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2019 Joint Agency Commercial Imagery Evaluation—
Land Remote Sensing Satellite Compendium

Joint Agency Commercial Imagery Evaluation
JACIE
NASA • NGA • NOAA • USDA • USGS

Circular 1455

U.S. Department of the Interior
U.S. Geological Survey

Cover. Image of Landsat 8 satellite over North America. Source: AGI's System Tool Kit.

Facing page. In shallow waters surrounding the Tyuleniy Archipelago in the Caspian Sea, chunks of ice were the artists. The 3-meter-deep water makes the dark green vegetation on the sea bottom visible. The lines scratched in that vegetation were caused by ice chunks, pushed upward and downward by wind and currents, scouring the sea floor.

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By Jon B. Christopherson, Shankar N. Ramaseri Chandra, and Joel Q. Quanbeck

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DAVID BERNHARDT, Secretary

U.S. Geological Survey
James F. Reilly II, Director

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Preface

The U.S. Geological Survey (USGS) National Land Imaging Program (NLIP) has a responsibility to provide imagery for the Nation in support of science, land management, and other needs. The USGS NLIP operates the Landsat series of satellites, and actively manages 46 years of imagery from diverse sources as a continuous record of our changing planet.

To understand the user needs for Earth observation, measurement, and monitoring, the Requirements, Capabilities, and Analysis for Earth Observation (RCA-EO) Project has been established.

One of the missions of the RCA-EO Project is to identify and catalog existing and planned capabilities for measuring and monitoring the Earth. The RCA-EO Project also supports the Joint Agency Commercial Imagery Evaluation (JACIE) mission and developed this compendium as one of the USGS contributions to the JACIE effort.

This publication was produced by the USGS NLIP RCA-EO Project Team (Gregory Stensaas, Project Manager) under the Observing Systems Branch (Jennifer Lacey, Branch Chief) at the USGS Earth Resources Observation and Science (EROS) Center.

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Acknowledgments

In the 1990s and 2000s, William “Bill” Stoney, after a long and distinguished career at NASA including serving as Director of NASA’s Earth Observation Programs, compiled and maintained a list of land-imaging satellites. He shared this list for general reference and for the general benefit of the remote sensing community. Bill realized the beginnings of the rapid growth of Earth observation and, through his list, helped others understand what was happening in the industry. The American Society of Photogrammetry and Remote Sensing published the 2008 version of Bill’s ASPRS GUIDE TO LAND IMAGING SATELLITES on the American Society of Photogrammetry and Remote Sensing website, where it remains available. In recent years, calls have been made for a new, updated version of the “Bill Stoney list.” We hope that this compendium is an answer to those calls and begins to fill the niche that Mr. Stoney created. Thanks, Bill!

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Contents

JACIE

JACIE

JACIE

Figures

JACIE

Tables

Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Flow rate	
meter per second (m/s)	3.281	foot per second (ft/s)
meter per hour (m/h)	3.281	foot per hour (ft/h)
kilometer per hour (km/h)	0.6214	mile per hour (mi/h)
	Mass	
kilogram (kg)	2.205	pound avoirdupois (lb)

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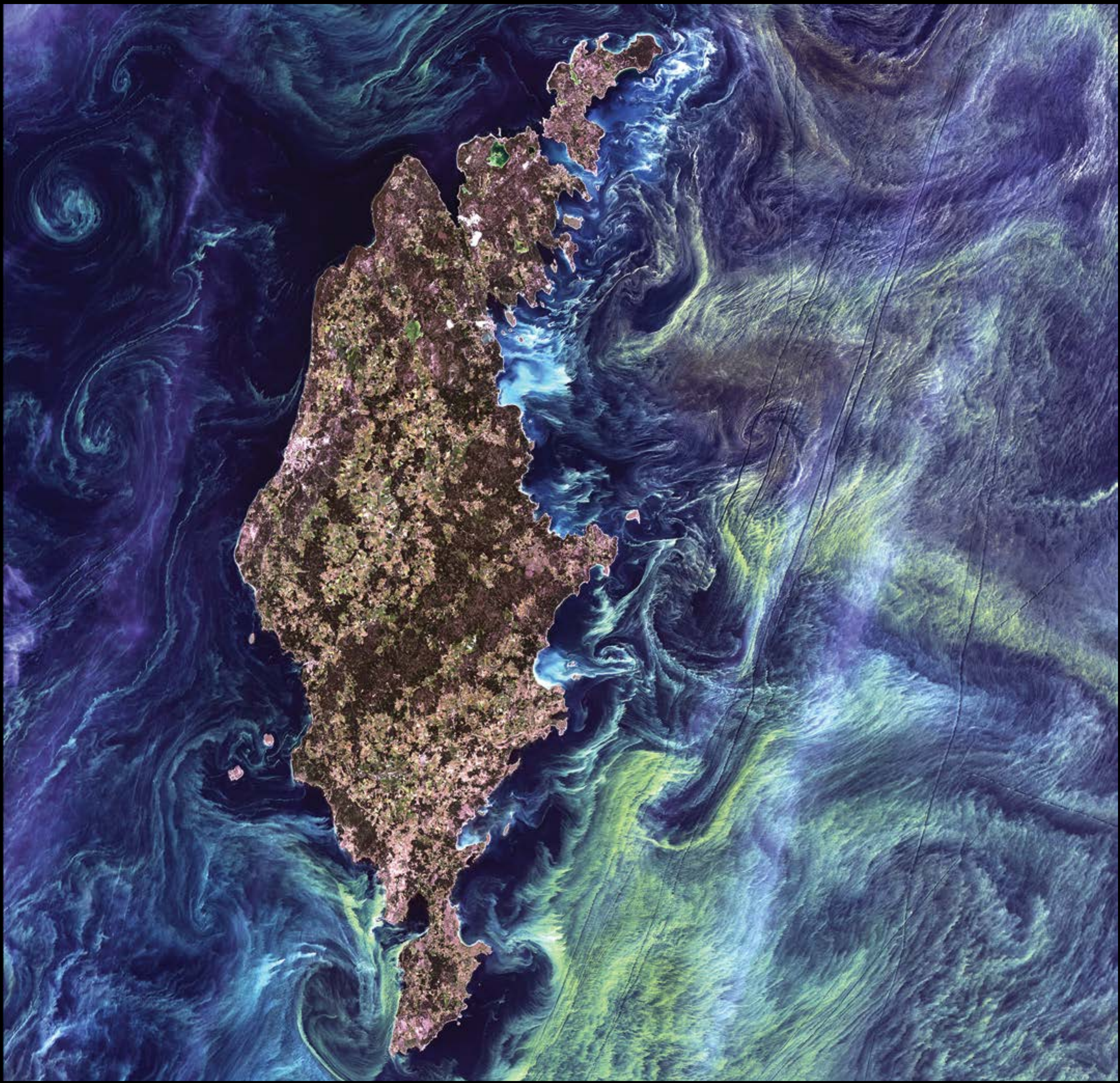
Abbreviations

ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CAC	Chinese Aerospace Corporation
CASC	China Aerospace Science and Technology Corporation
CBERS	China-Brazil Earth Resources Satellite
CNSA	Chinese National Space Agency
CRC	combined repeat cycle
EROS	Earth Resources Observation and Science [Center]
ERTS	Earth Resources Technology Satellite
GSD	ground sample distance
ISS	International Space Station
JACIE	Joint Agency Commercial Imagery Evaluation
NASA	National Aeronautics and Space Administration
NGA	National Geospatial Intelligence Agency
NLIP	National Land Imaging Program
NOAA	National Oceanic and Atmospheric Administration
RCA-EO	Requirements, Capabilities, and Analysis for Earth Observation [Project]
SAR	synthetic aperture radar
SSO	Sun-synchronous orbit
SSTL	Surrey Satellite Technology, Ltd.
UN	United Nations
UN RSP	United Nations Remote Sensing Principles
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VNIR	visible plus near infrared

In the style of Van Gogh's painting "Starry Night," massive congregations of greenish phytoplankton swirl in the dark water around Gotland, a Swedish island in the Baltic Sea. Phytoplankton are microscopic marine plants that form the first link in nearly all ocean food chains. Population explosions, or blooms, of phytoplankton, like the one shown here, occur when deep currents bring nutrients up to sunlit surface waters, fueling the growth and reproduction of these tiny plants. Source: Landsat 7.



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Introduction

Joint Agency Commercial Imagery Evaluation

The Joint Agency Commercial Imagery Evaluation (JACIE) is a collaborative multiagency group that began in 2000 between the National Aeronautics and Space Administration (NASA), the National Geospatial-Intelligence Agency, and the U.S. Geological Survey (USGS) to assess the quality and capabilities of newly launched commercial high-resolution satellites. Each agency had potential interest in using these commercial datasets in fulfilling their missions and in determining if imagery from these new systems had the quality, accuracy, and repeatability necessary to support science, land management, and other Government needs. In the initial years, JACIE assessed imagery from Space Imaging's IKONOS, DigitalGlobe's QuickBird, and ORBIMAGE's Orbview-3. The JACIE agencies shared the results of their individual assessments with each other, the satellite owners/operators, and the public. The assessments from the JACIE agencies have helped satellite owners improve the data quality from their commercial satellites. Since these early efforts, two more agencies have joined JACIE: the U.S. Department of Agriculture and the National Oceanic and Atmospheric Administration (NOAA). Each agency brings its own needs and strengths to the JACIE mission.

The JACIE group hosts an annual workshop to present the results of their findings, as well as characterization results from universities, satellite owners, and others from the remote sensing community. Satellite data assessment and calibration methods also are presented and discussed. In addition, the JACIE workshop has a forward-looking aspect because plans for future systems are presented and discussed.

The Compendium of Land Remote Sensing Satellites

Since about 2012, the JACIE group has observed ever-increasing numbers of remote sensing satellites being launched. This rapidly growing wave of new systems creates a need for a single reference for land remote sensing satellites that provides basic system specifications and linkage to any JACIE assessment that may have been completed on existing systems. This volume has been assembled by the Requirements, Capabilities, and Analysis for Earth Observation Project under the USGS National Land Imaging Program as a contribution to the JACIE community. This is the first edition of the JACIE compendium, which is planned to be updated and released annually.

This document consists of two primary parts. The first part contains pertinent and relevant information for the remote sensing community, including articles related to the history and growth of land remote sensing from space, a background on remote sensing law and policy, and a discussion of the primary drivers behind the growth in government and commercial land remote sensing. Also included in this part are short articles giving a brief overview of the Chinese and Russian Earth observation programs and a description of the types of orbits used for remote sensing.

The second part is a set of appendixes containing data on more than 100 land-imaging and land-measuring satellite systems. The appendixes contain a listing of recent and future satellite launches, graphics, and data sheets on more than 100 land remote sensing satellites and systems. Assessment results on individual systems are viewable on the USGS Earth Resources Observation and Science (EROS) Calibration Center of Excellence website, which is available at https://www.usgs.gov/land-resources/eros/calval/jacie and can be linked to from the individual data sheets.

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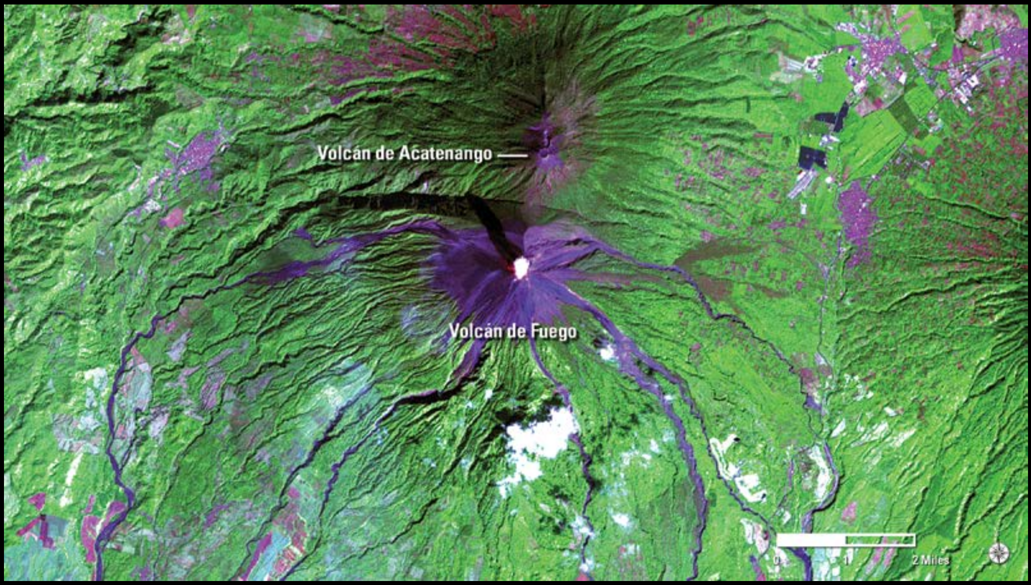
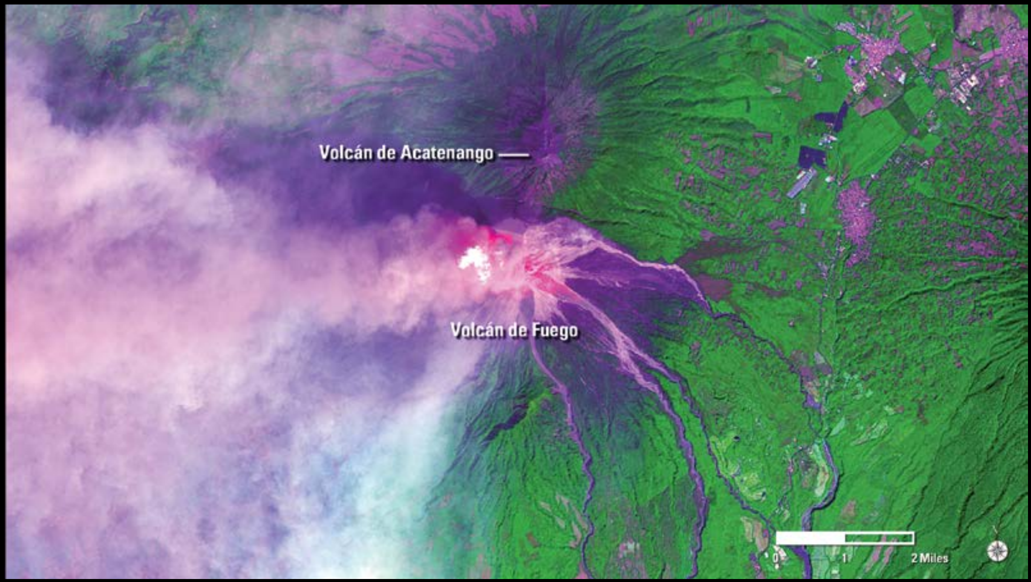
Volcán de Fuego in Guatemala erupted on January 31, 2018, and Landsat 8 acquired an image of the eruption a day later. A plume of ash rises from the mountain's peak to an altitude of 6,500 meters (21,300 feet). Wind has carried the ash 40 kilometers (25 miles) to the west and southwest.

The stratovolcano has erupted on and off for centuries. Evidence of previous eruptions can be seen in the Landsat 7 image from January 8, 2018. The spidery streaks coming from the volcano's peak are previous pyroclastic and lava flows. A puff of steam casts a narrow shadow toward the northwest in that image as well. Just north of Volcán de Fuego is its twin Acatenango.

The instruments onboard Landsat 8 have been spotting volcanic eruptions, floods, wildfires, and myriad other changes to the Earth's surface since the satellite launched on February 11, 2013. After 5 years in orbit, Landsat 8 continues the Landsat Program's unprecedented record of natural and human-induced changes on the global landscape.



Source: Landsat 7, January 8, 2018



Source: Landsat 8, February 1, 2018

Changes in Remote Sensing

The world of remote sensing is undergoing change and development at a remarkable pace, more so than any single period since the dawn of spaceborne remote sensing in the 1960s and 1970s. A confluence of factors has made it easier to build, launch, and operate satellites while simultaneously it has become much easier and more efficient for users to access and develop applications with data remotely sensed from space.

