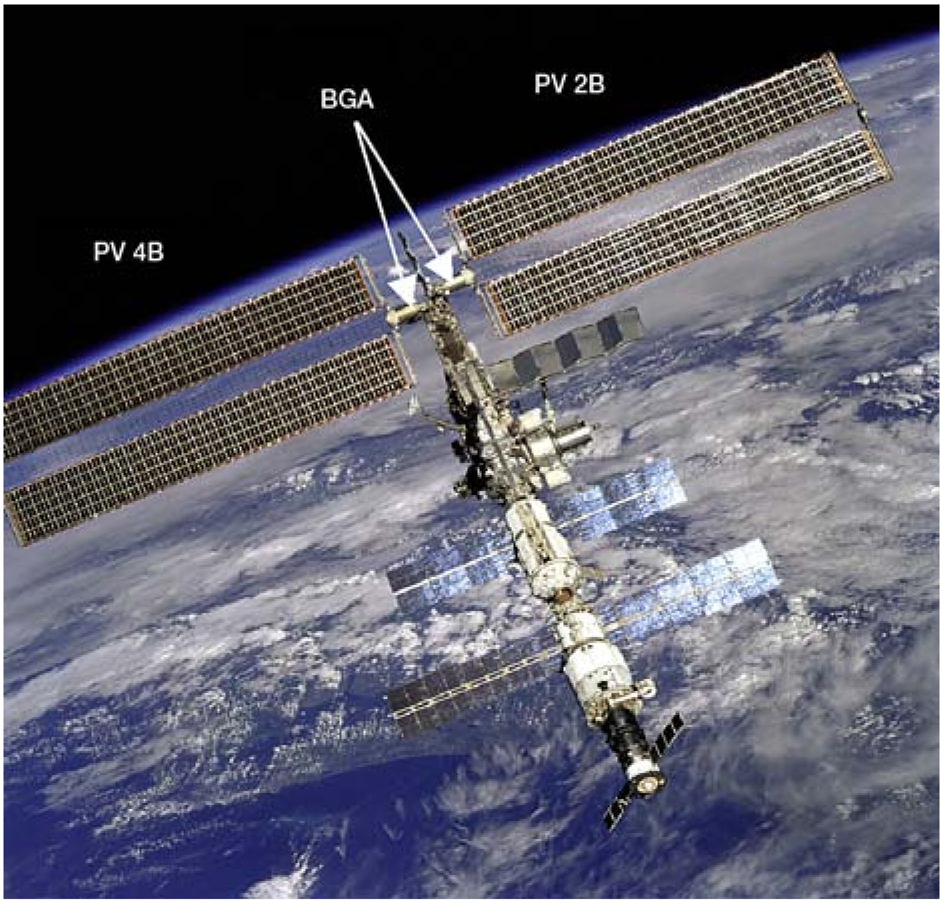
Space Station Power Generation Investigated in Support of the Beta Gimbal Anomaly Resolution

