



# The Use of Photo-Luminescence as an Emergency Egress Guidance System on ISS

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## The Situation

- Emergency situation on ISS requires the crew to evacuate even with failed lights
- Safety requires the evacuation path be visibly marked independently of the general power
- Accomplished using thin strips of LED's powered by a battery charged by the ISS power system
- The battery power that switched on with the loss of ISS power would light up just enough to mark the hatch opening. This system was called the emergency egress lighting system (EELS).
- EELS were strategically placed to mark the evacuation path from any of the modules to the Russian segment of ISS where two Soyuz vehicles are always parked



## The Problem

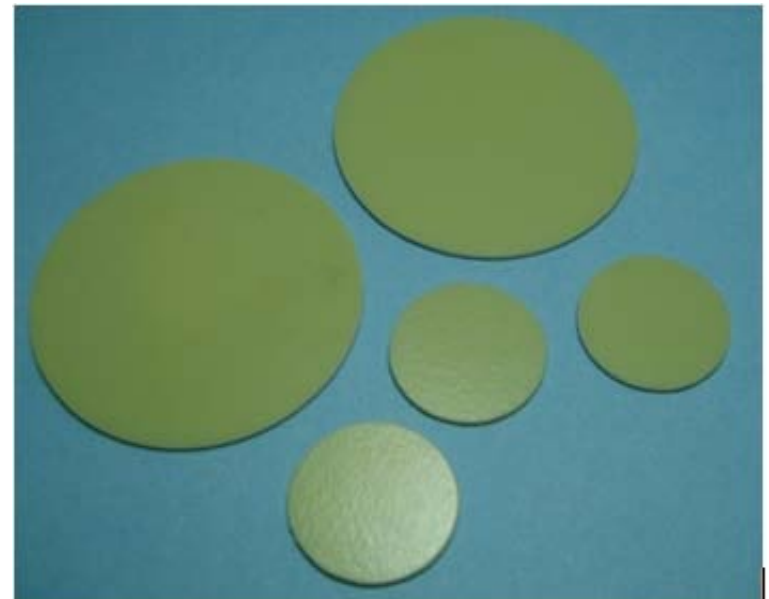
- Battery system requires regular maintenance and replacement of 15 separate EELS
- All units regularly checked for operational readiness by testing the batteries and lights
- Performed by the crew quarterly at a cost of ~18 hours per year (**crew time is valuable**)
- Replacement must be done near end of life projection to insure continuous operations
- Ground based inventory of flight certified replacements needed to be maintained
- As ISS grew and matured, crew time and upload priorities made the cost of maintaining the EELS a concern.

## Solution

- The advancement in the performance of photo-luminescent materials based on a “strontium aluminate” based formulation could provide a solution.
- For ISS emergency egress, any photo-luminescent based system would require it to be visible for at least 8 hours in the dark after a suitable exposure to light.
- A PVC material imbedded with the highest rated grade of “strontium aluminate” provided that capability.

## ISS Emergency Egress Guidance System (EEGS)

- Photo-luminescent markers are used on hatches marking the exit path for emergency egress.
- The system marks the path in the event of light failure during an emergency.





## What is photoluminescence?

“Photoluminescence describes the phenomenon of light emission from any form of matter after the absorption of photons (electromagnetic radiation). (Wikipedia)

What is the activate ingredient for photoluminescent material used on ISS?

“Strontium aluminate (SRA,  $\text{SrAl}_2\text{O}_4$ ) is a solid odorless, nonflammable, pale yellow powder, heavier than water. It is chemically and biologically inert. When activated with a suitable dopant (e.g. europium, then it is labeled  $\text{SrAl}_2\text{O}_4:\text{Eu}$ ), it acts as a photoluminescent phosphor with long persistence of phosphorescence.”  
(Wikipedia)

Strontium aluminate is ten times more persistent than copper activated zinc oxide. It is available in many forms such as tape, PVC, paint, thread and has been imbedded into metal sheets. The natural glowing color is generally a blue-green or aqua tone, but the material can be dyed to produce other hues though not as persistent.

