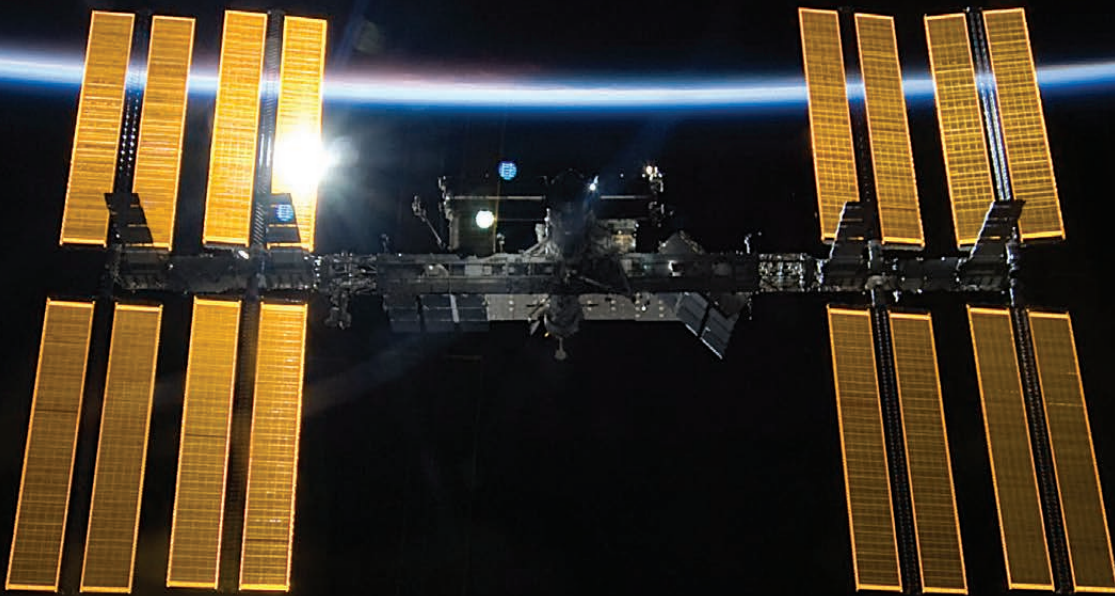




SAGE III

Stratospheric Aerosol and Gas Experiment



on the International Space Station



Acknowledgments

SAGE III on ISS
sage.nasa.gov

The SAGE III instrument is funded by NASA's Science Mission Directorate (SMD). A special thanks is given to the SMD and to the SAGE III science team for making this publication possible.

Content: Kristyn Damadeo, Heather Hanson

Design: Sally Bensusen

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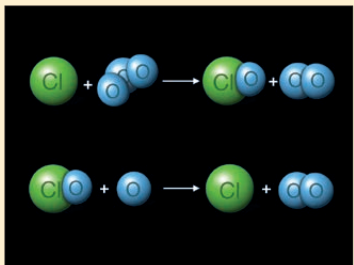


Ozone and Aerosols in Earth's Atmosphere



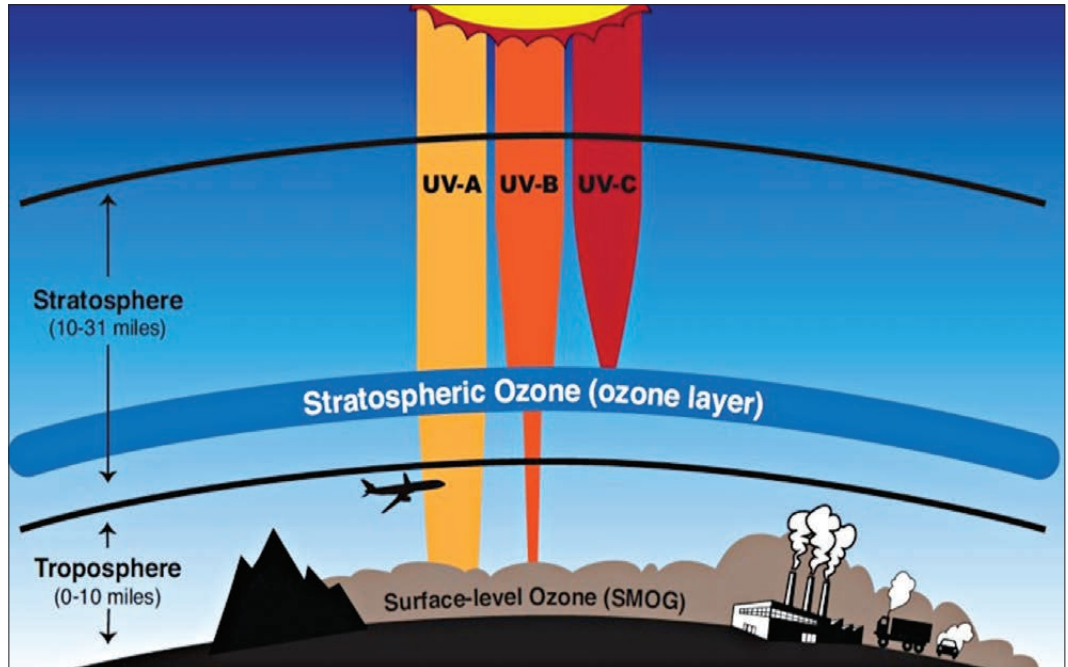
Credit: NASA

Earth's thin atmosphere is mainly comprised of nitrogen (78.09%), oxygen (20.95%), and argon (.93%). The remaining gases account for the roughly 1% of other gases, most of which are greenhouse gases such as water vapor, carbon dioxide, methane, nitrous oxide, and ozone. The most variable of these is water vapor, which varies significantly from around 10 parts per million by volume in the coldest portions of the atmosphere to as much as 5% by volume in hot, humid air masses. This photo, taken from the International Space Station on January 8, 2012, shows the moon and Earth's atmosphere (blue).



Credit: NASA

Stratospheric ozone is created and destroyed naturally through reactions with chlorine (Cl), mediated by sunlight.



Credit: NASA

The sun is a source of the full spectrum of ultraviolet (UV) radiation, which is commonly subdivided into UV-A, UV-B, and UV-C. UV-C rays are the most harmful and are almost completely absorbed by our atmosphere. UV-A and UV-B rays are the harmful rays that cause skin damage. This graphic shows how the stratospheric ozone layer functions as Earth's "sunscreen" and blocks the majority of the sun's UV radiation (i.e., most UV-B and all UV-C) from reaching the planet's surface. It also shows ozone in the troposphere, which is closer to Earth. Surface-level ozone is called smog and is a pollutant.

