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February 18, 2014

Mr. Robert Kerr, PhD  
Director, Arecibo Observatory  
HC 03 Box 53995  
Arecibo, P.R. 00612

Re: Earthquake Damage to Main Support Cable M8-4

Dear Dr. Kerr:

After reviewing photographs and following discussions with Michael Nolan and Felipe Soberal, personnel from Ammann & Whitney performed a hands-on site inspection on January 16<sup>th</sup> and 17<sup>th</sup> to assess the damage sustained by the telescope during the January 13<sup>th</sup> 2014 magnitude 6.4 earth quake. This letter is a formal report of our findings and repair recommendations.

Inspections by the Arecibo platform crew indicated that all main suspension cable fittings were not damaged by the seismic event except for Main Cable 8-4. This particular cable is an anomalous condition since it was originally fabricated approximately 12-foot short. To rectify this condition a splice box and an additional section of cable were added. Original fabrication drawings are not available for review but site measurements and industry practice would indicate that the splice was accomplished by installing dead end sockets on both ends of the extension cable and machining a steel box to transfer cable tensions in bearing (see the attached sketch). The final splice box is a 14"x14"x28" block of steel and weighs some 1600 pounds.

We note that in addition to adding a substantial local mass to Cable 8-4, the short splice section is considerably stiffer than the longer main cable length. It is our belief that this concentrated mass and relatively stiff structural member resulted in an amplified response (when compared to the other cables) to the ground motions. Additionally the upper end of the cable would be subject to water infiltration and there may be corrosion inside of the splice box that contributed to the observed failure.

During the field visit by Ammann and Whitney personnel a number of items were noted:

- 1) The splice box was rotated approximately 15 degrees from the horizontal. A review of photographs taken during the 2011 condition survey indicated that this is a new condition.
- 2) 9 wires were observed to be broken (in addition to 3 previously recorded breaks) and had separated from the main cable mass.
- 3) Paint damage was noted at the location of the broken cables and at an upper section. The paint in the vicinity of the upper dead end socket was also observed to be

damaged. Essentially there was a significant torsional loading imposed on the 12' cable splice section.

- 4) Paint damage was not observed on the section of the splice box at the downhill (main cable) end. This indicates that the observed permanent rotation of the splice box occurred at the upper end.

Our field observations could only assess the visible sections of the cable and it is also possible that additional internal damage exists in the upper cable section. Even if it could be established that the remaining wires are undamaged, it is our opinion that the observed damage to the cable splice section is significant enough to warrant concern.

Following the field investigations, Ammann & Whitney personnel performed calculations to determine the probability of collapse should Cable 8-4 completely fail. These calculations indicate that a catastrophic failure of the platform suspension system would not be likely as the remaining cables 8-1, 8-2 and 8-3 would function at a factor of safety of 1.5, below the minimum recommended factor of safety for new cables of 2.0 but still above the failure threshold. A check of the tower and tower saddle indicated that there should also be sufficient torsional strength to resist the asymmetric condition that would exist with a failure of Cable 8-4.

While the platform and towers would likely survive the complete failure of the cable we note that the cable falling from the tower would cause significant damage to the main reflector and any structures supporting the reflector. Even without the 1600 pound splice box the cable itself weighs over 10,000 pounds.

Based on our field and office investigations it is our opinion that a structural repair should be effected at the earliest possible time to ensure that a complete failure of Cable 8-4 will not result in damage to the main reflector and serious injury to any personnel who may be within the area of damage. Given the fact that a sudden failure of the cable might produce significant, unpredictable loads on the main platform while loads transfer from the failed cable to the remaining suspension system we also note that there is a risk to personnel working on the main platform. For this reason we also recommend that an area defined by a 60 degree angle under Cable 8-4 and the platform should be restricted to all but absolutely essential personnel until a repair can be effected.

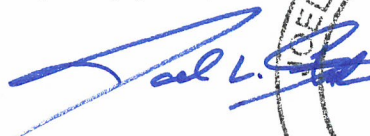
We have performed a structural design for an emergency repair that makes use of a beam built up from two channels (this arrangement is commonly called a "strongback"). The strongback would be erected above and below the cable bank and extend past each end of the cables. The channels making up the strongback would bear on the downhill side of the splice box. There are two empty slots on each side of the existing cable saddle that were originally used for erection cables. Our design uses these slots to anchor two new, 3" diameter, high strength threaded steel rods. These rods would pass through the strongback and be provided with bearing washers and nuts. The rods would be installed with a minimal pretension. Should additional wires break in the Cable 8-4 splice section load would transfer from the cable into the new threaded rods. An engineering drawing for this repair is attached for your reference.

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We would note that this repair should be considered as a temporary fix. The repair does nothing to mitigate the additional mass and stiffness that exists with the current situation and, in fact, adds additional mass and stiffness to the total system. While the splice box exists on this cable it will continue to be susceptible to potential damage during significant earth quakes. It is our strong recommendation that Cable 8-4 be replaced in its entirety with a cable of proper length.

Please feel free to contact me at 212-462-8583 or [jstahmer@ammann-whitney.com](mailto:jstahmer@ammann-whitney.com) should you have any questions concerning the content of this report.

Very truly yours,



Joel L. Stahmer PE  
Vice President



Encl.

Cc: J. Gould, A&W