National Aeronautics and Space Administration

The Earth Observer. November - December 2015. Volume 27, Issue 6.

the earth observer

Editor's Corner

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Quicker than seems possible, another year is drawing to a close. For NASA's Earth Science Division, the year began with three successful launches—CATS to the ISS to study clouds and aerosols, SMAP to study soil moisture and freeze-thaw state from space, and NOAA's DSCOVR mission, which includes two NASA Earth Science instruments now transmitting data from the Lagrange point 1 (L1[1]). CATS is functioning nominally, and is now providing Level-1B and Level-2 products—including the heritage CALIPSO algorithm, as well as browse imagery (all available at *cats.gsfc.nasa.gov/data*). As reported in our last issue, the SMAP radar ceased operations in early July, however the mission will be able to continue to provide soil moisture and other important science quality products. Preliminary Level-2 and Level-3 SMAP radiometer data are now available—see the *Announcement* on page 11 for details. With regard to DSCOVR, NASA launched a new website in late October for the world to see full sunlit browse images of the Earth from the Earth Polychromatic Imaging Camera (EPIC[2])—*epic.gsfc.nasa.gov*. This site will post at least a dozen color composite images of Earth acquired 12 to 36 hours earlier by EPIC. The success of our Earth Science endeavors is a tribute to all the mission and instrument teams that work so hard, often behind the scenes, to keep these missions operating smoothly.

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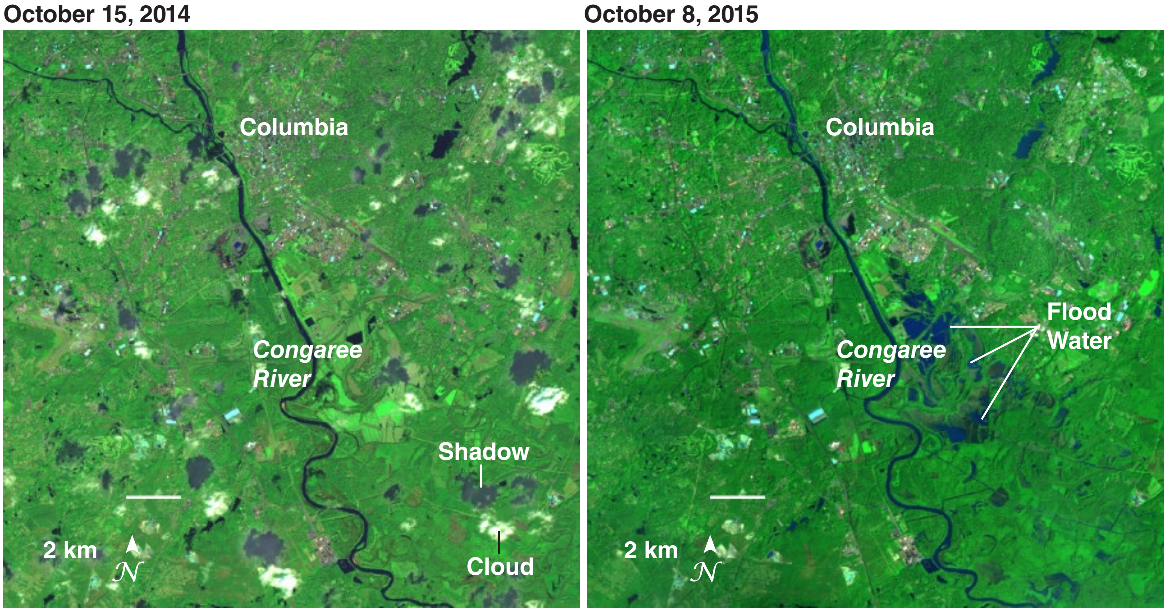
[1] Please refer to the Editorials written during 2015 in *The Earth Observer* for more information on the launches and subsequent progress of the missions referred to throughout this article.

[2] EPIC measures in the ultraviolet, visible and near-infrared areas of the spectrum. The data from all 10 wavelengths are posted at *eosweb.larc.nasa.gov/project/dscovr/dscovr_table*. All images are in the public domain.

