform shop acceptance testing of the system.*

MERLAB will perform acceptance testing of the system at its facility. This task is complete when the acceptance testing checklist has been completed.

2.1.4 Shipping Tasks

SOW 2.1.4.1: *MERLAB will package the components in a manner suitable for shipping to Arecibo Observatory.*

MERLAB will separate the tested system into components suitable for shipping. Then, using a local shipping store (*e.g.*, UPS or Fedex), MERLAB will package these components for shipping to Arecibo Observatory. This task is complete when the components are packaged and ready to ship.

SOW 2.1.4.2: *Arecibo Observatory will provide the shipping of the components to their site.*

Shipping costs are not included in this proposal. Arecibo Observatory will either cover shipping directly under their account number with the shipper, or will reimburse MERLAB for any shipping charges. This task is complete when tracking numbers have been obtained for each of the packages.

2.1.5 Field Testing Tasks

SOW 2.1.5.1: *MERLAB will reassemble the system in a laboratory at Arecibo Observatory.*

MERLAB will send at least one person to Arecibo Observatory to repeat the assembly of the system in a laboratory space to be provided for the purpose. Operation and adjustment of the system will be demonstrated on the test fixture. This task is complete when the system has been demonstrated according to the acceptance test checklist.

SOW 2.1.5.2: *Arecibo Observatory will install the system on the rotating platform.*

Arecibo Observatory staff are responsible for the installation and alignment of the system on the rotating platform of the receiver cabin. If this is conducted during the same week as the laboratory testing, then the MERLAB staff present on site will supervise and consult.

However, a second site trip for this purpose is not included in this proposal. This task is complete when the system has been installed on the rotating platform.

2.2 Special Considerations

Because of constraints on the funding and timing of the project, the project must be completed by September 30, 2011. Further, payment for purchased or fabricated components must occur as soon as possible to ensure their timely arrival and availability of funding. This implies that long-lead items, such as the shutter, the actuator, and the motion control hardware must be ordered early, perhaps even before the design of other components has been completed.

2.3 Top-Level Specifications

The top-level specifications upon which this proposal is based are given below:

Safety Requirements

- Safe against falling
  - Minimum factor of safety for gravity and floor acceleration at any position: 2
  - Minimum number of independent means of support: 2
  - Minimum number of mounting bolts that can fail and still meet all specifications: 1
  - Fraction of platform mounting bolts that are captive: 100%
- Safe against blocked motion
  - Blocked motion timeout: 2 s
- Safe against unexpected rotary floor motion
  - Interference due to motion of rotating floor: None
- Safe against unexpected loading
  - Emergency survival point load: 1 kN
- Safe against undetected shutter opening
  - Minimum number of switches indicating shutter closure: 2
- Safe against unexpected motion
  - Minimum number of E-stops: 1
  - Minimum additional available connections to the E-stop chain: 2
  - Interference during ALFA rotation: None

Installation and alignment requirements

- Installation
  - Maximum number of technicians required for installation: 3
  - Max. # of technicians required to have rigging safety gear during installation: 2
  - Maximum number of other instruments to be removed during installation: 0
- Alignment
  - Maximum number of technicians required for alignment: 2
  - Max. # of technicians required to have rigging safety gear during alignment: 1
  - Minimum number of fiducial reference marks: 3

Geometric and general requirements

Maximum interference points with existing structure: 0

Maximum total system weight: 80 kg

Corrosion protection for fabricated parts: Alodyne for Aluminum parts, galvanizing for steel. Stainless and plastic parts require no additional protection.

Loading requirements

Orientation of the system

Zenith angle range: 0°–20°.

Floor rotation angle range: 0°–360°.

Inclination of the shutter with respect to the floor: 8.11°.

Combined Angles in direction of shutter motion: −8.11°–28.11°

Combined Angles across direction of shutter motion: ±20°.

Floor acceleration specifications

Center distance on rotating floor: 1.83 m.

Floor angular acceleration: $26^\circ/s^2$.

Floor angular velocity: 18°/s.

Shutter mechanism performance requirements

Open/Close Time

Maximum open/close time: 30 s

Minimum open/close time: 10 s

Minimum number of available TTL indications of limit switches to indicate open or closed positions: one per switch

Shutter Deflection: <0.5 mm, change from no loading to gravity loading when supported at designed pickup points.