## Spectral Characteristics

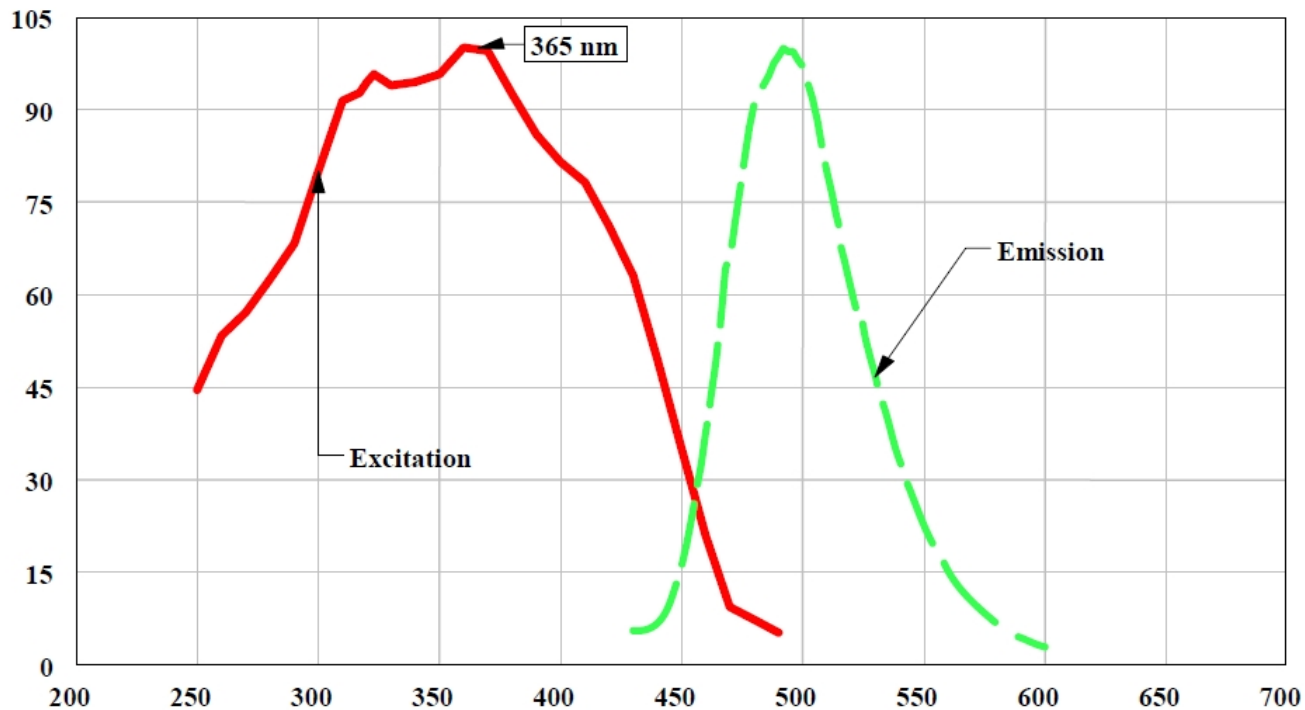


Figure 2: Excitation and emission spectra for strontium Aluminate pigment, showing the peak emission at 500nm (green)<sup>[1]</sup>

Absorbs photons at 250-480 nm wavelength and emits photons at 430-600 nm wavelength (blue-green region)

Source: Dr. S. O’Kell PhD, Technical Director – STG Aerospace Limited Rev IR, April 2008, “Charging Capabilities of LED and Fluorescent Light Sources on Photoluminescent Floorpath Marking Systems “