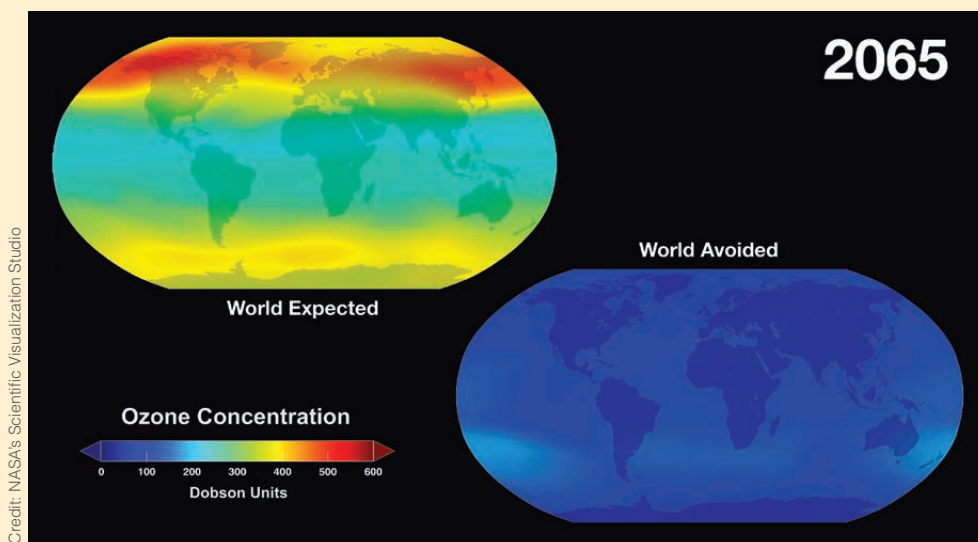
Ozone (O₃) is a highly reactive gas composed of three oxygen atoms, and although it represents only a tiny fraction of the atmosphere, it is vital for life on Earth. Ozone is both a natural and a man-made gas that can be found in Earth's upper atmosphere, called the stratosphere, and lower atmosphere, called the troposphere. Found mostly in the stratosphere, approximately 10-30 miles (~16 to 50 kilometers) above Earth's surface, stratospheric ozone reduces the amount of harmful ultraviolet (UV) radiation reaching Earth's surface. Commonly referred to as the ozone layer, a decrease in the concentration

of O₃ at this level could lead to more-intense UV radiation exposure at Earth's surface. This radiation exposure could subsequently lead to higher risks of contracting sunburn, more cases of skin cancer, increased incidence of cataracts, and reduced crop yields. Ozone found in the troposphere, near Earth's surface, is a pollutant.

Tiny, airborne solid and liquid particles, called aerosols, also impact Earth's atmosphere. Most aerosols are naturally occurring, including windblown dust from deserts, sea salt, smoke from wildfires, and ash from volcanic eruptions. However, about 10% of aerosols

The Hole Story on Ozone

Human-produced chemicals in our atmosphere—such as chlorofluorocarbons (CFCs), used for many years as refrigerants and in aerosol spray cans—are now known to have played a role in depleting Earth's ozone layer. Scientists first recognized the potential for harmful effects of CFCs on ozone in the early 1970s. By 1985, ozone levels around the globe had continued to drop and scientists discovered something peculiar over Antarctica—a significant thinning of the ozone layer, later coined as the Antarctic ozone hole. In 1987 governments around the world negotiated the Montreal Protocol—an international treaty designed to protect the ozone layer by banning CFCs and similar ozone-depleting chemicals. Since the mid-1990s, global ozone levels have become relatively stable. In fact, because of the Montreal Protocol, model simulations suggest that the ozone layer should recover to its pre-1970s levels by around the middle of the century (2040-2080).



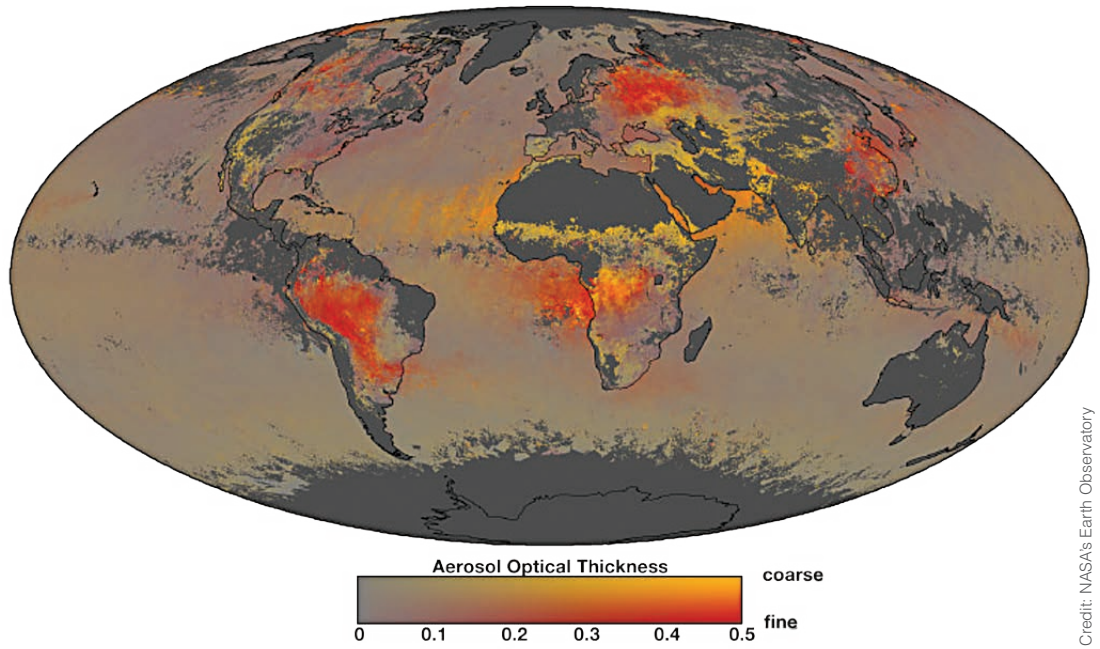
The above images present two cases: the 'world avoided' case, where the rate of CFC emission into the atmosphere is assumed to be that of the period before regulation (i.e., before the Montreal Protocol); and the 'world expected' case, which assumes the current rate of emission, post-regulation. Both cases extrapolate to the year 2065. With continued production of CFCs, ozone levels worldwide would have dropped to dangerously low levels.

are anthropogenic, or human-made, including particles produced by fossil fuel combustion or man-made fires.

Near Earth's surface in the troposphere, aerosol particles are pollutants that can exacerbate poor air quality conditions harmful to our health. Higher in the atmosphere, stratospheric aerosols come primarily from volcanic gases injected into the stratosphere, which are converted to sulphuric acid over a

few months. Volcanic ash can cause air traffic disruptions as well.

Depending upon their size, type, and location, aerosols can either cool Earth's surface, or warm the atmosphere. In general, dark-colored aerosols such as black carbon from fossil fuel combustion absorb radiation, heating Earth's atmosphere, while bright-colored aerosols such as sulfates from volcanic eruptions reflect radiation, acting to cool Earth's atmosphere.



Credit: NASA's Earth Observatory

Human activity, such as deforestation, agricultural practices, and urbanization, transform the land surface and alter the way natural aerosols are distributed. This map shows the global distribution of aerosols and the proportion of those aerosols that are large or small. Intense colors indicate a thick layer of aerosols. Yellow areas are predominantly coarse particles, like dust, and red areas are mainly fine aerosols, like smoke or pollution. Gray indicates areas with no data.

Aerosol particles can also affect the formation and properties of clouds (e.g., by activating early growth of cloud droplets and by changing the albedo, or reflectivity, of clouds). For example, aerosols impact the development of polar stratospheric clouds, which are clouds that are formed in the extremely low temperatures of the polar stratosphere in winter, when nitric acid and small traces of water vapor condense into clouds. These unique clouds play a key role in the formation of the ozone hole. The relationship between clouds and aerosols and the resulting influence on Earth's climate is therefore multifaceted, with impacts on Earth's energy balance, hydrologic cycle, and atmospheric circulation.

Ozone and aerosols are critical atmospheric constituents to study in order to help scientists better understand Earth's climate. Data records of other trace gases also provide additional pieces of the climate puzzle such as: nitrogen dioxide (NO_2), which affects ozone; water vapor, which is related to methane and the speed and circulation of the atmosphere; and nitrogen

trioxide (NO_3) and chlorine dioxide (ClO_2), both of which impact ozone variability.