October 15, 2014 **October 8, 2015**



After record-breaking rains pounded South Carolina in early October 2015, severe floods overwhelmed many parts of the state. This pair of images shows the interior of South Carolina on on October 15, 2014 [*left*], as observed by the Operational Land Imager (OLI) on Landsat 8 compared to the same region during the flooding on October 8, 2015 [*right*], as observed by the Advanced Land Imager (ALI) on NASA's Earth Observing-1 (EO-1) satellite. Floodwater covered broad swaths of farmland, forests, and wetlands east of the Congaree River in 2015. Note that the dark areas in the 2014 image are cloud shadows. **Credit:** NASA's Earth Observatory

In This Issue

Reminder: To view newsletter images in color, visit *eospso.nasa.gov/earth-observer-archive.*

NASA's Earth Observing-1 (EO-1) mission reached an impressive milestone in 2015, celebrating its fifteenth anniversary on November 21. Launched during the era of "faster, better, cheaper" as part of NASA's New Millennium Program, it far exceeded its original one-year mission and has served as an on-orbit testbed for new technologies, imaging techniques, and targeted data acquisitions.

Two of EO-1's instruments successfully demonstrated new technologies that are now being used in NASA's current and/or planned missions. The Advanced Land Imager (ALI) demonstrated then-new *pushbroom* techniques for multispectral imagery. The technology worked well and the results influenced the design of the Operational Land Imager (OLI) that now flies onboard the joint NASA–USGS Landsat 8 mission, and is planned for flight on Landsat 9. The Hyperion imaging spectrometer (aka *hyperspectral* imager) measures more than 200 adjacent wavelength bands, providing more complete—and spectrally continuous—coverage than multispectral imagers. Hyperion has given the science community invaluable experience working with complex hyperspectral data that are being incorporated into the design of future instruments, such as the imaging spectrometer on NASA's Earth Science Decadal Survey Hyperspectral Infrared Imager (HyspIRI) mission concept.

Perhaps the innovation that has been most essential to EO-1's longevity beyond the initial technology demonstration phase was its onboard computer, which provided excess onboard computing capability that allowed the EO-1 team to attempt activities not initially planned as part of the mission. The first such was the Autonomous Science Experiment, an onboard intelligent scheduling tool that allowed the satellite to determine which images Hyperion and ALI should acquire—a novel "customer-driven" approach to image acquisition—see image on page 1 for example.

On the occasion of the fifteenth anniversary of its launch, our congratulations to the entire EO-1 team! The mission's longevity is testimony to their hard work and dedication. *The Earth Observer* plans more complete coverage of EO-1's achievements in an upcoming article.

Two missions came to an end in 2015. The TRMM mission ceased operations this year after a phenomenal 17-year run[3], leaving behind a remarkable legacy. The GPM Mission, with its Core observatory and nine Constellation members, is nearing its second anniversary in space, continuing the precipitation measurements begun by TRMM, but also offering observational capabilities beyond those of its predecessor, such as the ability to study mid-latitude storms and lighter precipitation. Likewise, the Aquarius mission ended this year, after more than three years in orbit—exceeding its planned lifetime[4]. The sea surface salinity measurements from Aquarius add another to NASA's considerable list of multiyear time series of important climate parameters. Analysis of the almost-four-year data record from Aquarius has already led to advances in our understanding of the dynamics and interannual changes of the salinity field and links between salinity and other phenomena such as El Niño. Studies will surely continue for many years to come.

Another important measurement will resume in 2016. For nearly thirty years, NASA's Stratospheric Aerosol and Gas Experiment (SAGE) family of remote-sensing-satellite instruments continuously measured stratospheric ozone (O_3) concentrations, aerosols, water vapor, and other trace gases. However, there has been a nearly decade-long gap in SAGE measurements since the SAGE III Meteor-3M (launched in 2001) ended on March 6, 2006. I am happy to report that SAGE III on ISS is tentatively scheduled to launch on June 10, 2016, which will resume the SAGE measurement record. The article on page 4 of this issue provides details on the plans for SAGE III on ISS including its launch, installation on the ISS, the ground system, planned data products, and more.

