

60 Years of Earth Imaging from Satellites

By Don Hillger and Garry Toth

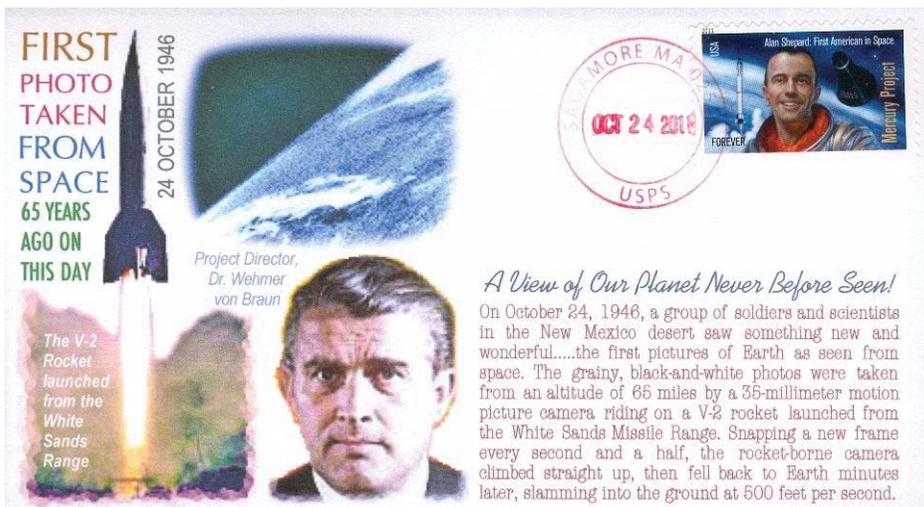
Satellite imagery is a common and integral part of modern life, from the frequent cloud photos used for weather analysis, forecasting and television illustrations to Earth-observing imagery for environmental monitoring. This flood of imagery is a modern phenomenon. Starting with the first artificial satellites in the late 1950s, the ability to view Earth from space has progressed steadily to the point that many terabytes of imagery are now obtained daily from satellites, which have become the main sources of the remote-sensing data that swell the archives of the scientific community.

The topic of satellite imagery and its history could fill a large number of volumes. The goal of this article is to outline certain aspects of satellite remote-sensing history (hitting the highlights, as it were) and, in particular, to focus on some of the innovative satellite imagery that has recently become available.

The First Earth Imagery

The first photo of Earth from space was not taken by a satellite, but rather from a German V-2 missile launched from White Sands Missile Range (WSMR) in New Mexico on Oct. 24, 1946. The story of that photo is documented in the Smithsonian *Air and Space Magazine* (www.airspacemag.com/space/the-first-photo-from-space-13721411/). The only postal item known to show this rocket-view image is a 65th anniversary cover for the launch of that V2 rocket. This cover sets the stage for the many items with satellite-based imagery that follow in the years after 1946, a theme that is well documented in space philately.

The first image of the Earth taken by an orbiting satellite was a badly-smearred photograph from Explorer-6, taken on Aug. 14, 1959. A postage stamp from Cameroun has a TV display of an image of Earth. The stamp refers to Explorer-6



First image of the Earth from space, from a V-2 rocket launched in 1946, for which this 2011 Coverscape cover commemorates the 65th anniversary of launch.

and includes the Aug. 7, 1959, launch date. Earth was hardly recognizable in the first image (not shown here) from the satellite. The stamp probably includes a depiction of what that image might have looked like rather than an accurate reproduction. On the TV screen we see a low-resolution satellite view that might have been possible from the highly elliptical orbit of Explorer-6, which reached a maximum altitude of 7,870 km above Earth. The image shows the Atlantic Ocean, with North and South America to the left and Europe and Africa to the right.