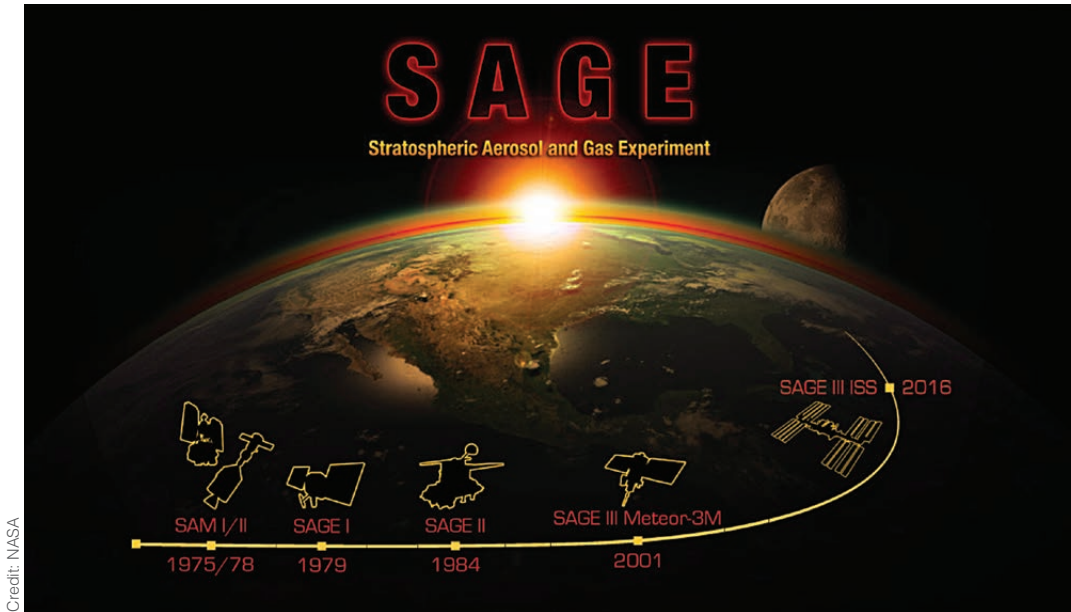
To predict changes in Earth's atmosphere and climate, scientists use an array of satellite, aircraft, and ground-based instruments to measure and monitor ozone, aerosols, water vapor, and other trace gases.



Credit: NASA JSC Earth Observations Lab

Aerosols injected into the stratosphere by the eruption of Mount Pinatubo cooled Earth for several years after the eruption. Pictured above, an astronaut aboard Space Shuttle Atlantis photographed a layer of aerosols lit by the setting sun on Earth's horizon.

Historic Measurements



Credit: NASA

The first SAGE mission was launched in 1979; in 1990 the U.S. Clean Air Act mandated that NASA continue to monitor ozone. As a result, the SAGE family of instruments observed ozone concentrations, along with water vapor, aerosols, and trace gases, from 1979 to 2006. The SAGE III instrument—planned for launch in 2016—will continue this legacy of accurate measurements—this time from the International Space Station (ISS).

NASA's Stratospheric Aerosol and Gas Experiment (SAGE) family of remote-sensing satellite instruments has long measured ozone concentrations, stratospheric aerosols, water vapor, and other trace gases that influence Earth's atmosphere. Before the first SAGE mission in 1979 there were two Stratospheric Aerosol Measurement (SAM) missions—SAM I and SAM II.

SAM I and II

Consisting of only a single-channel sun photometer—used to measure the sun's intensity—and a camera, SAM I flew on an Apollo spacecraft during the Apollo–Soyuz Test Project in July 1975. The mission proved that the concept of making observations of

stratospheric aerosol from space was viable. During the nine-day mission, solar photographs were taken and measurements were recorded by the sun photometer. A balloon-borne aerosol counter and a ground-based laser system later verified those SAM I observations.

Success with SAM I led to the launch of SAM II, which flew on the Nimbus-7 spacecraft from 1978 until 1993, and provided vertical profiles of aerosols over both the Arctic and Antarctic Polar Regions. Designed to develop a stratospheric aerosol database for the polar regions, data from SAM II allowed scientists to study changes in aerosol concentrations as a function of seasonal and short-term meteorological variations, atmospheric chemistry, cloud microphysics, volcanic activity, and other disruptions.

[Below] SAM, a small instrument operated by astronaut Deke Slayton during the historic Apollo–Soyuz mission, was the humble beginning of NASA's orbiting ozone and aerosol study.

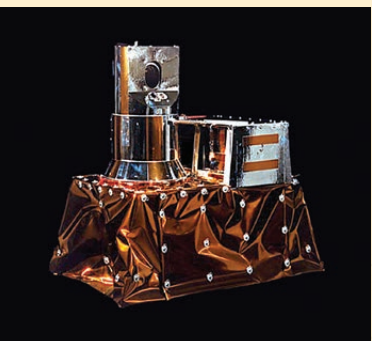


Credit: NASA



Credit: NASA

SAM II flew aboard the Nimbus-7 spacecraft and provided vertical profiles of aerosol extinction in both the Arctic and Antarctic polar regions. The SAM II data coverage began in October 1978 and extended through December 1993.



Credit: NASA

While SAGE I was active, it provided the scientific community with a global depiction of the distribution of aerosols, ozone, and nitrogen dioxide. Using these models of distribution, SAGE I contributed unique and crucial input to the understanding of global trends in stratospheric ozone.



Credit: NASA

SAGE I, which flew on the AEM-B satellite, contributed unique and crucial input to the understanding of global trends in stratospheric ozone.

SAM II was a spectrometer that used solar occultation as its measurement technique: The instrument pointed toward the sun as its light source and scanned the limb, or thin profile, of Earth's atmosphere. Together, the SAM II experiments demonstrated that solar-occultation measurements by photometer could be used to determine the vertical distribution of stratospheric aerosols. With this now-proven method, scientists and engineers began developing the first SAGE instrument.

SAGE I

The first SAGE mission (SAGE I) launched February 18, 1979, on the Applications Explorer Mission-B (AEM-B) satellite; it collected valuable data for nearly three years until the satellite's power system failed. Data from SAGE I were used to develop a database of global stratospheric concentrations of ozone (O₃), aerosols, and nitrogen dioxide (NO₂). These data are still used to study trends, atmospheric dynamics and transport, and potential climatic effects of these species.

SAGE II

SAGE II launched on Earth Radiation Budget Satellite (ERBS) in October 1984; it observed stratospheric ozone from 1984 until 2005. This long-term dataset has proven invaluable in determining trends in ozone distribution and amount. Data from SAGE II, in conjunction with data from SAM II and SAGE I, are used to estimate long-term constituent trends and identify responses to episodic events such as volcanic eruptions. Major results from SAGE II include the stratospheric impact of the 1991 Mount Pinatubo eruption, identification of a negative global trend in stratospheric ozone levels during the 1980s and the subsequent onset of ozone recovery beginning in the late 1990s, and quantitative verification of positive water-vapor feedback in current climate models. Data from SAGE II were integral in confirming human-

