Case Study: NASA's Deep Space Network

JPL Uses Load Cells and SNAP PAC System to Discover Cause of Failed Bearings in Deep Space Antennas

NASA's Deep-Space Network (DSN) consists of an international network of ultra-sensitive receiving systems and large parabolic dish antennas that enable and support interplanetary space missions and radio and radar astronomy observations of the solar system and universe. The DSN also supports selected Earth-orbiting space missions. To accomplish this, the DSN operates three deep-space communications facilities located approximately 120 degrees apart around the world—in California's Mojave Desert; near Madrid, Spain; and near Canberra, Australia. These installations enable 24/7 monitoring of satellites, space probes, and spacecraft (even as the Earth rotates) and make the DSN scientific telecommunications system the largest in the world.

One of DSN's three deep-space communications facilities, located approximately 120 degrees apart around the world.

Among the many missions the DSN is currently tracking are the famed Voyager 1 and Voyager 2 space probes, launched in 1977 and currently more than 9 billion miles from earth, headed for the outer reaches of our solar system. The Jet Propulsion Laboratory, founded in 1944 and managed by the California Institute of Technology, manages the DSN antennas for NASA, which uses these antennas to track Voyager and other probes and to receive scientific data about our planet and our universe.

This photo of Jupiter's big red spot was taken by Voyager 1 and sent to earth via NASA's Deep Space Network.

JPL has data coming in around the clock, some of it from probes that are traveling through space at a rate of more than 30,000 miles per hour. As a result, all antennas have to be meticulously maintained, or non-recoverable data could be lost forever.

The DSN Network Operations Control Center (NOCC), located within the Space Flight Operations Facility at JPL.

In Madrid, an antenna similar to this one will be equipped with load cell transducers and the SNAP PAC System to discover why cracks have developed in the large elevation bearing system.

Last summer at the DSN site in Madrid, during a time when a 230-foot antenna was already out of service for scheduled maintenance and upgrades, engineers detected cracks in the antenna's large elevation bearing system. These bearings support the 4-million-pound weight of the antenna as it rotates and tilts up and down. The cracks were detected in two pairs of elevation bearings in June 2006, and the antenna's return to service was extended from four to seven months so repairs could be made.

Having one of the large antennas out of commission created a real but manageable problem. As a remedy, smaller antennas were arrayed together to support the higher data rate capabilities of a 70-meter antenna. Alternatively, spacecraft data rates were lowered so that these missions could be supported by a 34-meter antenna.

Soon, however, JPL realized they were facing an even more serious problem. The cracking of the bearings in Madrid marked the second time this had occurred in approximately 16 years. Scientists and engineers determined there must be something unusual causing these premature failures.

To determine the precise nature of the problem, the Madrid 230-foot antenna's bearings will be lifted and the existing shim[1] pack removed and replaced with load cell transducers—devices that convert and express light, sound, pressure and other non-electrical forces as an electrical signal. The electrical signal output (normally in the order of a few millivolts) will then be plugged into an algorithm to calculate the force applied.

In the case of the DSN's Madrid 230-foot antenna, force will be measured to effectively weigh the antenna as it moves across the bearings. To accomplish this, JPL entered into a contract with Force Switch, Corp. of San Dimas, California (http://www.forceswitch.com/) to design and build custom 5/8" thick plates (each with 35 load cells) that will fit perfectly underneath the antenna without disturbing the alignment or compromising its ability to move in any way. In addition to this size specification, Force Switch (specialists in force-activated, weight-activated, and liquid level measurement solutions) will have to meet JPL's other requirements for the load cells—chief among these is signal conditioning.

These specially designed load cell plates will output milliamp signals rather than the typical millivolt type, which is very important because the load cells will be interfacing with an Opto 22 SNAP PAC System.

1. A *shim* is a thin and often tapered or wedged piece of material, used to fill small gaps or spaces between objects. Shims are typically used in order to support, adjust for better fit, or provide a level surface. They may also be used as spacers to fill gaps between parts subject to wear.

Specifically, SNAP analog input modules will connect the four individual plates (one for each set of bearings) to SNAP-PAC-EB2 processors (or "brains"), which will receive accurate load cell readings—expressed as analog current inputs in the –20 mA to +20 mA range—once every second.

