

Appendix B
Documents and Data Reviewed

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4.0 Documents and Data Provided by AO and UCF13

1.0 Introduction

Our investigation of the telescope's collapse partially relies on documents and data produced throughout the structure's history.

A primary source of documents is Cornell University's Rare and Manuscript Collections, which we refer to as the CU Archives. CU managed the Arecibo Observatory (AO) from 1969 to 2011, and their archives contain a large volume of documents including reports, contracts, drawings, meeting minutes and correspondence. As shown in Figure 1, the second upgrade of the telescope is particularly well documented. The documents reviewed are listed in Section 2.0 below, and the correspondence reviewed is listed in Section 3.0.

Most of the other documents used in our investigation were provided directly by AO and the University of Central Florida (UCF), who currently manages AO. These include documents produced after the end of the CU era in 2011, and some information that was only available on site such as maintenance records and monitoring data. The main documents and data sets provided by AO and UCF are listed in Section 4.0 below.

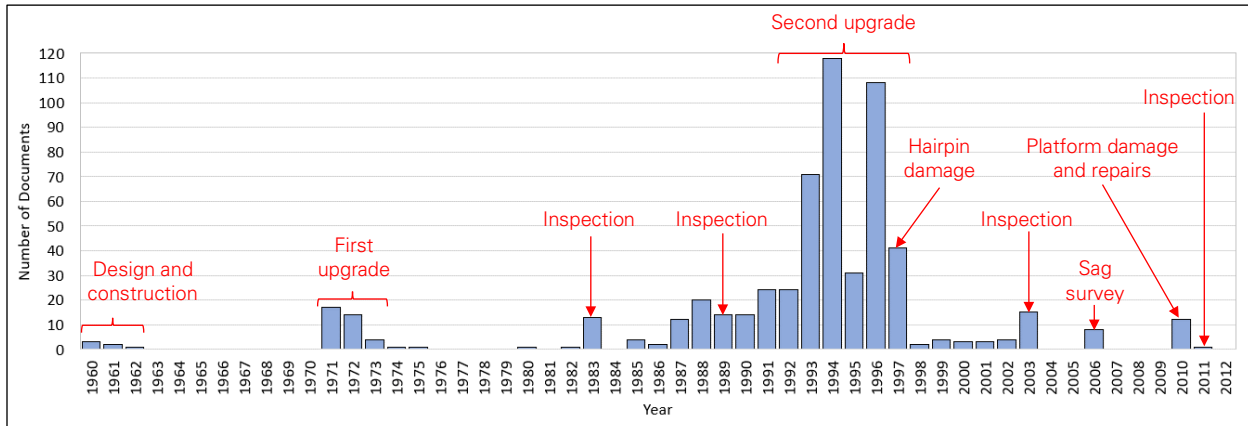


Figure 1: Production dates of reviewed documents retrieved from the CU Archives.

2.0 CU Archives Documents

Table 1: Reviewed documents retrieved from CU Archives.

Date	Title	Author Organization(s)	Contents	Type
1/1/1960	Original Tower Drawings	Von Seb, Inc	Original tower and backstay anchor structural drawings. Tower design is sloped, not stepped.	Drawings
7/19/1960	Boring Log	CU	Boring log from original construction with notes from Bill McGuire.	Report
12/1/1960	Cable and Anchorage Metalwork, Central Feed Structure	Von Seb Inc	Structural drawings of original telescope structure. Includes platform, cables and waveguide. Does not include towers or backstay anchors.	Drawings
6/28/1961	Tower and Backstay anchor structural drawings	Von Seb Inc, Garcia Commercial Inc	Final tower and backstay anchor structural drawings. This is the stepped tower design.	Drawings
7/5/1961	Platform Truss Details	Bethlehem Steel Company	Blueprints of platform and azimuth steel members and connections.	Drawings
1/1/1962	Telescope construction photos	AO	Telescope construction photos.	Media

Table 1: Reviewed documents retrieved from CU Archives.