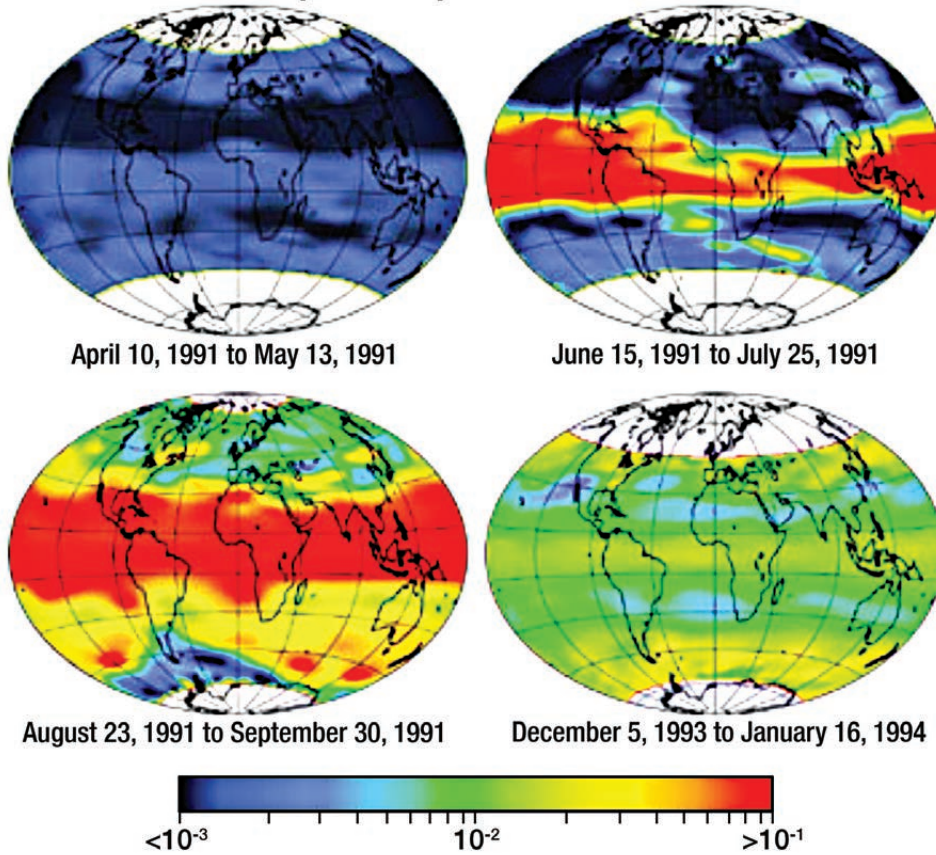
driven changes to ozone concentrations in the stratosphere, and thus influenced the decisions to negotiate the Montreal Protocol in 1987. Later, observations from SAGE II showed that ozone in the stratosphere stopped decreasing in response to the actions agreed to in the treaty.

SAGE III Meteor-3M

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 launched on the Russian Meteor-3M spacecraft on December 10, 2001; one was built specifically to fly on the International Space Station (ISS); and the third is a spare.

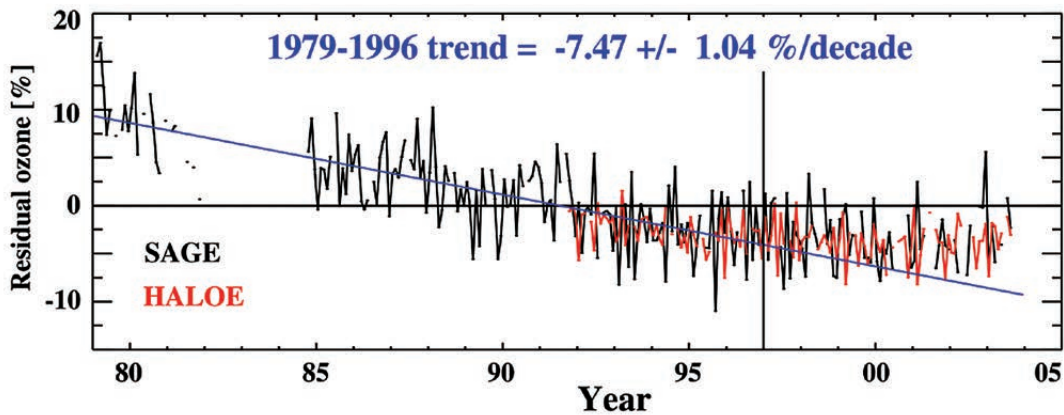
Launched in 2001, SAGE III Meteor-3M was a crucial element in NASA's Earth Observing System (EOS). Data from the mission enhanced scientists' understanding of natural and human-derived atmospheric processes. Observations from SAGE III Meteor-3M—that began with data from SAGE I and II—provided the basis for identifying five of the nine critical constituents called out in the U.S. National Plan for Stratospheric Monitoring, including profiles of aerosols, O₃, NO₂, water vapor, and air density. The multi-decadal ozone and aerosol datasets from SAGE instruments have undergone intense scrutiny, becoming the international standard for accuracy and stability as a result. Aerosol data from SAGE are recognized as necessary for understanding ozone trends and predicting climate change. The SAGE ozone product is accurate to better than 1%, and has a vertical resolution of 1 kilometer (~3280 feet) or better. The SAGE III Meteor-3M mission ended on March 6, 2006, when the pressurized Meteor-3M spacecraft lost pressure and electrical subsystems failed; this left a gap in valuable SAGE data.

SAGE II 1020 nm Optical Depth



Credit: NASA

SAGE II observed the long-term global effects of the June 15, 1991 eruption of the Mt. Pinatubo volcano in the Philippines. The eruption produced large quantities of aerosols in the upper atmosphere. The top-left graphic from SAGE II data shows a relatively aerosol-free atmosphere before the eruption. The top-right graphic reveals that aerosols in the tropics increased by almost a factor of 100 immediately following the eruption. The bottom-left graphic shows that aerosols had spread into Earth's mid-latitudes three months later. The bottom-right graphic illustrates how volcanic aerosols slowly decreased in the atmosphere over several years. The effects of Mt. Pinatubo lingered for up to 10 years following the eruption. The global distribution of aerosols as shown in these images is one of many important stratospheric processes that SAGE III will monitor.



Credit: Originally appeared in the 2006 WMO/UNEP Assessment, *Scientific Assessment of Ozone Depletion*



Credit: NASA

SAGE II is pictured above as it is being prepared for flight on ERBS. SAGE II lasted for more than two decades, providing more than 21 years of important data.



Credit: NASA

This photo shows the first copy of SAGE III being prepared for launch on the Russian spacecraft Meteor-3M.

[Left] This graph combines data from the first three SAGE instruments, with data from the Halogen Occultation Experiment (HALOE), which flew on the Upper Atmospheric Research Satellite (UARS) and launched from the Space Shuttle Discovery in 1991 and operated until 2005. It depicts the decline of ozone with a trend of $-7.47\% (\pm 1.04\%)$ per decade between 1979 and 1996. Ozone concentrations stabilized around 1997, ten years after the Montreal Protocol, and have since started to show signs of recovery.