Shutter Fabrication tolerances: As in the NAIC-provided drawing, but typically ±1 mm, with a flatness of 0.2 mm (±0.1 mm).

Shutter alignment in closed position

Average gap between shutter and ALFA ground plane around perimeter: 2 mm, minimum goal is 1 mm, non-contacting.

Parallelism: Gap variation of < ±0.5 mm.

Lateral alignment: ±1 mm

Electrical requirements

Power

Power source: 120 VAC single phase grounded outlet

Maximum power: 2 kW

Electromagnetic Attenuation: −50 dB, according to the NAIC design (outside of MERLAB's scope).

Electromagnetic Interference

Enclosure requirements: RFI/EMI shielded from Hoffman, all feedthroughs shielded.

External Communications: Fiber optic 100BaseFX, multimode ST connectors

Remote power off capability: via network power strip

Command Interface
Minimum command functions: ON, OFF, STATUS, OPEN, CLOSE
Minimum number of TTL indications available at a shielded feedthrough for each limit switch or interlock: 1

2.4 Deliverables

2.4.1 Design Deliverables

During the design, a brief weekly update summarizing the status and progress will be provided via e-mail. As the design progresses, the following documentation will be provided:

1. Shop drawings of all parts to be fabricated, including the final structural design of the shutter, in AutoCAD and PDF format,
2. A parts list (vendors and part numbers) of any items to be purchased,
3. Data sheets of any items to be purchased,
4. An installation procedure,
5. An alignment procedure,
6. An operation description, including any proposed commands and protocols for communication,
7. Pinout diagrams for all connectors on the electrical cabinet, and
8. A checklist showing the shop tests performed and their results.

2.4.2 Fabrication Deliverables

During the fabrication, a brief weekly update summarizing the status and progress of procurements and fabricated parts should be provided via e-mail. The principal deliverable is the final system, including the test fixture, ready for shipping. However, a document containing the results of the demonstration test will also be provided.

2.5 Schedule

If NAIC can accept the approach of purchasing the long-lead items before the completion of the rest of the system design, then MERLAB expects that the system can be completed and shipped within 3 months of the contract commencement date (CCD). For a CCD of July 1, 2011, the system should be complete by September 30, 2011. Approximate dates of significant milestones are as follows:

Week 2: Shutter out for fabrication
Week 3: Actuator, controller, and cables ordered
Week 5: Design complete, remaining parts ordered or sent out for fabrication
Week 8: Assembly starts
Week 10: Shop testing
Week 11: Shipping to site
Week 13: Site testing

3.0 Personnel

To accomplish the tasks given in the Statement of Work, MERLAB will initially assign Dr. David R. Smith. He will be available to perform the tasks within the scope of this proposal. Dr. Smith's curriculum vitae is attached.

4.0 Scope of the Quotation

This quotation covers all of the activities described in section 2.1. Additionally, it includes $3,500.00 USD to cover a one year increase in MERLAB's professional liability insurance from our customary $100,000.00 USD per claim to the $1,000,000.00 USD coverage required by NAIC's (Cornell University's) contracting policies. Since this level of insurance is not required by any other client, MERLAB will bill NAIC annually for the additional coverage as long as we maintain a contractual relationship. If NAIC wishes for MERLAB to maintain the higher level of coverage after the contractual relationship is terminated, MERLAB will issue a final invoice to cover the added costs for an additional three years and will commit to maintaining coverage for that time period. One trip of one work week to Arecibo Observatory is included in this proposal.

4.1 Quotation

MERLAB's firm, fixed price quotation is as follows:

Purchased or Fabricated Items:
- Shutter (task 2.1.2.1): **$30,000.00 USD**.
- Mechanism and test fixture (task 2.1.2.2): **$10,000.00 USD**.
- Controller Hardware and electrical cabinet (task 2.1.2.3): **$15,000.00 USD**.
- Subtotal of purchased or fabricated parts: **$55,000.00 USD**.

MERLAB
- Additional insurance required by Cornell University: **$3,500.00 USD**.
- Travel for one week site testing: **$1,500.00 USD**.
- Engineering (tasks 2.1.1.1–.4, 2.1.3.1–.3, 2.1.4.1, and 2.1.5.1): **$30,000.00 USD**.
- Subtotal MERLAB: **$35,000.00 USD**.

NAIC/Arecibo Observatory
- Arecibo Tasks (tasks 2.1.4.2 and 2.1.5.2, MERLAB will support): No cost included.