Date	Title	Author Organization(s)	Contents	Type
1/1/1971	Wind Tunnel Tests of the New Reflector Surface Proposed for the Arecibo Radar Telescope	Sage Action Inc	Results of wind tunnel test of new reflector surface for first telescope upgrade. Performed by Sage Action at Cornell, and Boundary Layer Wind Tunnel Lab at University of Western Ontario.	Report
9/17/1971	Arecibo Proposers Meeting with LTV Electrosystems	US Court Reporters	Meeting minutes of meeting between people from Cornell, LTVE, DBA Service, Bookhaven National Lab were present. LTVE responds to questions from NAIC.	Report
1/1/1972	Upgrade Drawings	AW	Drawings for 1st upgrade. Date is estimated.	Drawings
2/1/1972	Cornell-AW Agreement	CU	Engineering services agreement between Cornell, NAIC, and Amman & Whitney for upgrading the antenna feed positioning and tracking capabilities of Arecibo.	Admin.
2/1/1972	Summary of Modifications	AW	Summary of required modifications for 1st upgrade.	Report
2/28/1972	Arecibo Transmitter Engineering Report [incomplete]	Raytheon	Excerpts from report include table of contents, mechanical design and weight summary, and high-power dummy load design considerations.	Report
2/28/1972	Conceptual Design of a High-Power S-Band Radar Transmitter [incomplete]	Continental Electronics	Includes introduction and weight estimates on catwalk, Azimuth arm, carriage house.	Report
5/8/1972	Engineering Services Agreement - NAIC Upgrading project	CU	Contract between CU and AW to perform condition assessment of telescope structure and study feasibility of the first upgrade.	Admin.
7/15/1972	Arecibo Reflector Upgrading - Project Schedule	LTV	Construction schedule for telescope first upgrade.	Admin.
8/5/1972	Engineering Service Agreements - NAIC Upgrading Project	CU	Contract for AW to (1) evaluate the condition of the structure and (2) perform feasibility study of an upgrade.	Admin.
8/15/1972	Feasibility Study and Concept Development for Upgrading of Suspended Antenna Structure	AW	Report by AW on feasibility of an upgrade. Includes information about design basis and wind loads.	Report
8/15/1972	Results of survey of suspended structure and reflector cable anchorages.	AW	Survey data for platform and reflector anchorages.	Report
9/15/1972	Report on Inspection of cable System	AW	Inspection reports, including count of wire breaks on all cables.	Report
10/20/1972	Tiedown Cable System Anchorages	AW	Drawings for new anchorage tiedowns along with elevation vs. distance plots relative to the existing anchorages	Drawings
10/20/1972	Tie-down Cable System Plan, Elevation and Cable Details	AW	Drawings of tiedown system as modified by 1st upgrade. Mentions 110mph as survival wind speed.	Drawings
2/14/1973	Supplemental Agreement No. 5	CU, E-Systems Garland Division, AW	Agreement between Cornell and LTVE. Includes exhibits: Technical provisions for tie-down cable system, Results of Survey of suspended Structure and Reflector Cable Anchorages, Increase in contract price.	Admin.
3/22/1973	Test report on Hanger G2	AW	Weld testing report on weld on Hanger G2.	Report
9/25/1973	A&W On-Site Trip Report	AW	Notes from trip whose purpose was on-site review and coordination of the design drawing for the upgrade of the elevation railway.	Report
10/9/1973	Invitation for Bids - Site Work, Special Tasks	Continental Electronics	Continental Electronics is the contractor and is asking for bids to be its subcontractor for 6 different tasks.	Admin.
10/18/1974	The Upgraded Arecibo Observatory	Science	6-page paper on the first upgrade of the telescope.	Article
6/15/1975	Instructions, Arecibo Superstructure Analysis Program for use on IBM System/370 (Model 168) Computer at Cornell	CU	Instructions to use a dedicated computer program to analyze the telescope structure.	Report
11/1/1980	Gregorian feed concepts for the Arecibo Telescope	CU	Paper that presents conceptual designs for the Gregorian feed systems in the search for optimum designs.	Report
8/8/1983	Preliminary Cable grip design and quote	Lucker Manufacturing	Quote for a cable grip with capacity of 300 kip.	Admin.

Table 1: Reviewed documents retrieved from CU Archives.

Date	Title	Author Organization(s)	Contents	Type
8/8/1983	Summary of wire break and structural history up to 1983	AW	Part of a report containing map of wire breaks and discovery dates up to 1983. Confirms that all of the breaks are near a socket.	Report
5/9/1985	Radome Pressure Dist. Calculations	NAIC	Calculations of wind pressure on radome surface.	Calcs.
7/30/1985	Radome Wind Tunnel Study Contract (University of Western Ontario & Cornell University)	NAIC	Contract between NAIC and the University of Western Ontario to perform a wind tunnel test in preparation for the addition of a radome on the platform.	Admin.
1/1/1986	Condition of Steel Cable After Period of Service	CU	Paper by CU professors S.L. Phoenix, H.H. Johnson and Bill McGuire. Talks specifically about Arecibo Observatory, and B12-3 cable replaced in 1981 due to wire breaks. Also discusses cable sockets.	Article
11/25/1986	Subcontract Between Cornell and Pratt	CU, Pratt	Subcontract between Cornell and Pratt for Pratt to study seismic effects on the supporting towers.	Admin.
11/9/1988	Inspection "mini physical" scope and cost	AW	Scope and cost of inspection to be performed by AW.	Admin.
12/5/1988	Draft of Engineering service inspection agreement (AW & NAIC)	NAIC	Draft of agreement between NAIC and AW for AW to perform inspection of structure.	Admin.
5/1/1989	Mini Inspection Results	AW	1989 inspection results.	Report
7/1/1989	Report on the Project of Earthquake Related Upgrading of Tower 8 Support at the Arecibo Observatory	Dr. Mikolaj Wegrzyn	Report on upgrading the Tower 8 foundations for seismic reasons.	Report
1/3/1990	Arecibo Upgrade Study	TIW Systems	Report of third party review of preliminary design for the Gregorian upgrade. Mentions good condition of structure.	Report
1/3/1990	NAIC Gregorian Upgrade Drawings	AW	Structural drawings for Gregorian upgrade. Include platform reinforcement, new cables, and changes to backstay anchors and tower tops.	Drawings
9/16/1990	Upgrading Organization Chart	NAIC	Upgrade Planning/Design task group organizational chart and roster.	Admin.
10/2/1990	Proposed organization hierarchy and roles for upgrade	NAIC	Proposed organization charts for upgrade project.	Admin.
10/26/1990	Algorithm and Sample Calcs for Hagen's Geometry	NAIC	Sample calculation to convert six ranging measurements into pointing directions.	Calcs.
12/9/1990	Azimuth Rail Shimming Curve for Lifted Platform	NAIC	Analysis of azimuth rail shimming after the platform has been elevated.	Calcs.
1/17/1991	Revised Photogrammetric Survey Agreement	NAIC	Follow-up to phone call about revisions made to SRMC's proposal.	Admin.
8/19/1991	Proposal for Stress Analysis of the Ring-Girder Hangers at the Arecibo Observatory	Fracture Analysis Consultants Inc	Proposal for FE analysis of current and proposed hangers supporting the ring girder. File also includes related paperwork and correspondence.	Admin.
11/21/1991	Transmittal of Owner/Engineer Agreement between CU and AW	CU	Contract between CU and AW for Gregorian upgrade engineering. Includes NSF's authorization. Details scope of AW's work.	Admin.
1/1/1992	1992 Estimated Design Weight - Gregorian Weight	Unknown	Gregorian dome weight breakdown.	Data
1/1/1992	AO Upgrade Rigging Scheme	Canron	Plan view drawings of the post-Gregorian-upgrade site.	Drawings
1/14/1992	Gregorian Structural System Calculations 02141992	Research Engineers Inc.	STAAD model output includes node displacements, member forces, etc.	Calcs.
1/27/1992	Anchor Cable 8-2 Report	NAIC	Report about observed protuberances on backstay B8-2. Includes sag survey data. Includes note about previous survey error.	Report
2/10/1992	Gregorian Structural System Calculations 02101992	Research Engineers Inc.	STAAD model output includes node displacements, member forces, etc.	Calcs.
3/12/1992	Platform Average Elevation @ Corner of WP for 90°F	NAIC	Plot of average platform elevation between 1974 and 1992.	Data

Table 1: Reviewed documents retrieved from CU Archives.