SAGE III on ISS

Mission Overview



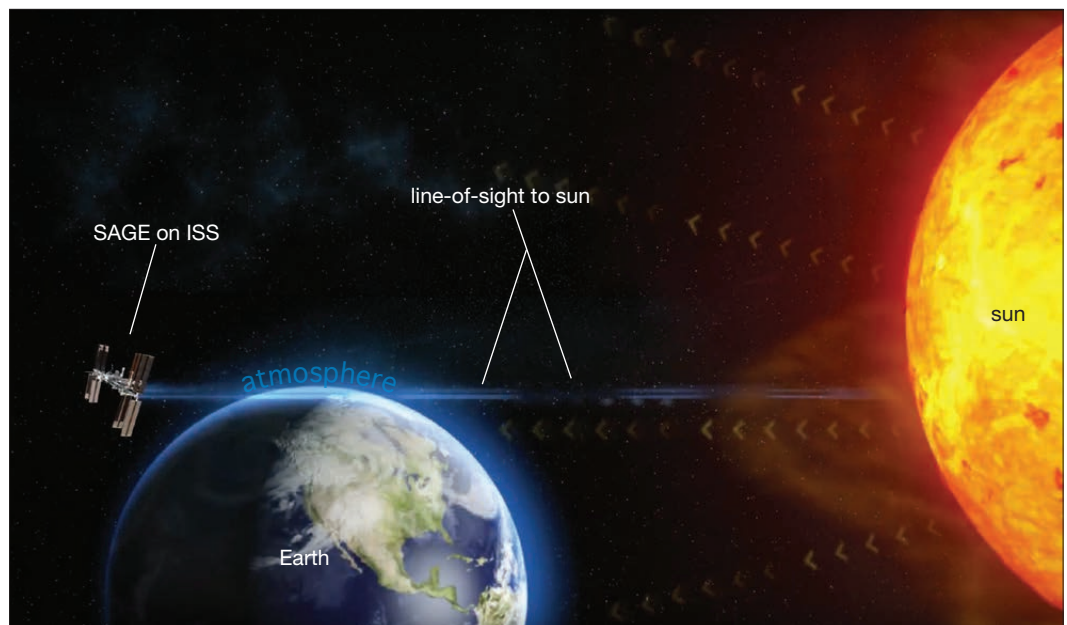
Credit: NASA

SAGE III on ISS is led by NASA's Langley Research Center with help from partners around the world including: NASA's Johnson Space Center, NASA's Marshall Space Flight Center, NASA's Goddard Space Flight Center, NASA's Kennedy Space Center, White Sands Facility, Ball Aerospace and Technology Corporation, Thales Alenia Space-Italy, and the European Space Agency.

The SAGE III instrument that was meant to fly on the space station went into storage until the station construction was complete. Work to prepare SAGE III for installation on the International Space Station began in 2011. Designed to operate for no fewer than three years, SAGE III will measure the composition of the stratosphere and troposphere from the space station. Onboard the station, SAGE III will orbit between 385 kilometers (~239 miles) and 415 kilometers (~257 miles) above Earth's surface at a 51.6-degree inclination with nearly a three-day repeat cycle.

Similar to its predecessors, SAGE III on ISS will provide vertical profiles of ozone,

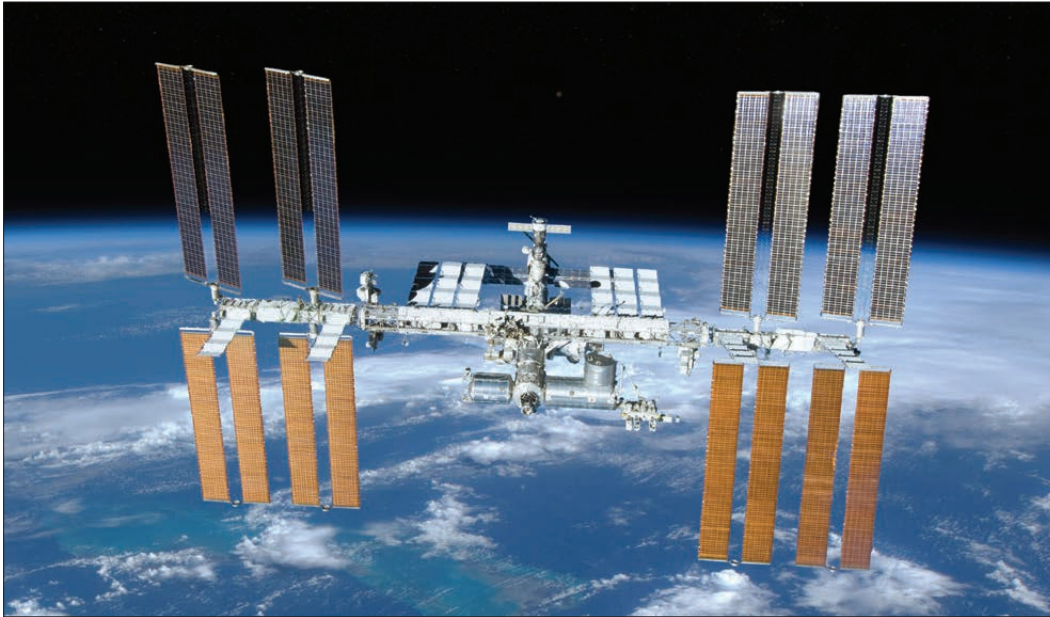
aerosols, nitrogen dioxide, and water vapor in Earth's atmosphere by taking occultation measurements when the sun or moon is rising or setting, about 15-16 times each day. In addition to light from the sun, the moon will also be used as a light source to detect ozone. The station's unique orbit path will allow SAGE III to observe ozone during all seasons and over a large portion of the globe. SAGE III on ISS will also measure ozone concentrations deeper into the atmosphere than ever before, reaching into the troposphere. Another benefit of flying onboard the ISS is that scientists and engineers will also have near-continuous communications with the payload.



Credit: NASA

By using the sun and the moon as light sources, SAGE can detect ozone, aerosols, and other trace gases in the atmosphere.

Credit: NASA



SAGE III on ISS is among a small number of continuous Earth-observing 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.

Measurements from SAGE III on ISS will be used to observe long-term trends of stratospheric ozone concentrations and determine whether the ozone layer is recovering as expected, as they are complementary to data from mapping instruments such as the Ozone Mapping and Profiler Suite (OMPS). In addition, data from SAGE III on ISS will 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

- Assess the state of recovery in the distribution of ozone.
- Re-establish the aerosol measurements needed by both Climate and Ozone models.
- Gain further insight into key processes contributing to ozone and aerosol variability.

Credit: NASA



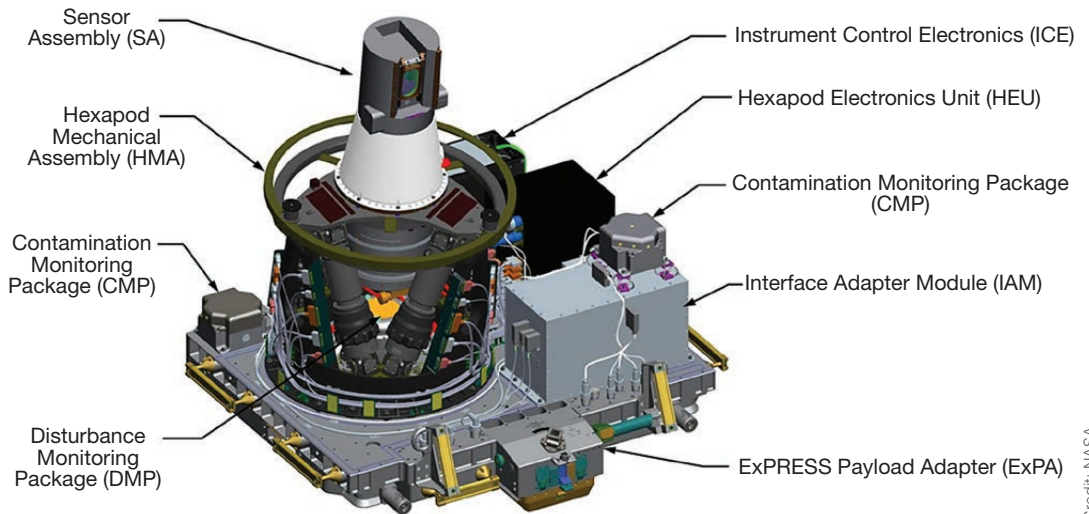
[Above] and [Below] The Instrument Payload was integrated over several months in a clean room at NASA's Langley Research Center.

Credit: NASA





Instrument Overview



Credit: NASA

This graphic illustrates the components that make up the SAGE III Instrument Payload.

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 kilograms (~1162 pounds) and a data rate of 2150 megabytes per day.

