

Hardware Testing for the Optical Payload for Lasercomm Science (OPALS)

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Abstract

Hardware for several subsystems of the proposed Optical Payload for Lasercomm Science (OPALS), including the gimbal and avionics, was tested. Microswitches installed on the gimbal were evaluated to verify that their point of actuation would remain within the acceptable range even if the switches themselves move slightly during launch. An inspection of the power board was conducted to ensure that all power and ground signals were isolated, that polarized components were correctly oriented, and that all components were intact and securely soldered. Initial testing on the power board revealed several minor problems, but once they were fixed the power board was shown to function correctly. All tests and inspections were documented for future use in verifying launch requirements.

Text

Optical communication is the use of visible or near-visible (i.e., infrared) light rather than radio-frequencies to send a data signal. The technology is valuable because it allows much higher data rates than radio communications can achieve. The proposed Optical Payload for Lasercomm Science (OPALS) project plans to establish an optical link between the International Space Station (ISS) and Earth, which would allow for the testing of vital algorithms for controlling optical communication equipment. When OPALS is installed on the ISS, it would lock onto a laser beacon transmitted by a telescope on the ground. The payload would then transmit a video modulated onto a laser beam back to earth.

The proposed payload consists of an optical head containing the laser transmitter and a camera for detecting the ground telescope's beacon, a gimbal to control the pointing of the optical head, and a sealed electronics box. This summer, OPALS team has been testing equipment for the gimbal and avionics subsystems, with integration and testing of other subsystems to occur later this year and next year and a launch baselined for early 2013.

The gimbal incorporates several safety features, called hard stops and microswitches, to prevent the laser from transmitting inadvertently, and potentially causing damage, while pointing in a direction it shouldn't. The hard stops are metal tabs that stick up and physically prevent the gimbal from rotating past a certain point (see figure 1). They ensure that the laser never could point in a direction that would be dangerous to other equipment. The microswitches are located just before the hard stops in the path of the gimbal's rotation. They do not hinder the gimbal's motion, but when pressed they cut power to the laser so that it would be harmless even if it did point at a sensitive instrument.

The microswitches were installed and tested to determine how far the gimbal would have to rotate to actuate (close) them. The requirement is that the microswitches actuate if the gimbal comes within 2° of either hard stop. Tests were also conducted to determine how much the angle would be affected by a small change in a microswitch's position, such as the movements likely to occur as a result of vibration during launch. For the test, a microswitch was shifted down by .005" at a time, and an analog of the angle at which it actuated was recorded after each movement. The change in angle of actuation caused by a .005" shift was inconsistent between movements, perhaps because the switch could have rotated unaccounted-for rather than simply shifting vertically during its adjustment (see "Methods" for a more complete description). Further testing must be done to verify that the microswitches will definitely actuate within 2° of the hardstops regardless of any shifting during vibration.

The circuit board providing electrical power to the rest of the payload was also tested. When it was first delivered to OPALS after being built, an inspection was conducted to ensure that all power and ground signals were isolated, that polarized components were correctly oriented, and that all components were intact and securely soldered. The board was then powered on to verify that each of its DC/DC converters (a component that takes a range of voltages as input and outputs a specific and stable voltage) was outputting the intended voltage. The DC/DC converters are vital because they generate the voltages required to power other payload subsystems such as the laser and the electronics controlling it. Several problems with the board's wiring were discovered during the testing process and fixed (see "Methods" for a more detailed description of the tests, problems encountered, and solutions). Because the hardware being tested would be used for flight, Assembly and Inspection Data Sheets (AIDS) were followed for all procedures. Problem/Failure Reports (PFRs) were written for any tests during which hardware did not perform as expected.

The next step for the power board is to begin load testing, which involves turning it on with some resistance added to the voltage outputs. The board needs to be left running for an extended period of time so that any inherently weak or defective parts would fail and could be replaced before flight. When load testing is complete and the board's proper functioning has been verified, it can be integrated with other subsystems.