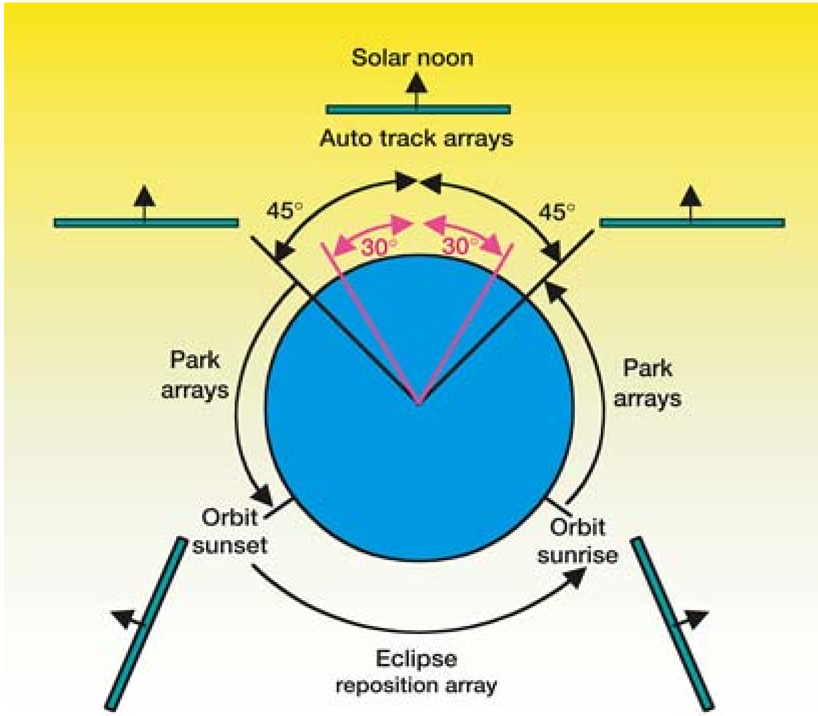


Location of the beta gimbal assemblies that rotate the U.S. photovoltaic arrays.

The International Space Station (ISS) is the largest and most complex spacecraft ever assembled and operated in orbit. The first U.S. photovoltaic module, containing two solar arrays, was launched, installed, and activated in early December 2000. After the first week of continuously rotating the U.S. solar arrays, engineering personnel in the ISS Mission Evaluation Room observed higher than expected electrical currents on the drive motor in one of the Beta Gimbal Assemblies (BGA), the mechanism used to maneuver a U.S. solar array (see the on-orbit photograph). The magnitude of the motor currents continued to increase over time on both BGAs, creating concerns about the ability of the gimbals to continue pointing the solar arrays towards the Sun, a function critical for continued assembly of the ISS. The BGA provides two critical capabilities to the ISS: (1) transfer of electrical power across a rotating joint and (2) positioning of the solar arrays. A number of engineering disciplines convened in May 2001 to address this on-orbit hardware anomaly. Over the course of a year, many scenarios were developed and used. Only two are discussed here: parked arrays and dual-angle mode.

In the first scenario, NASA Glenn Research Center personnel used Glenn's SPACE code (System Power Analysis for Capability Evaluation) to generate a set of power generation capabilities as a function of parked solar array position across the nominal solar β range. Using these data, the ISS power resource operations experts on the BGA Anomaly Resolution Team determined that if a subset of the electrical loads are transferred from one array to the other, only one BGA needs to rotate reliably for the next three assembly missions to be completed successfully.

By June 2001, the root cause team had identified two possible data trends: (1) the long-duration unidirectional BGA motion appeared to exacerbate the high motor current anomaly, and (2) the motor current performance appeared to return to nominal levels after the direction of the BGA was reversed. Taking these observations into consideration, the BGA Anomaly Resolution Team developed the dual-angle-mode operational concept (see the following diagram). This technique is unique in that, should the BGA stall or become stuck, the solar array position is guaranteed to be within a range of Sun-facing positions when the vehicle is in insolation, thus minimizing the potential impact on power generation. The SPACE results proved that the dual-angle-mode technique could generate 85 to 90 percent of the power realized from a Sun-tracking solar array in the nominal ISS solar β regime ($|\text{solar } \beta| < 37°$). SPACE analysis also showed the walkoff from using the same BGA target angles over the solar β range of 28° to -28°, indicating that the worst case loss would be 400 W out of a total capability of 10 kW. This analysis proved that a single set of BGA target angles could be used for dual-angle-mode tests lasting as long as 11 days with only a 4-percent loss in total power generation capability.



Dual-angle-mode operational concept (90° and 60° sweep).

Long description. The following example is provided for a 90° sweep interval:

- Beginning at orbit dawn until 45° before orbit noon, the array is parked such that, at 45° before orbit noon, the array is normal to the Sun.
- From 45° before orbit noon to 45° after orbit noon, the array tracks the Sun.
- From 45° after orbit noon until orbit sunset, the array is parked.
- Finally, during orbit eclipse, the array is returned to its starting position by back-driving the BGA through the beta gimbal sweep traversed in isolation

The dual-angle technique continues to be used successfully. The operations team in conjunction with Glenn developed successful methods of managing ISS energy balance while supporting the overall team goal of minimizing cumulative BGA travel.

Find out more about this research at http://space-power.grc.nasa.gov/ppo/

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Special recognition: SPACE was a runner-up for NASA Software of the Year for 2003. Ann Delleur received a Silver Snoopy award for her BGA Anomaly Resolution Team work.