Instrument Payload

The SAGE III Instrument Payload is home to the Sensor Assembly—a grating spectrometer that measures ultraviolet and visible light and has a two-axis pointing system. 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, bromine monoxide, and iodine monoxide, as well as measure larger aerosols. The SAGE III Sensor Assembly consists of three subsystems: the scan head, imaging

optics, and the spectrometer detector. 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 nanometers 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 O₃, aerosols, water vapor, and NO₂. Additional aerosol information is provided by a discrete photodiode—a semiconductor device that converts light into current—at 1550 nanometers.

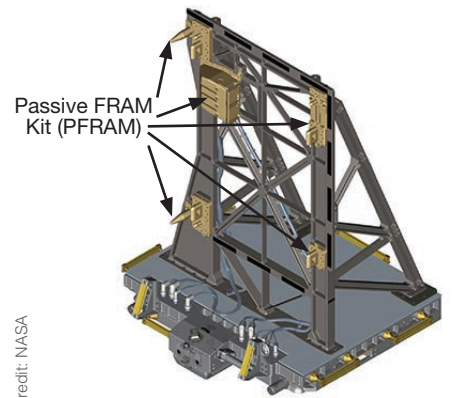
Several busy operations take place on the ISS, such as visiting vehicle traffic and thruster operations. To avoid contamination from such operations, the Instrument Payload includes two Contamination Monitoring Packages, designed and built at NASA's Langley Research Center, to monitor the environment surrounding the instrument. If the space station environment contains elevated contamination levels, a clear contamination door will close to protect the instrument's sensors while allowing measurements to continue to be taken.

The payload also includes an Interface Adapter Module, a Disturbance Monitoring Package, the Hexapod Pointing System (Hexapod Electronics Unit and Hexapod Mechanical Assembly), and the Instrument Control Electronics box. The Interface Adapter Module, also designed and built in-house at NASA's Langley Research Center, 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 of the small motions from the space station. 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 acts as the "legs" of the payload, which keep the instrument level in orbit. It was developed by the European Space Agency and designed and built by Thales Alenia Space-Italy.

Nadir Viewing Platform

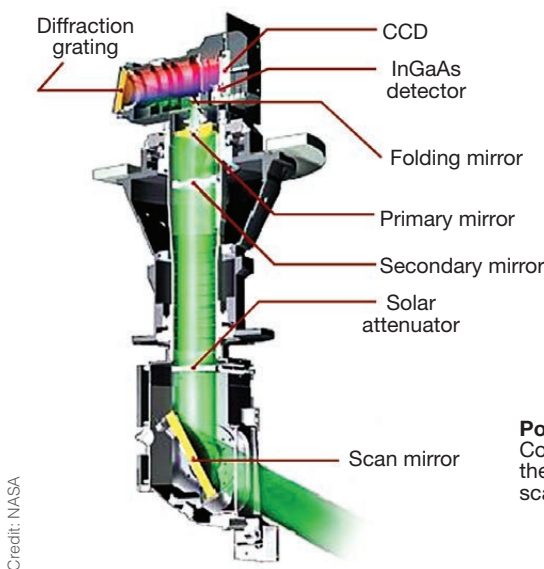
To orient SAGE III facing nadir, or toward Earth, a special L-shaped mounting bracket called the Nadir Viewing Platform was designed, built, and tested at NASA's Langley Research Center. The Nadir Viewing Platform will attach to ExPRESS Logistics Carrier-4 (ELC-4) onboard the station, perpendicular to the plane of the ELC, providing the nadir-orientation needed by the Instrument Payload. It replicates



Credit: NASA

Illustrated here, SAGE III will attach to the Passive FRAM Kit on the flat side of the Nadir Viewing Platform.

the standard ELC exposed payload attachment. The ELC-4 will provide electrical power, as well as 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, i.e., turned a traditional ELC site into a nadir-oriented site.



Credit: NASA

The SAGE III Sensor Assembly is pictured here.

Spectrometer Subsystem

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

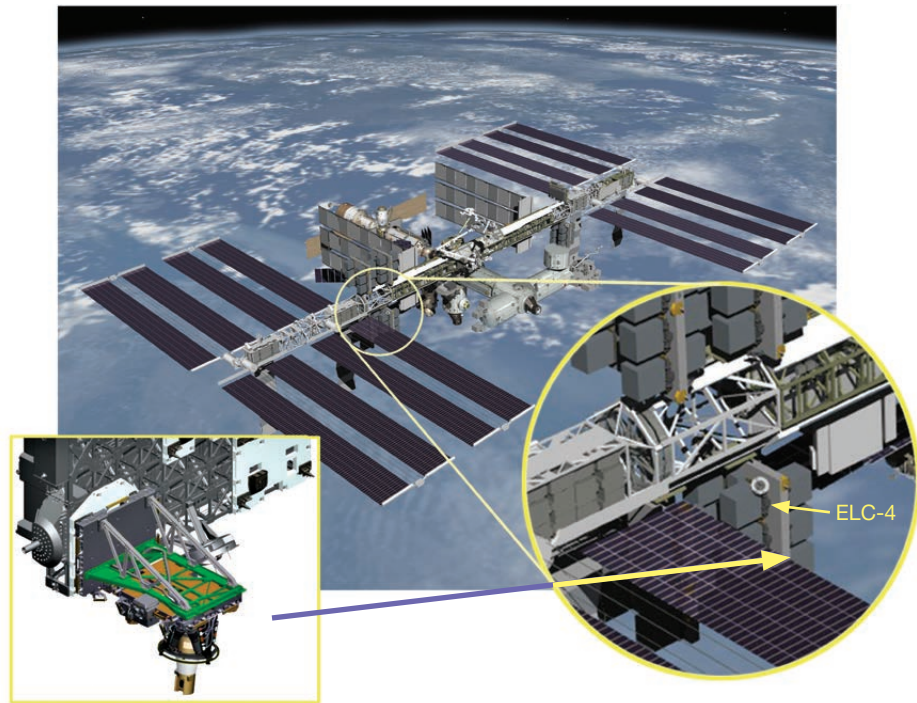
Imaging Subsystem

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.

Launch and Installation



Credit: NASA

This illustration shows the Instrument Payload attached to the Nadir Viewing Platform on the ECL-4.

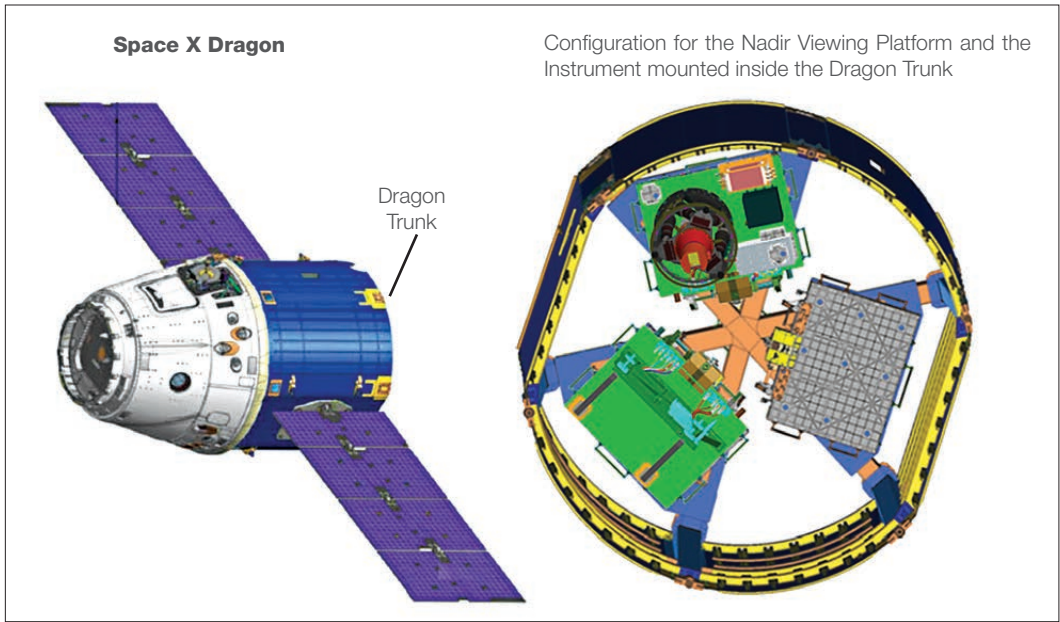
For their ride to the space station, the SAGE III Instrument Payload and Nadir Viewing Platform will be installed in the unpressurized section of the SpaceX Dragon “Trunk” as separate payloads. Prior to launch, the Dragon will provide power to the Instrument Payload to power its heaters, which are necessary to maintain the temperature of the SAGE Instrument and its other sensitive electronics at safe levels. The Nadir Viewing Platform does not require heater power during transfer. The Dragon, with both SAGE III payloads installed, will launch atop the SpaceX Falcon 9 rocket. About 10 minutes after liftoff, the Dragon will separate from the launch vehicle upper

