

Acronym: CEO

Title: Crew Earth Observations

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Sponsoring Agency: National Aeronautics and Space Administration (NASA)

Increment(s) Assigned: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

Brief Research Summary (PAO): Crew Earth Observations (CEO) takes advantage of the crew in space to observe and photograph natural and human-made changes on Earth. The photographs record the Earth's surface changes over time, along with dynamic events such as storms, floods, fires and volcanic eruptions. These images provide researchers on Earth with key data to better understand the planet.

Research Summary:

- Astronaut acquired imagery documents human impacts on the Earth, such as city growth, agricultural expansion, and reservoir construction and other natural phenomenon like volcanoes and hurricanes. Today, handheld photography of the world from human spaceflight missions, spanning more than 40 years, provides valuable insight into Earth processes and the effects of human activities on the planet.
- Through their photography of the Earth, International Space Station crewmembers will build on the time series of imagery started with the first human spaceflights, ensuring that this continuous record of Earth remains unbroken. Photographs taken from ISS accounts for almost 1/2 of all Earth photographs from human space flight.
- During Increment 15 through Increment 18, a new activity is being conducted in collaboration with International Polar Year activities. Crew Earth Observations - International Polar Year (CEO-IPY) is an international collaboration of scientists for the observation and exploration of Earth's Polar Regions from March 2007 to March 2009. The ISS crewmembers will photograph polar phenomena including auroras and mesospheric clouds in response to requests made from the scientists on the ground.

Detailed Research Description: Crewmembers use handheld cameras and a variety of lenses (including an 800-mm lens) to take Earth observation photographs. The photographs are cataloged for use as educational and research tools, as well as historical records of global environmental change, special geological and weather events, and the growth and change of human-made features, such as cities. CEO is conducted from any nadir-viewing window on the ISS, including the optical-quality window in the U.S. Laboratory Module, *Destiny*.

The window in *Destiny* can view 39.5 degrees forward along the axis of the Station, 32.2 degrees aft, and a total of 79.1 degrees from port to starboard. The window is constructed of four panes. The outermost pane, made of fused silica, is designed to withstand orbital debris and can be changed out by extravehicular activity (EVA) if it becomes damaged. The two center panes, also made of fused silica, are the primary and redundant pressure panes. The interior pane, made of glass laminate, is called the scratch or "kick" pane. This pane protects the primary pressure pane from scratches and damage caused by contact with the crew, and has an ultraviolet/infrared coating to protect the crew and improve picture quality. The windows in the Russian Zvezda Module are also available for hand-held photography.

Project Type: Payload

Images and Captions:



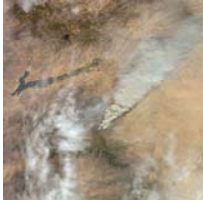
NASA Image: ISS013E67242 - An oblique high magnification view of Christchurch New Zealand taken in August 2006. This represents the 250,000th image of Earth taken from ISS. Now about 35% of the images of Earth taken by astronauts come from ISS, with the first images from Apollo predating Earth observing satellites.



NASA Image: ISS0013E6947 - The terminus of the Viedma Glacier, is shown in this photograph taken from ISS by the Expedition 13 crew. The image was the image of the week on NASA's Earth Observatory, and published with an explanation of the various data sets scientists are using to monitor the effects of global climate changes on glaciers worldwide.



NASA Image: ISS017E10303 - One of the largest and most destructive fires raging across California over the July 4th weekend was the Basin Fire, threatening Big Sur, and covering the coast in a thick blanket of smoke. Astronaut Greg Chamitoff, observing the fires from 344 km above the Earth (215 miles) aboard the International Space Station, was able to capture the regional view of the smoke pall. At the time this image was taken, more than 300 fires were burning in California alone. This Basin Fire was triggered by a thunderstorm, has burned 77,000 acres, and is still only partially contained.



NASA Image: ISS017E10310 - The Piute fire, burning south of Lake Isabella in the Sequoia National Forest in the southern Sierra Nevada Mountains, is one of the more than 300 wildfires burning across the state of California. The fire started June 28 just north of Twin Oaks, California, and has burned nearly 14,000 acres so far. Current estimates by fire officials suggest the fire may not be brought under control for another 2 weeks.



NASA Image: ISS009E09952 - Solitons Mosaic, Strait of Gibraltar, taken during Increment 9. These subsurface internal waves occur at depths of about 100 m, but appear in the sunglint as giant swells flowing eastward into the Mediterranean Sea. This is one of the best pictures to date capturing the full phenomenon. The Navy is funding an "Atlas of Internal Waves" that is drawing heavily on astronaut photography of the phenomenon to identify patterns of waves around the world. The ability to predict internal waves is growing, and ISS astronauts are also working to get photographs of areas where they are predicted, but have not yet been documented to make sure the atlas is complete. Human photographers are uniquely able to use sunglint to get the most informative photographs by choosing the second at which they take the image to get the optimum sunglint.