# Persistence or Decay Characteristics

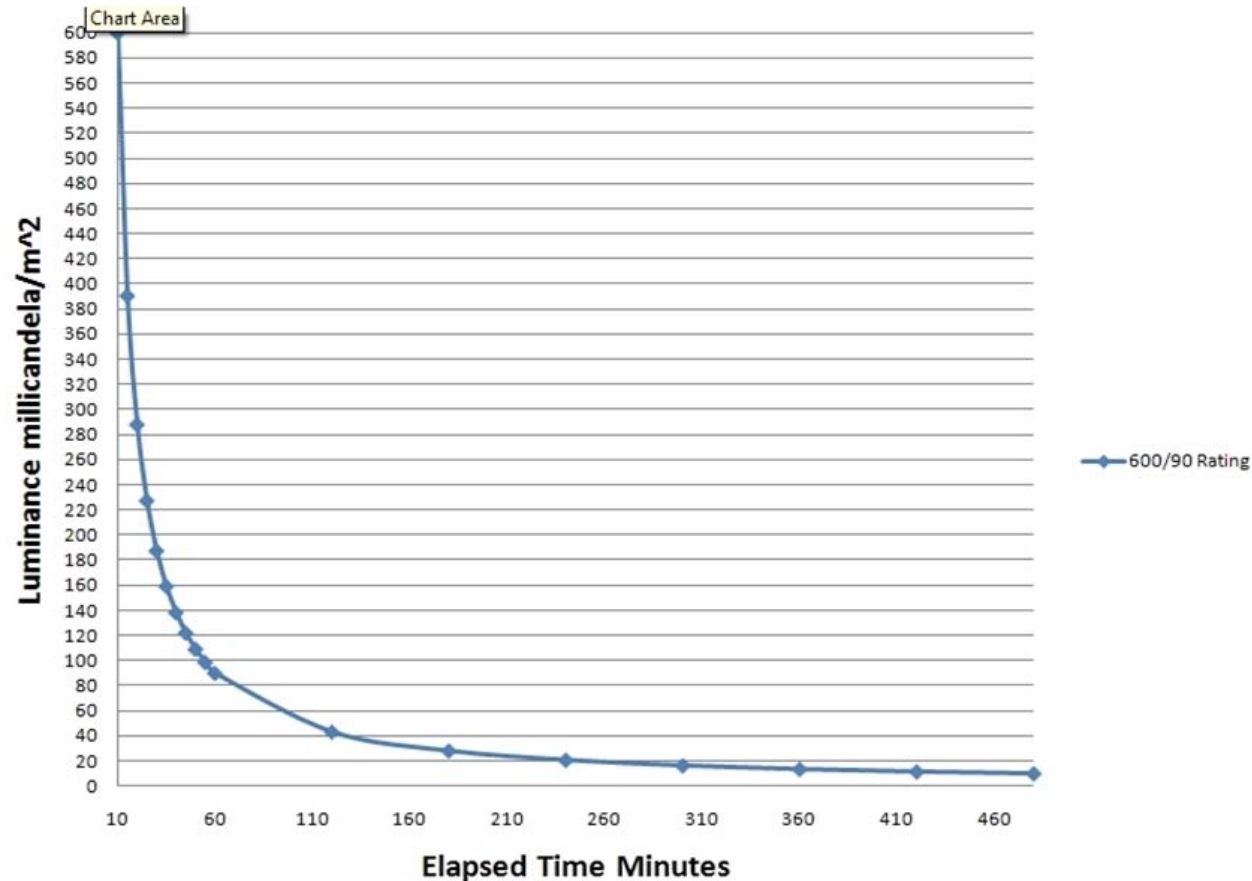


Figure 3.5 Decay Rate for 600/90 Rated Material

This is the decay rate for the 600/90 rating. This curve is characteristic for any photo-luminescent material discharge or decay.

Luminance =  $A / \text{time}^B$  where A and B are vary according to the decay rating, amount of illumination used for charging and the time of exposure.



