From: "secretary@areciboscience.org" <secretary@areciboscience.org>
Subject: **[asapmembers] ASAP Member Newsletter: Earthquake Damage and Planned Repair**
Date: February 11, 2014 8:17:00 PM EST
To: asapmembers@areciboscience.org
10 Attachments, 5.0 MB

Dear ASAP Member,

As many of you may have heard, the Arecibo Observatory suffered serious damage to one of its main support cables during the January 13 magnitude 6 earthquake. The damaged cable was the "short" cable delivered 12 feet too short by Bethlehem Steel in 1962 and then spliced so it could go into service at that time. The other cables retain sufficient strength to support the platform; however, should the damaged one give way, it would fall in a manner that would do severe damage to the reflector and its precise alignment.

Observatory engineers identified the breakage the morning after the earthquake. Then consulting structural engineers from Ammann & Whitney in NYC flew in promptly to assist in assessing the scope of the damage and strategizing about its repair. Head Maintenance Engineer Filipe Soberal has now designed a temporary repair to the damaged cable, and most telescope motion and access to the bowl and platform are mostly curtailed pending completion of the repair. Several science programs that do not require telescope motion, however, remain in progress. The heavy steel materials for the repair have been ordered, and the detailed machining of the various parts is underway. Under current plans the repair will be completed by March 11.

A more detailed series of photographs and explanation of the damage and repair prepared by NAIC Director Bob Kerr is attached below. We will keep you informed about how the work continues and is completed.

We salute the platform maintenance staff at the Observatory for their extraordinary skill and ingenuity at this critical time. It is remarkable and highly admirable that a repair of this magnitude and complexity can be carried out by the Observatory engineers and platform staff internally.

With sincere thanks and regards,
The ASAP Board

Hello ASAP Members

During original AO construction, in 1962, one of the original 12 platform suspension cables was delivered too short, and a short cable section (12') was "spliced" to a 568' cable section running from tower T8 to the triangle corner — to provide sufficient reach to the platform. That cable segment and splice, near the top of one of the telescope towers, was consequently more rigid than the balance of the suspension system. When the earthquake shook the site, just after midnight on January 13, 2014, it is that short cable, and splice "box", that suffered damage. You might say that our structural Achilles heel was exposed.

The photo "Tower 8 Top.jpg" shows the top of tower 8, post-quake. In this photo you can see the rectangular cuboid that is the "splice box".

A protocol structural survey following the January 13 earthquake revealed serious damage to that short cable section, with apparent breach of several cable strands. An experienced structural engineering firm, Ammann & Whitney in New York, was brought to assess the damage, and to consider repair options.

The photos "OVERALL EXTENSION CABLE 20110302.jpg" and " OVERALL EXTENSION CABLE 20140117.jpg" show the 12' extension cable pre-quake (03/02/11) and post-quake (01/17/14), respectively. (We had a structural survey performed in 2011 as a matter of structural stewardship.) Note the additional paint that was wrenched from the cable section, by quake motion — near the "saddle block" end of the cable.

The photo "UPHILL Splice Box.jpg" shows the end of the 12' extension cable going into the splice box,

post quake. Note loose cable strands, likely broken.

The two photos "DOWNHILL SPLICE BOX 1.jpg" and "DOWNHILL SPLICE BOX 2.jpg" show the splice box at the side where the 568' cable runs from the box on out to the platform - from two perspectives. No damage to cable strands on this side of the splice box, the platform side, is evident. Ammann & Whitney conclude that swaying motion in the long cable absorbed the energy of the quake motion, but that the shorter side of the cable arrangement, the extension cable, was more rigid, and more brittle, and thus the damage to the shorter, extension cable component.

The photo "EXTENSION CABLEIN SADDLE.JPG" shows the end of the short, extension cable, within the saddle block atop the tower. At this end too, A&W believe there may be extensive damage to the cable strands, including internally, that cannot easily be assessed.

A&W believe there was a significant "friction override" within the splice box, as the entire box was pivoted 15 degrees by consequence of quake motion. No one really knows what is inside that box, but A&W surmise it is arranged as in the drawing "SPLICE BOX.pdf" — with two "button sockets" on the end of each cable, fitted into the steel box. These button sockets are similar to those you can see at the end of cables in the saddle block. The photo "OVERALL EXTENSION CABLE 20110302.jpg" shows the button socket ends of the back-stay cables fitted into saddle block, as examples.