NASA Image: ISS006E18372 - This picture is a shot taken during Increment 6 of an Aurora with the Manicouagan impact crater on the surface. The Manicouagan Crater in northern Canada is one of the oldest impact craters known. Formed during a surely tremendous impact about 200 million years ago, the present day terrain supports a 70-kilometer diameter hydroelectric reservoir in the telltale form of an annular lake.



NASA Image: ISS017E005600 - The Expedition 17 crew captured this image of the Tropical Cyclone Nargis in the Bay of Bengal prior to landfall in Burma on May 2, 2008.



NASA Image: ISS017E006216 - This photograph of the May 2, 2008 eruption of Chaitén Volcano in southern Chile show the volcanic ash plume. Scientific research indicates that the last eruption of this volcano occurred around 7400 B.C.



NASA Image: ISS008E8951 - Thinning Upper Atmosphere: From a vantage point about 360 km (225 miles) over the Earth, Space Station crewmembers photographed the crescent moon through the upper layers of Earth's atmosphere. At the bottom of the image, a closed deck of clouds is probably at about 6 km (3 miles). The shades of blue grading to black are caused by the scatter of light as it strikes gas molecules of the very low density upper atmosphere. Models predict that emissions of carbon dioxide are causing the upper atmosphere to cool and contract, and therefore reduce the density of gases in the layer spanning from 90 to 649 km (60 to 400 miles) above the surface-known as the thermosphere. According to a study by the Naval Research Laboratory, the density of the thermosphere has decreased about 10 percent over the last 35 years. These findings are important both for space science and for Earth science. Spacecraft in orbit, such as the International Space Station, experience less drag and need fewer boosts to maintain their orbit. At the same time, space debris also remains in orbit longer, which increases hazards to spacecraft. Most importantly, the study validates models of the "greenhouse effect" of increased carbon dioxide release on the dynamics of the atmosphere.



NASA Image: ISS012E13692 - A 25-kilometer long smoke plume from a fire in the Upper Ouachita National Wildlife Refuge in northeastern Louisiana. The fire started at approximately 1:00 p.m. on January 2, 2006, and this image was acquired approximately three and a half hours later as the International Space Station passed over the Texas-Louisiana border, to the southwest of the scene. The long extent of the plume reflects the strong westerly winds that drove the fire eastwards and damaged an estimated 200-300 acres of the wildlife refuge.



NASA Image: ISS013E82951 - Astronaut Jeff Williams, Expedition 13 NASA Science Officer and Flight Engineer, smiles for the camera while surrounded by assorted camera gear onboard of the International Space Station. Williams took many images of the Earth throughout his mission.



NASA Image: ISS013E24184 - Expedition 13 ISS Science Officer and Flight Engineer Jeff Williams captured the eruption of the Cleveland Volcano, Aleutian Islands, Alaska on May 23, 2006. This eruption was first reported to the Alaska Volcano Observatory by astronaut Williams. This image, acquired shortly after the beginning of the eruption, captures the ash plume moving west-southwest from the summit vent. The eruption was short-lived; the plume had completely detached from the volcano summit two hours later. Ash plumes from Cleveland Volcano have reached heights of 12 kilometers and can present a hazard to trans-Atlantic jet flights. The fog bank visible at image top center is a common feature of the Aleutian volcanoes. Cleveland Volcano, situated on the western half of Chuginadak Island, is one of the most active of the volcanoes in the Aleutian Island chain extending west-southwest from the Alaska mainland.

Operations Location: ISS Inflight

Brief Research Operations:

- Crewmembers are responsible for photographing various sites, which are up-linked daily.
- ISS allows essentially continuous research with trained observers, monitoring seasonal changes as well as ephemeral events such as volcanic eruptions and plankton blooms. Of particular interest are such things as urban land use, agriculture and deforestation.

Operational Requirements: Crew members spend approximately 10 minutes a day, five days a week, recording their Earth observations. Some crew members have found Earth observations very enjoyable, and have dedicated extra time to photographing the beautiful and extraordinary views from the windows of ISS.

Operational Protocols: A list of regions to be photographed is uplinked to the ISS daily, except during docked operations; crew members also select regions to photograph. Currently, all CEO images are captured with an electronic still camera and downlinked daily. All imagery is cataloged and stored by the Earth Sciences and Image Analysis Laboratory at Johnson Space Center and are accessible via the [Gateway to Astronaut Photography of Earth](#).