Also planned for 2016 is the launch of Jason-3, which aims to continue the decades long record of sea surface topography that began with TOPEX/Poseidon and continued with Jason-1 and OSTM/Jason-2. One key application of sea surface height data has been monitoring the progress of ENSO events in the tropical Pacific, such as the current El Niño that is unfolding in a very similar way to some of the strongest ones on record—e.g., 1982-83 and 1997-98 events. The 2015-16 El Niño is the first major El Niño to unfold under the watchful "eyes" of our EOS fleet—all of which launched since 1999. Once launched, Jason-3 will join Jason-2 in making observations of sea surface topography. As reported in our last issue, the Jason-3 launch was delayed from August 2015 because of the loss of the SpaceX Falcon 9 resupply mission to the ISS on June 28. NASA has been working with NOAA, CNES, SpaceX, and the Western Test Range at Vandenberg Air Force Base (the launch site) to reschedule the launch; dates in early 2016 are under consideration, but as of this writing the exact date has not been set. Read more about NASA plans to monitor the El Niño in the *News story* on page 34.

Each year the AGU Fall Meeting in San Francisco, CA provides scientists from around the world a forum to showcase the latest results from their research. If you are planning to attend, we invite you to visit us at the NASA booth in the exhibit hall, December 14-18. More than 40 Hyperwall talks are scheduled throughout the week, as well as several other in-booth science "flash talks" that will demonstrate data tips, tools, and tutorials. There will also be a wide range of other demonstrations, printed materials, and scientists and outreach personnel to interact with[5]. For more information on AGU, see the *Announcement* on page 17. We hope to see you there!

On behalf of *The Earth Observer* staff, our sincere appreciation to those of you who provided content for the newsletter over the past year. From its earliest days, contributions from our readers have been crucial to the success of our publication. While things look considerably different than when we began in 1989, it remains true that there would not be a newsletter without our community of authors contributing features, summaries, and other content on a regular basis. Thank you and best wishes to all in the coming year. ■

[3] To learn more about the circumstances surrounding the end of the TRMM mission please refer to the Editorial in the May–June 2015 issue of The Earth *Observer* [**Volume 27**, **Issue 3**, pp. 1-2].

[4] To learn more about the circumstances surrounding the end of the Aquarius mission please refer to the Editorial in the July–August 2015 issue of *The Earth Observer* [**Volume 27**, **Issue 4**, pp. 2-3].

[5] A schedule of Hyperwall presentations and other events taking place at the NASA exhibit will be posted at *eospso.gsfc.nasa.gov*.

Note: List of undefined acronyms from the *Editor's Corner* and the *Table of Contents* can be found on **page 39**.

SAGE III on ISS: Continuing the Data Record

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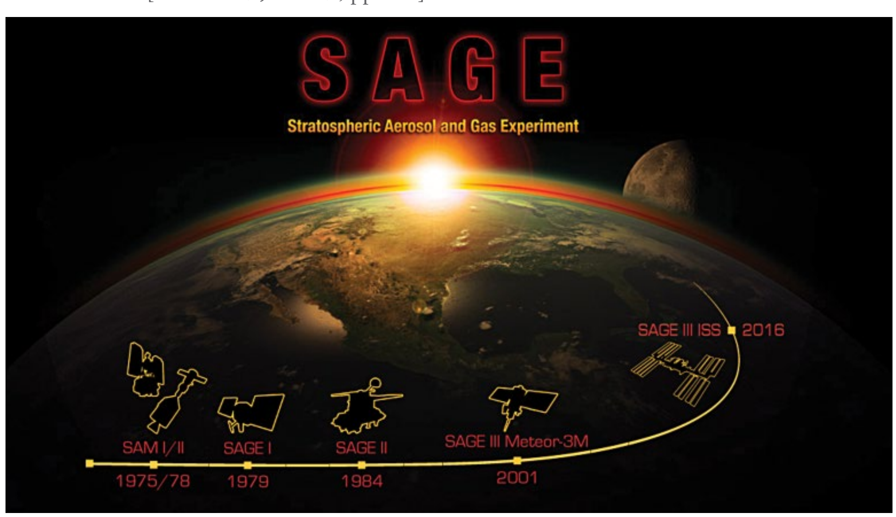
Introduction