## Example of ISS Requirements for Emergency Egress

### SSP-41000 BN Requirements met by EEGS

#### 3.3.6.11.2 Emergency egress.

The on-orbit Space Station shall provide for safe emergency IVA egress to the remaining contiguous pressurized volumes and have the capability to isolate from other flight pressurized volumes within three minutes, in the event of an emergency. ***EEGS sensitivity assessment shows as little as 3 lux of illumination for 5 minutes and 108 lux for 10 seconds will charge EEGS to be visible for 3 minutes in darkness.***

#### 3.7.8.3.3.1.3 Control emergency egress lighting.

The Node 3 shall automatically turn on the emergency egress lighting within one second subsequent to the loss of power to all general area lighting. ***Charged EEGS becomes visible instantly when power to lights fails.***

#### 3.7.8.3.3.2.3 Indicate emergency egress hatches.

The Node 3 shall visually indicate emergency egress hatches for the USOS and the starboard side port pressurized module exits in the absence of power to Node 3 general area lighting. ***EEGS will be placed in the hatch area such that they will be visible to the crew as a guide to the hatch.***

## Performance Evaluation Results

**TABLE 3.1 LUMINESCENCE AFTER 108 LUX EXPOSURE**

Exposure Time	Initial Luminance (mcd/m <sup>2</sup> )	Discharge Time	Final Luminance (mcd/m <sup>2</sup> )
60 min	780.0	8 hr	6.0
10 min	380.0	8 hr	4.0
5 min	100.0	8 hr	3.0
30 sec	7.0	3 min	3.5
10 sec	4.0	3 min	2.0

**TABLE 3.2 LUMINESCENCE AFTER 50 LUX EXPOSURE**

Exposure Time	Initial Luminance (mcd/m <sup>2</sup> )	Discharge Time	Final Luminance (mcd/m <sup>2</sup> )
15 min	81.0	8 hr	3.0
10 min	56.0	8 hr	3.0

108 Lux is the minimum general illumination requirement for ISS measured at 30 inches from the floor.

50 Lux is the minimum illumination requirement for translation between hatches

**ISO 16069** defines the minimum luminance as 2 mcd/m<sup>2</sup> for an installed component after an exposure of 50 lux for 15 minutes.

EEGS achieved this minimum after 3 lux exposure for 5 minutes or 20 lux for 30 seconds.

**Table 1 — Minimum requirements for luminance decay properties**

Time from withdrawal of excitation illumination min	Luminance mcd/m <sup>2</sup>
10	20
60	2,8
340	0,3

**Table 2 — Minimum requirements for luminance of installed components**

Time from withdrawal of excitation illumination min	Luminance mcd/m <sup>2</sup>
10	≥ 15
60	≥ 2
Requirements given in this table are minimum requirements; an increase in the luminance properties of the material, the area and frequency of application of SWGS components and the excitation illumination is considered as an increase in the effectiveness of the system.	

Reference: ISO 16069 - 1<sup>st</sup> Edition 2004-11-01  
Section 7.3 Luminance requirements for  
phosphorescent components of a  
Safety way guidance systems (SWGS)

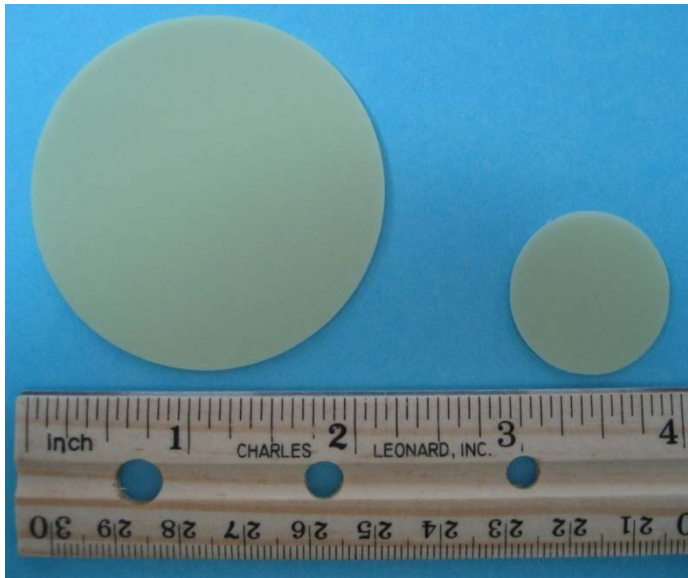
## Marker Details

Made of PVC material with high persistence rating.