Total: **$90,000.00 USD**.

4.2 Payment Terms

As shown in section 4.1 below, most of the cost contained in this proposal is for purchased or fabricated parts. Further, over half of that cost is for the shutter alone. To manage the cash flow required for the early purchase of parts, MERLAB proposes the following payment terms.

1. 100% of the estimated shutter cost, upon contract commencement (**$30,000.00**). Alternatively, in lieu of this payment, NAIC can contract with the shutter fabricator directly, with MERLAB providing the local contact and supervision.

2. 50% of the estimated cost of other purchased of fabricated parts, upon contract commencement (**$12,500.00**).

3. The remaining 50% of the estimated cost of other purchased parts (**$12,500.00**) upon shipping of the system to Arecibo Observatory.

4. Engineering hours will be billed monthly as they are incurred, with a not-to-exceed limit of 240 hours.

5. Travel and insurance to be billed at the end of the contract.

4.3 Valid Dates

This price is valid if the contract commencement date (CCD) is before September 1, 2011. The target delivery of September 30, 2011 is valid for a CCD of July 1, 2011, but MERLAB will apply its best efforts to meeting the target delivery date even with a slightly later CCD.

4.4 Out of Scope Activities

If additional work is contracted from MERLAB beyond the scope of this quotation, it will be subject to the MERLAB's standard policies and hourly rates. For reference, the rates and policies for 2011 are attached to this proposal.

MERLAB, PC Rates and Billing Policies

Hourly Rates valid 1/1/2011 through 12/31/2011

During its normal business hours, MERLAB, PC charges the following rates:

Direct charges

Principal Engineer: $75.00/hr

Indirect Costs (54.0%):

Includes hardware, software, general services (legal, payroll, accounting), facility, network/basic telecommunications, part time student filing/clerical help, general and professional liability insurance ($100,000 limit).

Total costs: $115.50/hr

Fee (8%)

Total Billing Rate: $124.74/hr

MERLAB, PC: Billing Policies

Expenses

The following expenses are billed as they occur, and do not incur indirect costs or fees:

Travel costs

Airfare, rental cars, lodging, meals, parking, tolls, taxis/limousines, and other directly incurred travel expenditures

Holidays

MERLAB, PC maintains its usual business hours from 8am-5pm, Eastern Time, Monday through Friday, except for the following holidays:

New Years Day	Martin Luther King, Jr. Day
President's Day	Memorial Day
Fourth of July	Labor Day
Thanksgiving (Wed-Fri)	Christmas Eve
Christmas Day	

Chargeable hours

When MERLAB, PC agrees to provide services at times other than normal working hours, or at locations other than the main office, hourly charges will be modified according to the following table:

Description	*Modification*
Evenings/Weekends	1.5× hourly rate
Holidays (except as below)	2.0× hourly rate
Thanksgiving (Wednesday-Sunday) Christmas Eve Christmas Day	3.0× hourly rate
Travel	The lesser of 10 hrs/day or actual time away from office

David Rowland Smith, Ph.D., PE

MERLAB, PC
357 S. Candler St.
Decatur, GA 30030-3746
Voice: (404)378-2138 FAX: (404)378-0822
David_Smith@merlab.com

I. Education

Ph.D. in Mechanical Engineering, Georgia Institute of Technology, with Minors in Mathematics and Engineering Design, June, 1990.

Master of Science in Mechanical Engineering (MSME), Georgia Institute of Technology, March, 1988.

Bachelor of Mechanical Engineering (BME) with Highest Honor, Georgia Institute of Technology, December, 1986.

II. Work Experience

Principal (2000–present), MERLAB, PC, Mechanical Engineering Research Laboratory. Duties include:

Performing engineering analysis and mechanical system design
Conducting field testing and commissioning of telescope control systems
Providing technical review of existing designs and analysis
Conducting vibration and wind response testing of large structures
Recent projects
  Design of a phased array feed positioner for the Arecibo 305m telescope.
  Control system design, testing, and commissioning for the KVN 21m telescope.
  Control system testing and commissioning for the LMT 50m radio telescope
  Design of replacement S-Band shutter for the Arecibo 305m radio telescope

Visiting Associate Professor (2010, 2004), Dept. of Physics, Agnes Scott College.
Taught courses in Classical Mechanics (2010) and Scientific Computing (2004).

