

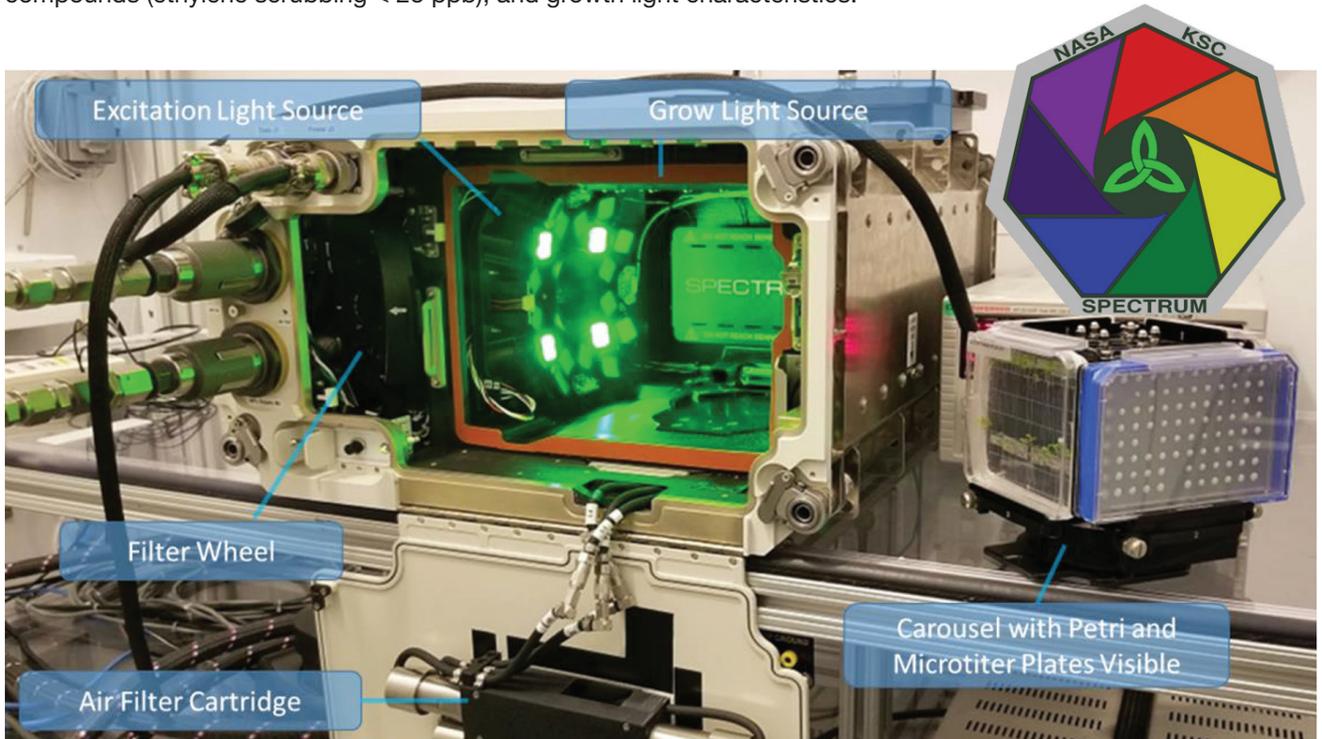


Spectrum

Scheduled for launch to ISS on NG-12

Spectrum is a multi-spectral fluorescence imaging system designed for capturing *in vivo* genetic expression in the low to zero-gravity environment of the International Space Station (ISS). Observation of organisms expressing fluorescent reporters will allow the scientific community to further understand biological responses of these organisms when subjected to space environments. Model organisms that may utilize multispectral imaging on the ISS include unicellular organisms (e.g. *Saccharomyces cerevisiae*), plants (e.g. *Arabidopsis thaliana*), and invertebrates (e.g. *Caenorhabditis elegans*).

Spectrum will accommodate standard 100 mm x 100 mm Petri plates, 128 mm x 82 mm multi-well culture plates, and other custom containers within the growth and imaging chamber. Principal Investigator (PI) defined scripting logic provides for automated chamber management and the continuous collection of chamber environment information, supporting the primary function for capturing 71 megapixel images of fluorescent emission from biological organisms under highly uniform illumination. Scripting logic also provides for control of chamber temperature (18 to 37° C), humidity, CO₂ (ranging between 400 ppm up to ISS-ambient levels), volatile organic compounds (ethylene scrubbing < 25 ppb), and growth light characteristics.



The Spectrum flight unit and subsystems during Testing at KSC.

Imaging Subsystem – Based on the Illunis 71-megapixel monochromatic camera with Birger Engineering lens adapter for automated control of camera lens focusing and aperture, and a Canon EF 20 mm f/2.8 USM lens that achieves a pixel resolution near 13 μm, which is similar to a dissecting microscope. With substitution of up to 100 mm Macro lens, Spectrum can achieve higher resolution imagery with resolution to about 2.5 μm.