Perma-light product # 81-1028 rated at 600/90 (ASTM standard rating index for photoluminescent material).

600 = millicandela/m<sup>2</sup> after 10 minutes in dark

90 = millicandela/m<sup>2</sup> after 60 minutes in dark

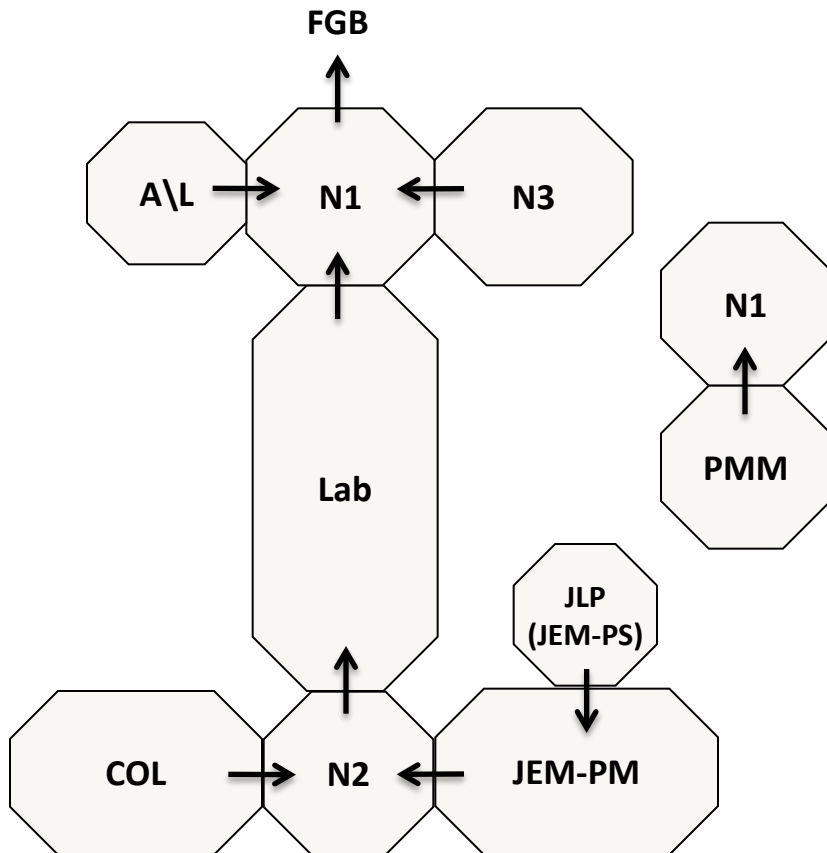


**EEGS Markers**

Marker size was restricted to be a maximum 4 square inches placed at a minimum 2 inches apart (ISS Fire constraints). This meant that labeling markers with “EXIT” would reduce visibility so a 2.25 inch diameter circle was chosen as a distinct shape for labeling the “EXIT”. One inch diameter circles were needed in Columbus module because of limited placement areas. The circle design also had no corners and was easy to install (no alignment issues).