Date	Title	Author Organization(s)	Contents	Type
4/30/1992	1992 Upgrading Platform Maintenance Report	NAIC	Upgrading platform maintenance report.	Report
6/26/1992	Tensioning of Cable System	AW	Jack set-up to tension auxiliary backstays at ground end.	Drawings
7/1/1992	Auxiliary cable fabrication requirements	NAIC	Requirements for fabrication of auxiliary cables.	Admin.
7/1/1992	Technical Specifications and List of Drawings for Gregorian Upgrading	AW	Specifications and a list of gradings for the 1992 Gregorian upgrade.	Drawings
7/22/1992	Final Report of Structural Analysis of the Existing and Proposed Hangers for the Arecibo Ring Girder	Fracture Analysis Consultants, Inc	Report on FE analysis of existing and proposed ring girder hangers.	Report
9/21/1992	SETI Project	Geotec	Report on geotechnical investigation for SETI project.	Report
10/1/1992	Addendum No. 1 to Specifications for Gregorian Upgrading	AW	Revisions to the specifications for Gregorian Upgrading.	Admin.
1/11/1993	Cable Tensioning Sequence	NAIC	Cable tensioning sequence for Gregorian upgrade. Includes description of steps and weight increase. Overrides previously defined tensioning sequences.	Report
1/11/1993	Cable Tensioning Sequence	AW	Revised cable tensioning procedure.	Procedure
6/14/1993	Design Pressure Coefficients for Spherical Domes	TEMCOR / West Wind Laboratory	Report on wind tunnel tests of lon-span domes. This is a generic test of domes, not specifically of Arecibo's Gregorian dome.	Report
7/9/1993	Submittal of Welding Certifications and Mill Certifications.	RSI	Mill certifications from Bethlehem Steel.	Report
8/5/1993	Wind Tunnel Testing of Dome	RSI	Proposal to perform wind tunnel test of Gregorian dome.	Admin.
8/10/1993	Measurement of the Structural Response of a New Ring-Girder Hanger at the Arecibo Observatory	Fracture Analysis Consultants Inc	Report on in-situ strain gage analysis of the new ring girder hangers.	Report
8/17/1993	Modulus and Ultimate Strength Testing of Six Structural Strands	Williamsport Wire rope Works Inc	Results of strength and stiffness tests of cables for 2nd upgrade, performed at Leghigh University.	Report
9/3/1993	Anchor Dimensions	RSI	Discussion of the dimensions of the aux. backstay anchors, which impacts the length that the cables must be cut at.	Drawings
9/28/1993	Cable Raw Material Certification and Strength Test Results	RSI	Mill certifications and strength test results for auxiliary cables.	Report
10/8/1993	Various mill certifications and steel test reports	Tubular Steel Inc	Mill certificates.	Report
10/17/1993	Revised Cable Length Calculations and Revised Drawings	RSI	Sketches showing aux. cable dimensions based on later survey data.	Drawings
11/11/1993	Various mill certifications and steel test reports	Multiple steel fabricators	Mill Certifications and other test reports.	Report
12/1/1993	Wind study of Arecibo Radio Observatory	West Wind Laboratory	Report on wind tunnel test of Gregorian.	Report
1/26/1994	Waveguide Moment Calc	NAIC	Calc of moment introduced by thermal expansion of the waveguide and its effect on the moment on the joint.	Calcs.
2/9/1994	Transmitter Room Floor Deflections	NAIC	Calc that analyzes the deflection of the transmitter room floor due to load included by transmitter installation and its potential effects on the integrity of the torque tube.	Calcs.
2/14/1994	Borehole logs	Geotec	Bore logs near backstay anchors made in preparation for Gregorian upgrade.	Report
3/25/1994	Feed Platform Erection Plan - Phase 2	RSI	Plan to install X Bracing, Replace the center bearing, and replace some of the bolts.	Procedure

Table 1: Reviewed documents retrieved from CU Archives.