Finally, documentation was prepared for the avionics Hardware Review/Certification Review (HRCR). The purpose of the HRCR is to ensure the hardware is ready for integration and testing (I&T). An important aspect of preparation for the HRCR is to put together a complete record of the state of the hardware at the time it is turned over to I&T. As such, copies of all AIDS, Inspection Reports (IRs), and PFRs were assembled, along with lists of which documents had been closed and which were still open (unresolved). For open documents and action items, there must be an explanation for why they are still open and a plan for closing them. With help from Quality Assurance, as many AIDS forms as possible were closed.

This summer I assisted with the testing and documentation of flight hardware for the proposed OPALS project. As with all flight projects, the success of OPALS relies on many different components and subsystems working correctly individually and as part of the integrated whole. To maximize the chances that all equipment will function properly during the mission, it must be tested extensively beforehand. Furthermore, there must be proof in the form of thorough documentation of the test procedures and results. This is particularly important for OPALS since it would be installed and operated on the ISS and must not endanger astronauts or interfere with or damage any of the other experiments there.

The avionics and gimbal testing this summer allowed the team to identify several problems (or potential problems) with the hardware in time to fix them, retest, and demonstrate correct operation. Documentation was created and maintained in the form of AIDS, IRs, and PFRs so that when the team needs it they will know exactly what the hardware has been through and how it performs under various conditions. In the future, the OPALS team must test the other subsystems and then integrate them and test the payload as a whole. When testing is complete, there will be a record allowing the team to verify for the ISS that OPALS does not pose an undue risk, which would in turn allow the mission to launch.

Methods

Microswitch testing

A microswitch was shifted down by .005" at a time. After each movement of the switch, a shim (a flat piece of metal) was inserted just inside the hardstop (see figure 1). Shims of increasing thickness were used until the gimbal was just barely able to turn far enough to actuate the switch. The thickness of the shim can be used to calculate the number of degrees away from the hardstop at which the switch actuates. A .005" microswitch movement was found to change the required shim thickness by between .000" and .020". Because there was so much variation in the results, the test was aborted. The microswitches will be retested when a more controlled method of moving them is developed.

Safe to mate procedure¹

This procedure ensures that it is safe to use a GSE (ground support equipment) cable to attach a lab power supply to the flight power board. This procedure must be performed prior to the power board turn on test. Use a multimeter to measure the impedances between all power lines on the GSE cable. Also measure the impedances between all grounds and between powers and grounds. Turn on the power supply and set it to 28V. Use the multimeter to check that the output really is 28V. Turn off the output of the power supply and attach the GSE cable to it. Then turn the power supply output back on and record the voltages on the free end of the GSE cable. Turn off the output of the power supply. Measure the power, ground, and power-to-ground impedances of power board connector 2003SE-PB-J9. Finally, connect the GSE cable to 2003SE-PB-J9.

Power board turn-on test²

As always when working with ESD-sensitive hardware, first check that the relative humidity in the lab is at least 30%. Attach jumpers between the inhibit pin of each DC/DC converter and ground so that all of the converters are inhibited. Also jumper the sense line to converter output and sense return to ground. This is necessary because if the sense line is left floating the converter will continually ramp up its output to try to make the sense line voltage match the converter's nominal output, causing a cycle of ramping up and resetting that results in an undesirable varying output. Use a multimeter to confirm that all jumpered pins are electrically connected.

Set the voltage of the power supply to 28V and the current limit to 500mA. Remove the inhibiting jumper from U1, the DC/DC converter that would supply 28V to the laser. Turn on the output of the power supply while monitoring the input and output voltages of U1. Turn off the output of the power supply. Repeat with U2, U4, U5, and U10, the converters supplying 28V to the gimbal motor driver, 12V, 5V, and 3.3V. If at any point an unexpected voltage is observed, stop procedure and begin troubleshooting. Use an oscilloscope to record the timing of the run time and turn on time of the DC/DC converters. Turn off the power supply and oscilloscope. Secure the power board in an ESD-safe bag inside the flight hardware cabinet.