NASA's Stratospheric Aerosol and Gas Experiment (SAGE) family of remote-sensing-satellite instruments has long measured ozone (O_3) concentrations, stratospheric aerosols, water vapor, and other trace gases that influence Earth's atmosphere[1]. The first SAGE mission (SAGE I) launched February 18, 1979, on the Applications Explorer Mission-B (AEM-B) satellite. The mission collected valuable data for nearly three years until the satellite's power system failed. SAGE II launched onboard the Earth Radiation Budget Satellite (ERBS) in October 1984, and observed stratospheric O_3 from 1984 until 2005. Data from SAGE II were integral in confirming human-driven changes to O_3 concentrations in the stratosphere, and thus influenced the decisions to negotiate the Montreal Protocol in 1987. Later, observations from SAGE II showed that O_3 in the stratosphere stopped decreasing in response to the actions agreed to in the treaty.

SAGE III on ISS is led by NASA's Langley Research Center with the cooperation of partners around the world including several NASA field centers (Johnson Space Center, Marshall Space Flight Center, Goddard Space Flight Center, and Kennedy Space Center), NASA's White Sands Facility, Ball Aerospace & Technology Corp., Thales Alenia Space-Italy, and the European Space Agency. **Image credit**: NASA

Building on previous successes, a third-generation instrument was developed to ensure continuous measurements and to generate new data products. When SAGE III was developed, three identical instruments were built: one was launched on the Russian Meteor-3M spacecraft on December 10, 2001; one was built specifically to be flown on the International Space Station (ISS); and another is a spare. The SAGE III Meteor-3M mission ended on March 6, 2006, when the Meteor-3M spacecraft lost pressure and electrical subsystems failed; this left a gap in the invaluable SAGE data record. Planned for launch in 2016, SAGE III on the ISS will continue the legacy of accurate SAGE measurements.

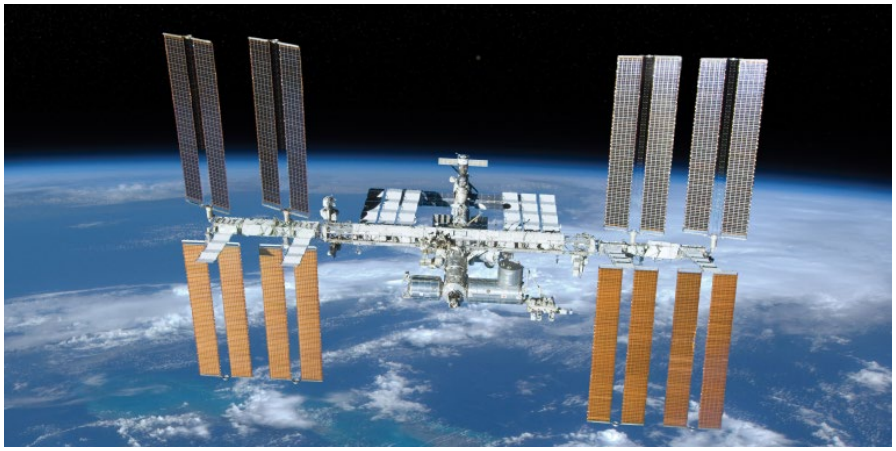
[1] Before the first SAGE mission in 1979 there were two Stratospheric Aerosol Measurement (SAM) missions—SAM I and SAM II. To learn more about the historic measurements leading up to SAGE III on the International Space Station, read "The SAGE Legacy's Next Chapter: SAGE III on the International Space Station" in the September-October 2013 issue of *The Earth Observer* [**Volume 25, Issue 5**, pp. 4-8].