Two factors substantially influencing this change are (1) the rise of small satellites, referred to as smallsats, and (2) the emergence of commercial corporations actively engaging in Earth observation from space.

Smallsats are defined as satellites with a mass of 500 kilograms (kg) or less (table 1). Bryce Space and Technology (2018) reported that from 2012 to 2017, more than 1,000 smallsats were launched, and 6 times as many were launched in 2017 than in 2012. More than 700 of these smallsats were CubeSats. In 2017 alone, 335 smallsats were launched, 87 percent of which were CubeSats. The same report stated that 67 percent of smallsats launched provide commercial services and that 85 percent of all commercial satellites are for remote sensing. It was in this environment of rapid change, with the launch of so many new satellites with broadly differing capabilities, that the idea for this land remote sensing compendium was conceived.

Table 1. Classes of satellites by mass [modified from Federal Aviation Administration Office of Commercial Space Transportation, 2018].

Satellite classes by mass		
	Group name	**Mass, in kilograms**
	Extra heavy	Greater than 7,000
	Heavy	5,400–7,000
	Large	4,200–5,400
	Intermediate	2,500–4,200
	Medium	1,200–2,500
	Small	600–1,200
Smallsats	Mini	200–600
Smallsats	Micro	10–200
Smallsats	Nano	1–10
Smallsats	Pico	0.1–1.0
Smallsats	Femto	Less than 0.1 (100 grams)

CubeSats

A “CubeSat” is not a mass “class” but a description of a smallsat of certain volumes. A basic CubeSat is a cube that is 10 centimeters (cm)×10 cm×10 cm. This volume is designated as one “mu”; thus, a 3-mu (μ) CubeSat would be 30 cm×10 cm. Because of their small size, all CubeSats are smallsats, but not all smallsats are CubeSats.

Compendium Coverage, Conventions, and Caveats

The compendium coverage, conventions, and caveats are given in detail below.

- This first edition of the compendium provides a focus on satellites thought to be of the most interest to the JACIE community; therefore, it does not provide data sheets for the numerous Chinese and Russian systems. The two articles in the first section of the compendium describe the Chinese and Russian Earth observation programs and provide insight into the relevant efforts of those two countries.
- Many reference sources were mined for the data and information presented in this compendium. Information sources and how the information has been integrated into this circular are provided in appendix 1.
- A table with data for recent and future satellite launches is included in appendix 2.
- The data sheets in appendix 3 are arranged alphabetically by satellite or constellation name with their respective sensors arranged after each satellite. In some instances, satellites are known by more than one name.
- When data in appendix 3 were not available or were unknown, a dash (—) was used to indicate the lack of that information.
- The compendium focuses heavily, but not exclusively, on land-imaging satellites and land-measuring sensors. Satellites with multiple instruments (for example, Terra or Aqua) will only include the instrument descriptions that are important to land imaging or land measuring.

Because of the ongoing rapid development within the remote sensing industry, some of the information presented in this compendium may have changed or may be out of date by the time of publication. Information in this compendium was gleaned from numerous sources that also are striving to keep pace with an already fast-paced era for space-based remote sensing.

Landsat sensor technology has come a long way since the days of the Return Beam Vidicon cameras on the first three Landsat satellites. Known as the RBV, it was originally intended to be the satellites' primary sensor. But the Multispectral Scanner, or MSS, became the more stable and superior instrument.

Compare these images of glaciers in Alaska's Chitina River Valley from 1980. There is more background noise in an RBV image than there is in an MSS image. The RBV on Landsat 3 had a slightly higher spatial resolution, but the low signal-to-noise ratio makes it harder to pull out surface detail.

The 2018 image from Landsat 8's Operational Land Imager has even better signal-to-noise ratio and higher resolution than both early sensors. The image reveals more detail about the roughness and flow of the ice. Landsat 8's shortwave infrared bands provide a better distinction between ice and rock or soil.

Although Landsat sensor technology has improved, RBV data still play an important role in this long-term record of changes on the earth.

History of Land Remote Sensing from Space

First Images of the Earth from Space

Space is defined as an altitude of 100 kilometers (km) above the surface of the Earth (Kármán line). The first images of the Earth taken from space were captured in 1946 above White Sands, New Mexico. These first images were taken by a motion picture camera installed in a captured German V-2 rocket. The grainy pictures (see fig. 1) were the first to hint at the capabilities of imaging Earth from space.

A newsreel (Internet Archive, 2018) shows excerpts of these earliest videos from space at https://archive.org/details/1946-11-21_White_Sands_NM_V-2_rocket.

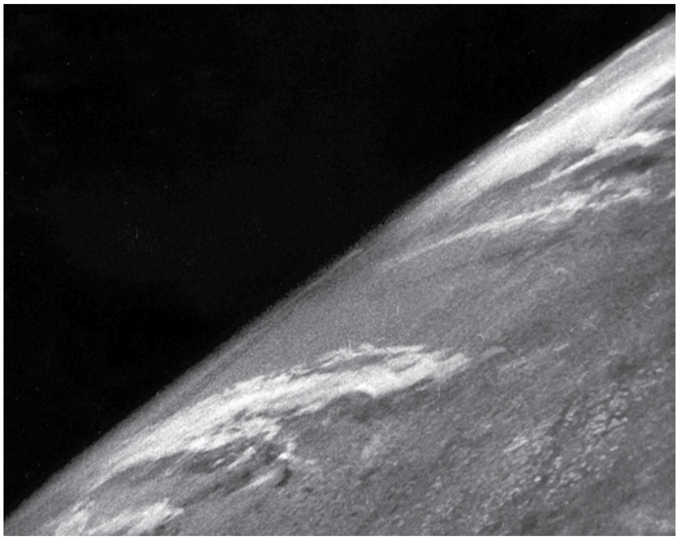


Figure 1. First imagery of the Earth taken from space, October 24, 1946 [Source: White Sands Missile Range/Applied Physics Laboratory].

First Imagery from Orbit

The first image of the Earth taken from orbit was captured by the Explorer VI satellite on August 14, 1959 (fig. 2). Crude and barely recognizable, the image shows a sunlit part of the central Pacific Ocean and clouds.

Figure 2. First image of Earth from orbit taken by Explorer VI on August 14, 1959 [Source: NASA].

Early Drivers of Earth Remote Sensing

Weather and defense intelligence were the two primary needs driving early space-based observations of Earth. These early efforts focused on the safety and protection of national populations, which helped warrant the substantial costs and effort to overcome the major technical challenges in completing these goals.

Weather Imaging

On April 1, 1960, NASA launched the first Television Infrared Observation Satellite, TIROS-1, which returned the first television image of the Earth from space (fig. 3). Considered the first successful weather satellite (other satellites had carried nonimaging meteorological instruments that operated with some success), the TIROS and subsequent Nimbus program (fig. 4) provided valuable information to weather forecasting, although their imagery was considered too coarse for land mapping or science purposes.

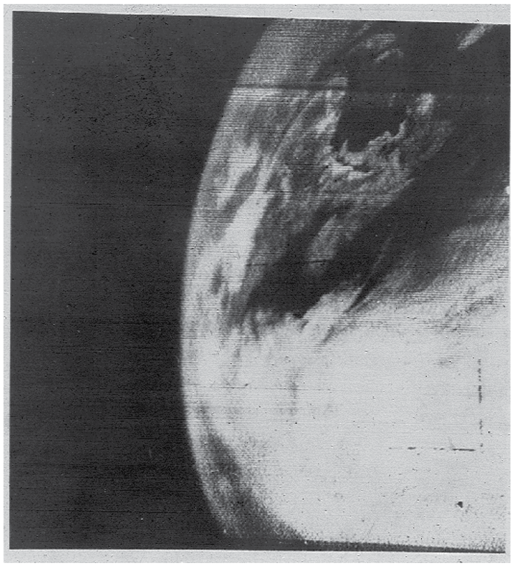


Figure 3. First television image of the Earth from TIROS-1 from April 1, 1960 [Source: NASA].

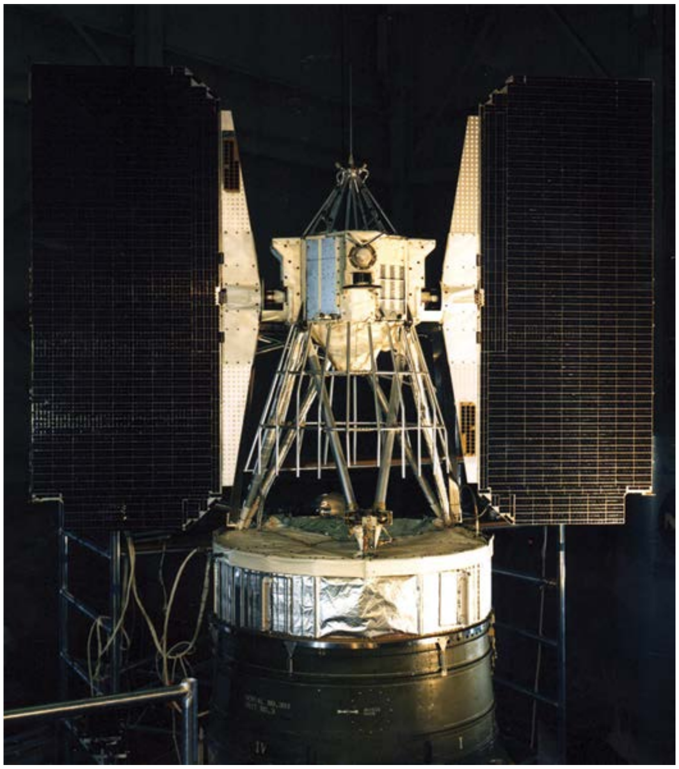


Figure 4. Nimbus-A, which became Nimbus-1 on orbit, continued progress in meteorological satellites [Source: NASA].

Figure 5. Midair retrieval of a film capsule reentering from a classified U.S. reconnaissance satellite [Source: National Reconnaissance Office].

Defense Reconnaissance—Corona

Fears and concerns generated by the Cold War and uncertainties regarding the capabilities of foreign countries created a strong desire to use newly developed space capabilities to capture overhead imagery of other nations. The United States began developing the Corona Program, initially under the cover name "Discoverer." The first launch of this program, Discoverer 1, took place on February 28, 1959. The first polar orbit was achieved by Discoverer 2. Numerous launch difficulties and ambitious technical goals proved challenging, but the program finally returned imagery 1 1/2 days after the launch of Discoverer 14 on August 18, 1960. All imagery was collected on film that was then deorbited in reentry capsules and retrieved while parachuting to Earth (fig. 5).

The first Coronas provided 12-meter (m; 40-foot [ft]) resolution imagery. Improvements to later Corona satellites produced imagery with 1.5-m (5-ft) resolution and better. By the time the last Corona satellite was launched in 1972, more than 100 missions had been launched using several improved versions of satellites.

The former Soviet Union, facing the same Cold War concerns, developed their own reconnaissance satellites beginning with the Zenit series, which were all referred to as "Kosmos" (Cosmos) satellites. The Zenit satellites used many of the same components of the proven Vostok manned spacecraft that carried the first Soviet cosmonauts to orbit (fig. 6). The cosmonauts were replaced with film cameras, and the capsule was returned to Earth. The spacecraft required heavy lift capability, weighing in at more than 4,500 kg (10,000 pounds [lbs]), but provided a pressurized, temperature-controlled environment ideal for instrument operation. Recovery of the capsule meant that the cameras could be reused. The first successful Zenit satellite, Kosmos 4, launched April 26, 1962. More than 500 Zenits were flown before this series came to an end in 1994.

Figure 6. Zenit satellite displayer in St. Petersburg showing camera ports [Source: Wikimedia Commons, licensed under the Creative Commons Attribution-Share Alike 2.5 Generic license].

The Corona and Zenit systems returned film imagery from space back to Earth to be developed and analyzed, which meant delays of days to weeks for the imagery to reach analysts. Typical missions lasted only for days or a few weeks, necessitating the large numbers of reconnaissance satellites flown during those years.

Dedicated Civil Land Imaging

Scientists and land managers had long used overhead imagery from aircraft in their work. Photos of the Earth taken by Mercury and Gemini astronauts spawned interest and excitement among the Earth science agencies to build a dedicated land-mapping and measuring satellite system. NASA worked with the Department of the Interior and, on July 23, 1972, the Earth Resources Technology Satellite (ERTS) was launched with two land-imaging sensors on board.

Response to the imagery delivered by ERTS, soon renamed Landsat 1, was rapid and positive. By 1975, NASA Administrator James Fletcher said, “If I had to pick one spacecraft, one space age development to save the world, I would pick ERTS and the satellites which I believe will be evolved from it later in this decade” (National Research Council, 2013, p. 1). Subsequent Landsat satellites have continued to record the Earth’s land surface for more than the last 46 years. Landsat 9, planned for launch in 2020, will extend this record well into its sixth decade.

1972–99—Slow, Steady Growth

Landsat 1 was followed by Landsats 2 and 3. In 1982 and 1984, Landsats 4 and 5 were respectively launched with improved resolution and multispectral capabilities. Landsat 5 continued its mission in orbit until 2013, making it the longest operating land remote sensing satellite to date.

In 1986, the French Space Agency, Centre National d’Etudes Spatiales, launched its first Satellite Pour l’Observation de la Terre (SPOT). This satellite, known as SPOT-1, joined Landsat in the intentional mapping and monitoring of the Earth’s surface. The recently launched SPOT-6 and SPOT-7 (now Azersky) satellites continue this 32-year legacy.

France was followed by more nations launching their own land monitoring satellites. India launched IRS-1A in 1988; Russia launched ALMAZ-1, which carried a synthetic aperture radar (SAR) instrument that resulted in some environmental applications; and Japan launched the Japan Earth Resources Satellite, JERS-1, in 1992 with optical and radar instruments.

In 1992, the Russian Government began selling high-resolution panchromatic imagery captured by its military reconnaissance satellites with resolution as fine as 2 m. This was the highest resolution space imagery available outside of the intelligence community. Space Imaging LLC began selling 1-m imagery on January 1, 2000, from their IKONOS satellite.

Throughout the 1990s, nations continued launching more Earth observation satellites. NASA began its Mission to Planet Earth by launching satellites that became known as the Earth Observing System. The Earth Observing System, conceived in the 1990s, was an ambitious NASA program to launch numerous satellites carrying a broad variety of instruments to gather comprehensive measurements of the Earth’s lands, oceans, and atmosphere.

2000–Present—Accelerating Rapid Growth

The previously referenced IKONOS not only supplied high-resolution imagery but also was the first commercially developed and launched Earth observation satellite. IKONOS was joined in 2001 by DigitalGlobe’s high-resolution QuickBird satellite. The two firms are generally regarded as the forerunners of the commercially funded and operated remote sensing from space industry.

Surrey Satellite Technology, Ltd. (SSTL), a commercial spinoff of the University of Surrey in England, launched UK-DMC in 2003. SSTL was the first of a series of Disaster Monitoring Constellation satellites that were built, launched, and operated for paying customers. Using low-cost technology and low-cost launches aboard converted Russian intercontinental ballistic missiles, SSTL could quote customers an on-orbit, fully functioning satellite for $11 million. This satellite was more than an order of magnitude less costly than other Earth observation satellites available at that time. The dramatic reduction in the price brought many new providers to the community of satellite owners, including Algeria, Turkey, and Nigeria. Space was no longer only for large, developed nations. The low-cost satellite development trend continued and now at least 54 countries have, or have had, Earth imaging satellites (figs. 7 and 8).

Today, the most rapid growth in Earth observation satellites is within the private sector. In recent years, the development of smallsats, particularly CubeSats, combined with rapidly growing launch opportunities, has allowed for the launch of hundreds of commercial satellites into orbit in this decade. The number of Earth observing satellites is growing rapidly, from government and commercial efforts. Multiple factors, primarily technological, are converging to drive this impressive growth.