A relatively low-cost ($80,000) repair option has been designed, and materials are being procured to complete a repair that we expect will bring the telescope back into full service. While the project awaits full review by the National Science Foundation, necessary steel materials for the repair are being shipped to the Observatory at this writing. Our estimated completion date for this repair project is March 11, 2014.

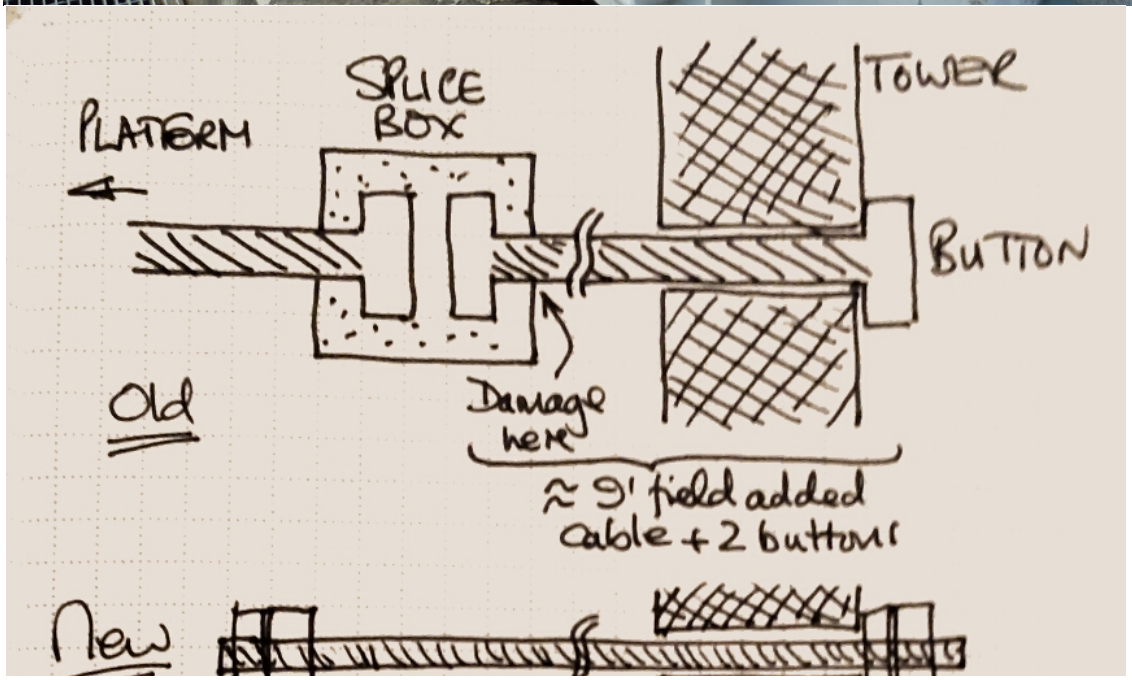
A rough drawing of the A&W repair design appears in the file "Short term repair.pdf" - courtesy of Tony van Eyken. (Of course, we now have very detailed CAD drawings of the repair design detail.) Basically, the saddle block has two empty slots - by design. These extra slots were used for cables that originally hoisted the platform, as the final suspension cables were tensioned and attached. Once erected, these cables were removed, and the empty slots could be used for necessary strengthening, additional cables, or possible repairs. (Brilliant!). The photo "OVERALL EXTENSION CABLE 20110302.jpg" shows one empty slot in the saddle block, and there is another, eclipsed in the photo, on the other side of the saddle block. Basically, we will connect two long (15') "lead screws" into these slots, and attach a large steel "C" channel to their other end — grabbing the entire splice box on the undamaged, platform side. (There is a lot more detail - but this is the basic idea.)