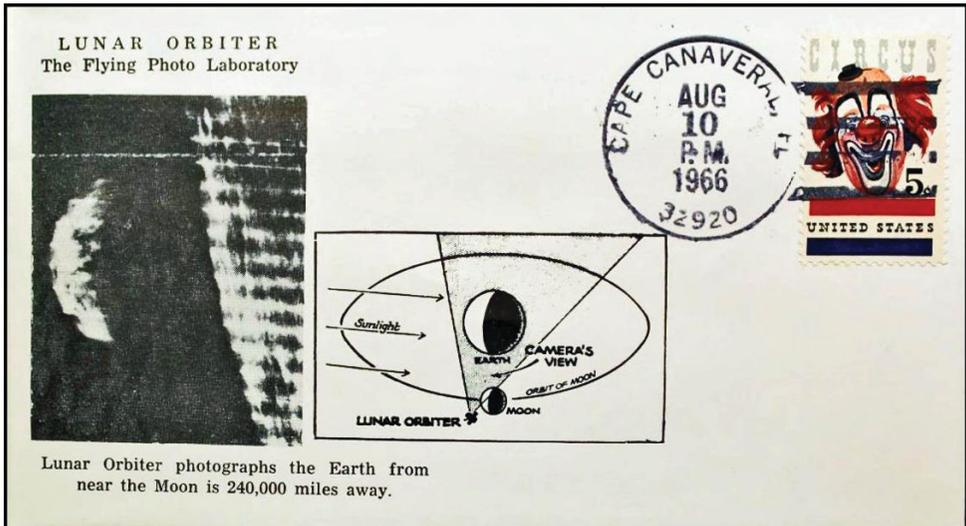


Explorer-6 schematic image of Earth: Cameroun, Scott C99, Michel 533, 1968.

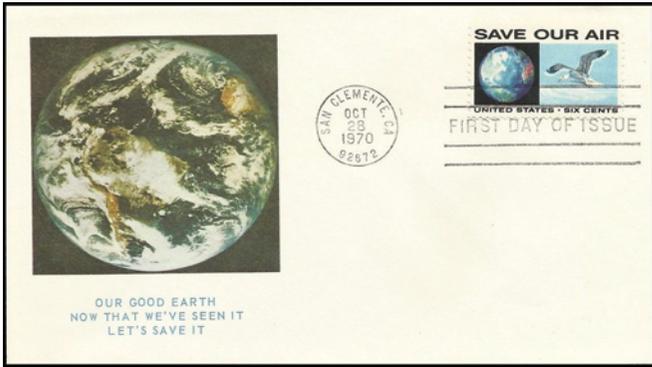
At about the same time, a few satellites were sent out of Earth orbit, and some of them had cameras that could look back at the planet. On Aug. 23, 1966, the Lunar Orbiter-1 satellite caught Earth in an image it took while in lunar orbit. A launch cover from Aug. 10, 1966, reproduces that image in its cachet. The full disk of Earth is present, though only a crescent of the planet is illuminated and visible. To the authors' knowledge, this is the earliest full-disk Earth image to appear in any philatelic item. The stamp and cancel must have been applied to a blank envelope on Aug. 10, with the cachet added later when the image became available. The cachet maker is unknown.

First True Color Images of the Earth

In 1967, nearly a decade after the dawn of the satellite era, the Applications Technology Satellite 3 (ATS-3) provided the first full-disk "true color" images of



Lunar Orbiter-1 launch cover; Cape Canaveral cancel. The cachet includes an image of Earth above the lunar horizon taken on Aug. 23, 1966.



ATS-3 true-color image of Earth: United States, FDC, Scott 1413, Michel 1015, 1970.

of geostationary satellites returned, until relatively recently, to single-color visible images with additional infrared images for day and night use. While single-band visible imagery satisfied basic user requirements for daytime imagery, the loss of true-color capability and its inherent ability to distinguish a wide range of atmospheric and surface features via coloration left a notable void. True-color imagery was relegated to polar-orbiting satellites, such as the Earth Observation Satellites (EOS), Terra and Aqua satellites that will be mentioned later. However, it was not until nearly a half-century after ATS, with the launch of Japan's Himawari-8 satellite in October 2014, that there was once again a geostationary sensor, the Advanced Himawari Imager (AHI), that contained the multispectral visible bands required for true-color imaging. That was followed by a similar capability on the U.S. geostationary satellite GOES-16 launched in late 2016. True-color imagery is now a primary product generated for full-disk multi-spectral imaging of the Earth. But that's getting ahead of ourselves. Let's see what else transpired between the earliest images and the present with respect to Earth imaging.

Blue Marble 1972

Full-disk images of the Earth were routinely available in black and white from numerous weather and environmental-observing satellites in geostationary orbit dating back to the 1970s. Earth was also often photographed in black and white from space for many years from manned spacecraft, but none of those photos are as impressive as true-color images. However, some true-color images from manned spacecraft were also made.

The most famous and single-most widely used full-disk true-color image of the Earth is the so-called Blue Marble image. Never has a particular image of the Earth become as popular. The Blue Marble photograph was taken on Dec. 7, 1972, by the crew of *Apollo-17* as the astronauts made their way to the moon. The sun was behind them, so Earth

The first Blue Marble image of the Earth, taken from *Apollo 17* on Dec. 7, 1972.