Date	Title	Author Organization(s)	Contents	Type
4/11/1994	Submittal of Plan for the Removal of the Tie Down Cables.	RSI	Plan to remove existing tiedowns.	Procedure
4/14/1994	Arecibo Factory Inspection/Test Submittal Report	RSI	Mill Certifications and other test reports.	Report
4/15/1994	Arecibo Factory Inspection/Test Submittal Report	RSI	Mill certifications.	Report
4/15/1994	Arecibo Factory Inspection/Test Submittal Report	RSI	Mill Certifications and other test reports. Test reports and manufacture of C's Bolts, Nuts and Washers.	Report
4/15/1994	Secondary Submittal of Plan for the Removal of the Tiedown Cables.	RSI	Revised plan to remove existing tiedowns.	Procedure
5/23/1994	Additional Loading of Anchor Blocks by Gregorian Antenna	Geotec	Report on backstay anchor capacity to support additional load from Gregorian upgrade.	Report
6/6/1994	Cable Joint and Saddle Gap	NAIC	Photo and sketch of gap raising future corrosion concerns.	Report
7/5/1994	Feed Platform Erection Plan - Phase 2. Revision A.	RSI	Plan for implementing platform upgrades (cross-bracing, bolt replacement, center bearing installation).	Procedure
7/5/1994	Feed Platform Erection Plan, Revision A	RSI	Plan to implement platform modifications as part of the second upgrade.	Procedure
7/13/1994	AO Upgrade - Structural Upgrade Rigging Schematic	North American Tower King	Rigging drawing for installing the aux. cables.	Drawings
8/3/1994	[8-3-1994] Submittal of Procedure, Cable Tension Monitoring	RSI	Plan for monitoring the cable tensioning procedure. Includes details of the procedure.	Procedure
8/7/1994	Cable Installation and Tensioning Work Plan	RSI	Detailed procedure for aux. cables installation.	Procedure
8/18/1994	Feed Platform Erection Plan - Phase 2. Revision B.	RSI	Revised plan for implementing platform upgrades (cross-bracing, bolt replacement, center bearing installation).	Procedure
8/18/1994	Feed Platform Erection Plan, Revision B	RSI	Revised plan to install X Bracing, Replace the center bearing, and replace some of the bolts.	Procedure
8/24/1994	Cable Installation and Tensioning Work Plan, Rev A	RSI	Detailed procedure for aux. cables installation.	Procedure
9/6/1994	Platform Main Truss reinforcement installations	NAIC	Report that platform reinforcement installation is complete.	Report
9/21/1994	Auxiliary Cable detail structural drawings	RSI	Structural drawings of auxiliary cables and associated hardware (sockets, threaded rods).	Drawings
10/7/1994	Visitor Center for the Arecibo Observatory	Geotec	Report on geotechnical investigation at location of Visitor Center.	Report
11/1/1994	Waveguide modified supports	NAIC	Sketches of modified supports for the waveguide.	Drawings
12/15/1994	Change Order Reference [15-Dec-1994]	CU, RSI	Change orders for Gregorian construction. Supporting information mentions design wind speed and subsequent Gregorian design changes.	Admin.
12/26/1994	Unbalanced Moment, Feed Arm Active Control, Tie Downs	AW	Calculations on feed arm unbalance and tiedown tensions.	Calcs.
1/30/1995	Tower Deflection Monitoring Log	RSI	Tower deflection monitoring log for a few days in January 1995.	Data
8/30/1995	Tower Deflection report	RSI	Plots of tower deflection vs time	Report
10/1/1995	Gregorian Dome Weight	Unknown	Detailed breakdown of Gregorian dome weight.	Data
10/6/1995	Tie Down Jack Design	NAIC	Drawings of power lines and supports for tiedown jacks.	Drawings
10/13/1995	Platform Tie Down Jack	NAIC	Drawings of tiedown jacks.	Drawings
10/30/1995	Update to Permitted Zenith Angle Combinations	NAIC	Provide acceptable combinations of zenith angles for the Gregorian and Line Feed, after Joe Vellozzi increased the allowable unbalance moment on the azimuth.	Calcs.
11/10/1995	Dome Weight, Permitted Zenith Angle, Tie Down Tensions	NAIC	Includes: Gregorian Dome Weight estimate; Electronics Shelter Drawings; Memo "Permitted Zenith Angle Combinations"; Memo Required Tie-down Tensions.	Calcs.

Table 1: Reviewed documents retrieved from CU Archives.

Date	Title	Author Organization(s)	Contents	Type
11/17/1995	Cable Installation and Tensioning Work Plan	RSI	Procedure to install and tension the aux. cables.	Procedure
12/14/1995	Intermediate Tensioning and Tower Deflection Report	RSI	Cable tensioning and tower deflection intermediate report.	Report
1/1/1996	The second Arecibo upgrade	IEEE	6-page paper on the Gregorian upgrade.	Article
3/14/1996	Aux Cable Tensioning	AW	Alternate cable tensioning procedure.	Procedure
4/9/1996	Platform Height Change during dome liftoff on 3 April 1996	NAIC	Monitoring data for platform height as Gregorian upgrade is being implemented.	Report
4/9/1996	Technical Report - Second Intermediate Tensioning	RSI	Report of 2nd intermediate cable tensioning. Includes cable forces and tower deflection measurements.	Report
5/23/1996	Report - 3rd Intermediate Tensioning	RSI	Detailed report on 3rd intermediate tensioning of the cables. Includes cable force measurements.	Report
6/4/1996	Backstay and Main Cables Catenary Sag	NAIC	Sag survey of Tower 4 and 12 cables.	Data
6/4/1996	Tower Deflection after cast tension of auxiliary main cables	NAIC	Sketch and tower deflection measurements.	Data
6/6/1996	A-12 backstay catenary resurvey	NAIC	Results of Tower 12 catenary sag survey.	Report
7/17/1996	Bill McGuire - Proposed Consulting Agreement	NAIC	Proposal to hire Bill McGuire as consultant on cable issues during the Gregorian upgrade.	Admin.
8/15/1996	Optical Lab Project	Geotec	Report on geotechnical investigation at location of Optical Lab.	Report
9/19/1996	Arecibo Observatory - Cable Tension Inconsistencies	NAIC	Report on 1st, 2nd and 3rd intermediate tensioning steps, and cable tension inconsistencies observed.	Report
9/23/1996	Cable Tension Inconsistencies	RSI	Report on difficulties in measuring cable tension during jacking, and inconsistencies in results. Includes summary of previous measurements, and recommendations.	Report
10/28/1996	Joe Vellozzi Draft Procedure, final backstay tensioning	NAIC	Procedure to finish tensioning the backstays.	Procedure
11/14/1996	Feed Platform Weight Audit	RSI	Feed platform weight audit 6/14/1996-11/14/1996	Data
11/14/1996	RSI Platform Weight Data	RSI	RSI Platform Weight Data 6/14/1996-11/14/1996	Data
12/12/1996	(12-12-96) Anchor Cable Broken Wire	NAIC	Photos of a broken wire at Tower 4 backstay anchor.	Media
12/12/1996	Tower Deflection Monitoring Procedure	RSI	Procedure for monitoring the deflection of towers. Includes a log from 1994-1996.	Procedure
2/5/1997	Map of cuts in damaged hairpin	NAIC	Map of cuts in damaged hairpin.	Data
2/6/1997	Arecibo Hairpin Material Property Analysis	LPI	LPI proposal to perform material testing on hairpin.	Admin.
2/6/1997	Hairpin details, damage and updated arrangements	AW, NAIC	Sketches and notes on hairpin damage.	Drawings
2/15/1997	Dome Weight Calibration	AW	Calcs and correspondence about the effect of dead load cable tensions on the deflection and tilt of the gregorian dome.	Calcs.
2/15/1997	Photos (hairpin)	Unknown	Photos of damaged hairpin rod and related laboratory tests.	Media
2/21/1997	Tensioning results from 2-21-97	NAIC	Status report on tensioning activities.	Report
2/25/1997	Evaluation of 3in Diameter Rod - Arecibo Hairpin	LPI	LPI report on testing of damaged hairpin rod.	Report
2/25/1997	Evaluation of 3-in Diameter Rod - Arecibo Hairpin	LPI	LPI test results for hairpin.	Report
2/25/1997	Take-up at T4	NAIC	Comparison of planned vs actual platform position. Includes monitoring data.	Data
3/3/1997	A Proposal to NAIC for Fracture and Fatigue Analyses of a Damaged Hairpin Rod at Arecibo.	Fracture Analysis Consultants	Proposal to analyze damaged hairpin. Scope includes analysis and testing.	Admin.