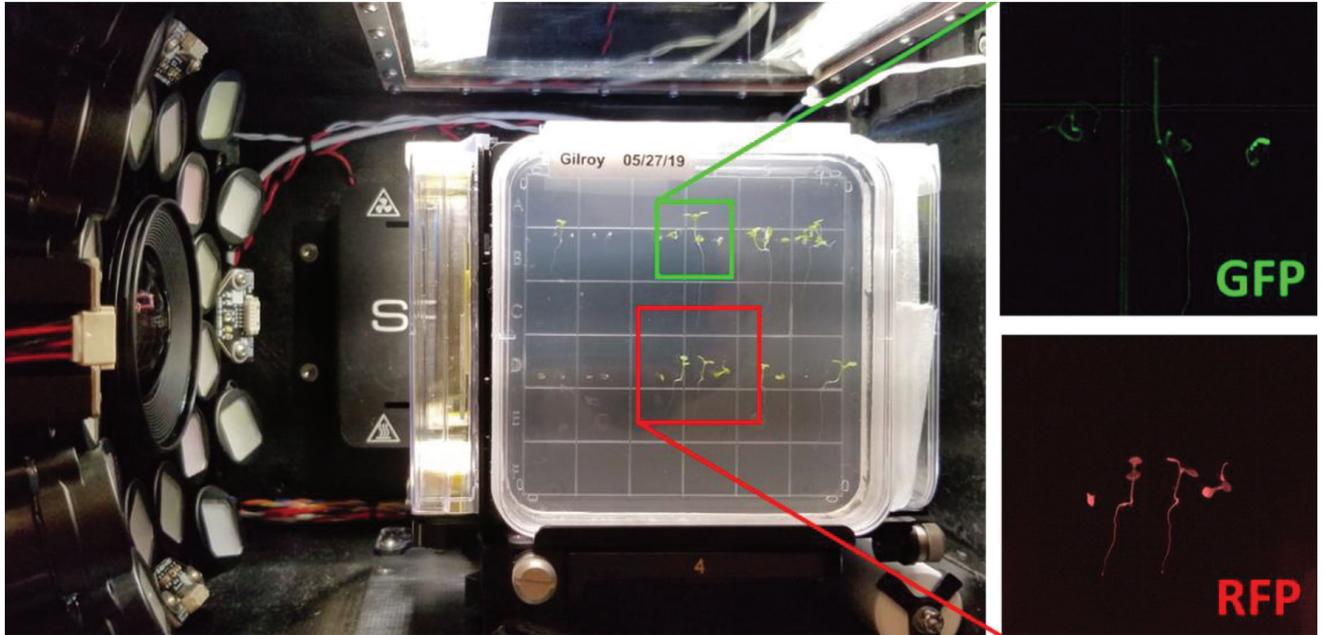
Excitation Light Source – A ten-position motorized filter wheel for fluorescence emission filters is paired with an Excitation Light Source (ELS) using RPC Photonics engineered diffusers to achieve an 80% uniform illumination of the target samples. Additional filters are provided to support color and infrared images. This capability allows researchers to image several fluorescent proteins in a single biological specimen providing the ability to perform in-depth multispectral analysis.

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Grow Light Subsystem – Calibrated banks of LEDs illuminate biological samples from a single direction. The growth light cap is equipped with broad-spectrum white (400-750 nm), red (630-660 nm), blue (400-500 nm), and green (520-530 nm) LED's with an intensity range of 0-1000 $\mu\text{mol m}^{-2}\text{s}^{-1}$.

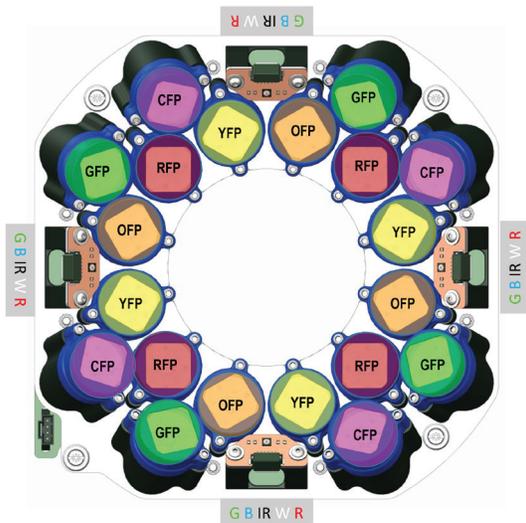


View of the ELS and Carousel subsystem within the Spectrum Growth Chamber. Insets are images of Arabidopsis plants expressing GFP and RFP fluorescence taken with the Spectrum ELS and camera system.

Carousel Subsystem – Four 100 mm x 100 mm Petri plates can be mounted and rotation controlled through a 360 degree axis of rotation that was designed to control placement of the Petri plate position to +/- 0.1 degree after rotation, and can be customized for any size or shape within a 10 x 12.7 cm footprint. The carousel is capable of continuous rotation for low accelerations up to 33 rpm and is removable to allow PI provisioning of custom sample holding and positioning equipment. Chamber air is ducted through the Carousel to suppress condensation on the inside of Petri plate covers.

Data Commanding and Storage – Spectrum is commanded from the ground and internally collects and stores time stamped images with the option to downlink data retrieval for near-real time evaluation by the investigator team.

Orbital Replaceable Units (ORU) – Principal Investigators (PI) may consider modifications to Spectrum for tailoring to new science requirements, including the Excitation Light Source (ELS) and the Emission filters, camera lenses, chamber sensors, carousel assemblies, and the Air Filter Cartridge. Furthermore, Spectrum software can be modified during flight.



Spectrum ELS mapping by fluorescent protein.

Filter Wheel	Description	Excitation Filter [nm]	Emission Filter [nm]	Mnemonic Color
1	Bayer Blue		458/64	Blue
2	Bayer Green		535/50	Green
3	Bayer Red		650/100	Red
4	Transparent		409/LP	White
5	CFP	435/40	482/25	Cyan
6	GFP	466/40	512/25	Green
7	YFP	504/12	539/30	Yellow
8	OFP	534/20	585/40	Orange
9	RFP	572/28	629/56	Red
10	CHLOR	CFP & GFP	680/42	Dark Red

Spectrum Filter Wheel mapping for emission and imaging.