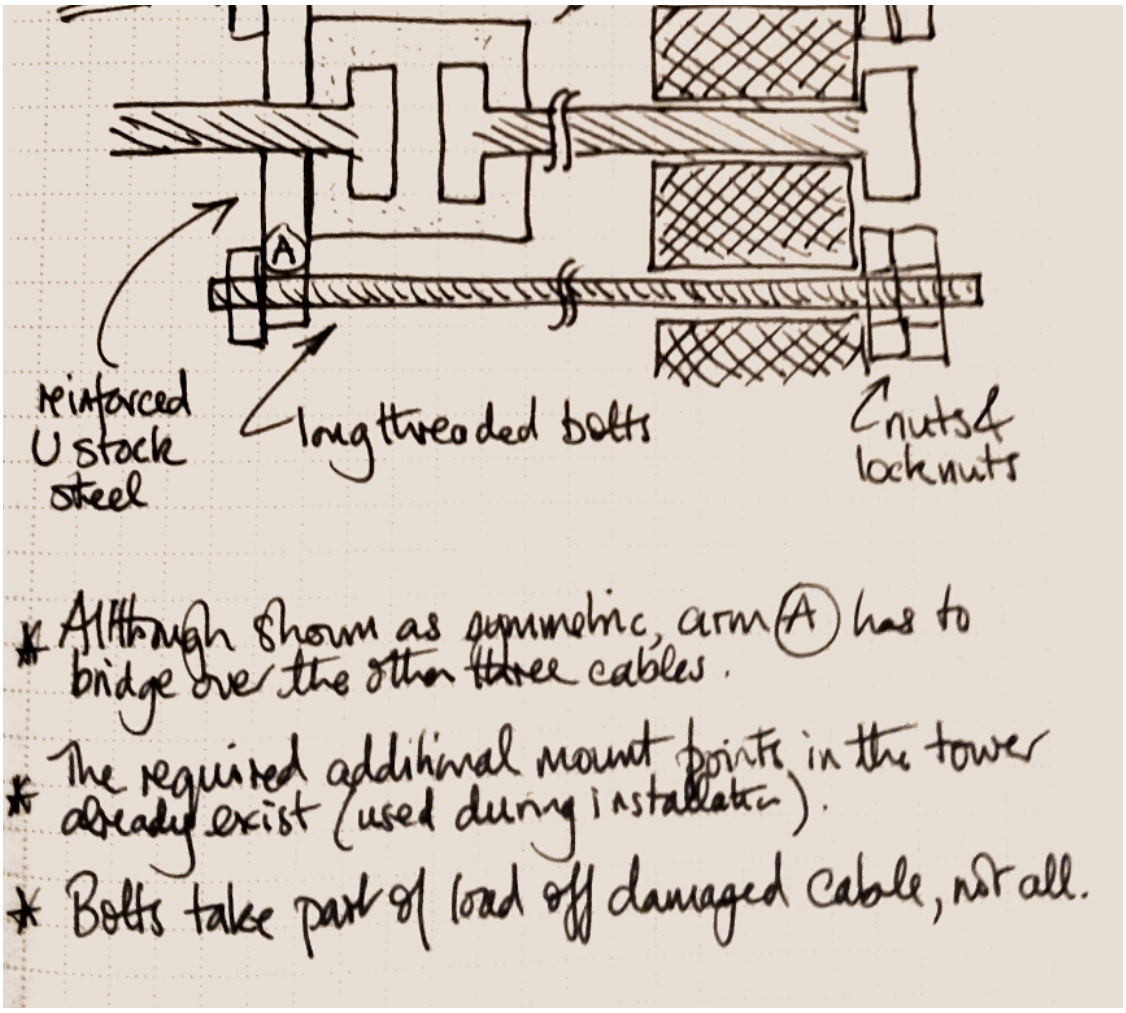
In the meantime, in an abundance of caution, telescope motion has been very limited. Despite that, the telescope has continued its science mission by participation in a ten-day global ionospheric study in late January, by a continuing a productive search for pulsars in the sky above Arecibo, and by a search for fast radio bursts (FRBs).

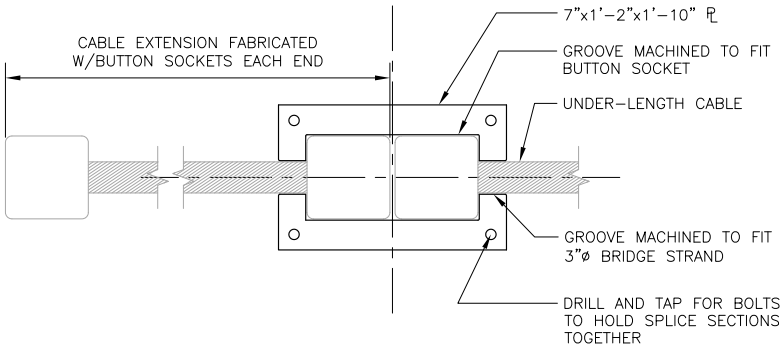
Arecibo Observatory proceeds on schedule to complete this emergency repair as expeditiously and safely as possible. We do consider the repair to be temporary, and a more comprehensive long-term cable repair design is being developed. Nevertheless, we do expect the Gordon telescope to return in full service to the Astronomy, Atmospheric Science, and Planetary communities in March. The nature of the repair is also "rigid", like the 12' cable extension kluge, itself. And so the structure will remain susceptible to quake damage, at this location, until a more comprehensive cable replacement effort might be made....