stage and begin a two day trip to reach the International Space Station.

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 that attaches to Canadarm2. The process to install the SAGE III payloads to their planned location on ECL-4 begins when Dextre removes the Instrument Payload from the Dragon Trunk and installs the Instrument Payload to Dextre’s temporary platform. After extraction, the Instrument Payload heaters will not receive power until the payload is installed on the temporary platform. The

SAGE III on ISS is scheduled to launch onboard the SpaceX Cargo Resupply-10, or SpaceX-10, in 2016, from NASA’s Kennedy Space Center. Image credit: NASA’s Kennedy Space Center

Credit: SpaceX



Prior to launch, the SAGE III Instrument and Nadir Viewing Platform will be strategically mounted inside the Dragon Trunk on SpaceX.

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.

The Nadir Viewing Platform will be installed to ELC-4 by Dextre first; then the Instrument Payload will be removed from Dextre's

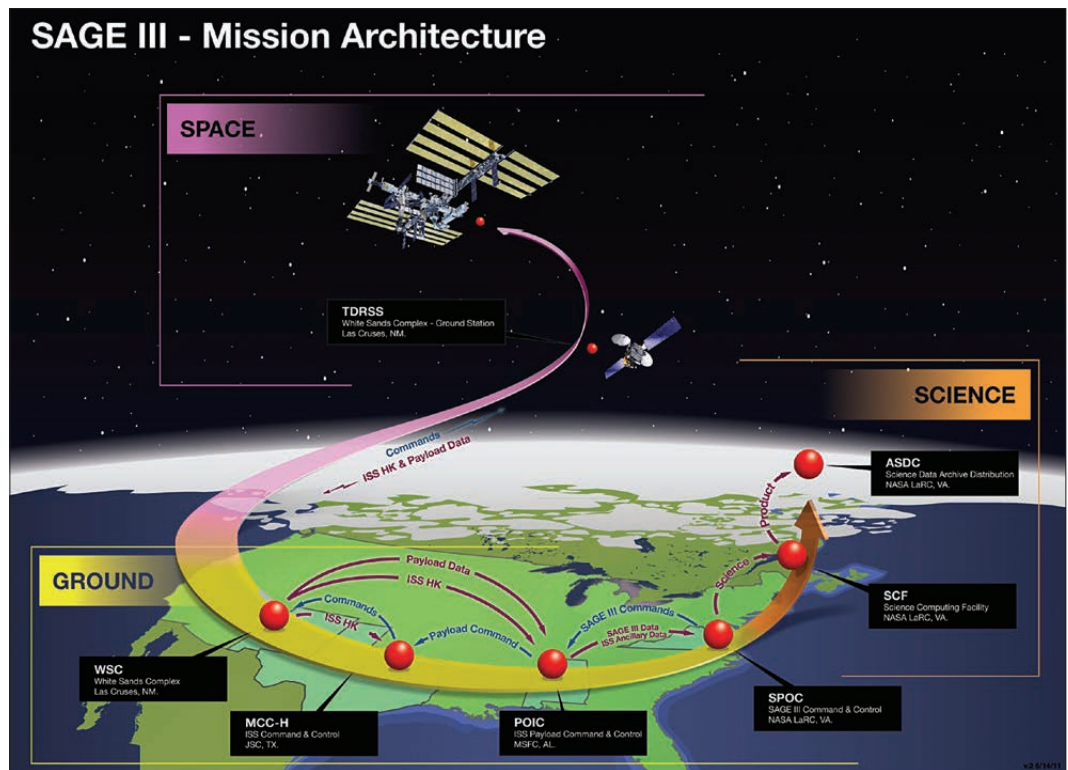
temporary platform and installed to the Nadir Viewing Platform. During transfer from the temporary platform to the Nadir Viewing Platform, the Instrument Payload heaters will not have access to power, so the duration of the transfer will be closely controlled and monitored. After the Instrument Payload is installed, ISS controllers on the ground will command the ELC-4 to enable heater power to the assembled SAGE III payload. After approximately 3-4 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.

Credit: NASA



Once the Dragon trunk docks with the space station, the robotic arm will remove the Instrument Payload, followed by the Nadir Viewing Platform and place them on a temporary platform while they move to ELC-4. Once at the correct location, the Nadir Viewing Platform will be attached to ELC-4, followed by the Instrument Payload.

Ground System and Data



This graphic shows how data travel from SAGE III on ISS to the SCF and get released through the ASDC.

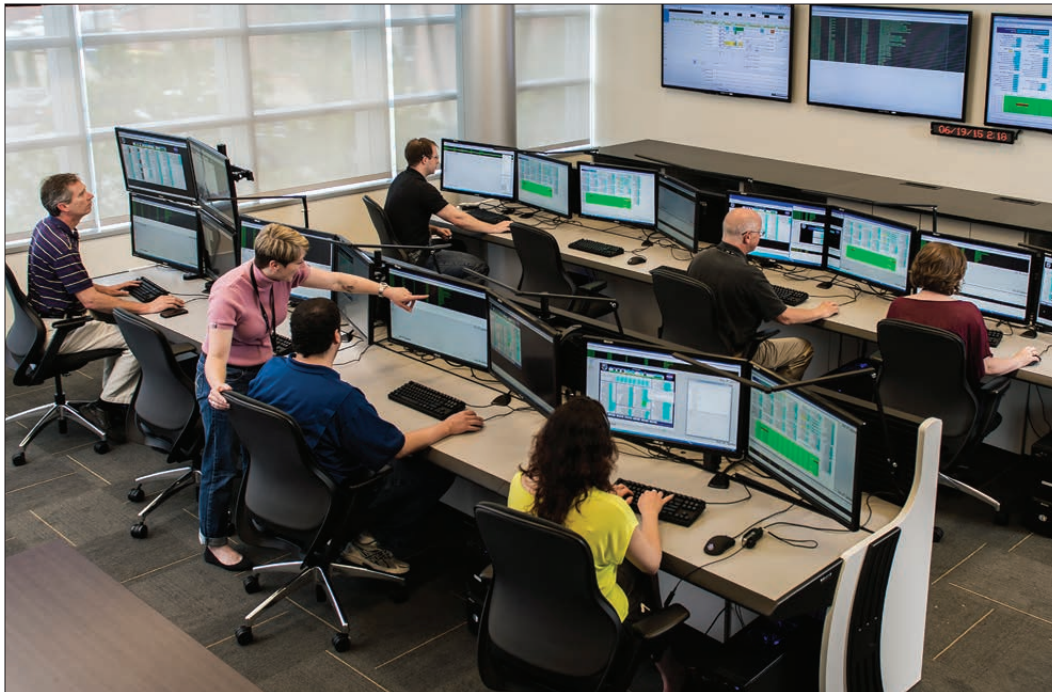
The Flight Mission Support Center (FMSC) at NASA's Langley Research Center, together with the ISS Command and Control group at the Mission Control Center at NASA's Johnson Space Center and the Payload Operations Integration Center (POIC) at NASA's Marshall Space Flight Center, will command and operate the instrument, as well as manage and distribute data. This includes oversight of the installation and instrument checkout, managing routine planning and command loads, data analysis, and resolution of any issues that may arise.

