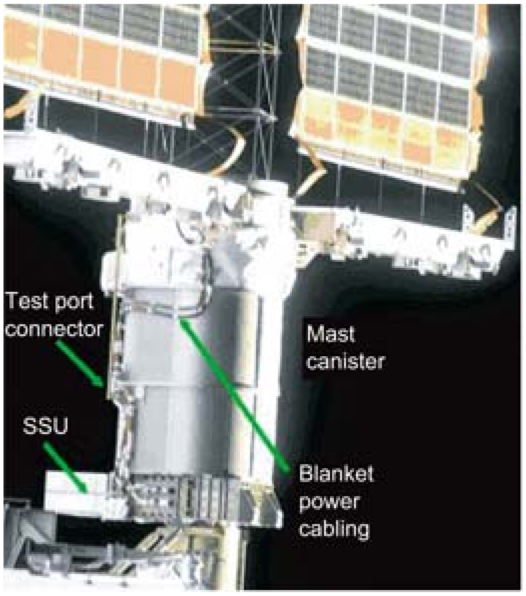
Options Studied for Managing Space Station Solar Array Electrical Hazards for Sequential Shunt Unit Replacement

The U.S. solar array strings on the International Space Station are connected to a sequential shunt unit (SSU). The job of the SSU is to shunt, or short, the excess current from the solar array, such that just enough current is provided downstream to maintain the 160-V bus voltage while meeting the power load demand and recharging the batteries. Should an SSU fail on-orbit, it would be removed and replaced with the on-orbit spare during an astronaut space walk or extravehicular activity (EVA) (see the photograph). However, removing an SSU during an orbit Sun period with input solar array power connectors fully energized could result in substantial hardware damage and/or safety risk to the EVA astronaut. The open-circuit voltage of cold solar-array strings can exceed 320 V, and warm solar-array strings could feed a short circuit with a total current level exceeding 240 A.



Sequential shunt unit (SSU) mounted on the beta gimbal platform (below the mast canister).

Replacing the SSU during eclipse when the array is not in sunlight would seem optimal, except that the maximum eclipse period is only 36 min. This does not provide sufficient time to remove and replace the SSU while allowing for contingencies. Several other options for the SSU remove-and-replace procedure were assessed at the NASA Glenn Research Center, including

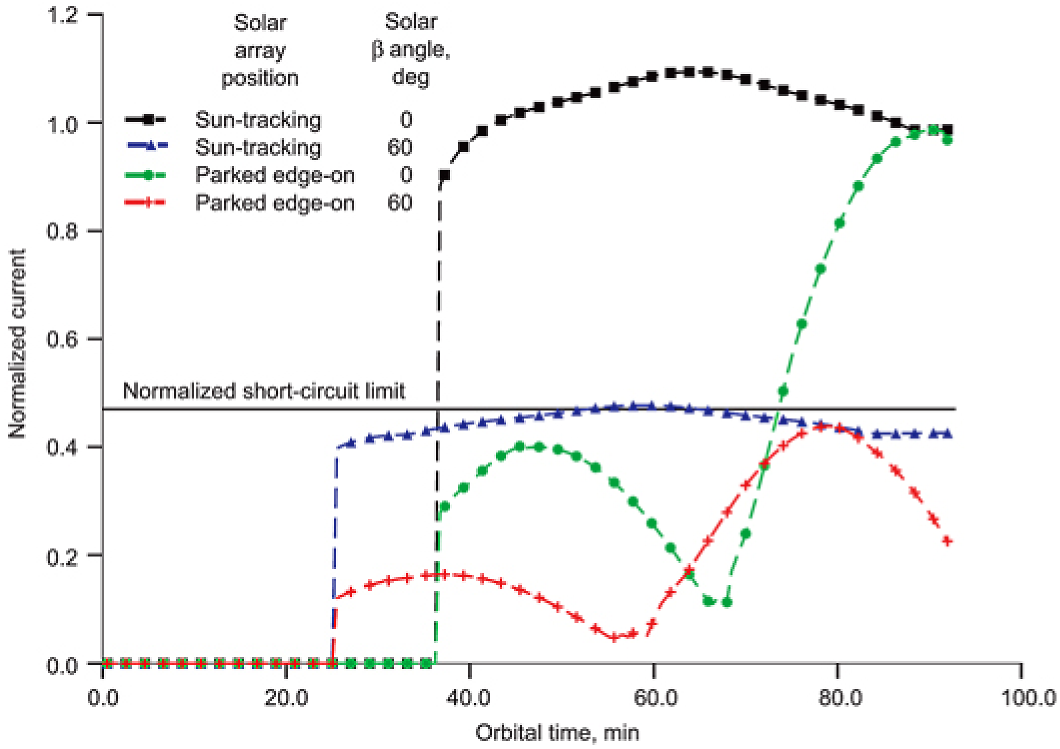
1. Leave the failed SSU in place.
2. Change-out the SSU during one eclipse period.

3. Change-out the SSU during several eclipse periods.
4. Retract the solar array; then change-out the SSU during multiple-orbit Sun and eclipse periods.
5. Design, build, and install a temporary shunting plug on the solar-array string power connectors, and change-out the SSU during several orbit eclipse periods.
6. Design, build, and install a temporary shunting plug on the solar-array-string test-port connectors, and change-out the SSU during several orbit eclipse periods.

From the perspective of defining and managing solar-array-string electrical hazards, this analysis identified option (6), installing a shunt plug on the solar-array-string test-port connectors, as a workable SSU replacement procedure via EVA.

In this option, the test-port-connector shunt plug would collapse the array string voltage and dissipate string short-circuit current I_{sc} through a low-resistance electrical shunt that is passively cooled. This approach would afford the EVA crew multiple orbits to accomplish the SSU remove-and-replace procedure. Also, this approach would not introduce additional risk for damaging SSU power connectors because shunt plugs would be inserted in the test-port connectors. The test-port connectors are located away from the SSU and, thus, do not impede the SSU remove-and-replace operations.

The only undesirable feature of this option is that there are restrictions on the allowable array string I_{sc}. The normalized string I_{sc} must be 0.47 or lower to maintain an acceptably low temperature in the test-port-connector 22-gauge wire bundles. Operational strategies were devised that maintained the normalized I_{sc} value at acceptably low values for the International Space Station flight in the solar inertial flight mode for a wide range of solar β angles and the preferred solar-array park angle for EVA operations (see the graph). Array string current and voltage capability predictions were generated using the bifacial solar-array model incorporated in Glenn's System Power Analysis for Capability Evaluation (SPACE) electrical-power-system performance code.



Normalized short-circuit current, I_{sc}, versus orbit solar β angle (angle between the orbit plane and the Earth-Sun line). Velocity vector for the International Space Station (ISS) is aligned with the ISS +x-axis in this figure.

Long description of figure. Graph of normalized current versus orbital time in minutes, showing normalized the short-circuit limit and data for solar b angles of 0 and 60 degrees for sun-tracking and parked edge-on solar array positions.

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

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