Visiting Engineer (2006–07), Arecibo Radio Observatory.
Provided advice on mechanisms and structures for the telescope and instrumentation.

Associate Professor (1998–2000),
Assistant Professor (1992–98), Dept. of Mechanical Engineering, University of Massachusetts Lowell. Tenured August, 1998.

Co-director of Modal Analysis and Controls Laboratory (MACL) 1998–2000.
Taught and developed undergraduate and graduate Engineering Design courses
Conducted research in characterization, design and control of Smart Structures

Advised graduate and undergraduate students
Served on departmental and college committees.

Summer Faculty Fellow (Summer 1997 and 98), NASA Goddard Space Flight Center.

Developed a testbed for vibration control of space-based instrumentation
Assisted in the design, development, and testing of a novel vibration isolation actuator.

Visiting Research Engineer (Summer 1995), Instituto Nacional de Astrofísica, Óptica, y Electrónica (INAOE), Tonantzintla, Puebla Mexico.

Designed and analyzed measurement approaches for large active surfaces

Visiting Research Engineer (Summer 1993), Five College Radio Astronomy Observatory (FCRAO), Dept. of Physics and Astronomy, University of Massachusetts Amherst.

Developed strategies for the figure control of the active primary reflector of a large aperture millimeter-wave telescope

Research Engineer (1990–92), Five College Radio Astronomy Observatory.

FCRAO
- Conducted feasibility studies of active surface systems
- Analyzed structures and mechanisms for use on the FCRAO 14m telescope

Two Micron All Sky Survey (2MASS)
- Designed the control of the secondary mirror for the prototype survey camera
- Implemented and tested the control system at the 1.3m telescope at Kitt Peak

III. Professional Associations

Registered Professional Engineer, Massachusetts #41067, Georgia #026440
Full Member of American Society of Mechanical Engineers (ASME)
SPIE – The International Society for Optical Engineering
SPIE International Technical Group on Smart Structures and Materials (1998–2005).
SPIE Program Committee for the Astronomical Structures and Mechanisms Technology Conference, 2004–08.

IV. Other Skills

Operating systems: Windows 95/98/XP/NT/Vista, Mac, VMS, and Unix
Programming: FORTRAN, C, C++, X-Windows toolkits, M68HC11 assembly
Internet: HTML, perl, cgi-bin scripts, Java applets, JavaScript, Web page administration
Language Skills: conversational and technical Spanish, rudimentary German
Commercial Pilot, airplane single and multi-engine, instrument rating (COM ASMEL-IA), with Private Pilot privileges in Helicopters (PPRH).
Open Water SCUBA Diver (SSI # 450093)

RECENT PUBLICATIONS

1. Smith, D.R., and Souccar, K., "Main axis control of the Large Millimeter Telescope," *SPIE symposium on Astronomical Telescopes and Instrumentation*, San Diego, CA, 2010.
2. Smith, D.R., and Souccar, K., "Friction compensation strategies in large telescopes," *SPIE symposium on Astronomical Telescopes and Instrumentation*, San Diego, CA, 2010.
3. Smith, D.R., "Thermal imaging of the Large Millimeter Telescope structure," *SPIE symposium on Astronomical Telescopes and Instrumentation*, San Diego, CA, 2010.
4. Smith, D.R., and Souccar, K., "A Polynomial-Based Trajectory Generator for Improved Telescope Control," *SPIE symposium on Astronomical Telescopes and Instrumentation*, Marseille, France, June 2008.
5. Souccar, K., and Smith, D.R., "Initial Results with the Large Millimeter Telescope Tracking System," *SPIE symposium on Astronomical Telescopes and Instrumentation*, Marseille, France, June 2008.
6. Smith, D.R., Souccar, K., and Kendall, J., "Design and Field Performance of the KVN Main Axis Control System," *SPIE symposium on Astronomical Telescopes and Instrumentation*, Marseille, France, June 2008.
7. Smith, D.R., "Achievable Alignment Accuracy and Surface Hardness of a Large, Welded Azimuth Track," *SPIE symposium on Astronomical Telescopes and Instrumentation*, Orlando, FL, May 2006.
8. Greve, A., Smith, D.R., and Bremer, M., "A Multi-Layered Thermal Model of Backup Structures for mm-Wavelength Radio Telescopes," *SPIE symposium on Astronomical Telescopes and Instrumentation*, Orlando, FL, May 2006.