The first SAGE mission was launched in 1979. In 1990 the U.S. Clean Air Act mandated that NASA continue to monitor O_3. As a result, the SAGE family of instruments observed O_3 concentrations, along with water vapor, aerosols, and trace gases continuously from 1979 to 2006. **Image credit**: NASA

Mission Overview

The SAGE III instrument that was meant to be flown on the space station went into storage until the station's construction was complete. Work to prepare SAGE III for installation on the ISS began in 2011. Designed to operate for no fewer than three years, SAGE III will measure the composition of the stratosphere and troposphere—see *Science Goals* on page 6. Onboard the station, SAGE III will orbit between 385 km (~239 mi) and 415 km (~258 mi) above Earth's surface. The station's orbital inclination of 51.6° provides coverage between 70° N and 70° S latitude with a nearly three-day repeat cycle.



SAGE III on ISS is among a small number of Earth-observing, continuous-measurement systems to be installed on the space station to demonstrate ISS-based operational science capabilities. Two other Earth-observing instruments, the Rapid Scatterometer (RapidScat) and Cloud-Aerosol Transport System (CATS), were installed on the station in September 2014 and January 2015, respectively. More are planned for the future. **Image credit**: NASA

Similar to its predecessors, SAGE III on ISS will provide vertical profiles of O_3, aerosols, nitrogen dioxide (NO_2), and water vapor in Earth's atmosphere by taking occultation measurements when the sun or moon is rising or setting, about 15-16 times each day—see **Figure 1**. In addition to light from the sun, the moon will also be used as a light source to detect O_3. The station's unique orbital path will allow SAGE III to observe O_3 during all seasons and over a large portion of the globe. SAGE III on ISS will also measure O_3 concentrations deeper into the atmosphere than previous SAGE measurements, reaching down into the troposphere. Another benefit of flying onboard the ISS is that scientists and engineers will also have near-continuous communications with the payload.

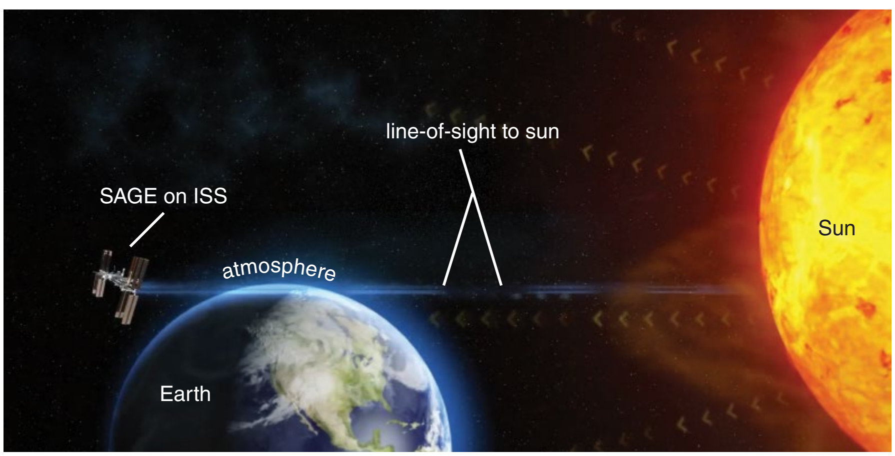


Figure 1. By using the sun and the moon as light sources, SAGE can detect O_3, aerosols, and other trace gases in the atmosphere. **Image credit:** NASA

Measurements from SAGE III on ISS will be used to observe long-term trends of stratospheric O_3 concentrations. Combined with data from mapping instruments such as the Ozone Mapping Profiler Suite (OMPS[2]), scientists will be able to determine whether the ozone layer is recovering as expected. In addition, data from SAGE III on ISS will

[2] The Ozone Mapping and Profiler Suite (OMPS) is the next generation of back-scattered ultraviolet radiation sensors, following on the instruments that flew onboard Nimbus and NOAA Polar Operational Environmental Satellites (POES). The first OMPS is currently flying onboard the Suomi National Polar-orbiting Partnership satellite. OMPS builds on the success of the Ozone Monitoring Instrument (OMI) onboard Aura and Solar Backscatter Ultraviolet (SBUV/2) instruments that flew from 1984–2009 on several NOAA satellites..

be used to help refine the accuracy of three-dimensional models used to understand the atmosphere and predict future atmospheric changes. SAGE III on ISS is a key part of NASA's mission to provide crucial, long-term measurements that will help humans better understand and care for Earth's atmosphere, providing the foundation for sound environmental policy.