# Installation Map of EEGS on ISS

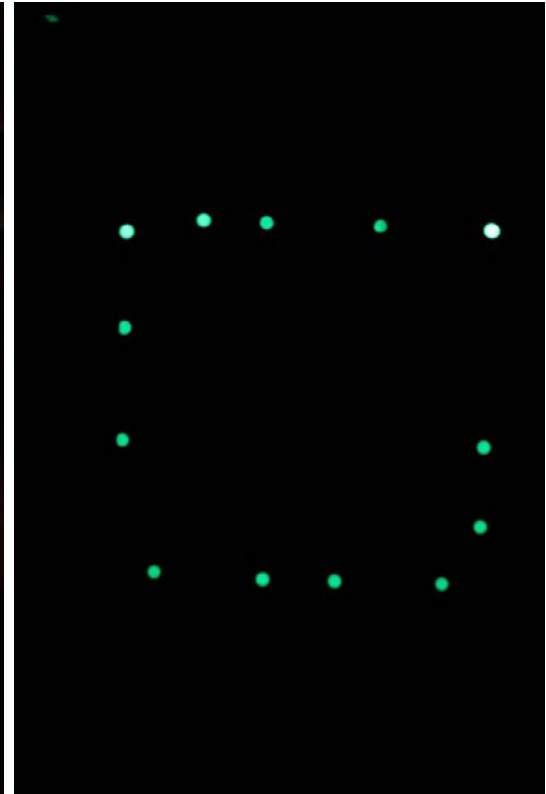
EEGS markers have been installed on following ISS modules



EEGS Deployment Status	Module	Large 57.15 mm	Small 25.4 mm
Installed Jan 2011	Node 1	14	
Installed Jul 2010	PMM	16	
Installed Jan 2011	Node 3	14	
Installed Jan 2011	Airlock	7	
Installed Jan 2011	Lab	12	
Installed Jan 2011	Node 2	13	
Installed Oct 2011	Columbus	4	6
Installed Aug 2011	JPM (JEM)	12	
Installed Aug 2011	JLP	12	
Spares To be installed as needed	Adhesive expiration date Feb 1, 2012	20	4
Total Markers		124	10

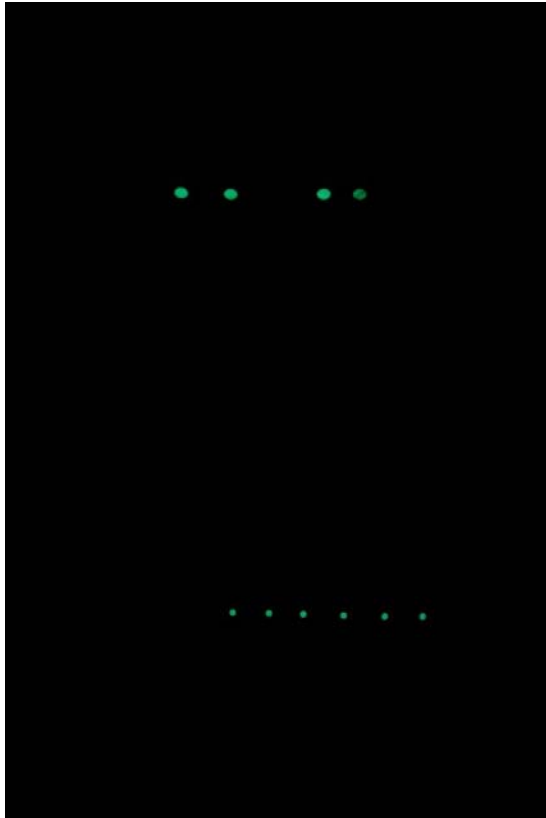
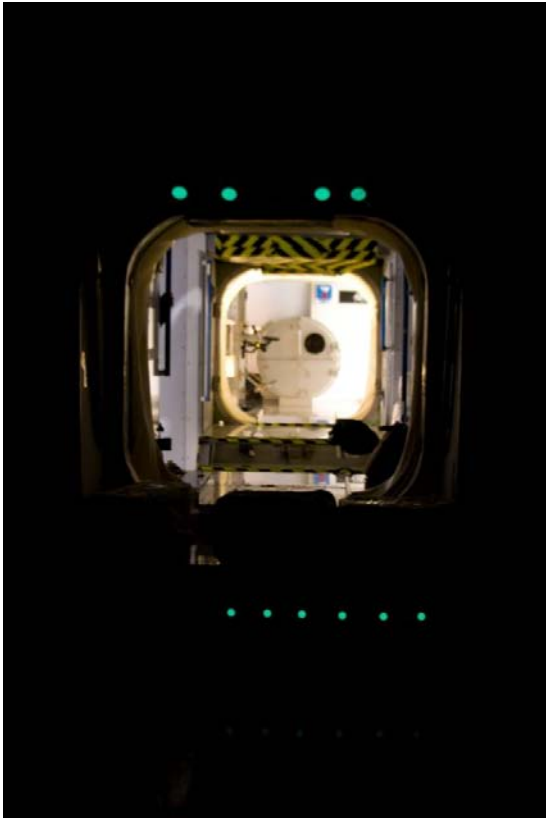