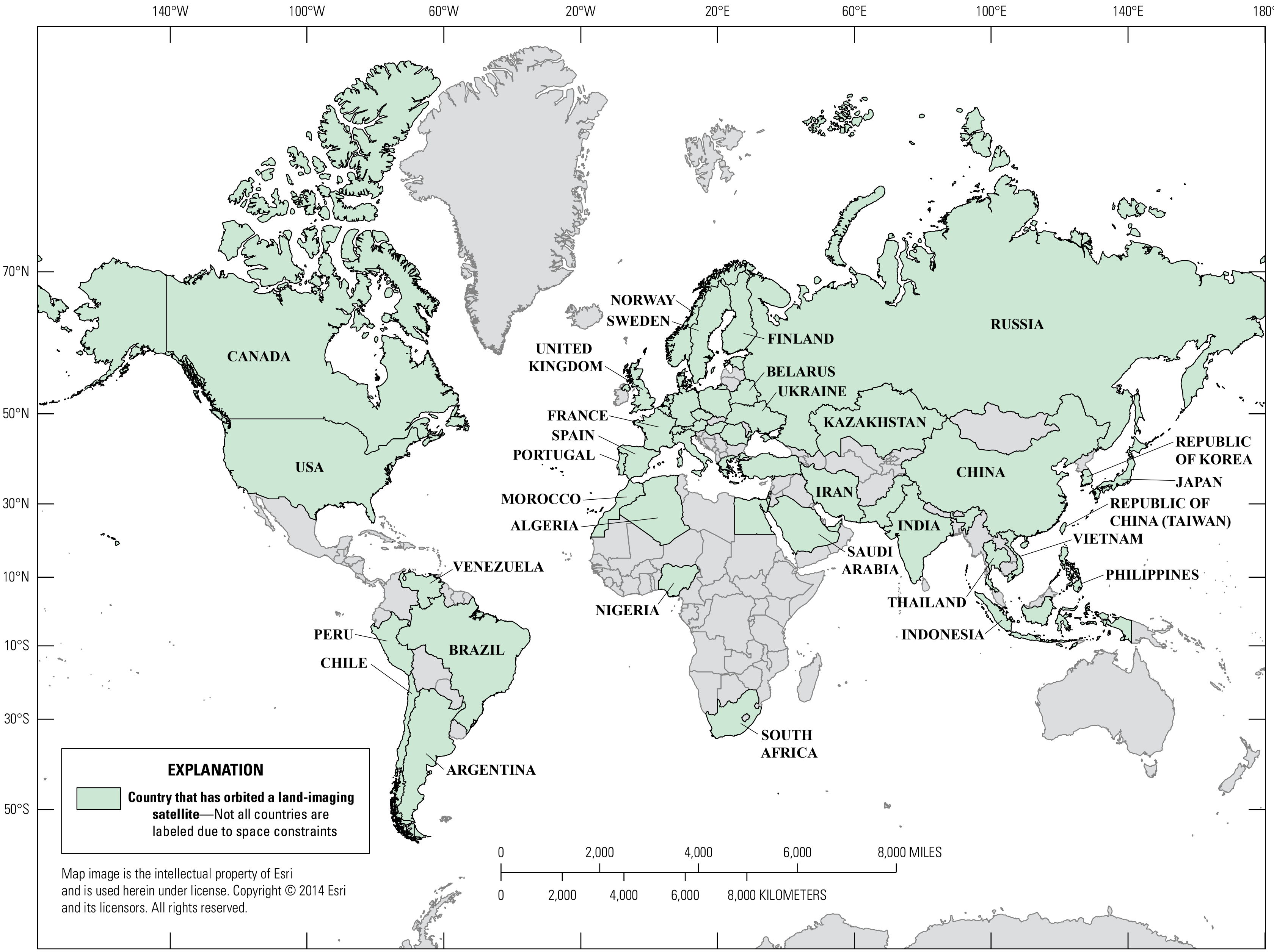


Figure 7. Countries that have orbited land-imaging satellites.

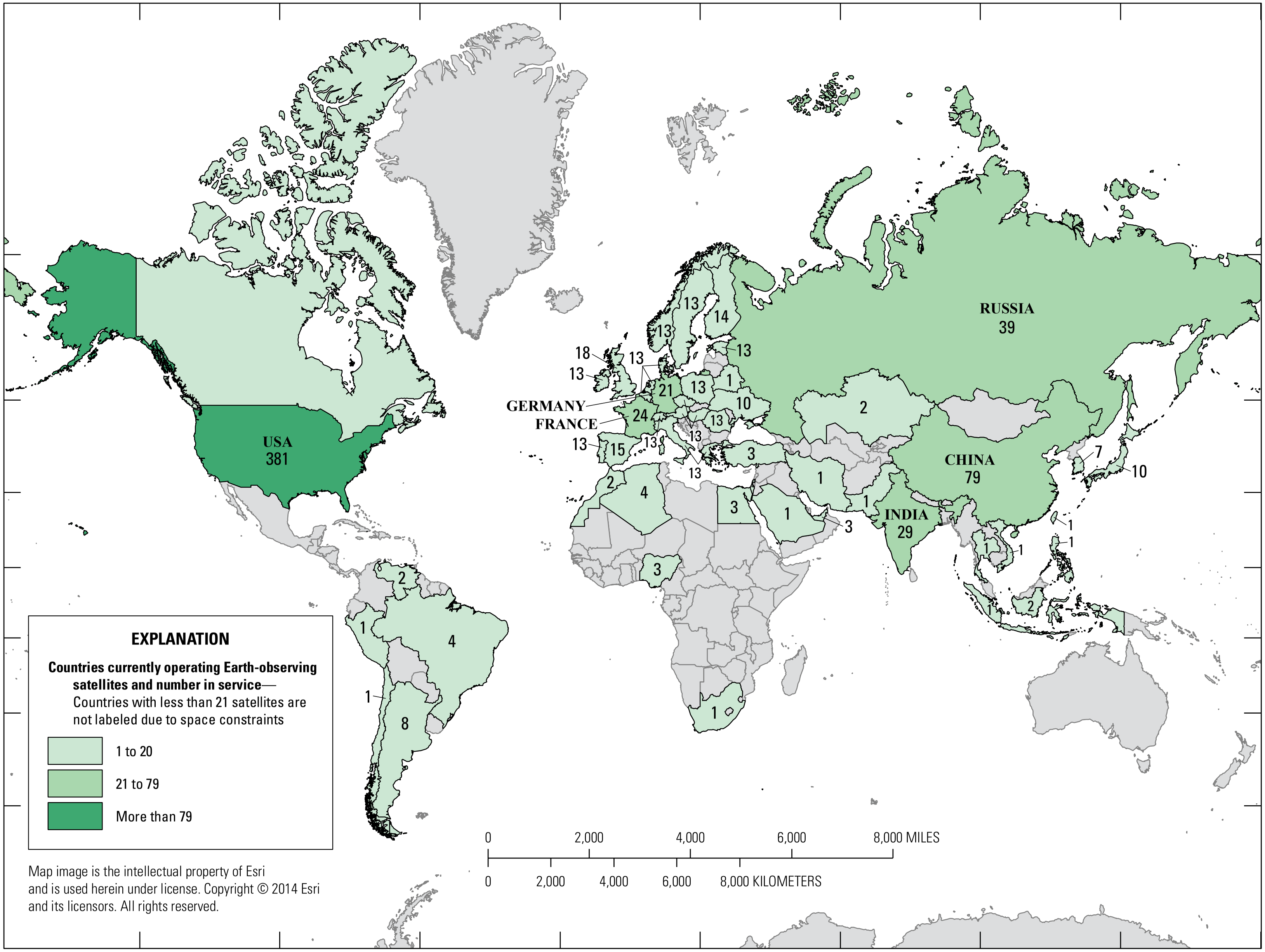


Figure 8. Countries currently (2018) operating Earth observing satellites with number in service.

Contributing Trends—Space is Cheaper and Easier

Several factors stand out in making access to space and operations in orbit less difficult and lower in cost than before. Specifically, satellites can be made smaller, cheaper, and more reliable than in past decades. Also, the number of launch vehicles available to put satellites into orbit is growing rapidly while the costs of launch are coming down. Finally, new models for space operations—command, control, and communications—also are reducing on-orbit operational costs.

Satellite Costs and Reliability

As space technology matures, the availability of better components with greater reliability has increased. Also, satellite manufacturers are experimenting with componentry that is not traditionally classified as space-qualified hardware. As more experience has been gained in satellite development, components have become cheaper and more accessible. Today, it is possible to purchase what is essentially a "do-it-yourself kit" to build one's own CubeSat for a few thousand dollars. This is a favorite method of universities, and more than 300 university-built CubeSats have been launched to date.

Launch Services—Availability and Cost

Often, a substantial part of the cost of a satellite mission is dedicated to the launch. In an October 19th, 2017 press release, NASA announced a contract for $153.8 million to launch Landsat 9 into orbit in 2020. Typical U.S. Government Earth observation missions can cost hundreds of millions of dollars, even approaching $1 billion, with expensive launches contributing strongly to the total mission costs. Launch costs have long been a barrier to entry into Earth observation from space, but recent changes have reduced these costs, greatly lowering the barrier to entry.

Now, more countries than ever have space-launch capabilities. The Federal Aviation Administration's Compendium of Commercial Space Transportation 2018 lists 72 rockets from 11 countries currently in operation or development that can launch payloads into orbit. Those interested in launch services have numerous choices now to fit schedule, budget, and orbital needs. The company, Planet, in orbiting its full Mission 1 constellation of satellites, launched its Flock of Dove satellites on at least 9 types of rockets from 4 different countries.

New and well-established launch providers are competing to push down the cost of access to orbit. On their website, https://www.spacex.com/about/capabilities, SpaceX prices a Falcon 9 launch, which can put 22,800 kg (50,265 lbs) into low Earth orbit, at $62 million (SpaceX, 2018). There are numerous smaller low-cost launchers as well. Launch has become a commodity widely available at lower costs than ever before.

Chief among the technologies used to lower costs is the capability to launch multiple satellites from one launch vehicle. Doing so can distribute the cost of a single launch across multiple payloads, resulting in each satellite incurring only a fraction of the total launch cost. Multiple-launch capability was demonstrated most dramatically when India established a new multiple-launch record in February 2017 by successfully delivering 104 individual satellites into orbit for multiple customers in 1 single Polar Satellite Launch Vehicle launch.

Supporting Infrastructure

Several technologies that have lowered operational costs and improved the capabilities and success of operating Earth observation satellites have emerged. Examples of these technologies are Global Positioning System and other global navigation satellite systems. These technologies have simplified precisely determining the location of satellites for satellite operators, which has improved the geolocation of their data products. The availability and reliability of high-speed internet transmission allows rapid data movement at low cost, which shortens the time from area of interest overflight to data availability for customers. Operating constellations of satellites can result in a lower cost per satellite for mission operations. Ground receiving stations have become cheaper and more widely available. For example, a startup company has received funding to establish a business facilitating satellite operators sharing receiving antennas with one another, which reduces the effect of operational costs for both.

Contributing Trends—Remotely Sensed Data Usage

As impressive as the technological improvements and cost reductions are of going into space, the improvements on the ground for receiving, processing, archiving, and distributing the data and information provided from land remote sensing satellites have been even more dramatic.

Information Technology

In the early days of Landsat, the volume of digital data comprising a single Landsat scene was beyond the computing power of all but Federal Government agencies and a few research universities. Most early users of Landsat data did their work on photographic prints made from Landsat images. Large photographic prints of Landsat images being developed at the USGS EROS Center circa 1976 are shown in figure 9.

From the beginning of the Landsat era in 1972 to the present day, computing power has grown exponentially while

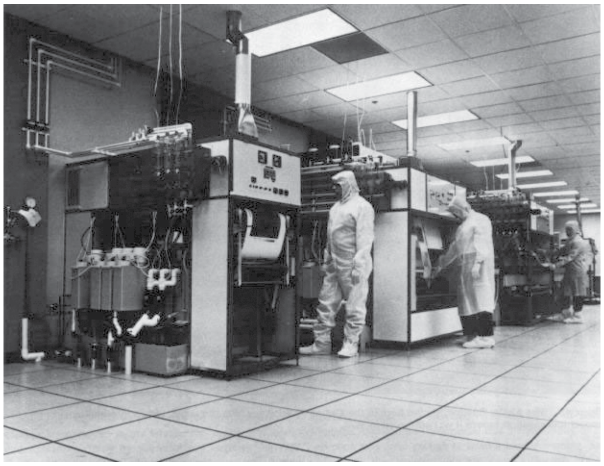


Figure 9. Photographic Landsat images being processed at the U.S. Geological Survey Earth Resources Observation and Science Center [Source: USGS EROS Data Center].

becoming cheaper and more commonplace. Working with a single Landsat digital image in the 1970s required computer "mainframes" found only in the largest business, universities, or government facilities; today it is done easily on modest personal computers. Similar advances have also occurred in data storage and transmission technologies and costs. The computing power necessary to work with remotely sensed imagery that had once been available to only a few is now available to nearly anyone.

Supporting Factors

Although the stunning growth of information technology is responsible for much of the improvement to using remotely sensed data on the ground, other factors have also affected the growth and acceptance of using Earth observation data. Education is among the first of these influencers.

When Landsat was first launched, the field of satellite Earth observation did not exist. Users had to be shown the potential of these new data and trained in their use. A primary mission of the USGS EROS Center within its' first decades was to educate and train users from around the globe, enabling them to benefit from this new wealth of Earth observation data. As universities, with the help of government agencies, developed Earth science programs and, through research, built a solid base of knowledge using these data, more people were exposed to the potential of using Earth observing imagery and data. Technology has advanced from simple red, green, blue images to land-imaging sensors collecting data in many tens to hundreds of wavelengths, not to mention active remote sensing capabilities.

As of 2018, progress is rapidly being made in what is referred to as "the cloud," a term referring to enormous collections of thousands of computer processors and associated storage being offered by several large firms. Using the collective processing power and storage offered in these cloud services, users of remotely sensed data can execute queries algorithms across vast amounts of data records from multiple satellites and rapidly arrive at solutions for current challenges experienced across the globe today. The promise of being able to directly, efficiently, and quickly extract information is becoming a reality.

Although advancements have been made in making remotely sensed data more usable to scientists and professionals, another presence has made remotely sensed imagery available and accepted by millions: online mapping. Online mapping programs began in the 1990s with line-drawn maps. With the advent of Google Earth and Google Maps in the mid-2000s, along with similar products and services offered by others shortly thereafter, the popularity of online mapping applications has continued to increase. These tools and applications brought to the masses the ability to overlay maps with actual satellite imagery of the Earth. Suddenly, digital imagery over the planet with reasonable geolocation was available to anyone with an internet connection. Land remote sensing satellite data are no longer the exotic tool of the few but a common tool within reach of billions of people around the globe.

Trends in Satellite Land Remote Sensing

As the JACIE team has worked with the growing satellite remote sensing community, several potential trends have been noted and discussed. Trends such as the rapid growth in numbers of commercial satellites launched (fig. 10) have been mentioned already, with Planet being the largest single contributor to the number of satellites up to this point. However, the number of individual satellites launched may trend downwards somewhat in the coming years as new technologies allow low-cost smallsats and CubeSats to do more.

The spectral capabilities of land-imaging systems launched during this recent surge have been dominated by the 3-band or 4-band satellites delivering only visible or visible plus near-infrared (VNIR) imagery as shown in figure 11. The technology for producing imagery in these spectral ranges lends itself well to small, low-cost imagers; however, there has been growth in the number of multispectral instruments (5–36 bands) and even a few super-spectral or hyperspectral instruments.