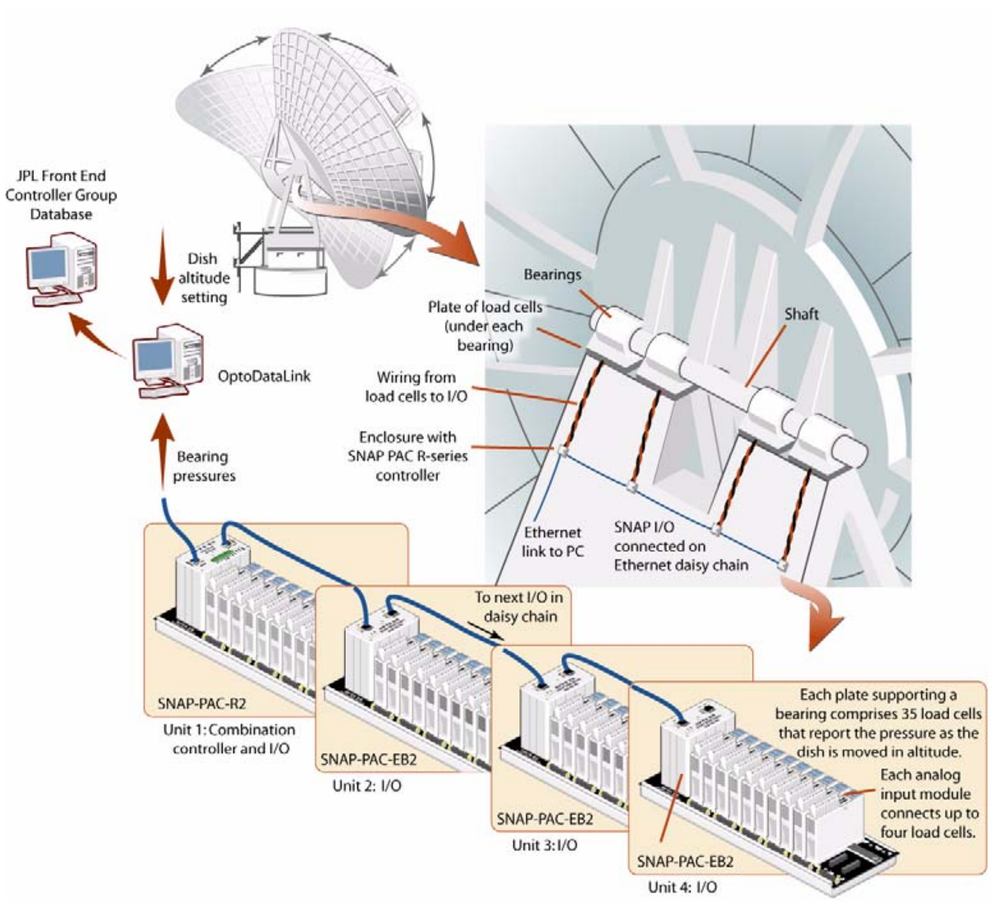
Released this spring, the EB2 is one of the newest additions to Opto 22's SNAP PAC family of products for automation, monitoring, and data acquisition.

"The SNAP-PAC-EB2 processor has dual, switched 10/100 Mbps Ethernet interfaces, which is perfect for multi-drop architectures like the one JPL requires," explains Tom Edwards, Senior Technical Advisor at Opto 22.

Edwards (and other engineers at Opto 22) provided pre-sales support for JPL and helped define the requirements for the Deep Space Network antenna project. Together, they determined that the project is going to require long cable runs (approximately 300 feet) with distributed I/O at the four load cell/bearing locations. Edwards says that the SNAP-PAC-EB2 brain is going to give JPL the ability to "daisy-chain"[1] distributed I/O and bring all of the load cell readings aggregated by the EB2s back to one intelligent controller, likely Opto 22's SNAP-PAC-R2 programmable automation controller. From there, data will be sent to a JPL database via OptoDataLink, which provides multiple connections for exchanging data between the SNAP PAC System and SQL databases.

Currently, JPL is working with Opto 22 to design the system to read the 140 analog signals at 1 Hz (once per second) and as close to synchronously as possible. Eventually, the frequency could be increased to 4 Hz or possibly more.

With the SNAP PAC System continuously monitoring and recording load cell data from multiple locations as the antenna moves over the bearings, JPL will soon be studying the data, formulating theories, and determining why the bearings have been cracking.



1. In electrical and electronic engineering, a *daisy chain* is a wiring scheme in which, for example, Device A is wired to Device B, Device B is wired to Device C, Device C is wired to device D, and so on. Daisy chains may be used for power, analog signals, digital data, or a combination thereof.

About Opto 22

Opto 22 develops and manufactures hardware and software for applications involving industrial automation and control, remote monitoring, and data acquisition. Opto 22 products use standard, commercially available networking and computer technologies, and have an established reputation worldwide for simplicity, innovation, quality, and reliability. Opto 22 products are used by automation end-users, OEMs, and information technology and operations personnel. The company was founded in 1974 and is privately held in Temecula, California, USA. Opto 22 products are available through a worldwide network of distributors and system integrators. For more information, contact Opto 22 headquarters at 951-695-3000 or visit www.opto22.com.

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