## Node 2 Mockup Digital Photograph After Lights Out





# Columbus Mockup Digital Photograph After Lights Out



## On Orbit View of Egress Hatch from Node 1 to FGB with EEGS markers installed.

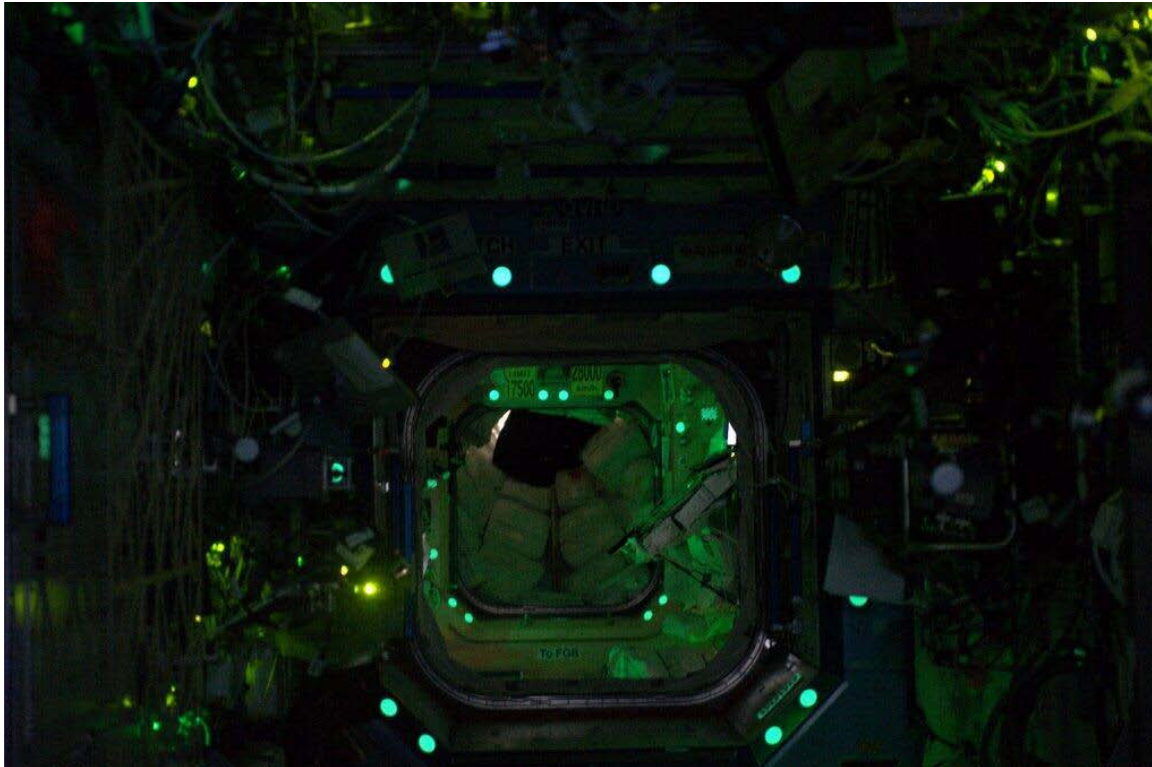


## On Orbit View of Egress Hatch from U.S. Lab to Node 1 with EEGS markers installed



ISS026E014265

## On Orbit View of U.S. Lab and Node 1 Egress Hatch Areas After Lights



**EEGS at night inside ISS**

<https://twitter.com/Astrollini/status/403293364432297985/photo/1>



## **Differences in utilization of photo-luminescent materials for emergency egress on ISS and industry (IBC-2009)**

Industry (IBC-2009) requires the emergency exit markers have the word EXIT on the sign and text be visible at minimum distance of 75 feet. Because of restrictions on the size of markers, word “EXIT” would be too small so ISS adopted the circular shape as substitute for word “EXIT”.

Industry (IBC-2009) requires 60 minutes of illumination on photoluminescent materials before a building is occupied. On ISS, this is not practical or possible. However, because the primary exit or egress path on ISS is illuminated for up to 16 hours a day and the highest rated photoluminescent materials are used for EEGS, the markers are visible for more than 8 hours in the dark. In addition, for EEGS markers that have been in the dark longer than 8 hours, the time to charge them for a minimum of 3 minutes of visibility in an emergency is 10 seconds at 108 lux of illumination (minimum general illumination).

Industry (IBC-2009) provides for regular physical safety inspections of egress markers. On ISS, inspections are regularly performed but done remotely using video.



## **Summary:**

Because ever increasing performance, photoluminescence has moved from “glow in the dark” toys to greatly expanded use in offices, factories, homes and many other places where it can be charged regularly by light and seen clearly and effectively in the dark for extended periods of time.



## Time Line for Utilization of Photoluminescent Egress Markers

Year	