The Four Resolutions

There are four resolutions that contribute to the utility of land imagery: spatial, spectral, temporal, and radiometric resolution. Particularly as commercial remote sensing has grown over the last two decades, JACIE has observed progress made first in spatial resolution, followed by improved spectral resolution, and now in temporal resolution as high agile satellites and large constellations provide near-daily or daily coverage. During this same period, governmental systems

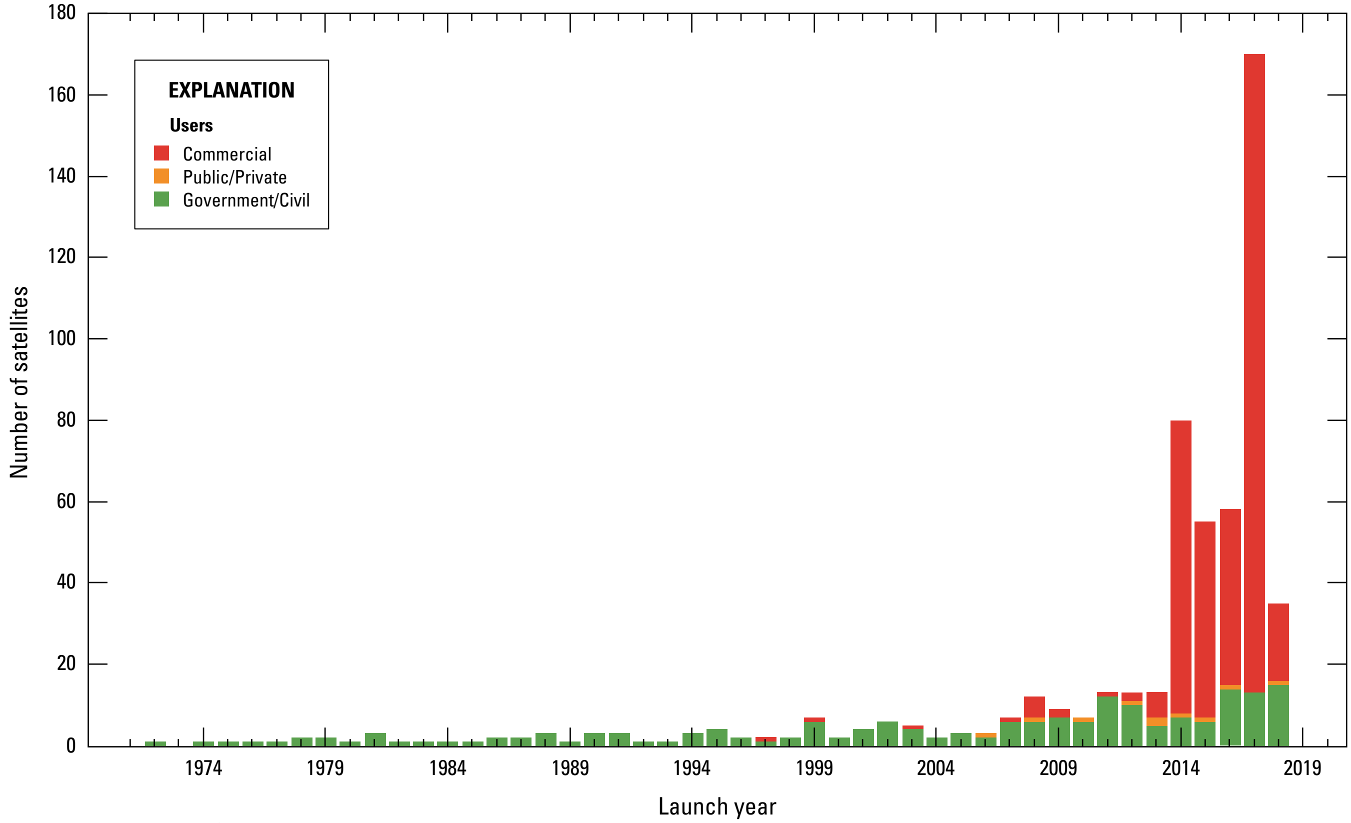


Figure 10. Satellite launches by year.

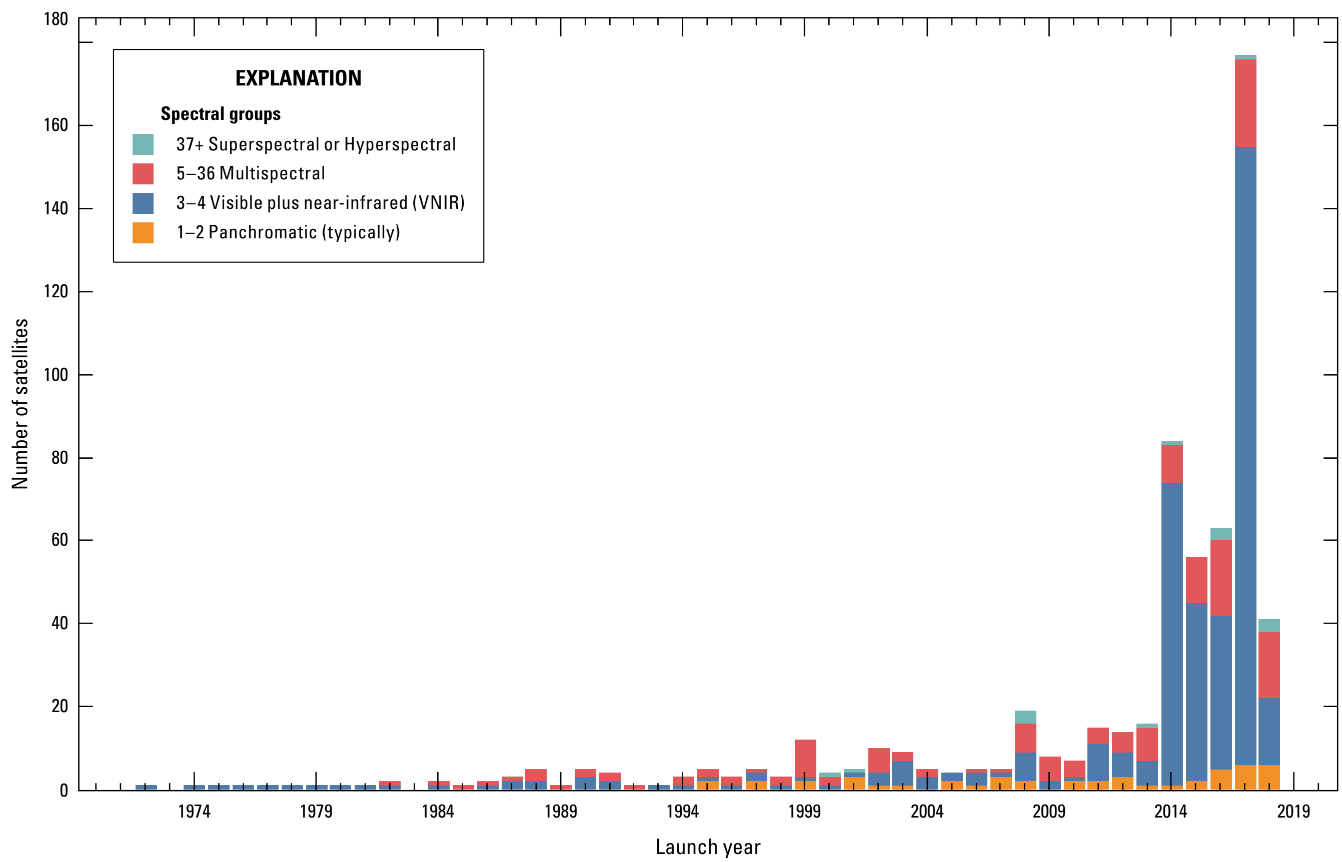


Figure 11. Spectral capability trends.

have improved their radiometric resolution from typical 8-bit resolution to 12-bit and now 14-bit resolution.

Synthetic Aperture Radar—The Promise of Radar

Using radar to measure the Earth's land masses moved out of the classified realm and into the civilian and commercial world with the launch of Canada's Radarsat-1 in 1995. Radarsat and other satellites like it use SAR to measure the Earth's surface at increasingly finer resolutions of 1 m or less during day or night and even through clouds. Adoption and wide use of these datasets were initially hindered by the complexity of SAR data and the processing power they required. Technical advances have reduced these limitations substantially, and the number of SAR satellites being launched, although still less than that of optical imagers, has grown in recent years. The year 2018 saw the first launches of SAR smallsats from companies planning constellations of SAR satellites for the commercial market (fig. 12).

A

B

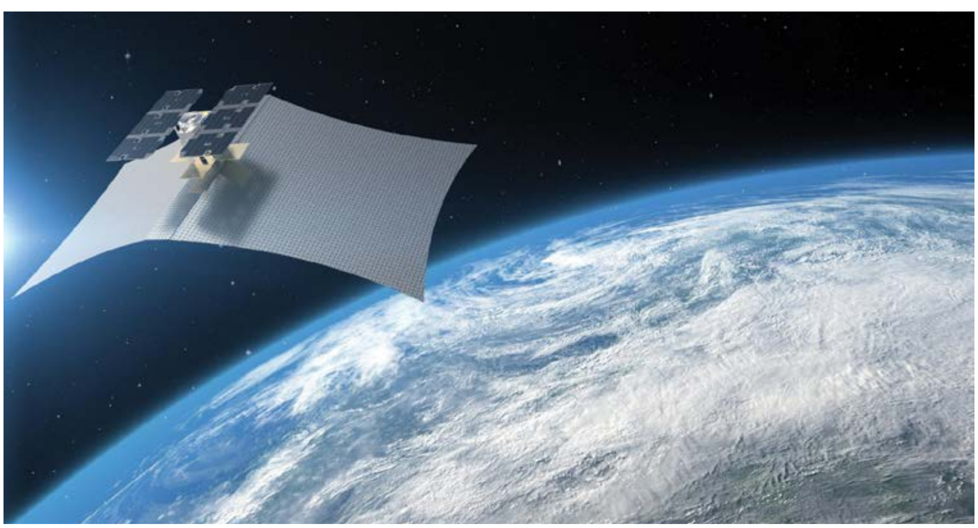


Figure 12. Images of two new commercial synthetic aperture radar satellites launched in 2018. *A*, IceEyeX2; and *B*, Capella Space [Source: ICEYE, Capella Space, used with permission].

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National Research Council, 2013, Landsat and beyond—Sustaining and enhancing the Nation's land imaging program: Washington, D.C., The National Academies Press, 76 p. [Also available at https://doi.org/10.17226/18420.]

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Satellites have captured views of the numerous major fires burning in California.

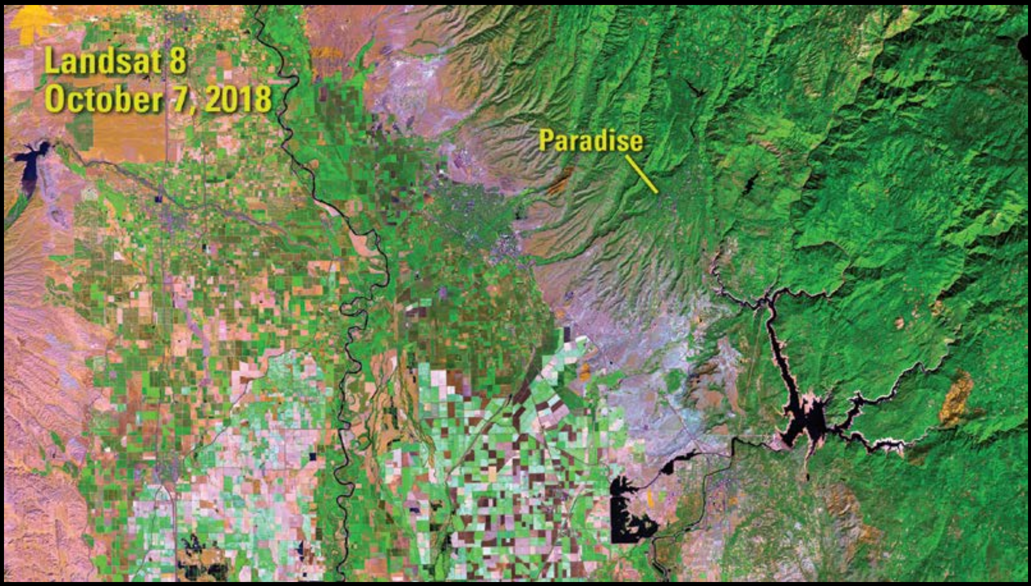
An image acquired on November 9, 2018, from NASA's MODIS sensor on the Terra satellite shows smoke pouring out of two major fires, the Camp Fire and the Woolsey Fire, which both ignited the day before.

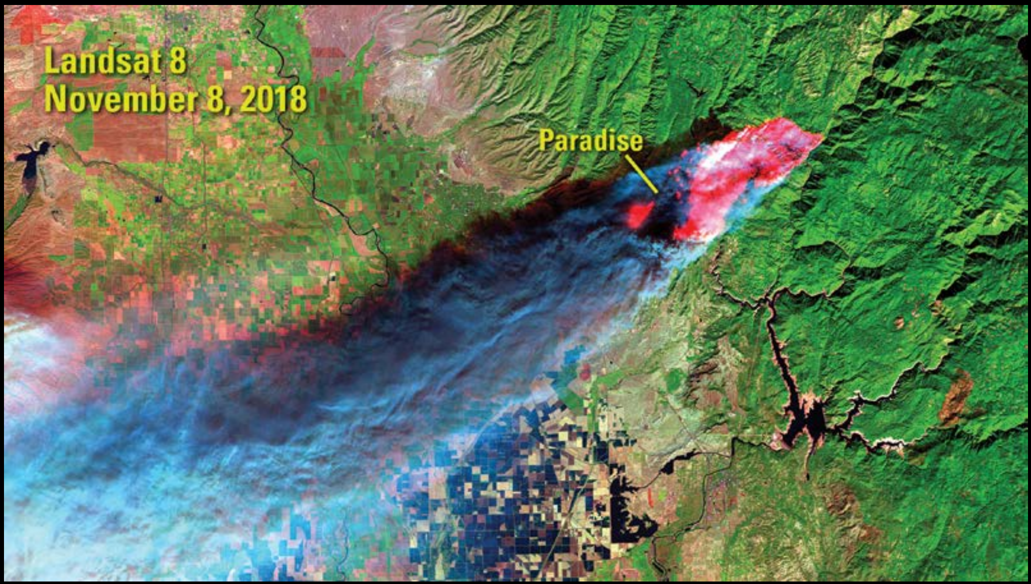
In the north, the Camp Fire quickly became the deadliest wildfire in the State's history. Landsat 8 captured an image of the fire hours after it started, and intense northeasterly winds and dry fuels caused the fire to spread rapidly. The Camp Fire burned over 100,000 acres in just 2 days.

Over 6,500 homes were destroyed, most of them in Paradise, a city of 27,000 people.

In southern California, Santa Ana winds fanned the flames of the Woolsey Fire. This fire has burned over 97,000 acres.

The enormous fire scar is the maroon color between the urban areas of Los Angeles, Thousand Oaks, and Malibu. The scar from the Hill Fire is also visible to the northwest.





Orbits of Earth Observation Satellites

Earth observation satellites differ in terms of orbit, sensor payload, sensor or satellite agility, and spectral and spatial resolutions. These parameters are designed based on the mission requirements and applications. Although some orbits provide high revisit frequency, wide swaths, and low resolution, others provide lower revisit frequency with higher resolution. The orbits most commonly used for Earth observation are discussed below.

Sun-Synchronous Repeat Orbits

In a Sun-synchronous orbit (SSO), the angle between the satellite's orbital plane and the Sun is constant. To maintain this constant angle as the Earth revolves around the Sun, the plane of an SSO must also rotate, or precess, around the Earth at the same rate that the Earth orbits the Sun—once per year or 0.986 degree (°) per day. This precession is caused by the Earth's oblateness interacting with a satellite in an orbit that is slighting inclined beyond a perfectly 90 ° polar orbit. The precise angle of inclination necessary to provide the proper rate of precession changes with orbital altitude (fig. 13).

An SSO can either be circular or elliptical. The nodal precession of the circular SSO is a function of its altitude and inclination, whereas, for an elliptical SSO, it is a function of altitude, inclination, and eccentricity. The maximum altitude for a circular SSO is 5,964 km with a corresponding inclination of 180 °.