Science Goals

The science goals of the mission are to:

- Assess the state of recovery in the distribution of O_3;
- re-establish the aerosol measurements needed by both climate and O_3 models; and
- gain further insight into key processes contributing to O_3 and aerosol variability.

Instrument Overview

SAGE III on ISS consists of two separate payloads—the Instrument Payload and the Nadir Viewing Platform. Combined, the SAGE III payloads have a mass of 527 kg (~1162 lbs) and a data rate of 2150 MB per day.

Instrument Payload

The Instrument Payload includes a Sensor Assembly, Interface Adapter Module, a Disturbance Monitoring Package, the Hexapod Pointing System (Hexapod Electronics Unit and Hexapod Mechanical Assembly), two Contamination Monitoring Packages, and the Instrument Control Electronics box—see **Figure 2**. Building on the success of its predecessors, SAGE III has a few upgrades. The new design incorporates a charge coupled device (CCD) array detector that enhances measurement capability and may allow for new experimental data products like methane (CH_4), bromine monoxide (BrO), and iodine monoxide (IO).

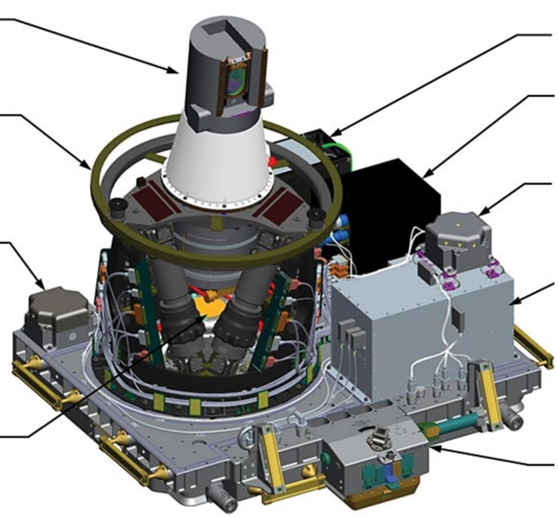
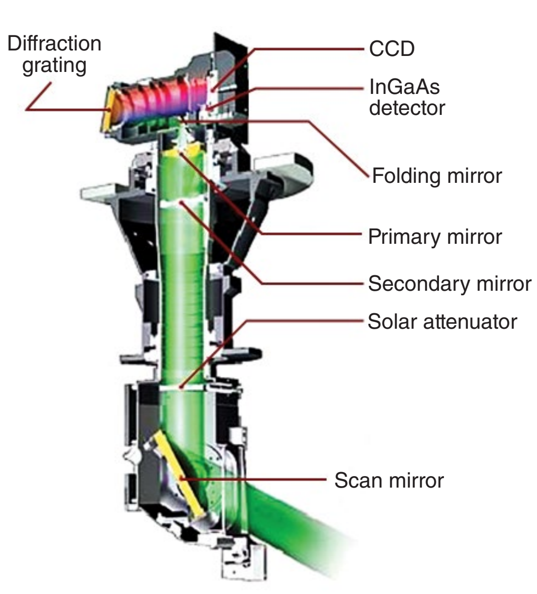


Figure 2. Illustration of the components that make up the SAGE III Instrument Payload. *ExPRESS stands for EXpedite the PRocessing of Experiments for Space Station. **Image credit:** NASA

The SAGE III Sensor Assembly—a grating spectrometer that measures ultraviolet (UV) and visible light and has a two-axis pointing system—consists of three subsystems: the scan head, imaging optics, and the spectrometer detector—see **Figure 3**. These subsystems are employed to acquire light from either the sun or moon by vertically scanning across them. Once the instrument is powered on, light that is brought into the spectrometer by the telescope is broken up into UV, visible, and infrared wavelengths from 280 to 1040 nm by the grating spectrometer and sent to the CCD array. The measurements are made using a ratio: the amount of light passing through the atmosphere compared to the amount of light coming directly from the sun outside the atmosphere. By measuring the amount of absorption of radiation at various heights throughout the atmosphere at different wavelengths, SAGE III can infer the vertical profiles of O_3, aerosols, water vapor, and NO_2. Additional aerosol information is provided by a discrete photodiode at 1550 nm.