Earth. An example of that image appears in the cachet of a U.S. first-day cover from 1970. With its depiction of blue oceans, golden deserts and green forestlands beneath white clouds, the imagery captured the Earth in a way that resonates strongly with human perception. However, after ATS-3, the standard fare



was fully illuminated when the photograph was taken. Geostationary weather satellite images are taken from the geo-synchronous altitude of 35,000 km, while the Blue Marble photo was taken from somewhat farther away (45,000 km).

The original Blue Marble image is shown nearby, for comparison with the postal items that will follow. The image is centered over the western Indian Ocean just to the east of Africa. Except for brown and slightly-green land features, the tones are mostly blue, thus inspiring the Blue Marble name given to this image. Identifiable features in the image are the cloud-free Sahara Desert and Arabian Peninsula in the north. South of that, patchy clouds cover equatorial Africa,



Blue Marble 1972 image: Qatar, Scott 947, Michel 1181, 2001.

and still farther south, a large frontal system of thick white clouds, visible as an inverted “comma,” creates a distinguishing feature that is immediately noticeable even on small renditions of the image. Other cold fronts are visible to the west and east of the main “comma.” At the

bottom, Antarctica appears mostly white in a combination of snow and ice surfaces and clouds, fully lit at what is nearly the peak of the Southern Hemisphere summer.



Blue Marble 1972 image: Poland postal card, 2003.

The Blue Marble image can be found on a large number of postal items. Aside from the beauty of the image, it is very popular because it is in the public domain. Some postal items reproduce it more or less faithfully, while others alter it in various ways. In some reproductions, the colors have been changed or the image has been cropped from the original full-disk version. In others, the Blue Marble image has been rotated, flipped, or both, when compared to the original orientation with North on top. The rotated and flipped images can be hard to identify, though the big white comma cloud generally stands out. Its shape is useful to guide the transformations to flip and/or rotate an image on a stamp back to the original orientation.

About 200 postal items from 70 countries have been found to include the Blue Marble image, though some are simply postal derivatives, such as FDCs or



**The 2001 Blue
Marble composite
images of the Western and
Eastern Hemispheres, respectively.**

other covers. In this article, two postal items with the best Blue Marble images are shown: a stamp from Qatar and a postal card from Poland. The Blue Marble image on the Polish postal card is rotated slightly clockwise, compared to the image on the stamp from Qatar. All Blue Marble items known to the authors, including those with small or difficult-to-interpret images, can be examined on the website whose URL is included at the end of this article.

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The 2001 Blue Marble

The 1972 Apollo-17 Blue Marble is not the only true-color image of the Earth that was widely reproduced on postage stamps and covers, nor is the Blue Marble name unique to that photograph. A second official NASA Blue Marble was created in 2001, this time one that covers more of Earth, with views of both the Eastern and Western Hemispheres.

This 2001 Blue Marble image is not made from a single photograph. Rather, it is a composite from numerous true-



**Blue Marble 2001
Western Hemisphere
image: Jordan, Scott
2127, Michel 2168, 2012.**

color images acquired by the Terra (EOS-AM) and Aqua (EOS-PM) satellites. On board both satellites are Moderate Resolution Imaging Spectroradiometer (MODIS) instruments that take continuous visible and infrared images that cover the entire surface of the Earth every one to two days from their sun-synchronous polar orbits.

From single MODIS images, none of which see more than a 2,330-km-wide swath of the Earth at any time from an altitude of 705 km, computer software was able to piece together thousands of “granule” images, as they are known, each of which contains five minutes of data. To create the Blue Marble full-disk image, individual “granules” have been stitched together and any gaps between orbits filled with imagery from previous or later orbits. The resulting composite has land surface, ocean and sea ice features acquired from June through September 2001. Cloud features were acquired on two separate days: June 29, 2001, for the Northern Hemisphere, and Nov. 16, 2001, for the Southern Hemisphere.

The 2001 Blue Marble is presented here in two parts, with views of the Western and Eastern Hemispheres. In the Western Hemisphere view, Earth is tilted south so that more of the Northern Hemisphere is shown. Emphasis is placed on North America, and much of the North polar region can be seen. The Eastern Hemisphere image also has Earth tilted to the south, but less drastically, so that none of Antarctica can be seen, while Asia, Europe and part of Africa are clearly visible. Since these are composite images, almost any orientation of Earth is possible, and some other orientations are found on philatelic items in the authors’ checklist in the URL presented later.