Subrecurrent Orbit

A satellite in a subrecurrent orbit repeats its original orbit after a certain period, typically days, which enables the satellite to observe the same area at regular intervals. A subrecurrent SSO is the most commonly chosen orbit for land remote sensing. In such an orbit, a satellite observes the Earth from the same viewpoint at the same local solar time and minimizes changes in illumination and other diurnal variability, thus aiding in subsequent analysis. The near-polar inclination of SSOs also provides coverage of nearly the whole Earth, as illustrated in figures 14 and 15.

The first Sun-synchronous satellite was the Satellite and Missile Observation System (SAMOS-2), launched on January 31, 1961, for U.S. military photographic reconnaissance. Meteorology was the first civilian use of SSO, with the satellite Nimbus-1 launched on August 28, 1964. Nimbus-1 was followed by the TIROS-9, TIROS-10, and Defense Meteorological Satellite Program satellites.

The first use of an SSO for U.S. civilian land remote sensing was Landsat in 1972. Every Landsat has been launched into an SSO. Other early missions to use SSOs were the French SPOT, the European Remote Sensing Satellites, the Indian Remote Sensing Satellites, and the Russian Resurs satellites. Today, most, although not all, land-imaging satellites are in Sun-synchronous orbits. Numerous subrecurrent SSOs are shown in figure 16.

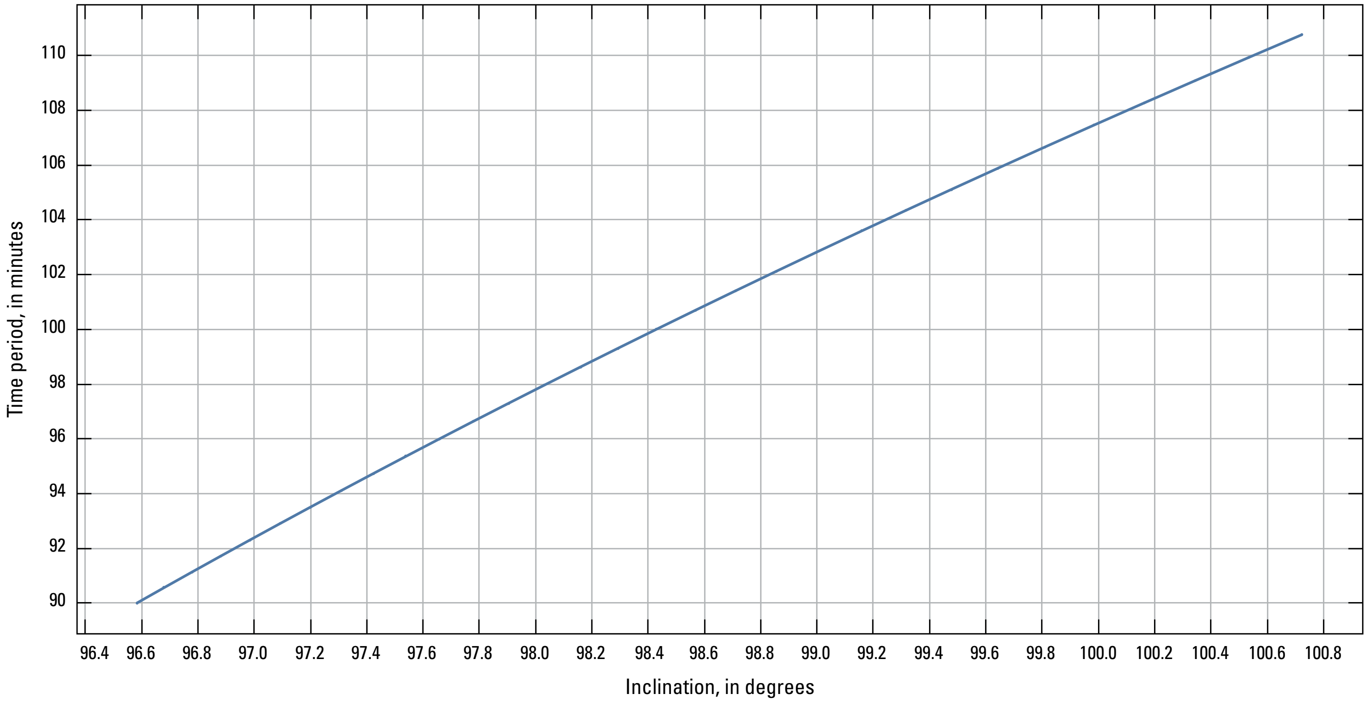


Figure 13. Period differing by inclination angle.

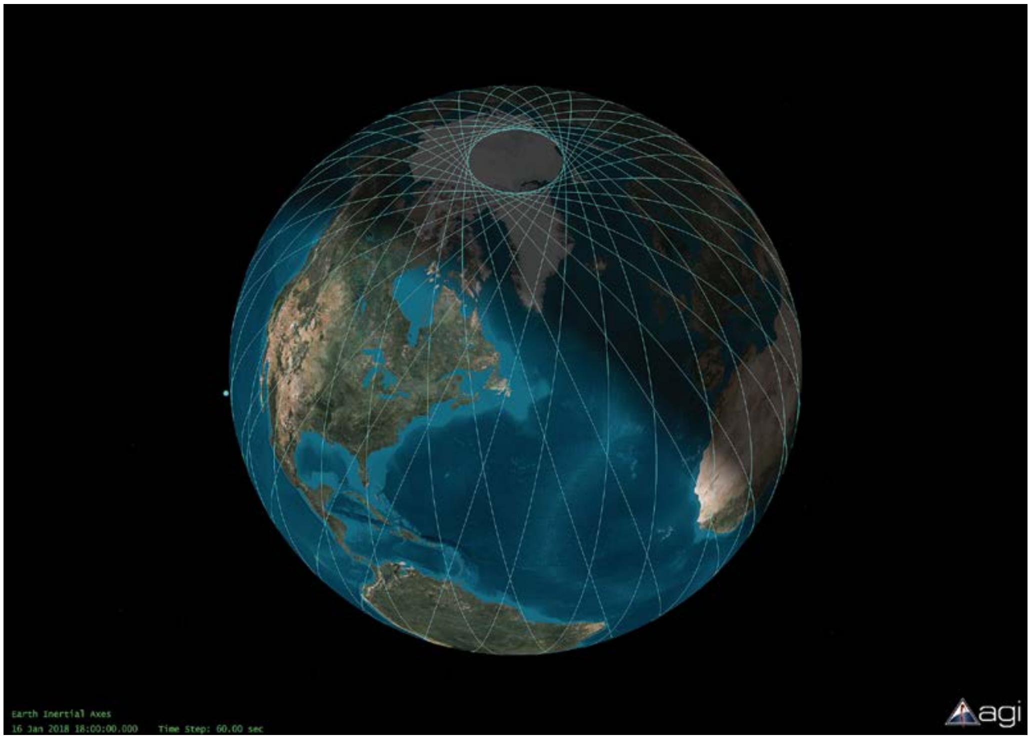


Figure 14. Example coverage constraints for a Sun-synchronous orbit satellite—three-dimensional view.

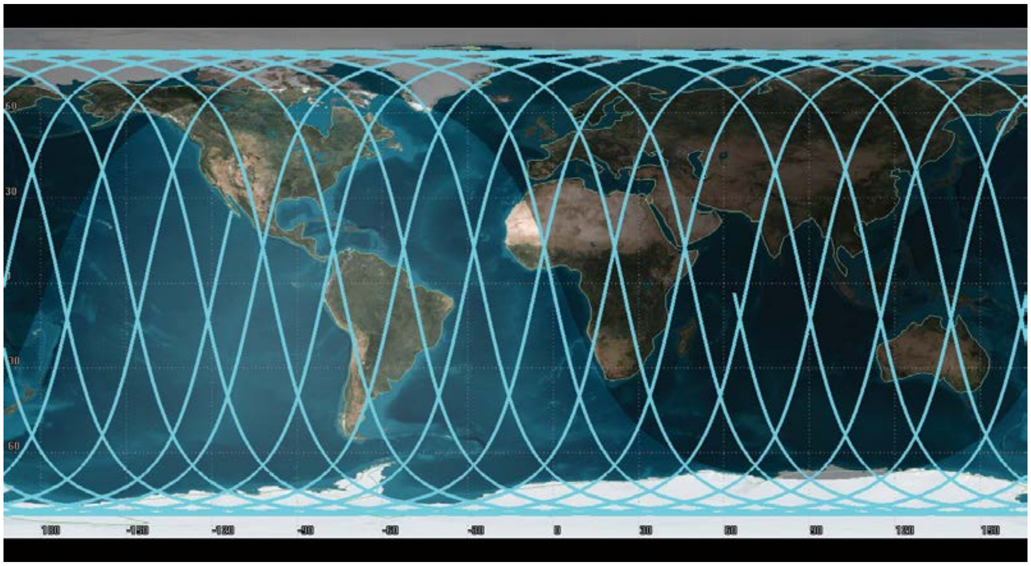


Figure 15. Coverage constraints of a satellite in a Sun-synchronous orbit—two-dimensional view.

Geosynchronous Orbit

A satellite is said to be geosynchronous if its motion around the Earth and the rotation of the Earth about its axis have the same angular frequency. Geostationary orbit is a special kind of geosynchronous orbit with zero inclination and a constant altitude. These orbits circle the Earth above the equator at an altitude of 35,786 km. At this altitude, the satellite's orbital period matches the Earth's rotational period and, therefore, the satellite appears to be stationary over a fixed position. The speed of a geostationary satellite is about 3.07 kilometers per second (km/s) or 11,068 kilometers per hour (km/hr; 6,878 miles per hour). Geostationary orbits are useful for weather monitoring, communication, and Earth observation because they can provide a continuous view of the same surface area. However, because satellites in geostationary orbits can only see one side of the Earth (see fig. 17), their views become increasingly slanted as one moves farther to the "edges" of the side of the Earth being viewed. Because of the much greater distance from the Earth, 50 or more times the distance of typical land-imaging satellites, the resolution achievable using geostationary orbit is proportionally coarser.

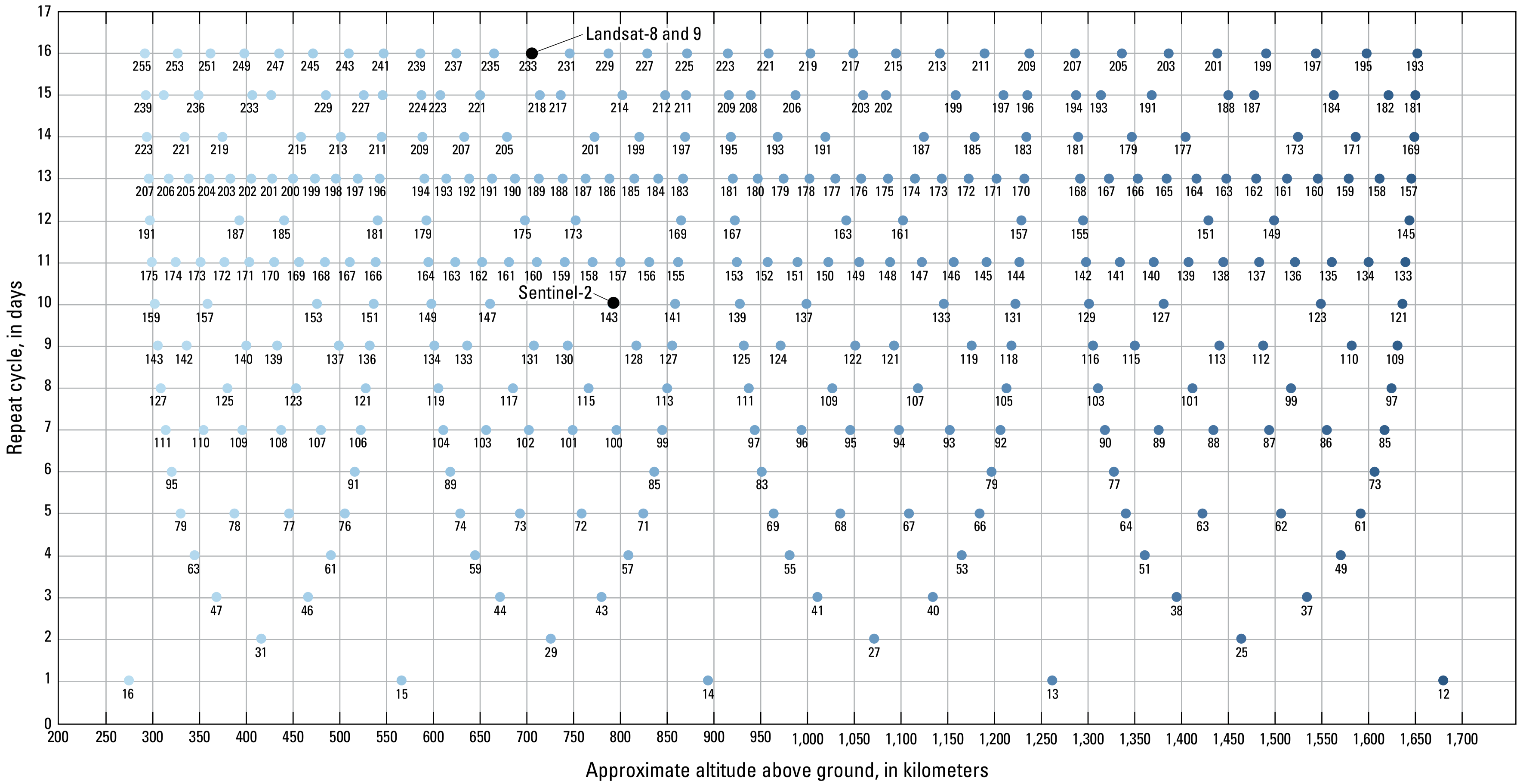


Figure 16. Satellite altitude versus repeat cycle in a subrecurrent Sun-synchronous orbit. Increasing color intensity shows the increasing trend of inclination with increasing altitude, and the number beside each point is the number of orbits required before repeating.

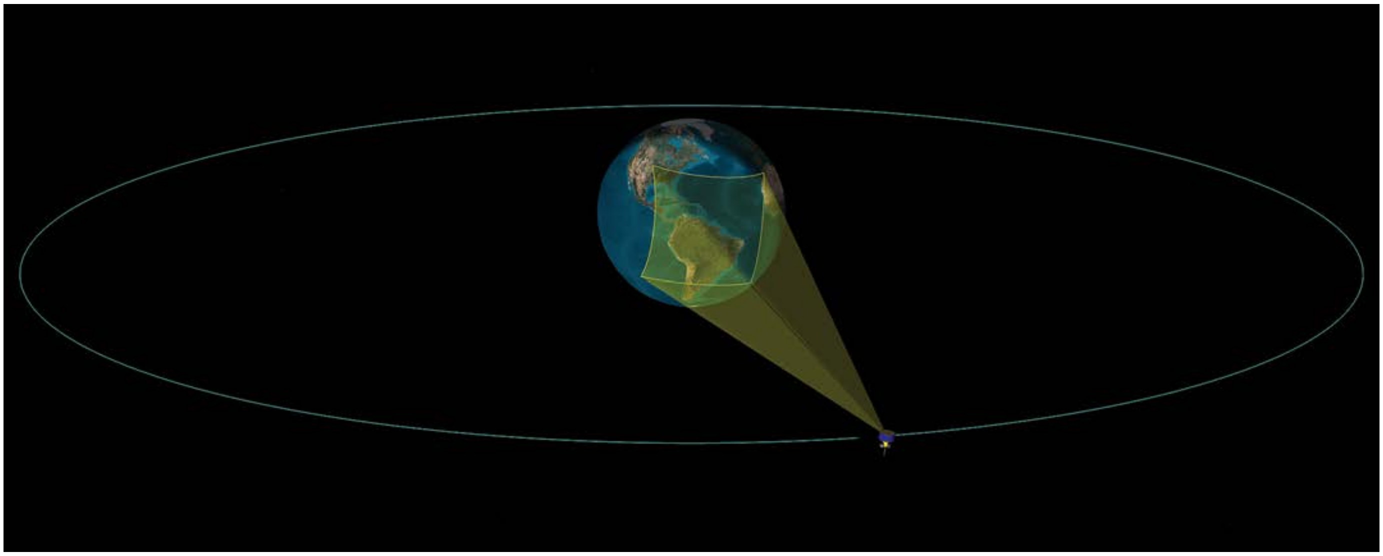


Figure 17. Coverage constraints of a satellite in geostationary orbit—three-dimensional view.