Troubleshooting for power board turn-on test^{3,4}

On the first run through of the power board turn-on test, the output of U1 (the DC/DC converter supplying 28V for the laser) was observed to be ground, even after the inhibiting jumper was

¹ Wilson, Thor. "Safe to mate GSE from flight power board to lab power supply." OPALS Assembly and Inspection Data Sheet No. 506160.

² Wilson, Thor. "Power up of OPALS flight power board." OPALS Assembly and Inspection Data Sheet No. 506136.

³ Wilson, Thor. "OPALS flight power board debug." OPALS Assembly and Inspection Data Sheet No. 506163.

⁴ Wilson, Thor. "OPALS flight power board debug 2." OPALS Assembly and Inspection Data Sheet No. 506170.

removed. Probing the inhibit pin with an oscilloscope during power up revealed that the converter was remaining inhibited indefinitely. The power board's soft start circuit, which feeds into the converters' inhibits, was suspected. The soft start circuit offsets the powering on of various components from each other to minimize inrush (the current spike that occurs when electronics are first turned on). It contains several comparators whose output signals are supposed to go high at different times during power up, in turn uninhibiting the various converters at different times. It was discovered by probing the output of the comparator supplying U1 that its output was never going high.

The comparators had to be attached with wires ("haywired") rather than soldered directly to the power board because some of the traces going to their footprints were attached to the wrong pads. Visual inspection of the haywiring revealed that the wires which were supposed to supply power and ground to the comparators were missing. The problem was fixed by wiring the power and ground pins of each comparator to the appropriate power and ground on the power board. When the board was turned on again, U1 behaved as expected.

Unfortunately, one of the other converters, U5, appeared to be outputting 1.5V rather than the nominal 5V. The problem was with the oscilloscope used to probe the voltage. The converter output should have been 5V referenced to secondary ground, but the oscilloscope was connected to primary ground. Because the grounds are all isolated from one another, 5V above secondary ground was only 1.5V above primary ground. Grounding the oscilloscope to secondary rather than primary ground solved the problem.

Figures

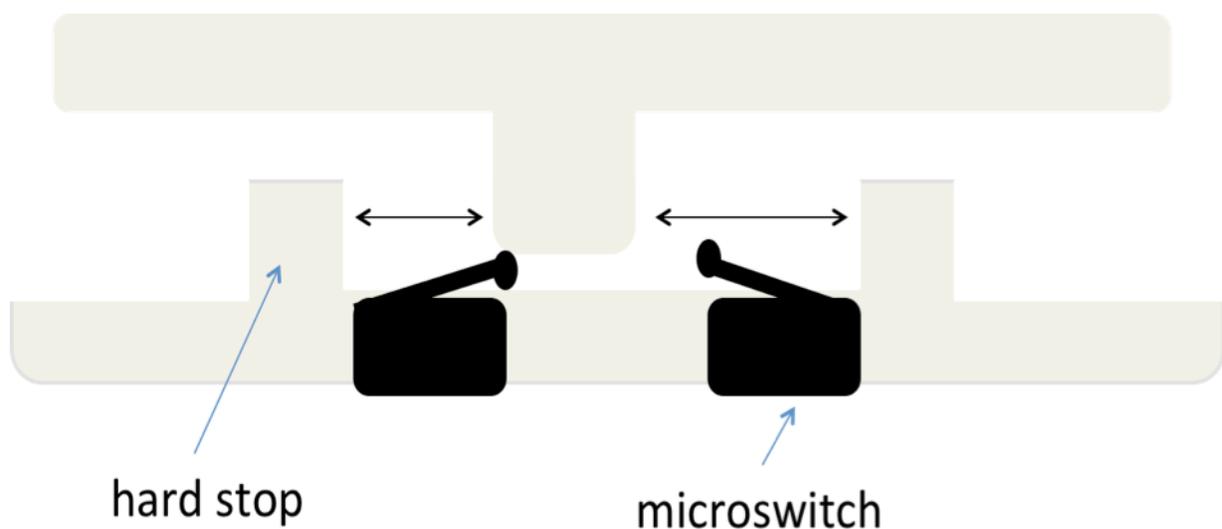


Figure 1. Gimbal's range of motion

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