Review Cycle Status: PI Reviewed

Category: Observing the Earth and Educational Activities

Sub-Category: Observing the Earth

Space Applications: The imagery captured by astronauts during long duration missions provide insight for planetary surveys within our solar system and anomalies that occur in low Earth orbit.

Earth Applications: Earth observations have been an activity of choice for astronauts since the beginning of the human space program. Scientists focus on current dramatic changes in dynamic regions and request the crew to photograph these sites from their orbiting outpost. These interesting and often beautiful photographs provide valuable information that allow a better understanding and awareness of our planet from many perspectives; which include Earth's short and long-term events (hurricanes, floods, fires, volcanic eruptions, coral reefs and droughts), the impacts of human intervention (agricultural

development, biomass burnings, urban and suburban sprawl, and pollution), and features that are analogous to structures on other planets (craters, river deltas, and dried rivers).

Through their photography of the Earth, International Space Station astronauts will build on imagery started in 1961, ensuring that this continuous record of Earth remains consistent. These images are available on the Internet, which allows the general public to study and view the living Earth from the unique perspective of space. These images are quite popular as evidenced by the fifteen million viewers who visit this NASA Earth Observation website monthly.

Manifest Status: Continuing

Supporting Organization: Space Operations Mission Directorate (SOMD)

Previous Missions: Crew Earth Observations have been ongoing since 1961 and more than 300,000 images have been taken during the first seven years of ISS operations.

Results: ISS provides a unique opportunity to capture a variety of sites on Earth by providing repeated overflight passes of the Earth. Through CEO, ISS crewmembers share their view of the Earth with the public and take pictures of some of the most dramatic examples of change on the Earth's surface. These sites have included major deltas in south and east Asia, coral reefs, cities, smog over industrial regions, areas that typically experience floods or droughts triggered by El Nino cycles, alpine glaciers, tectonic structures, and features on Earth, such as impact craters, that are analogs to structures on other planets. Some of the unique images of Earth taken by astronauts from station from 2000 - 2003 provides information concerning the Earth not available from any other source, and is available in an online collection of ISS Greatest Hits. In 2004 and 2005, station astronauts took key photographs of the four Florida hurricanes, the December 2004 tsunami affects, Hurricanes Katrina, Wilma and Rita, and the aftermath of Hurricane Katrina.

From Expedition 1 through December 2006, ISS crewmembers took more than 270,000 images of Earth, almost one half of the total number of images taken from orbit by astronauts since the first Gemini missions. Scientists and the public around the world have access to CEO images captured by astronauts on station through the Gateway to Astronaut Photography of Earth Web site (<http://eol.jsc.nasa.gov>). Approximately 700,000 to 800,000 NASA digital photographs of Earth are downloaded by the public each month. The Web site also features an "Image of the Week" and searchable access to all the photographs. Scientific analyses using CEO data have been published in scientific journals in a wide variety of disciplines. A few highlights of these publications are summarized here.

Spatial resolution is a measure of the smallest object that can be resolved by the sensor, or the size of the area on the ground represented by each pixel determined by geometric properties of the altitude of the spacecraft, lens magnification, size of the original image, and look angle. To achieve maximum potential spatial resolution, a camera system must capture information at sufficient speed to eliminate the effects of relative ground motion. Using handheld motion compensation, station crewmembers have achieved a spatial resolution of less than 6 meters in photographs of Earth from ISS. The ISS provides great potential as a remote-sensing platform capable of providing high-resolution imagery of the Earth's surface (Robinson and Evans 2002).

CEO images captured from ISS of Pacific Ocean atolls (islands consisting of a circular coral reef surrounding a lagoon) allowed for an assessment of spatial resolution on estimates of landscape parameters of the atolls. Data gathered indicated that landscape parameter estimates were fairly accurate regardless of spatial resolution changes from 5 to 30 meters. This study of ISS imagery showed that spatial resolution, as well as spectral resolution, is of equal importance when studying these formations (Andrefouet et al. 2003). The most detailed images of Fangatau atoll, taken from ISS, were used to measure the biomass of the giant clam fishery at Fangatau Atoll with accuracy similar to that obtained from aerial photography (Andrefouet et al. 2005). Astronaut photographs of reefs in the Indian Ocean have been used as base maps for dive surveys of reef resources in the region (Quod et al. 2002).

