Advanced Photoluminescence Technology as an Emergency Guidance System on the International Space Station

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The Graphics Research and Analysis Facility (GRAF), Lighting Evaluation and Test Facility, and Flight Crew Integration team in the Habitability and Human Factors Branch at the NASA Johnson Space Center worked closely with the International Space Station (ISS) Program Office to find an innovative and low-cost solution to a crew egress concern. During the assembly phases of the ISS when the electrical system was being deployed in stages, a battery backup system was used to power light-emitting diode (LED) light strips around designated hatch areas in the event of a power failure for general illumination in a module. This system, known jointly as the Emergency Lighting Power System (ELPS) and emergency egress lighting strips (EELS), required regular battery testing of the deployed system on orbit and replacement units on the ground. As the ISS electrical system matured, its reliability and redundancy increased to the point that the ELPS and EELS became less critical and its cost benefit became questionable. To reduce the costly maintenance of testing batteries and flying replacements in efforts to provide emergency egress guidance, a photoluminescent solution was investigated and implemented.

Photoluminescent materials ("glow-in-the-dark" or afterglow capabilities) have been used for decades. For safety applications, they first appeared in the marine industry for ships and oil rigs and were later approved by the Federal Aviation Administration for airplane cabins and aisle pathways. The technology has improved significantly in the past 10 years, and Underwriters Laboratories has begun certifying high-performance formulations for use as exit signs in buildings. The grading system used to rate performance of photoluminescent materials was developed by the ASTM [American Society for Testing and Materials] International. The standard minimum luminance properties of manufactured components (manufacturing quality control) is rated at 20/2.8 or 20 milli-candelas (1/1000 of a candela) at 10 minutes and 2.8 milli-candelas at 60 minutes in the dark after exposure to 1000 lux for 5 minutes (E2072-04). The standard minimum luminance of installed components is rated at 15/2.0 (ISO 16069). These standards also require a minimum target area of 25.6 mm.

NASA has been using photoluminescent markers to label emergency egress path, but only in conjunction with its ELPS as a complete emergency lighting system because the photoluminescent materials used did not provide sufficient luminance for extended periods of time in darkness. The goal was to find a product that would provide the extended visibility needed to cover long periods of possible darkness to support crew activity. All of the products offered low cost and low maintenance. Figure 1 shows the results of a trade study between the two most competitive products. Product B, in its rigid form, is the material used previously. Product A, in a rigid form, is used for the photoluminescent-based Emergency Egress System (EEGS) being deployed on the ISS for future use. It is rated at 600/90. Additional evaluations have shown that if exposed to 108 lux of illumination for 10 minutes, EEGS will be visible in total darkness for as many as 14 hours. In the case of a short exposure time, EEGS will be visible for as many as 3 minutes after 10 seconds of 108 lux of illumination.

Luminance decay rates comparisons after illumination for 8 hours @ 100 lux (ISS minimum is 108 lux)	Initial mcd	mcd @ 3 min. (mininum evacuation time)	mcd @ 10 min	mcd @ 60 min	mcd @ 8 hrs (interpolated) (minimum crew sleep period)	Nominal Shelf Life (yrs)
Vendor A (Rigid)	435.0	79.0	46.0	29.0	15.0	10.0
Vendor B (Flexible)	236.0	65.0	37.0	20.9	9.8	3.0
Vendor A (Flexible)	250.0	76.0	40.0	21.4	9.5	10.0
Vendor B (Rigid)	63.0	17.0	4.0	2.0	0.5	3.0

Fig. 1. *Product comparison.*

The human factors team assessed the ISS hatch areas, looking at available real estate and nearby light fixtures. All of the EEGS potential hatch locations, with their respective ISS general lighting systems illuminating them, were modeled using Radiance (a validated light-modeling system used in the GRAF). The more advantageous locations were evaluated to see whether they received the appropriate illumination for charging the photoluminescent material. These locations were then documented for use in the installation kits developed for the crew. Figure 2 provides an example of the on-orbit ISS U.S. Laboratory installation. The other module bulkheads have similar patterns in place.