About 80 postal items have been found with the 2001 Blue Marble image, but only two examples will be presented here. Shown are a stamp from Jordan with a Western Hemisphere version of the 2001 Blue



Blue Marble 2001 Eastern Hemisphere image: Bulgaria, Scott 4426, Michel BL291, 2007.

Marble and a souvenir sheet from Bulgaria with the 2001 Blue Marble centered on the Eastern Hemisphere. Readers who wish to examine the full set of items are referred to the authors’ website at the URL found at the end of this article. The Blue Marble on each item was identified by the patterns of land, water, ice and cloud, even in cases where only portions of the full disk image are included.

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The 2012 Blue Marble

In 2012, NASA created yet a third Blue Marble image, this time composited from Visible Infrared Imaging Radiometer Suite (VIIRS) imagery from the Suomi

National Polar-Orbiting Partnership (S-NPP) satellite at an altitude of 824 km. Single VIIRS “granule” images are 3,040 km wide, but only 570 km long in the along-orbit direction. That amount of data is obtained in only 90 seconds of scanning by the instrument. At first glance, this composited Blue Marble image appears to be similar to imagery from geo-synchronous orbit, but the extra-large size of North America, compared to the entire Earth, betrays its creation from a lower-orbit satellite.

At the time of writing, only one reproduction of this latest Blue Marble image has been found, on a postage stamp from the United States from 2016. However, the authors expect that it is just a matter of time before more philatelic images will be produced.

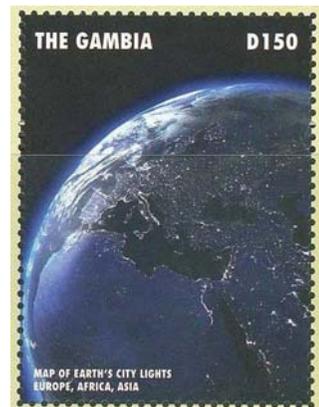


Blue Marble 2012 image:
United States, Scott 5071,
Michel 5245, 2016.

Day/Night Band (DNB) Imagery

Along with its visible and infrared imagery, the VIIRS instrument obtains unique Day/Night Band (DNB) imagery. That imagery is available at a much higher spatial resolution (750 m) and at much lower light levels than its predecessor nighttime imagery from U.S. military satellites. Nighttime visible imagery has become a popular way of observing via reflected moonlight what would normally be seen only during the daytime via reflected sunlight. DNB imagery also sees city lights and other human and natural light sources as if someone were on the International Space Station viewing Earth below. The DNB also observes Earth during the daytime, as the name implies, but that imagery is largely indistinguishable from other daytime visible imagery.

Among the philatelic items featuring this new nighttime imagery are: a set of stamps from The Gambia, a souvenir sheet of three stamps from The Netherlands (with the nighttime imagery in the background/margins) and another sheet of two stamps from Bosnia and Herzegovina (again with the nighttime imagery in the background). On this last sheet, the nighttime portion of the DNB image (on the left) shows city lights, but in the daytime portion (on the right) any human/city lights are too weak to show up, given the solar illumination reflected by the Earth's surface. In this case, the right side of the background is true-color imagery created from the red, green and blue component images from VIIRS.



Day/Night Band imagery:
Gambia, Scott 3653,
Michel unknown, 2015.

60 jaar EUROPA postzegels



Lesland, Finland, IJsland, Frankrijk, België, Nederland, Italië, Oostenrijk

Above: Day/Night Band imagery, Netherlands, Scott and Michel not yet listed, 2016.

Left: Day/Night Band imagery, Bosnia and Herzegovina (Croat Administration), Scott 330a, Michel BL36, 2016.

Below: Day/Night Band imagery in lower-left margin of souvenir sheet of 4 stamps released for the 60th anniversary of Sputnik-1: Ivory Coast, Scott and Michel not yet listed, 2017.