Table 1: Reviewed documents retrieved from CU Archives.

Date	Title	Author Organization(s)	Contents	Type
3/3/1997	Fracture and Fatigue Analyses of a Damaged Hairpin Rod at Arecibo	Fracture Analysis Consultants, Inc	Report on analysis and monitoring of damaged hairpin.	Report
3/31/1997	Upgrade Weight Tracking	NAIC	Document tracking weight of the platform from 1993 through 3/31/97	Data
4/5/1997	Aux Hairpin Details	AW	Sketches of auxiliary cable hairpin.	Drawings
5/2/1997	Damage to T8 hairpin	RSI	Notice form RSI to Cornell that they will be seeking compensation from Cornell for the extra effort cause by the hairpin damage.	Admin.
6/19/1997	Some facts (and a little history) about Arecibo	Cornell Chronicle	Summary of Arecibo's history, including both upgrades.	Article
9/25/1998	Hurricane George	NAIC	Report on damage sustained by Hurricane George. Mentions 1/16" movement at sockets.	Report
1/25/1999	Seismic Risk Survey, Arecibo Observatory	EQE International	Proposal to perform a seismic risk assessment.	Admin.
8/15/1999	Analysis of survey data taken in June 1999	CU	Analysis of survey of secondary reflector.	Report
10/1/1999	Seismic Risk Survey NAIC Arecibo Observatory	EQE International	Report on seismic risk. Partly based on the review of a 1986 report by Pratt University.	Report
3/15/2000	Main Cable Data (length, weight, angles)	AW	Cable force calculation from cable sag.	Calcs.
12/4/2000	Visitor Center at Arecibo Radio Observatory	Geotec	Report on geotechnical investigation at location of Visitor Center.	Report
12/8/2000	Administration Building at Radio Observatory	Geotec	Report on geotechnical investigation at location of Administration Building.	Report
1/8/2001	North V.S.Q. Building at Arecibo Observatory	Geotec	Report on geotechnical investigation at location of Visiting Scientists Quarters.	Report
2/15/2001	Gregorian Antenna Feed Module Weight Survey	NAIC	Weight of some equipment in the Gregorian. Total is 24 kip.	Data
1/1/2002	The National Astronomy and Ionosphere Center's Arecibo Observatory in Puerto Rico	Single Dish Radio Astronomy	24-page paper on the history of Arecibo Observatory up to 2002.	Article
10/29/2002	Evaluation of Fracture Bolt - Arecibo antenna	LPI	Analysis and testing of a broken bolt.	Report
2/27/2003	Gregorian weight measurements 1998, 2003	NAIC	Results of Gregorian weight measurements performed in 1998 and 2003. Trolley weight is shown separately.	Data
3/27/2003	Weight added to Gregorian by Maintenance Department since December 1993	NAIC	List and weight of items added to the Gregorian between 1993 and 2003. Total is 12 kip.	Data
5/13/2003	Condition Assessment of Radio Telescope - Arecibo Observatory	LPI	Report on assessment of anchor bolts.	Report
5/15/2003	Arecibo telescope Structural Condition Survey 2003	AW	AW report on structural condition survey.	Report
5/28/2003	Suspended Structure Weight Measurement	AW	Sag survey and derived cable forces and platform weight.	Report
7/15/2003	Dome Weight with Jacks	NAIC	Jack pressures during dome weight measurement.	Data
12/4/2003	Arecibo Telescope Structural Review	CU	List of items requiring remedial action, based on AW structural review. Includes condensation in Tower 4 backstay socket boxes.	Report
12/5/2003	Arecibo Telescope Structural Review	NAIC	List of deficiencies identified by the AW 2003 survey.	Report
12/5/2003	Feed Support System Balancing Requirements and Use Limitations	AO	List of constraints and allowances for the feed system and azimuth arm weight and positioning	Calcs.
8/29/2006	Suspended Platform Weight and Main Cable Tensions from Measured Sags	AW	Results of 2006 sag survey, including cable tensions and platform weight. Also includes platform weight from 2003 and 1992 sag surveys.	Report

Table 1: Reviewed documents retrieved from CU Archives.

Date	Title	Author Organization(s)	Contents	Type
2/1/2010	Report on the Geotechnical Investigation At the Proposed Site for the New Arecibo Observatory Reference Antenna	Sierra Geotechnical Group	Report on geotechnical investigation at location of Reference Antenna.	Report
2/3/2010	Photos (slipped bolts, buckled lacing)	NAIC	3 photos showing slipped bolts and buckled lacing.	Media
2/16/2010	Proposed Repair Procedure	AW	Procedure and drawings to repair damaged member/connection.	Drawings
3/15/2010	Report on the Geotechnical Investigation At the Proposed Site for the HF Antennas	Sierra Geotechnical Group	Report on geotechnical investigation at center of reflector in preparation for installing the 6 HF antennas.	Report
4/6/2010	P-886 soil sample HF Antennas Boring Location	Sierra Geotechnical Group	Boring locations for geotechnical investigation at center of reflector, in preparation for installing the 6 HF antennas.	Drawings
9/8/2010	Proposed reinforcement drawing, 2010 updates	AW	Structural drawings for the reinforcement of 4 platform members.	Drawings
9/8/2010	Proposed Reinforcement Sequence	AW	Order in which 4 platform members are to be reinforced and required azimuth and Gregorian position at each step.	Drawings
3/15/2011	Arecibo Telescope Structural Condition Survey 2011	AW	Full report on condition survey. Includes photographs, drawings with observation locations, and LPI test reports.	Report

3.0 CU Archives Correspondence

Table 2: Reviewed correspondence retrieved from CU Archives.