The first use of geosynchronous orbits started with the U.S. satellite series synchronous communications satellite (Syncom) in 1963 for experimenting with communications from space. The first images from geostationary satellites were taken by the Application Technology Satellite (ATS-1), but the first meteorological satellite on this orbit belonged to the Synchronous Meteorological Satellite (SMS) series, launched in 1974. These were followed by the Geostationary Operational Environmental Satellite series launched by NOAA starting in 1975.

Low-Altitude Orbits—International Space Station Orbit

The International Space Station (ISS) is a unique scientific platform that enables researchers from all over the world to put their talents to work on innovative experiments that could not be done anywhere else. The ISS orbits the Earth in a 90-minute, 400-km low Earth orbit at a 52 ° inclination to offer a unique vantage point covering more than 90 percent of the Earth's population (figs. 18 and 19). This orbit also provides improved spatial resolution because of a lower altitude than typical SSOs used for Earth observation. Earth observing satellites and sensors operating in this orbit contend with varying lighting conditions.

The ISS is a multinational effort to advance science and technology. The participating nations use the platforms on the ISS for remote sensing of the Earth. Current platforms aboard the ISS include Teledyne-operated DLR Earth Sensing Imaging Spectrometer (known as DESIS), NASA's Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station (known as ECOSTRESS), Urthecast's Theia and Iris sensors, and many more. ISS-based low Earth orbits have also been used by Planet for several of their Dove satellites to acquire higher-resolution Earth imagery, particularly during their demonstration and development phase.

Combined Repeat Cycle of Sentinel-2 and Landsat Satellites

The combined repeat cycle (CRC) is the repeat cycle achieved with two or more satellites. Landsat 7 and Landsat 8 are currently operational in an SSO at an altitude of 705 km with a 16-day repeat cycle. The sensors on both satellites have a swath width of 185 km at nadir. The offset between these satellites in orbit provides a CRC of 8 days to image any point on the Earth. When it launches in 2020, Landsat 9 is planned to replace Landsat 7 and to continue the same 8-day CRC with Landsat 8.

The European Space Agency, with its Copernicus Mission, launched Sentinel-2A and Sentinel-2B into an SSO at an altitude of 786 km with a 10-day repeat cycle. The sensors have a field of view of 20.6 ° to provide a swath width of 290 km. Both Sentinel-2 satellites are in the same orbit 180 ° apart (that is, on opposite sides of the Earth) to provide a CRC of the Earth of 5 days.

A combination of two Landsat satellites and two Sentinel-2 satellites can be used to achieve a high revisit frequency for acquiring imagery. Locations at high latitudes are imaged more frequently because of overlapping footprints. As shown in figure 20, the combination of two Landsat satellites and two Sentinel-2 satellites allows imaging revisits varying from a maximum of 5 days between imaging to a minimum of same-day imaging at locations near the equator. Locations at higher latitudes benefit from increasing the overlap produced by the decreasing distance between orbital paths, allowing many areas to be imaged at even shorter revisit rates.

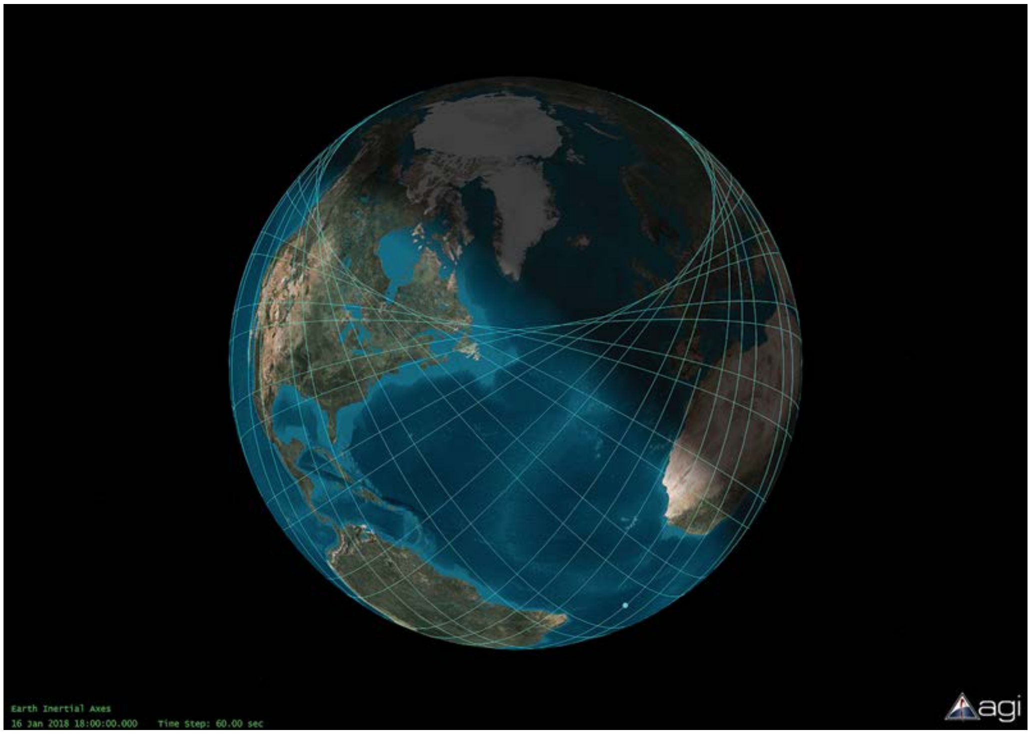


Figure 18. Coverage constraints of a satellite in International Space Station-based orbit—three-dimensional view.

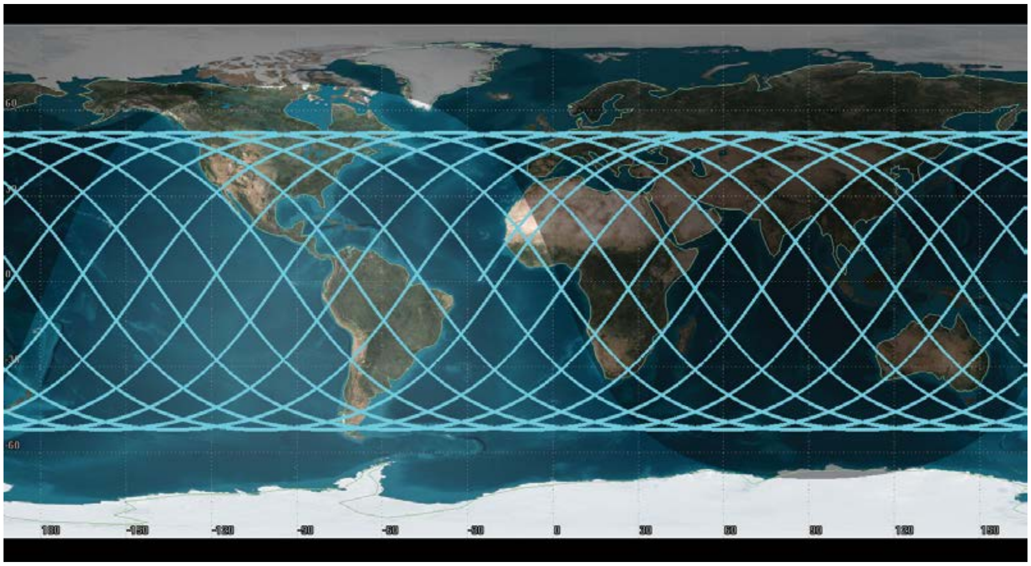


Figure 19. Coverage constraints of a satellite in International Space Station-based orbit—two-dimensional view.

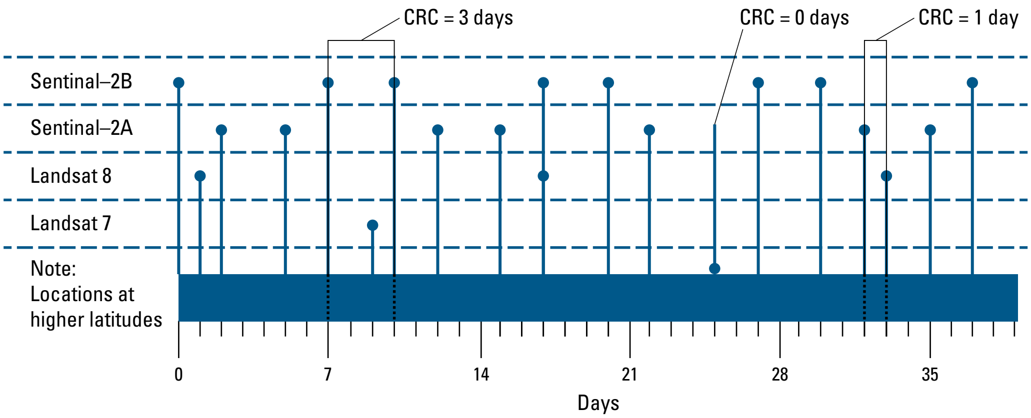


Figure 20. Combined repeat cycle (CRC) of two Landsat satellites and two Sentinel-2 satellites.

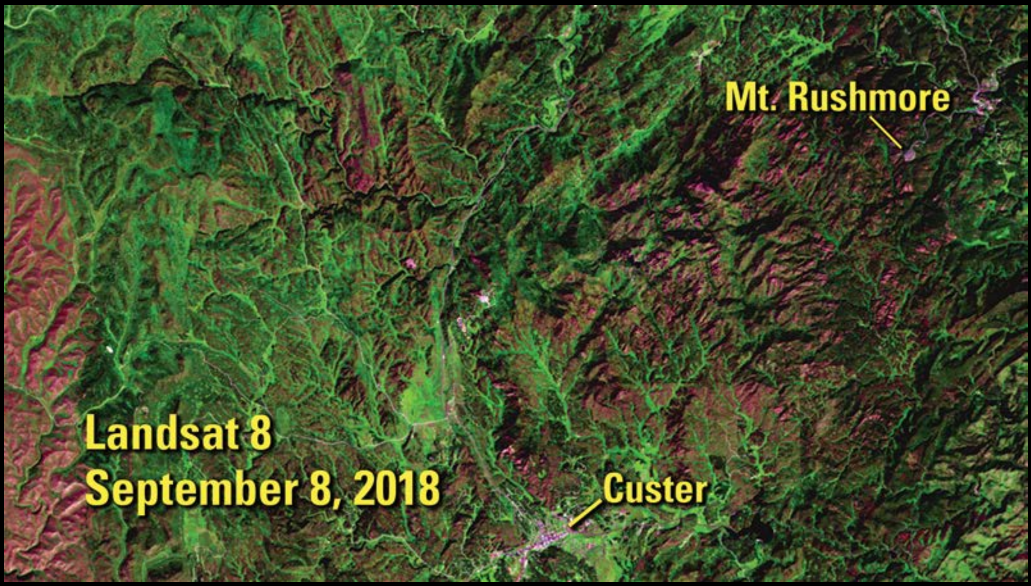
The images below show the ponderosa pine forests in the Black Hills of South Dakota.

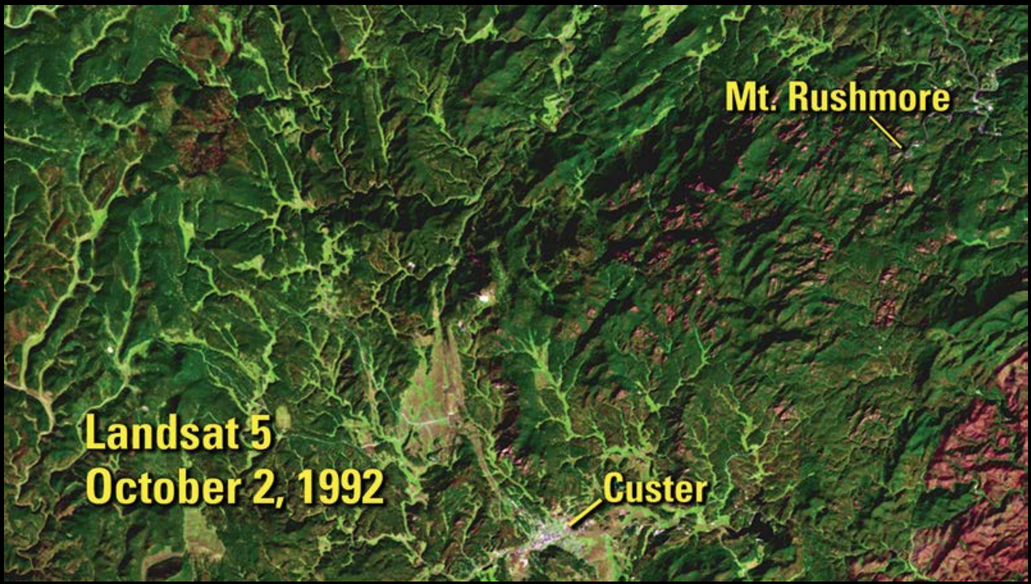
Mountain pine beetles are about the size of a grain of rice, so of course we cannot see them from space in satellite images. What is visible is what the beetles can do to a pine forest. The washed-out pink color indicates large areas of standing dead or damaged trees.

Cold winters normally kill beetle eggs and keep the population down. Recent winters have been warmer than normal. Prolonged dry conditions in the early 2000s also weakened the trees and made them easier for the beetles to attack. These factors together led to a massive epidemic.

In 2018, precipitation in the Black Hills was above normal, and the beetles have remained at normal levels. The damage is done, however, and current Landsat imagery still shows the degraded forest.

Landsat is well suited to studying forest change over large areas. The Landsat record covers more than 46 years, and its visible and near-infrared range can pinpoint the beginning of future beetle attacks.





Remote Sensing Law and Policy

Historic Development—Reconnaissance to Commercial Remote Sensing Policy

Remote sensing was developed by the early space pioneers, the United States and the former Soviet Union, to gather intelligence information for defense planning. Both countries agreed on a common policy that allowed them to view each other's territories with reconnaissance satellites. The United States operated Corona satellites, while the Soviet Union relied on Sputnik and Kosmos satellites for reconnaissance. The first satellite image of a Siberian airbase taken by a U.S. reconnaissance satellite is shown in figure 21.

The policy between these two countries was formalized when the Outer Space Treaty was drafted by the United Nations (UN) in 1967. The Outer Space Treaty provided the foundation for the Principles Relating to Remote Sensing of the Earth from Outer Space, referred to here as the "United Nations Remote Sensing Principles" (UN RSPs). Concerns and discussions about remote sensing began with the Landsat age and, supported by multiple UN resolutions, took nearly 15 years of discussion amidst the different positions and conflicting interests of several nations before consensus was reached and the UN RSPs were formally adopted by the UN in 1986 (Ito, 2011).

The early proposals for UN RSPs were provided by participating UN nations. The United States proposed an open skies policy, providing the freedom to observe foreign territories from space. The open skies policy did not extend sovereign rights of states into space and insisted upon the freedom of remotely sensing and gathering information. Developing nations opposed the view held by the United States and argued that a country should have a sovereign right over remotely sensing their resources and the dissemination of any information regarding those resources. Most developed countries concurred with the United States, but the Soviet Union and developing nations opposed the open skies policy.

These initial proposals were followed by policy suggestions from Argentina, the Soviet Union, France, Brazil, the United States, Mexico, and Chile. Suggestions were focused on conditions for remote sensing including prior consent, limits on location and veto rights, priority access and controlled distribution of data, and international responsibility. Additional rules and suggestions for the dissemination of remotely sensed data were set forth during the Moscow convention of 1974 regarding the transfer and use of data for remote sensing of the Earth from space. This proposed 1974 policy would have prevented countries from disseminating data without the consent of the country being observed. The policy, however, was not ratified by the United States and other developed nations and, hence, failed to become globally accepted legislation on remote sensing.