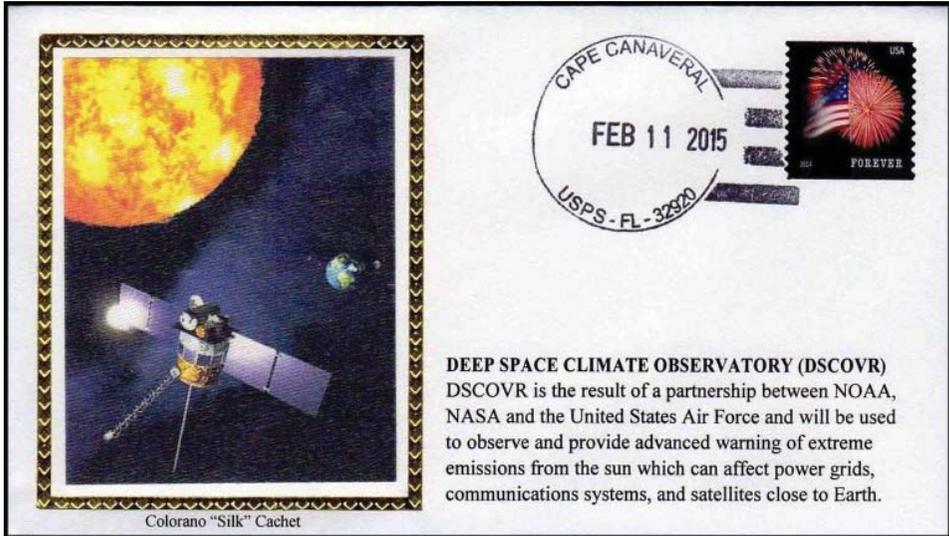


Day/Night Band imagery utilized in background of a souvenir sheet of single stamp for the 60th anniversary of Sputnik-2, carrying the first space dog Laika: Ivory Coast, Scott and Michel not yet listed, 2017.

With the increasing popularity of imagery of nighttime lights from space, postal items continued to appear in 2017. The following two items from Ivory Coast utilize DNB imagery in the margin or the background of souvenir sheets that mark the 60th anniversary of the launch of Sputnik-1 and 2, respectively. Since these items do not use the DNB imagery as the primary element, it's easy to miss such uses. Often the DNB imagery is combined with daytime true-color imagery, together making unusual and impressive images of Earth.

Earth imagery from farther outside Earth orbit

In 2015 a satellite was launched that became the latest operational solar-observing satellite. To be most effective at forecasting space weather for Earth, a satellite should continuously monitor the Sun and the solar wind at some point between the Sun and the Earth. An ideal location for doing this is the gravity-neutral point in space called the Lagrange point 1 or L1, at which, due to a balance of gravitational forces, a satellite orbits the Sun once per year, just like Earth. In other words, a satellite at L1 “hovers” constantly between Earth and the Sun. The satellite launched in 2015 is the Deep Space Climate Observatory (DSCOVR), which also views the Earth in full sunlight at all times by looking away from the Sun. Beautiful images of Earth, showing it spinning on its axis, can be found at <https://epic.gsfc.nasa.gov/>. The Earth images are a secondary mission for DSCOVR, but they can be useful for monitoring the weather and climate, with continuous views of the entire full-disk from about one million miles (1.6 million kilometers) away. The DSCOVR imagery is the first Earth imagery of its kind from these distances. No images of the Earth from DSCOVR have yet been found on any postal items, but launch covers exist, such as the one nearby.



Launch cover for DSCOVR satellite from 2015, whose primary mission is to monitor the Sun and space weather, but also provides full-disk Earth imagery.

The Current State of Satellite Imagery

Over the last 60 years, the capabilities of satellites have greatly improved, with images now regularly obtained at much higher spatial, temporal and spectral resolutions than ever before. The spectral resolution refers to the numerous spectral bands that are observed, ranging from visible to infrared wavelengths, including the true-color and nighttime visible imagery that were previously discussed.

The USA's primary weather satellite systems, JPSS (in polar orbit) and GOES (in geostationary orbit) provide vast amounts of information on the state of Earth for weather and other environmental-monitoring purposes. Similar satellites from Europe, Japan, Korea and China likewise monitor Earth as never before. The DSCOVR satellite provides a type of imagery not available from the weather satellites. Ever since the advent of satellites in the late 1950s, there has been an increasing level (resolution and frequency) of Earth imaging, but only recently is the imagery at space and time scales that can be considered to provide true global monitoring.

Additional online information

A checklist of satellite imagery on postal items is available at <http://rammb.cira.colostate.edu/dev/hillger/satellite-images.htm>. The authors would like to hear from anyone who knows of additional postal items that have been missed, particularly the Blue Marble and Day/Night Band imagery found on postal items. Email correspondence with the authors is welcomed, using the addresses on Page 60. 

Biographical notes

The authors have researched and written extensively on the subjects of weather, climate, and non-manned satellites on stamps and covers, as well as other topics. For a complete list and electronic reproductions of those publications, see <http://rammb.cira.colostate.edu/dev/hillger/stamp-articles.htm>.

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The authors also wrote ATA's handbook No. 166, *Space Weather*. Ordering information is found on Page 2.

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