Start Date	End Date	Instances	Author organization(s)	Subject
3/1/1971	11/18/1971	15	CU, LTV Electro Systems	Pre-Contract Correspondence
9/1/1972	-	1	CU	NAIC Upgrading Project – Comments on A&W Design
12/23/1982	-	1	Bethlehem Steel, CU	Confirmation of Cable Testing
1/10/1983	-	1	CU	Comments on AW Condition Survey Report
1/19/1983	-	1	CU, National Steel Erectors Corp.	Response to cable installation and wire breaking inquiry
4/1/1983	4/22/1983	2	NAIC	Feedback on AW condition assessment report
4/6/1983	-	2	NAIC, William McGuire	Feed Support System Correspondence
7/27/1983	-	1	NAIC, RSI	Testing for Structural Strand
8/8/1983	-	1	CU	Recommended engineering tests and companies for second telescope upgrade
8/8/1983	-	1	CU, Lucker Manufacturing	Proposed Cable Grip - Lucker Manufacturing
8/9/1983	-	1	United States Steel Corp, William McGuire	Strand Testing Correspondence and Meeting Minutes
8/19/1983	-	1	NAIC	Tower Top - Main Cable No. 4
9/30/1985	11/6/1985	2	CU, NAIC	Radome Wind Tunnel Study
4/1/1987	12/3/1987	12	AW, CU, Metropolitan Soils and Engineering Materials Laboratory, Inc., NAIC	Review of Geotec Subsoil Exploration Report
4/5/1988	-	2	NAIC, William McGuire	Cable deterioration concerns article
9/12/1988	9/25/1988	3	AW, NAIC	A12-3 slackening after 1981 installation
11/9/1988	11/21/1988	2	AW, NAIC	Suspended Structure “mini physical”
11/22/1988	-	1	AW, CU	Proposal to increase AW inspection scope to include NDT of welds
12/10/1988	12/16/1988	10	AW, CU, NAIC	Monitoring the Embedded Backstay Cables, mini physical, testing
1/11/1989	-	10	NAIC	Main Cable M4-4 Wire Broken
1/20/1989	-	1	CU, NAIC	Request for CU Facilities and Business VP to be a part of condition survey results conversation

Table 2: Reviewed correspondence retrieved from CU Archives.

Start Date	End Date	Instances	Author organization(s)	Subject
1/24/1989	-	1	AW, NAIC	Cracks in azimuth ring girder hangers
2/12/1990	-	3	NAIC, Planning/Design Task Group	Meetings #1-3 Minutes, Appendices
10/2/1990	-	1	NAIC, NSF	Proposed organization hierarchy and roles for upgrade
10/15/1990	-	1	NAIC	Platform Lift Discussion
12/7/1990	12/9/1990	3	NAIC, Planning/Design Task Group	Review of separate carriage house and feed system, Azimuth Rail, Carriage House Layout
1/16/1991	1/17/1991	4	NAIC, Southern Resource Matting Corporation	Photogrammetric Survey SRMC
2/11/1991	-	10	NAIC, Planning/Design Task Group, Composite Engineers	Meetings #4-9 Minutes, Appendices
7/16/1991	-	1	AW, NAIC	Platform Balancing Requirements and Use Limitations
8/27/1991	10/9/1991	3	Cirrus Consulting, NAIC	Arecibo Antenna Analysis
10/8/1991	-	1	Antenne-Kildal, NAIC	Synthesis of Gregorian Arecibo Feed
10/17/1991	-	1	NAIC	Report on NAIC Interaction with Scientific Technical Upgrading
10/18/1991	-	1	NAIC	Memorandum Ground Screen Configuration
1/12/1992	-	6	NAIC, Planning/Design Task Group	Meetings #10-14 Minutes, Appendices
2/18/1992	-	1	AW, NAIC	Necessary tiedown arrangement for structural and Gregorian considerations
5/11/1992	8/13/1992	2	AW, NAIC	Presentation/comments on AW 95% completed detailed design work
7/1/1992	-	1	AW	Confirmation of vertical tiedown outrigger stability
7/1/1992	-	1	AW, RSI	Design Wind Speed, Gregorian Dome
1/11/1993	-	1	Wire Rope Industries of Canada, Ltd	Prestretching Procedure
1/19/1993	-	6	NAIC	Meeting #15-20 Minutes, Appendices
2/4/1993	-	1	AW, NAIC	Proposed steel collars and new tower saddles, exceptions to cable specifications
5/6/1993	-	1	NAIC	Site Map Database
6/1/1993	-	4	AW, RSI	Anchor Bolt Alignment, Cables, Working Slab on Main anchors, Structural Cable Information
6/1/1993	-	2	RSI, Williamsport Wirerope Works	Elevated strength cable design and testing, Discussion of auxiliary cable testing loads and schedules
6/14/1993	-	1	RSI, Temcor, West Wind Laboratory	Design Pressure Coefficients for Spherical Domes
6/29/1993	7/1/1993	2	AW, NAIC	Anchor A8, Newly Discovered Shelf, Testing of Structural Strands
7/9/1993	-	6	AW, NAIC, RSI	Cable Length / Survey Data, Testing, Cable Joint, Anchor Dimensions
10/1/1993	1/1/1994	9	AW, NAIC, RSI	Gregorian Wind Tunnel Tests
10/1/1993	10/1/1996	24	Continental Electronics Corporation, NAIC, RSI, Temcor	Weight correspondences (43 pages)
10/17/1993	-	1	AW, RSI	Revised Cable Length Calculations and Revised Drawings
1/1/1994	-	2	Hart Consultant Group, Temcor, WWL	Design Wind Speed, Gregorian Dome Upgrading
1/4/1994	-	1	NAIC	WWL wind Tunnel test comments
2/2/1994	-	1	CU	Arecibo seismic upgrade comments
2/7/1994	-	1	RSI, Temcor	Dome design per clearance, deflection, and wind speed
2/17/1994	-	1	CU, NAIC	Earthquake design magnitude
2/26/1994	-	1	NAIC, William McGuire Consulting Structural Engineer	ASCE 7-95 Wind Loads
2/28/1994	-	1	NAIC	WR-2100 layout for 430 MHz Transmitter in Gregorian

Table 2: Reviewed correspondence retrieved from CU Archives.