Spectrometer Subsystem

Measures solar radiation from 280 to 1040 nm at 1 to 2 nm spectral resolution. An additional photodetector measures radiation at 1550 nm.

Imaging Subsystem

Produces a focused image of the target at a focal plane where the instrument's field of view is determined. Light passing through a tiny slit located here enters the spectrometer.

Pointing Subsystem

Consists of a scan mirror, which acquires the radiant target and performs vertical scanning across the target.

Figure 3. Pictured here are the three subsystems that make up the SAGE III Sensor Assembly. **Image credit:** NASA

Several busy operations onboard the ISS can interfere with science observations, e.g., visiting instrument traffic and thruster operations. To avoid contamination from such operations, the Instrument Payload includes two Contamination Monitoring Packages to monitor the environment surrounding the instrument. If the space station environment contains elevated contamination levels, a transparent contamination door will close to protect the instrument's sensors while allowing measurements to continue.

The Interface Adapter Module acts as the "brain" of the instrument payload, providing power and computing to the payload and acting as the interface between the instrument and the space station. The Disturbance Monitoring Package is a miniature inertial measurement unit that will measure all small motions from space station operations. These measurements will be used to help identify and reduce noise in the instrument signal caused by the space station's vibrations. The Hexapod Pointing System supports the payload and keeps the instrument level with respect to Earth while in orbit.

Nadir Viewing Platform

To orient SAGE III facing nadir, or toward Earth, a special L-shaped mounting bracket called the Nadir Viewing Platform was designed, built, and tested at LaRC. The Nadir Viewing Platform will attach to ExPRESS Logistics Carrier-4 (ELC-4) onboard the station, perpendicular to the plane of the ELC, providing the nadir-orientation needed by the Instrument Payload. It replicates the standard ELC exposed-payload attachment. The ELC-4 will provide electrical power and command and data-handling services, and the Nadir Viewing Platform provides electrical power and data services to the SAGE III instrument. Other space station-based payloads have already used the Nadir Viewing Platform's design, turning a traditional ELC site into a nadir-oriented site.

SAGE III on ISS is scheduled to launch on June, 10, 2016, onboard the SpaceX Cargo Resupply-10 mission, or SpaceX-10, from NASA's Kennedy Space Center atop a SpaceX Falcon 9 rocket.

Launch and Installation

SAGE III on ISS is scheduled to launch on June 10, 2016, onboard the SpaceX Cargo Resupply-10 mission, or SpaceX-10, from NASA's Kennedy Space Center atop a SpaceX Falcon 9 rocket. About 10 minutes after liftoff, the SpaceX Dragon will separate from the launch vehicle upper stage and begin a two-day trip to reach the ISS. For their ride to the space station, the SAGE III Instrument Payload and Nadir Viewing Platform will be installed in the unpressurized section of the SpaceX Dragon "Trunk" as separate payloads—see **Figure 4**. Prior to launch, the Dragon will provide power to the Instrument Payload to power its heaters, which are necessary to maintain the temperature of the SAGE Instrument Payload and its other sensitive electronics at safe levels. The Nadir Viewing Platform does not require heater power during transfer to the ISS.