Extracting clear water depths from a variety of sources allows the examination and mapping of shallow water from global to local scales. Scientists from the National Oceanic and Atmospheric Administration (NOAA) used four sources of data to map shallow water bathymetry near U.S. coral reef areas. These included the sea-viewing wide field-of-view sensor (SeaWiFS) on board the OrbView 2 Satellite (SeaWiFS, allows global mapping within 1 kilometer pixels), the IKONOS satellite (global mapping within 4 meters), the Landsat Satellite (global mapping within 30 meter pixels), and handheld photography by the ISS crew (CEO local mapping within 6 meters). A new technique was applied to the blue and green bands from astronaut photography, allowing construction of a bathymetry map for Pearl and Hermes reef with accuracies similar to that obtained from IKONOS (Stumpf et al. 2003).

High-resolution astronaut photography collected from station has provided useful data for urban analysis, especially vegetation measurements. The accuracy of the data obtained from the astronaut photographs was similar to the data obtained by satellite remote sensors. The high-resolution astronaut photography obtained by the CEO investigation gives insights into vegetation density in urban areas (Stefanov and Robinson 2003).

Imagery captured during ISS Expedition 6 by astronaut Don Pettit (example, right) has led to potential applications for urban analyses and modeling of cities at night. ISS photographs of cities at night are unique because they provide greater spatial resolution than any other source of city light data. Images of cities captured at night clearly provide data for urban density modeling and enhancing census estimates (Lulla 2003).

Astronaut handheld imagery acquired since the early 1980's, including those from the ISS, has permitted the first global geomorphic survey of megafans. Megafans are partial cones of river sediment usually laid down by a single switching river, characterized by areas on the order of $10^3 - 10^5 \text{ km}^2$, smooth plains, and slopes of <1 degree. Using examples mainly from South America, and based on stream behaviors common in megafans, models were developed which appear to have implications for the distribution and diversification of aquatic river organisms (Wilkinson 2006).

Results Status: Pending More Information

Results Review Status: PI Reviewed

Results Publications:

[Cembella AD, Ibarra DA, Diogene J, Dahl E. Harmful Algal Blooms and their Assessment in Fjords and Coastal Embayments. *Oceanography*. 2005 ;18\(2\):160-173.](#)

[Andrefouet S, Gilbert A, Yan L, Remoissenet G, Payri C, Chancerelle Y. The remarkable population size of the endangered clam *Tridacna maxima* assessed in Fangatau Atoll using in situ remote sensing data. *ICES Journal of Marine Science*. 2005 ;62\(6\):1037-1048.](#)

[Lulla K. 2003 Nighttime Urban Imagery from International Space Station: Potential Applications for Urban Analyses and Modeling. *Photogrammetric Engineering and Remote Sensing*. 2003 ;69:941-942.](#)

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[Stumpf RP, Holderied K, Robinson JA, Feldman G, Kuring N. Mapping water depths in clear water from space. Proceedings of the 13th Biennial Coastal Zone Conference. 2003 .](#)

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Wilkinson MJ, Allen CC, Oehler DZ, Salvatore MR. A New Fluvial Analog for the Ridge-Forming Unit, Northern Sinus Meridiani/Southwest Arabia Terra Mars. Lunar and Planetary Science. 2008 ;XXXIX: 1392 - 1393.

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Elvidge CD, Safran TB, Sutton P, Cinzano P, Petti DR, Arvesen J, Small C. Potential for Global Mapping of Development via Nightsat Mission. GeoJournal. 2007 ;69:45 - 53.

Kohlmann B, Wilkinson MJ. The Tarcoles Line: bioecographic effect of teh Talamanca Range in lower Central America. Giornale Italiano do Entomologia. 2007 ;12: 1 - 30. [Italian]

Related Publications:

Stern RJ, Beyth M, Bodechtel J, Wetzel H-U. Potential of the International Space Station for imaging Earth: Lessons from MOMS-2P aboard Mir. Geology. 2002 ;30:851-854.

[Lu E. Watching the World Go By. Earth Observatory. Oct 22, 2003 ;Online posting.](#)

[Robinson JA, Evans C. Astronaut Photography: Observing the Earth from the International Space Station. Earth Observatory. Feb 16, 2001 .](#)

[Robinson JA, Liddle DA, Evans CA, Amsbury DL. Astronaut-acquired orbital photographs as digital data for remote sensing: spatial resolution. International Journal of Remote Sensing. 2002 ;23:4403-4438.](#)

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Web Sites:

[The Gateway to Astronaut Photography](#)

[Science@NASA](#)

[NASA Fact Sheet](#)

[Cities At Night, The View From Space](#)

[Earth Observatory News](#)

[Astronauts View of the Home Planet](#)

[JSC Digital Image Collection](#)

[Astronaut Photography from ISS: Unique Observations of the Earth](#)

[Shooting for the Heart: Astronaut Finds Passion for Photography in Space](#)

[NASA - Hurricane 2005: A Hurricane Resource Site](#)

[The LTER Network News](#)

Related Payload(s): CEO-IPY, EarthKAM

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