Start Date	End Date	Instances	Author organization(s)	Subject
3/1/1994	-	2	AW, NAIC, RSI	Dome design wind speed clarifications
3/3/1994	-	1	CU, RSI	Arecibo Gregorian Upgrading Project
3/17/1994	-	1	NAIC	430 MHz Waveguide
4/1/1994	-	3	NAIC, RSI	Submittals of Plan for the Removal of the Tie Down Cables
4/7/1994	-	1	NAIC	Comments on Platform Erection Plan, Phase 2
5/1/1994	-	2	NAIC	430 MHz Waveguide
5/1/1994	8/1/1995	4	NAIC	Azimuth Feed Arm Center Bearing
5/4/1994	-	12	NAIC	Platform Main Truss Reinforcement Installations, Platform Erection Plan
5/18/1994	1/6/1994	3	AW, NAIC	Cable Joint Weldment Rat Hole Memo #4, Cable Joint and Saddle Gap
6/1/1994	4/1/1997	22	AW, NAIC, RSI	Cable Drape for Gregorian, Field issues
6/21/1994	-	1	AW, RSI	Main Aux Cables
6/21/1994	-	1	NAIC	Weldment #06 on RSI Drawing 15040
6/23/1994	-	6	NAIC	Auxiliary Main Cable Joints - Clip Angle Hole Reaming
7/5/1994	-	1	NAIC	Thoughts about the 430 MHz System in the Gregorian
7/19/1994	-	1	RSI, NATK	Review of Procedure
8/22/1994	8/29/1994	2	NAIC	Cable Installation and Tensioning Work Plan procedure comments
8/26/1994	-	1	AW, NAIC	Waveguide Realignment Detail
9/1/1994	4/1/1997	17	AW, NAIC	Tiedown Information
9/13/1994	-	1	NAIC	Exist Main Cable Adjustment
9/22/1994	-	1	NAIC, RSI	Cable Tension Monitoring Procedure
11/1/1994	-	1	NAIC	Waveguide modified supports
11/3/1994	-	1	NAIC	Additional Spacers on the Cable Fittings at the Tower Saddle
2/3/1995	-	11	AW, NAIC, RSI	Cable tensioning procedure, monitoring, comments
2/20/1995	-	1	NAIC	430 MHz Transmitter
2/23/1995	-	1	NAIC	A.O. Existing Jack Equipment
2/27/1995	-	1	AW, NAIC	Platform Weight
3/7/1995	-	1	AW, NAIC, RSI	Chafing Plate Rework
5/18/1995	-	1	NAIC	WR-2100 for Upgrade
10/6/1995	-	1	NAIC, RSI	First Intermediate cable tensioning
10/11/1995	-	3	AW, NAIC	Permitted Zenith Angle Combinations, Dome Weight, Tie Down Tensions
10/20/1995	10/23/1995	2	NAIC, RSI	Cable tensioning, shims
1/12/1996	-	1	NAIC, RSI	Tower Deflection
1/25/1996	-	1	NAIC	Updated weight tracking sheets
1/25/1996	-	2	NAIC, RSI	Relief from Backup Cable Tensioning Monitoring
2/2/1996	-	1	NAIC	430 MHz System
2/3/1996	-	3	NAIC	430 MHz Switch
2/8/1996	-	1	NAIC	Carriage House 1
2/8/1996	-	1	NAIC, RSI	Feed System Weight for Intermediate Tension
2/14/1996	-	1	NAIC, RSI	Intermediate Cable Tensioning #2
3/4/1996	-	3	NAIC	Platform Elevation
3/13/1996	-	1	AW, NAIC	Aux Cable Creep
3/14/1996	-	1	NAIC, RSI	Update of Dome Weight Estimate
3/27/1996	-	1	AW, NAIC	Final Cable Adjustments
4/17/1996	-	1	Elgood-Mayo, NAIC	Request for budget estimates for maintenance due to anticipated cable creep
4/29/1996	4/30/1996	5	AW, NAIC, RSI	2nd/3rd intermediate tensioning
4/30/1996	-	1	NAIC, RSI	Chairs for monitoring existing backstay

Table 2: Reviewed correspondence retrieved from CU Archives.