It is testimony to the remarkable expertise, capability, and bravery of the Arecibo Observatory staff that they will be able to effect this repair themselves, working 365 feet above the ground on a 900-ton steel suspension bridge system. I am doubtful that a comparable capability exists at any other U.S. science facility.

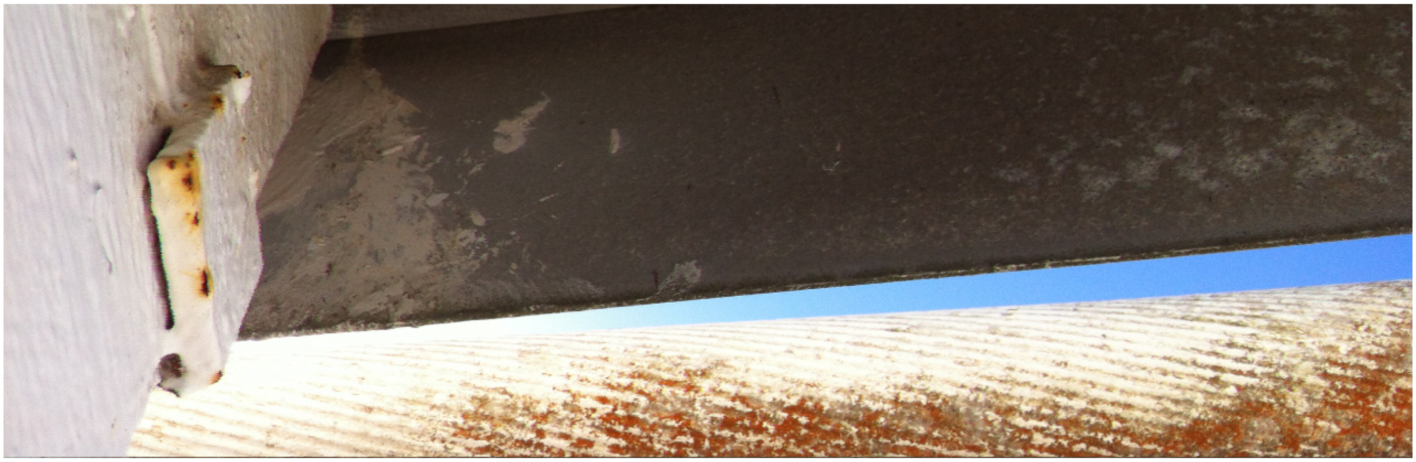
Sincerely,
Bob Kerr
Director, Arecibo Observatory
978-314-9760


PLATFORM
SPLICE BOX
TOWER
BUTTON
Old
Damage here
≈ 9' field added cable + 2 buttons
New


A
reinforced U stock steel
long threaded bolts
nuts & locknuts
* Although shown as symmetric, arm (A) has to bridge over the other three cables.
* The required additional mount points in the tower already exist (used during installation).
* Bolts take part of load off damaged cable, not all.


CABLE EXTENSION FABRICATED W/BUTTON SOCKETS EACH END
7"x1'-2"x1'-10" PL
GROOVE MACHINED TO FIT BUTTON SOCKET
UNDER-LENGTH CABLE
GROOVE MACHINED TO FIT 3"ø BRIDGE STRAND
DRILL AND TAP FOR BOLTS TO HOLD SPLICE SECTIONS TOGETHER

Project	ARECIBO OBSERVATORY BROKEN WIRE STUDY		
Description	ASSUMED DETAIL FOR SPLICE BOX		
Project No.		Date	1-21/14
Issue/Rev		By	JLS
File Name	SPLICE BOX.DWG		
Scale	1 1/2"=1'-0"	Sketch No.	SK.01



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