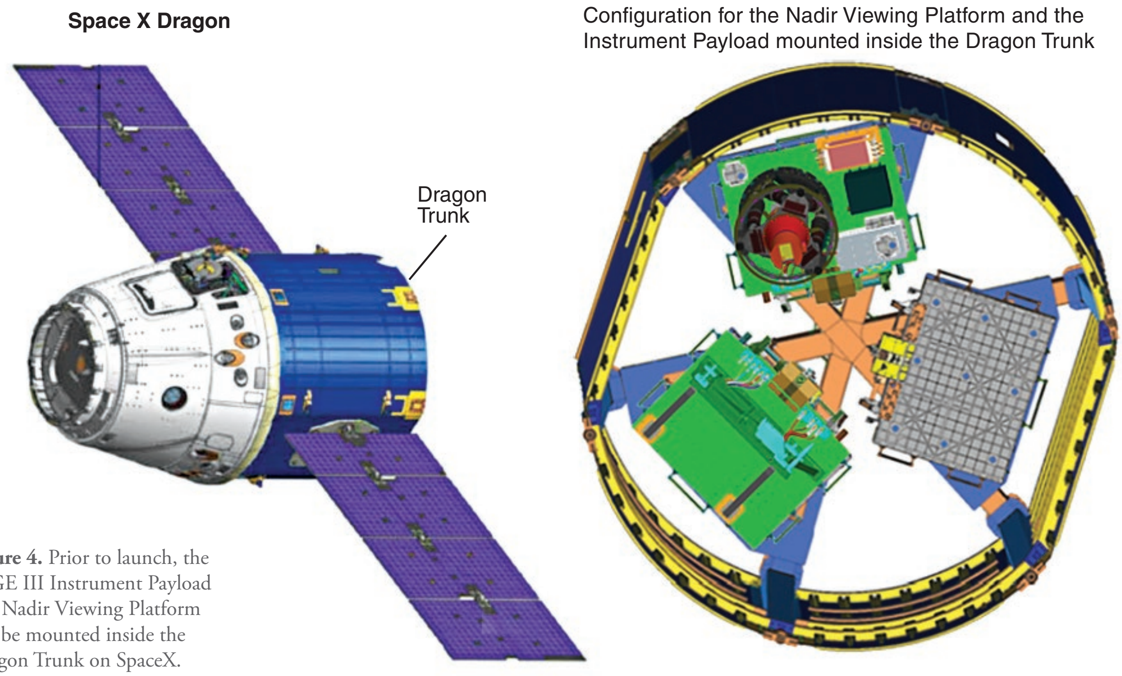


Figure 4. Prior to launch, the SAGE III Instrument Payload and Nadir Viewing Platform will be mounted inside the Dragon Trunk on SpaceX. **Image credit:** NASA

After Dragon reaches the ISS, the Canadarm2 robotic arm will grapple Dragon and secure it to the ISS. Extraction of the SAGE III payloads will require the use of Canadarm2 and also Dextre, a smaller robotic element (also Canadian built) that attaches to Canadarm2. The process to install the SAGE III payloads to their planned location on ELC-4 begins when Dextre removes the Instrument Payload from the Dragon Trunk and installs it onto Dextre's temporary platform. After extraction, the Instrument Payload heaters will not receive power until the payload is installed on the temporary platform. The duration of the robotic maneuvers are carefully coordinated to ensure that the Instrument Payload does not get too cold. Next, the Nadir Viewing Platform is removed from the Trunk by Dextre, but it does not need to be installed on the temporary platform since it does not need heater power. Once both payloads are removed from the Trunk, Canadarm2 and Dextre, with the SAGE III payloads attached, will be moved out to the starboard end of the main ISS truss, where ELC-4 is located.

After approximately three to four days, the SAGE III Mission Operations Team will work with the ISS Operations Team to enable operational power to SAGE III and begin checkout and commissioning of the payload.

The Nadir Viewing Platform will be installed to ELC-4 by Dextre first; then the Instrument Payload will be removed from Dextre's temporary platform and installed to the Nadir Viewing Platform. During transfer from the temporary platform to the Nadir Viewing Platform, the Instrument Payload heaters will not have access to power, so the duration of the transfer will be closely controlled and monitored. After the Instrument Payload is installed—see **Figure 5** on the next page—ISS controllers on the ground will command the ELC-4 to enable heater power to the assembled SAGE III payload. After approximately three to four days, the SAGE III Mission Operations Team will work with the ISS Operations Team to enable operational power to SAGE III and begin checkout and commissioning of the payload.