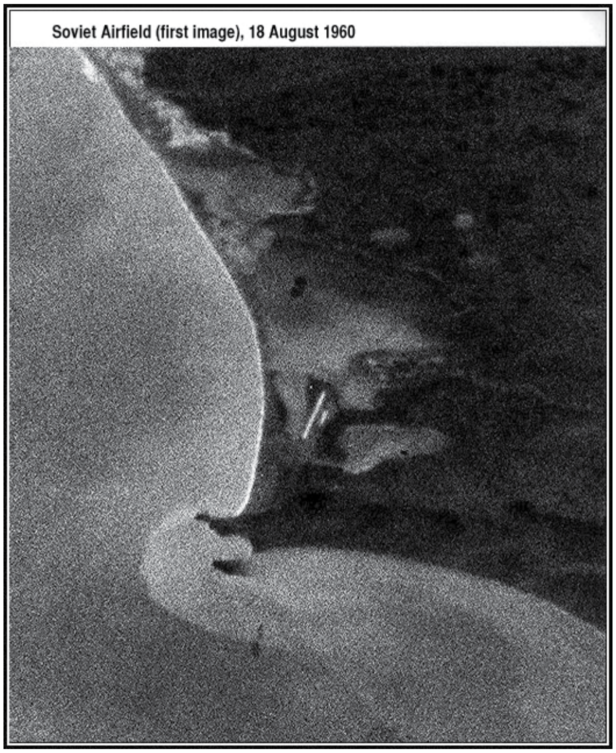


Figure 21. First satellite image of Siberian airbase in the Union of Soviet Socialist Republics [Source: National Air and Space Museum].

After the Moscow convention, consensus on a set of principles for remote sensing was achieved through difficult negotiations between developed and developing nations. With the emergence of civilian-operated remote sensing satellites, developed nations adhered even more strongly to the open skies policy. The United States began operating Landsat in 1972 with an open data policy and, in 1973, began working with international partners to offer direct downlinks of Landsat data at their own ground stations. The U.S. Land Remote Sensing Commercialization Act of 1984 was supported by France when they launched the SPOT system in 1986. The UN RSPs, which mainly reflected the view held by the United States with a high degree of compromise from developing nations, were drafted in 1986. Today these principles serve as a recommendation for international remote sensing activities. The parties, signatories and nonparties of the Outer Space Treaty are respectively shown in green, yellow, and red in figure 22.

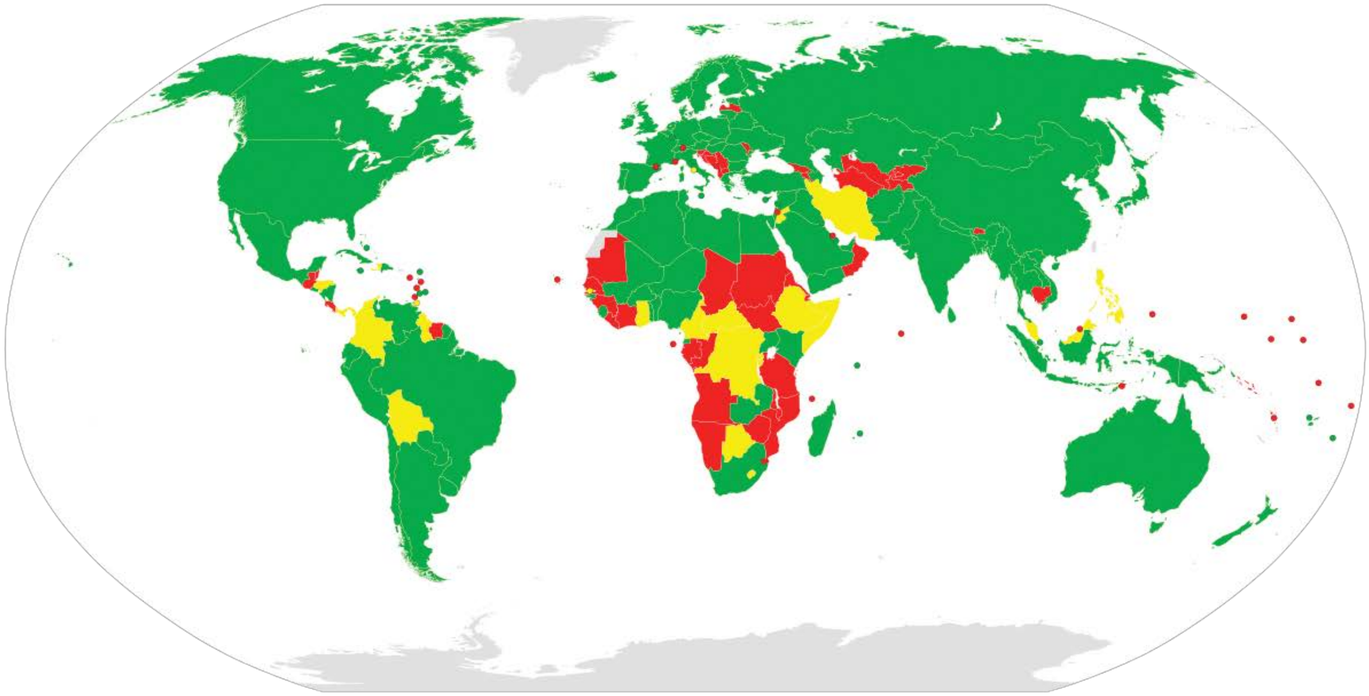


Figure 22. Green countries are parties of the Outer Space Treaty, yellow countries are signatories, and red countries are nonparties [Source: Wikimedia Commons, licensed under the Creative Commons Attribution-Share Alike 2.5 Generic license].

The UN RSPs comprises 15 principles that dictate the use of remote sensing activities for the benefit of all countries while improving natural resources management, land use, and the protection of the environment. Principle I defines basic terms of remote sensing, primary data, processed data, and analyzed information. Principle II states that the remote sensing activities should be carried out for the benefit of all countries. Principle III emphasizes that remote sensing activities be completed in compliance with the Outer Space Treaty. Principle IV states that the remote sensing activities should protect the sovereignty of all states and people over their own wealth and natural resources. Principle V mandates that countries completing remote sensing activities allow other countries to participate in such activities. Principle VI covers the establishment of ground stations to maximize the availability of benefits from remote sensing. Principles VII through IX discuss developed countries providing technical assistance to developing countries on mutual terms. Principles X and XI address use of remote sensing activities for disaster monitoring and protection of the environment. Principle XII, in the interest of developing countries, states that the acquired data over a developing country should be made available to that country on a nondiscriminatory basis. Principles XIII through XV discuss the peaceful use of space and remote sensing activities with international cooperation (United Nations Resolution 41/65, December 3, 1986).

The national remote sensing policies and laws drafted by countries regulate their remote sensing activities. In general, all national policies and laws contain the same fundamental principles: to use remote sensing activities for scientific, social, and economic benefit; to protect the environment; and for national security.

Differences exist in the usage of remote sensing data, such as resolution limits and data dissemination. National policies governing space remote sensing of major countries are discussed here.

Current Remote Sensing Policies of Major Space Remote Sensing Countries

United States

For more than 30 years, the remote sensing policy of the United States was guided by the needs of Landsat. In the last decade, however, satellite systems owned and operated by private organizations have emerged as complementary elements in U.S. remote sensing policy. The current policy supports civil and commercial observation satellites that are available and responsive to the Nation's diverse civil, national security, and commercial requirements for overhead imagery data of various types and resolutions (Williamson and Baker, 2004).

The remote sensing policy in the United States was developed to serve specific user purposes. The original policy drafted by the U.S. Government between the launch of Landsat 1 in 1972 and the Landsat Commercialization Act of 1984 was used as a basis to help draft the international principles for remote sensing. Following 1984, quasi-private entities were responsible for developing commercial policy. The principles of this commercial policy were included in the Land Remote Sensing Policy Act of 1992 (Public Law 102–555). After 1992, the focus remained on the improvement of the commercial policy while developing an environmental policy.

The Land Remote Sensing Policy Act of 1992 is the principle legislation governing U.S. remote sensing activities today and provides the overall framework for relevant policies. This act has been updated, complemented, and implemented by Presidential Decision Directive 23, the U.S. Policy on Foreign Access to Remote Sensing Capability, the Kyl-Bingaman Amendment to the 1997 Defense Authorization Act, the 2003 Commercial Remote Sensing Policy, and the 2006 Regulation on Licensing of Private Land Remote Sensing Space Systems.

The Land Remote Sensing Policy Act of 1992 designates the authority to license private remote sensing systems to the U.S. Department of Commerce. The U.S. remote sensing policy requires that national security and safeguarding foreign policy be considered in the licensing process. A company must disclose the amount of Government resources that go into the launch or operation of a system. The act states that the data generated by Government remote sensing systems are available on a nondiscriminatory basis. The commercial and public-private systems data should be provided "on reasonable terms and conditions" (Land Remote Sensing Policy Act of 1992).

The 2003 Commercial Remote Sensing Policy enhanced the competitiveness of private agencies by freeing restrictions on spatial, spectral, and radiometric resolution. The policy also indicates that the U.S. Government will encourage commercial industry and, when possible, will rely on the commercial data to fill the imagery and geospatial needs.

Canada

Remote sensing activities in Canada are regulated by the Remote Sensing Space Systems Act of 2005. This act applies to public, private, and public-private system operators in Canada. The Ministry of Foreign Affairs licenses remote sensing systems, taking national security and international relations and obligations into consideration. Raw data and remote sensing products acquired by the system about the territory of any country are made available to the government of that country within a reasonable time, on reasonable terms.

France

The remote sensing activities in France started with the launch of SPOT satellites in 1986. These activities are regulated by the general laws of the French Government. Remote sensing data collection and distribution also are protected by the 1986 UN RSP.

The law on space operations adopted by the French Senate in 2008 deals with the international obligations for authorization and control of activities in outer space and registration of space objects. Unlike other national remote sensing policies, the French policy requires the licensing entity to provide a declaration of its activities. The declaration should address the nature of the system and its objectives and should provide details on the following characteristics: data resolution, frequency of bands used, data accuracy, and data quality. The administrative authority of the French Government controls and monitors the licensee in protecting the fundamental interests of the nation.

Germany

Germany's domestic remote sensing policy is outlined in the Act on Satellite Data Security, which became effective in 2007 to address the first public-private partnership system, TerraSAR-X. The German Act establishes governmental control over the collection and dissemination of data to minimize threats to the security of Germany and other nations. Licenses are issued to satellite operators and data distributors for specific data transactions. Germany has a two-tiered security data policy, similar to the United States, and any mishandling of data can lead to incarceration.

India

The Indian Government is the sole and exclusive owner of the satellites and their data. The Indian Space Research Organization is the government organization responsible for the Indian space program. The National Remote Sensing Center, an organization under the Indian Space Research Organization, and Antrix Corporation, Ltd., under the Department of Space, is responsible for the acquisition and distribution of remote sensing data in India. Antrix Corporation, Ltd., is vested with the authority to disseminate Indian Remote Sensing Satellite data outside of India.

The Indian remote sensing policy is similar to the national laws and policies of other countries around the world. According to the Remote Sensing Data Policy of 2011, satellite data as fine as 1-m resolution are provided to all users on a nondiscriminatory basis. A screening process is defined for acquiring data of higher resolutions (Gabrynowicz, 2014).

Japan

Japan is in the process of building a space and data policy to regulate their remote sensing activities. The Remote Sensing Data Act is being developed to ensure adequate handling of satellite remote sensing data. The act establishes rules for proper use of remote sensing systems and regulates the distribution of remote sensing data to ensure the peace and security of the international community.

The Space Activities Act regulates the launch and control of the satellites in Japan. Nongovernmental entities require authorization from the Government of Japan to carry out launch activities. The Government of Japan completes prelaunch examinations to ensure compliance with safety standards and examine the capabilities and objectives of the systems.

Russia

The Law on Space Activities, published in 1993, regulates the licensing, launch and operations, and data distribution in Russia. Licenses are issued to entities and their systems to fulfill scientific purposes and improve the national economy. The development of the National Remote Sensing Development Concept is currently in progress. In 1992, Russia commercialized high-resolution data acquired by their reconnaissance satellites. Data at resolutions as fine as 2 m can be available for other countries with mutual agreements.

United Kingdom

The space activities in the United Kingdom are regulated by the Outer Space Act of 1986. According to this law, the Secretary of State is responsible for issuing licenses for space systems that comply with rules regarding the safety of the people, maintaining international peace, and national security.

China

China does not have a national space law but expects to introduce one by 2020. A space law was drafted into its national 5-year plan in 2013 (Wu, 2018). The current space activities in China are regulated by the UN RSPs.

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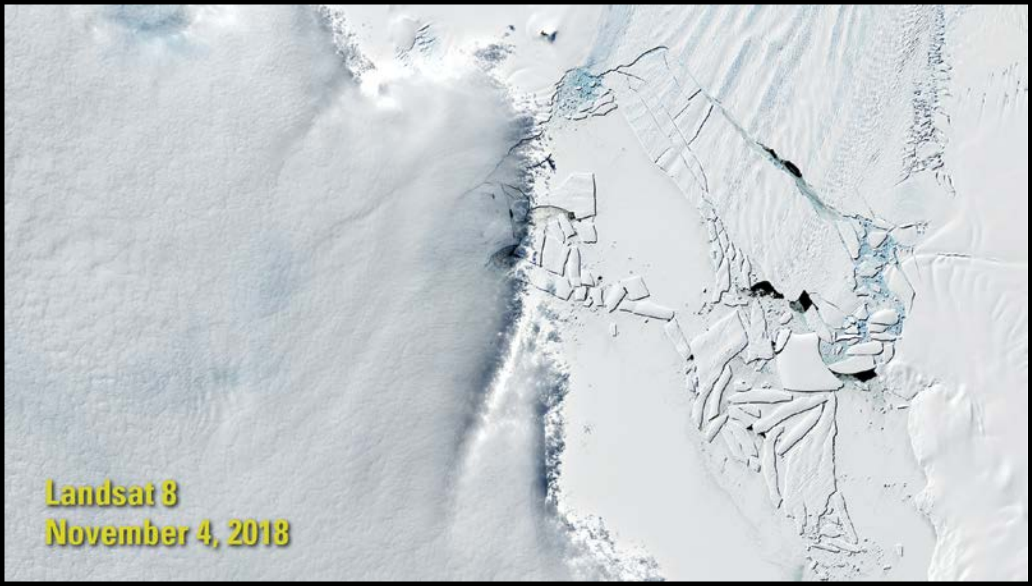
Another large iceberg recently broke off Pine Island Glacier, Antarctica. According to the U.S. National Ice Center, this iceberg, named B-46, has an area of 87 square miles. That is slightly larger than the iceberg that previously separated from the glacier in September 2017.

B-46 broke away on October 29, 2018, just a month after a rift first appeared. The October 1 image acquired by Landsat 8 shows the beginning of the rift.

Iceberg calving is natural part of glacial change, but these large breaks are happening more frequently on Pine Island Glacier. Since 2013, the glacier has calved four large icebergs.

A Landsat-1 image from 1973 compared to 2018 shows the glacier's retreat over 45 years.



An Overview of Russian Earth Observing Systems

Russia, formerly the Soviet Union, is a major space power and has completed many firsts in space including the first artificial satellite, Sputnik (fig. 23); the first man and woman in space; and the first lunar flyby. During the Cold War, the Soviet Union operated many satellites for military purposes. The Ministry of Machine-Building, established in 1965, was the civil agency responsible for space activities during the Cold War. It became the precursor for the Russian Space Agency after the dissolution of the Soviet Union in 1991. The current Russian state space corporation, Roscosmos, was formed in 2015 by a Presidential decree and combined the Russian Space Agency and the United Rocket and Space Corporation. The organization is currently chaired by former Deputy Prime Minister Dmitry Rogozin.