To communicate with SAGE III on ISS, the SAGE III Payload Operations Center (SPOC)

at the FMSC will send software commands to NASA's Tracking and Data Relay Satellite System (TDRSS). This system of satellites is used by NASA to communicate to and from other satellite platforms—in this case, SAGE III on ISS. Once data are transmitted and collected, they will be processed at the Science Computing Facility (SCF) and released to the public directly through the Atmospheric Science Data Center (ASDC).

Measurements from SAGE III on ISS will be validated just as they have been during previous SAGE missions: Data from a number of independent instruments using a variety

Credit: NASA



Credit: NASA



Pictured above, and at left, the SAGE Mission Operations team runs rehearsals leading up to the launch of SAGE III on ISS.

Once on orbit, SAGE III on ISS will be controlled from the FMSC—a brand new mission operations facility at NASA's Langley Research Center.

of techniques will be used to assess between-sensor biases and precision. Validation plans for SAGE III on ISS include working with ongoing ground-based operations, including the Network for the Detection of Atmospheric Composition Change, spaceborne sensors,

and balloon-based ozone measurements, including those from the Southern Hemisphere Additional Ozonesondes (SHADOZ) network. Data will be freely available for download at eosweb.larc.nasa.gov.

The table below lists the expected data products from SAGE III on ISS.

Product	Description	Measurement Type	Vertical Range (Km)	Vertical Resolution (Km)	Precision
1	Level 1B Transmissions	Solar	0* – 100	0.75	0.1%**
2	Aerosol Extinction Coefficients	Solar	0* – 40	0.75	5%
3	Aerosol Optical Depth	Solar	N/A	N/A	5%
4	Ozone (O ₃) Concentration	Solar	0* – 50	0.75	5%
5	Water Vapor (H ₂ O) Concentration	Solar	5* – 45	0.75	10%
6	Nitrogen Dioxide (NO ₂) Concentration	Solar	TP+2 – 45	0.75	10%
7	Ozone (O ₃) Concentration	Lunar	15* – 45	1.5	5%

Notes: *or cloud-top altitude **defined at 600 nm TP=altitude of the tropopause

A Continued Data Record

Benefits to Society



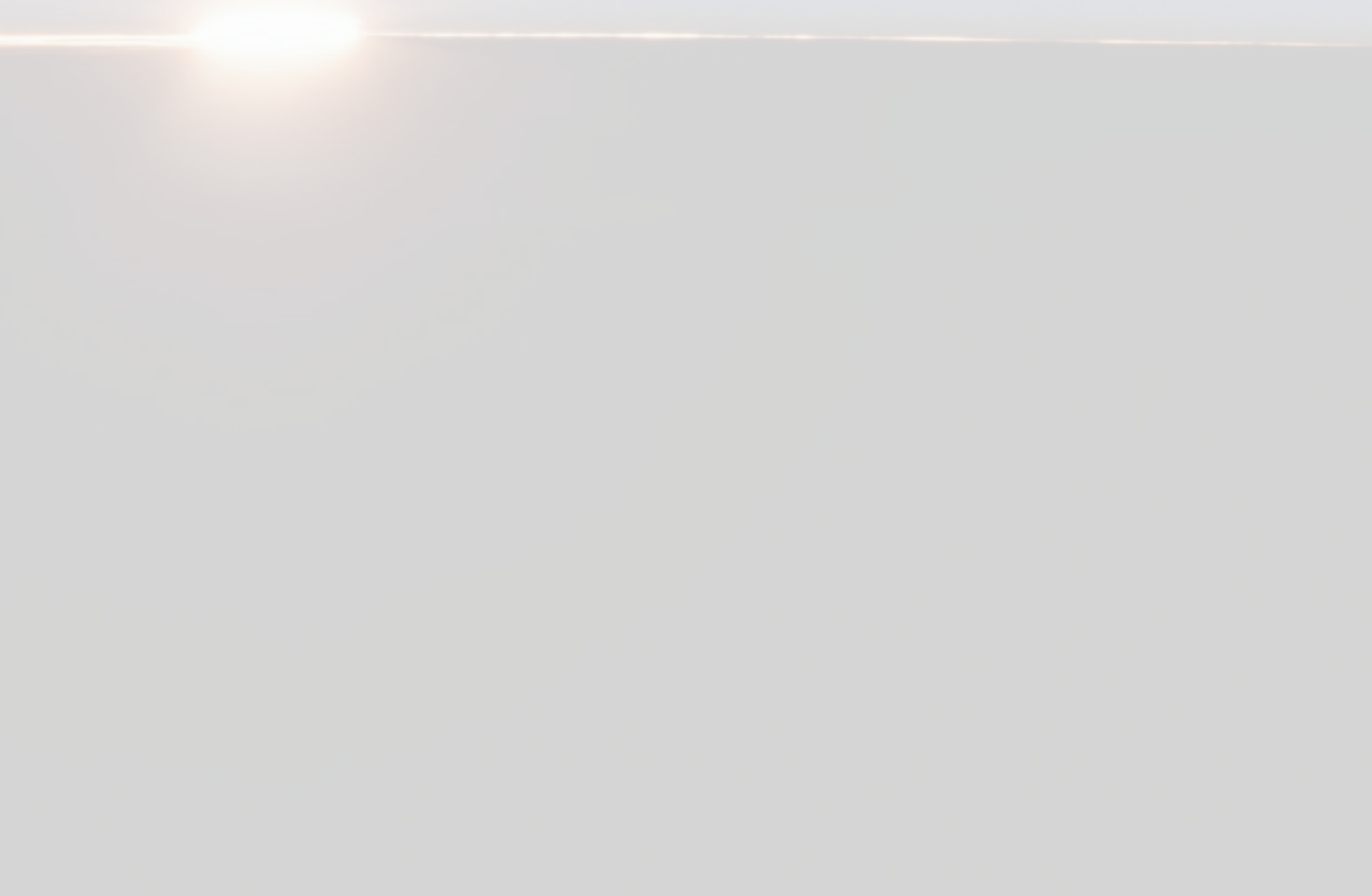
Credit: NASA

Data from SAGE III on ISS, coupled with model results, will allow scientists to monitor the health of the ozone layer and track the recovery of stratospheric ozone since ratification of the Montreal Protocol. By the 2020s—in most areas—expectations are that ozone will recover to about half of the amount lost from the pre-1980 levels. SAGE III will be valuable in assessing the performance of the Ozone Mapping and Profiler Suite flying on the Suomi National Polar-orbiting Partnership satellite. Data from SAGE III on ISS will also help to reinstitute aerosol measurements crucial for more-accurate long-term climate and

ozone models. In addition, if there are any new threats to the ozone layer, SAGE III data will help the scientific community identify the cause and assess the threat.

The remaining SAGE III instrument is being kept safe at NASA's Langley Research Center. After SAGE III on ISS, a new generation of instruments will be needed to continue the long-term record of stratospheric ozone and aerosol concentrations.

Notes





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