1989	California law requiring pathway marking for certain new buildings, ie schools, hospitals, etc.
1993	Internation Maritime Org. (IMO) adopted similar requirement for ships
1997	FAA authorizes use of photoluminescent egress markings in lieu of electric powered lights
1998	U.S. Navy mandated use of photoluminescent markings for egress paths on ships
2000	Dept of Defense (DOD) adopted ASTM 2030-99 for military installations
2001	Underwriters Lab (UL) revised UL924 to include photoluminescent signs
2003	World Trade Center Building Code Task Force recommends photoluminescent markers for egress paths in all buildings
2004	New York City mandated photoluminescent markers on all buildings higher than 75 feet
2009	International Building Code (IBC 2009) and International Fire Code (IFC) adpots similar code to NYC mandate
2010	10 states have adopted IBC-2009
2011	Photoluminescent markers used for emergency egress on ISS
2012	State of Texas passes rule 70.100 adopting IBC 2009

Source: Egress Safety Glow <http://egresssafetyglow.com/photoluminescence.html>



## Reference Documents

ASTM E2072-10 “Standard Specification for Photoluminescent (Phosphorescent) Safety Markings”

ASTM E2073-10 “Standard Test Method for Photopic Luminance of Photoluminescent (Phosphorescent) Markings”

ASTM E2030-08 “Standard Guide for Recommended Uses of Photoluminescent (Phosphorescent) Safety Markings”

ISO 3864-4 “Graphical symbols — Safety colours and safety signs”, “Part 4: Colorimetric and photometric properties of safety sign materials”



## Internet Links for information on photoluminescent materials

<http://www.activesafety.com/>

<http://www.americanpermalight.com/>

<http://www.hylinesafety.com/emergencylights.html>

[http://www.mt-berlin.com/frames\\_cryst/descriptions/long\\_afterglow.htm](http://www.mt-berlin.com/frames_cryst/descriptions/long_afterglow.htm)

<http://www.mss-int.com/prod05.html>

<http://www.cooper-ls.com/products/emergency-lighting>



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