Start Date	End Date	Instances	Author organization(s)	Subject
5/1/1996	-	1	NAIC	Tensioning – 3-inch rise after backstay tensioning
5/1/1996	5/2/1996	2	NAIC	Platform Height, 15 March - 15 May 1996
5/2/1996	-	1	NAIC	Dome lift line winch tension
5/6/1996	-	2	AW, NAIC	Main Cables/Anchors 4 and 12, Catenary measurement, backstays, aux mains
5/7/1996	5/8/1996	7	AW, NAIC, RSI	3rd Intermediate Tensioning, cable geometry/force calculations
5/7/1996	-	1	NAIC, RSI	Main aux cables additional jacking requirements
5/9/1996	-	1	NAIC, RSI	Work stopped on upgrade
5/9/1996	-	1	NAIC, RSI	Data on Hydraulic Cylinders
5/22/1996	-	1	NAIC	Platform Weight sheets - updated
6/1/1996	-	5	AW, NAIC, RSI	Monitoring of A12 backstays
6/6/1996	-	1	AW, NAIC	Platform Position Before and After Intermediate Tensioning
6/12/1996	-	1	AW, NAIC	Cable sags/tensions
6/26/1996	-	1	AW, NAIC	Cable Tension Summary
6/28/1996	-	1	NAIC	Cable Sag Survey
7/6/1996	-	1	NAIC	Weight Sheets
7/8/1996	-	1	William McGuire Consulting Structural Engineer, Construction Technology Laboratory	Cable tension measurement technique discussion
7/30/1996	-	1	NAIC, RSI	Cable Tension Verification with Sag Measurement
8/7/1996	8/12/1996	2	AW, NAIC, RSI, Temcor	Dome Correspondence
9/18/1996	-	10	AW, CEC, NAIC, RSI	Waveguide Correspondence
10/2/1996	-	1	Elgood-Mayo, RSI	Measurement accuracy and recalibration
10/11/1996	-	3	NAIC	A4,8,12 Cable oscillation period measurements
10/15/1996	-	1	AW, NAIC	Final Cable Tensioning and Raising of Platform
10/18/1996	-	1	AW, NAIC	Ballast Platform Weight
10/22/1996	-	1	NAIC, William McGuire Consulting Structural Engineer	Idea to install strain gages on aux backstays to monitor forces
10/23/1996	-	2	AW, NAIC, RSI	Tensioning and tiedown installation schedule clarification
10/30/1996	-	1	AW, NAIC	Jacking Testing Scheme
10/30/1996	-	1	NAIC, RSI	Weight addition/removal, context unspecified
11/1/1996	11/9/1996	2	AW, NAIC	A-4 Cable Catenary Sag
11/1/1996	1/1/1997	13	AW, NAIC, RSI	Final backstay tensioning (procedure, final measurements)
1/24/1997	1/31/1997	2	AW, NAIC	Platform Elevation Survey Following Tensioning at Corner 4, Cable U bolt cut on Main 8-4
1/25/1997	1/26/1997	2	AW, NAIC	Monitor tension, Final jacking tensions per cable
2/1/1997	-	10	NAIC, RSI	Final tensioning at all towers
2/2/1997	2/14/1997	6	Anthony Ingrassia Consulting Structural Engineer, AW, LPI, NAIC, RSI	Damage to T8 Hairpin, Summary, Testing, Examination
2/2/1997	-	1	AW, NAIC	Send 12" samples to LPI
2/15/1997	-	1	AW, NAIC	Dome Weight Calibration
2/17/1997	-	1	NAIC	Load Cell
2/18/1997	-	1	CU, RSI	Your Letter of February 5, 1997
3/10/1997	-	1	NAIC	Hairpin nuts
5/2/1997	-	1	NAIC, RSI	Damage to T8 hairpin
11/6/1998	-	1	AW, NAIC	Cable Tensions
1/12/1999	-	1	NAIC, EQE International	NAIC's request for a proposal to perform seismic risk assessment
11/14/2001	-	1	AW, CU	Gregorian Trolleys

Table 2: Reviewed correspondence retrieved from CU Archives.

Start Date	End Date	Instances	Author organization(s)	Subject
1/24/2002	-	1	NAIC	Dome Feed Module Load
9/18/2002	-	1	AW, NAIC	Shim Block Bolts
3/28/2003	-	1	NAIC	Dome Weight
5/12/2003	-	1	NAIC	Broken Wires in Cables
5/26/2003	-	1	AW, NAIC	Dome Weight from Platform Corner Displacement
7/23/2003	7/24/2003	2	NAIC	Anchor 8 Broken Wire, Gregorian Dome Weight
12/11/2003	-	1	NAIC, William McGuire Consulting Structural Engineer	Comments on azimuth drive/feed arm system
3/17/2006	-	2	NAIC	Catenary Survey
6/6/2006	-	1	CU, NAIC	T4 Auxiliary cable force discrepancy
7/21/2006	8/29/2006	2	AW, CU	Suspended Catwalk System Limiting Weight Study
8/31/2006	9/1/2006	2	CU, NAIC	Cable Reactions on Towers
2/11/2010	-	1	AW, NAIC	Notes on proposed connection repair
2/14/2010	-	1	AW, CU, NAIC	Arecibo Repair
4/20/2010	-	2	AW, CU, NAIC	Meeting
11/29/2010	-	1	William McGuire	Questions and Suggestions for Studies and Action Concerning Arecibo

4.0 Documents and Data Provided by AO and UCF

Table 3: Reviewed documents and data provided by AO and UCF.

Start Date	End Date	Title	Author Organization	Contents	Type
1/1/1969	12/31/1989	Quarterly Maintenance Reports	AO	Quarterly report describing the telescope's condition and maintenance performed.	Maintenance Records
1/1/1997	12/31/2017	Maintenance cards	AO	Logs of maintenance performed on the telescope.	Maintenance Records
1/1/2004	12/1/2020	Wind speed data	AO	Wind speed and direction recorded at platform weather station.	Data
6/1/2004	8/10/2020	Telescope operation data	AO	Azimuth, Gregorian and line feed angles and tiedown forces vs. time.	Data
1/14/2014	-	M8-4 splice photos	AO	Photos of broken wires in M8-4 splice box.	Media
3/11/2014	-	Earthquake Damage to Main Support Cable M8-4	AW	Report on M8-4 splice bypass	Report
4/24/2017	-	Arecibo Observatory – Main Cable Tensions and Suspended Platform Weight from LIDAR Measured Cable Sags	Louis Berger	2016 Sag Survey	Report
1/1/2018	12/1/2020	Maintenance Logs	AO	Logs of maintenance performed on the telescope.	Maintenance Records
8/10/2020	-	Platform position data	AO	Platform corner elevation and platform rotation before and after M4N failure.	Data
8/11/2020	11/30/2020	Drone inspection photos	AO	Drone inspection photos of cables and sockets near the towers and platforms, performed regularly after the first cable failure.	Media
9/1/2020	-	Cable sag survey	AO	Laser scans of the telescope's cables performed after the first cable failure.	Data