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continued

A circular shape was chosen because it requires no orientation, is highly detectable to the human eye, and has no corners for reduced peeling. The EEGS targets are mounted by adhesive (966 acrylic) to metal surfaces, with a maximum target size of 57.15 mm and a minimum target size of 25.4 mm (figure 3). The maximum size is determined by provisions of flammability testing for on-board ISS hardware, and the minimum is determined by ASTM standards.

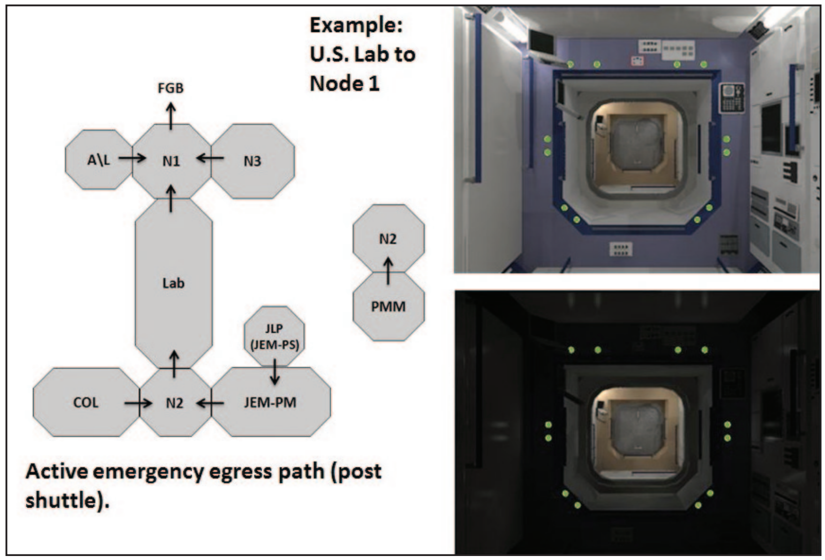

Fig. 2. Marked hatchways and example hatch layout for the Emergency Egress System.

The planned EEGS deployment for the designated emergency egress paths within ISS was approved to end at the Node 1 to FGB [functional cargo block] hatch (i.e., does not include Russian segments). At the time of this report, the EEGS has been installed on all hatch area segments except those of the international partners. Installation for the international partners is expected in the near future. The plans for deployment and the actual installations matched very closely, demonstrating the effectiveness of the installation kits and the choice of circular markers. At the time of reporting, stowage rules are being developed to protect the markers from blockage by future stowage. Redundancy was designed into the system (additional markers were installed) to help minimize this problem.

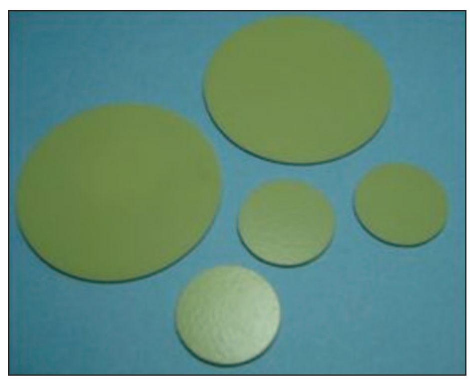

Fig. 3. Circular markers with adhesive backing.

In conclusion, the EEGS has been installed in U.S. ISS modules and is functioning as a successful guidance system for ISS during this transitional time period. The current Japan Aerospace Exploration Agency H-II Transfer Vehicle cargo transfer vehicles are using this application of photoluminescent technology, and it is anticipated that future cargo transfer and crewed vehicles will do so as well. As the ISS ages, it is expected that EEGS will provide adequate emergency egress functionality for some time. However, as the reliability of the on-board power system lessens, the need for a more active emergency light system may increase. Emergency egress systems that are hybrids of LED technology and photoluminescent technology are being developed that can enhance the charge of the photoluminescent material directly (i.e., no battery in the loop) with long extended durations as well as a low-power and -maintenance light source.