

# Space Integrated Global Positioning System/ Inertial Navigation System Firmware Upgrade

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The International Space Station guidance, navigation, and control (GN&C) system relies on several sensors to provide navigation and rate data. One of these is the Space Integrated Global Positioning System/Inertial Navigation System (SIGI). The SIGI is based on a commercial product that was modified for space applications. The development of the SIGI initial firmware was a joint venture between the government, private industry, and academia. The Space Station SIGI was the first global positioning system (GPS) sensor used in a space application to perform attitude determination in a closed-loop control system.

The initial firmware load, Release 1 (R1), was based on an aircraft design—the roll and pitch angles were assumed and the yaw angle was solved for. These three angles are referred to as the attitude solution. The Space Station contains four antennas in a rectangular configuration. By measuring the difference in arrival time of a satellite's signal at each of the four antennas, we can compute the relative orientation of the antenna frame with respect to the line-of-sight vector from the antenna frame to the satellite.

The R1 firmware load has been operating on the Space Station since April 2002, when the GPS antenna array was launched on flight 8A. Although it was able to provide the GN&C system with the data it needed, operation of the unit was labor intensive for the flight controllers. The Space Station attitude and dynamics control officers (ADCOs) had to spend a significant amount of time monitoring the firmware's performance, and sending initial attitude reference and power cycle commands to keep the SIGI tracking satellites and producing attitude solutions.

A team of civil servants spent two years upgrading the firmware. The team developed new algorithms to allow solution of all three attitude angles—yaw, pitch, and roll—without requiring an initial attitude reference. The team completely rewrote the new firmware, Release 2 (R2,) following the processes outlined in the NASA Johnson Space Center

Engineering Directorate's software work instruction and successfully passed formal qualification testing at the SIGI vendor in mid fiscal year 2004. The R2 firmware was loaded onto the Space Station SIGIs during the first half of FY05.

The ADCOs are very pleased with the performance of the new firmware. Power cycle commands are rarely used, and the new firmware can compute its own initial attitudes without being given an initial reference. The trajectory operations officers are also very impressed with the performance—the SIGIs now track satellites during Space Station reboost and have smaller periods of coverage outage. The GN&C personnel also noticed that their attitude filter converges in hours instead of in a day.

The team gained valuable hands-on experience in the development of flight software in support of a critical flight system, and now understands the firmware very well. No anomalies have been noted to date. The team will continue to upgrade the firmware over the next two fiscal years.