Roscosmos is the government body for all the space activities in Russia. It has many subsidiaries including Glavkosmos, NPO Energomash, Lavochkin, Reshetnev Company, TsNIIMash, and Krunichev State Research and Production Space Center. These organizations are responsible for activities such as manufacturing rockets, satellites, and launch facilities and for leading science. Military armaments and missile manufacturing organizations in Russia also work under the guidance of Roscosmos. Glavkosmos promotes the Russian space industry achievements in the world market and manages the commercial space projects. Reshetnev Company is the prime manufacturer for the Roscosmos spacecrafts.

Roscosmos is focused on human space flight and space exploration. Their Soyuz spacecraft is being used by NASA and the European Space Agency to carry astronauts to the ISS. Russia's current Earth observation efforts are limited compared to China and the United States. Russia's space budget has faced serious cuts in recent years. In 2014, the budget allocated for space endeavors in Russia equated to about $5 billion (U.S. dollars), equivalent to 28 percent of the NASA space budget. Because of depreciation of the ruble during the oil crisis in 2015 and 2016, Russia's space budget spending power fell to the equivalent of $1.6 billion (U.S. dollars) in 2016. For the 10-year period from 2016 to 2025, a federal space budget equal to $20.25 billion (U.S. dollars) was approved by Russia (Karash, 2016). Figure 24 shows a comparison between U.S. and Russian space budgets, in billions of U.S. dollars from 2014 projected out to 2023.

To proliferate their space programs, Roscosmos has been seeking international cooperation. Russia has signed an agreement with the Italian Space Agency to jointly launch a constellation of high-resolution satellites. The United States, in collaboration with Russia, is building a lunar gateway—a space station orbiting the moon. Russia also has plans to support China in building the Tiangong-3 space station.

During the Cold War, the Soviet Union had advanced Earth observing capabilities. Since the early 1960s, 2,500 Kosmos satellites have been launched to serve Earth sciences,

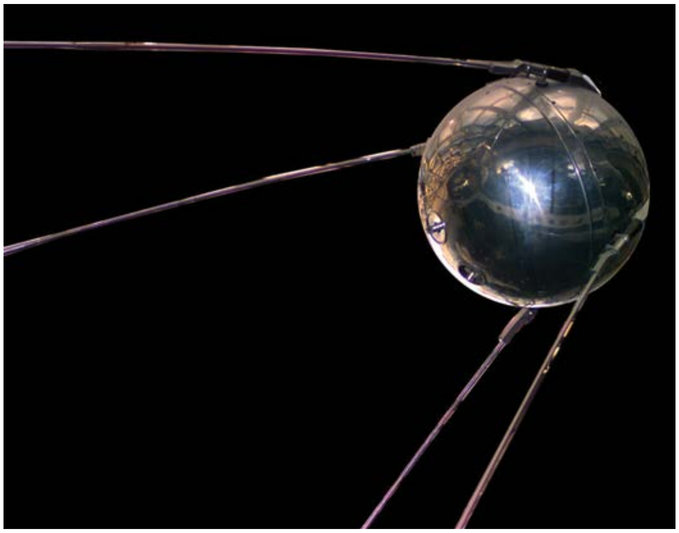


Figure 23. Sputnik—the first artificial satellite launched by the former Union of Soviet Socialist Republics [Source: NASA].

communications, meteorology, and military reconnaissance. Roscosmos has continued the launch of Kosmos satellites. Currently, Russia has more than 50 operational satellites in orbit. Russia has dedicated Earth observation programs to address key science needs, including Resurs for resource planning and natural disaster studies, Meteor-M for meteorological and ocean studies, Kanopus for disaster monitoring, and others serving civilian and military needs in Russia.

Resurs is one of Russia's most important operational Earth observation programs. The first satellite of the mission, Resurs-DK, was launched at the end of 2006 and was operational until 2016. Resurs-Prospective (Resurs-P) was the follow-on mission. The Resurs-P mission consists of three operational satellites launched in 2013, 2015, and 2016, and two more are planned to be launched in 2020 and 2021. The Resurs satellites carried a Geoton-L1 imager as the primary sensor designed to capture images of the Earth in the VNIR parts of the spectrum. The Resurs-P satellites also carried a GSA Hyperspectral Imager with 256 bands in the VNIR part of the spectrum and a medium resolution ShMSA multispectral imager imaging in VNIR. The main applications of the mission are to provide information for cartography, environment, and disaster monitoring and to monitor infrastructure development.

The Kanopus-Vulcan series of satellites for ecological monitoring, natural resources, mineral exploration, and topographic mapping started operations with the launch of Kanopus-1 in 2012. Kanopus-V-IK-1, an infrared satellite, was launched in 2017 to demonstrate infrared imaging capabilities. Kanopus V-3 and 4 were launched in February 2018 for high-resolution Earth imaging. All of these satellites are in SSOs at 500 km and carry multispectral and panchromatic imagers. The Kanopus series is planned to continue with the launch of Kanopus-VM satellites after 2020. An image of St. Petersburg, Russia, taken by the Kanopus-V-IK satellite is shown in figure 25.

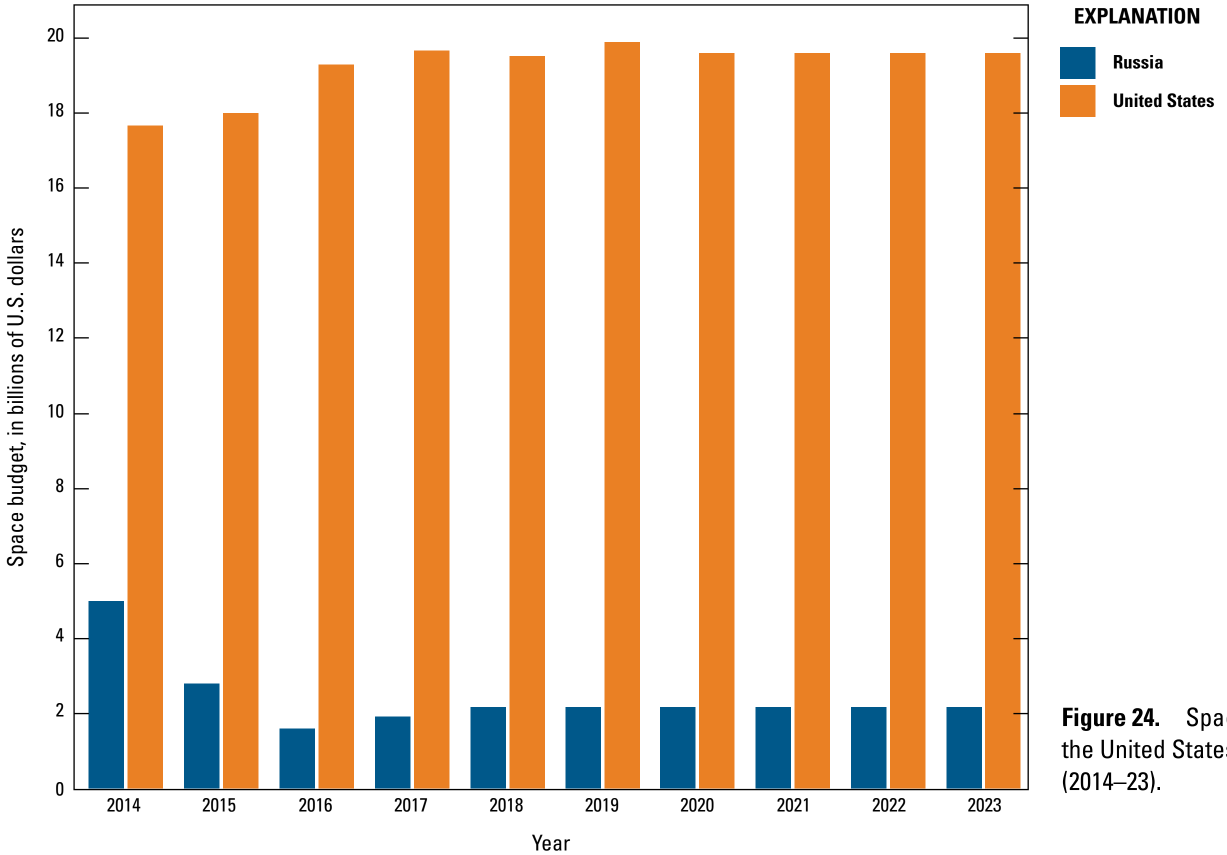


Figure 24. Space budgets of the United States and Russia (2014–23).

Figure 25. Kanopus-V-IK image of St. Petersburg [Source: Roscosmos].

Roscosmos began launching the Meteor-M series of satellites for meteorology and ocean monitoring in 2009 with Meteor-M N1, followed by Meteor-M N2 in 2014. Meteor-M N3 did not make it into orbit because of launch failure. Meteor-M N2 is currently operational with N2-2 and N2-3 planned to be launched in 2019 and 2021, respectively. Meteor satellites orbit the Earth in an 800-km SSO and carry two optical imagers (VNIR through thermal infrared [TIR] and an X-band SAR).

Electro-L1 and L2 are the second-generation geostationary satellites of Roscosmos, launched in 2011 and 2015, respectively, for ocean and weather monitoring. They are designed to capture real-time images of clouds and oceans using an optical imager operating in the VNIR part of the spectrum. Six more satellites are planned to launch in the Electro series by 2025. A complete disc of Earth captured by Electro-L satellite is shown in figure 26.

Obzor-O and Obzor-R are constellations of optical and radar satellites, respectively, planned for launch in 2019 and later. They will provide high-resolution images of Earth for resource monitoring, disaster mitigation, and cartography. The Obzor-O satellites operate in eight ranges of the spectrum, including visible and infrared, at a resolution of 5 m and 20 m, respectively. The Obzor-R satellites are planned to replace the Arkon-2M satellites, whose development was canceled in 2012. They carry a phased array radar to obtain all-weather images with resolutions as fine as 1 m.

Roscosmos also plans to operate the Kondor-FKA-M satellites based on the heritage of Kondor-FKA. The constellation of three S-band SAR satellites is planned for launch in 2019, 2020, and 2025 from the Vostochny spaceport. Applications include monitoring floods, forest fires, and snow avalanches; forecasting harvests; and monitoring ice along the northern sea route. Glavkosmos operates the AIST-2D satellite to test key remote sensing equipment and SAPSAN, a high-resolution multispectral satellite for commercial Earth observation.

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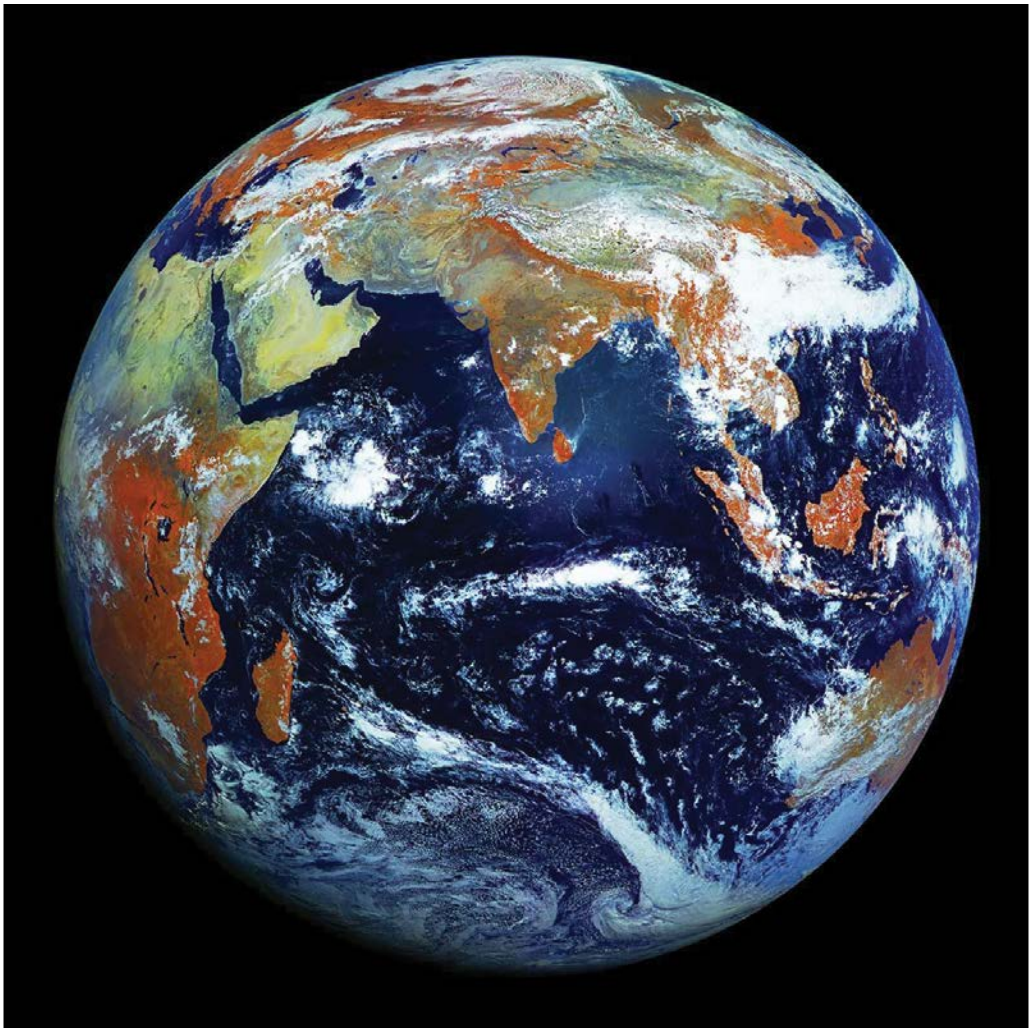


Figure 26. Electro-L image of Earth [Source: Roscosmos].

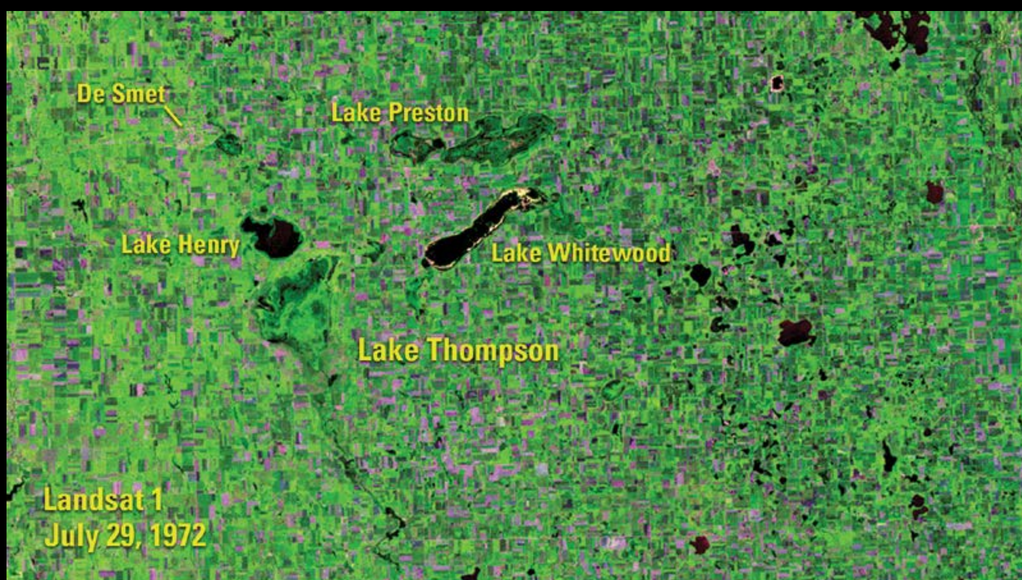
Many lakes in South Dakota's Prairie Pothole Region are expanding. Lake Thompson in eastern South Dakota is one that has displayed remarkable change in recent decades.

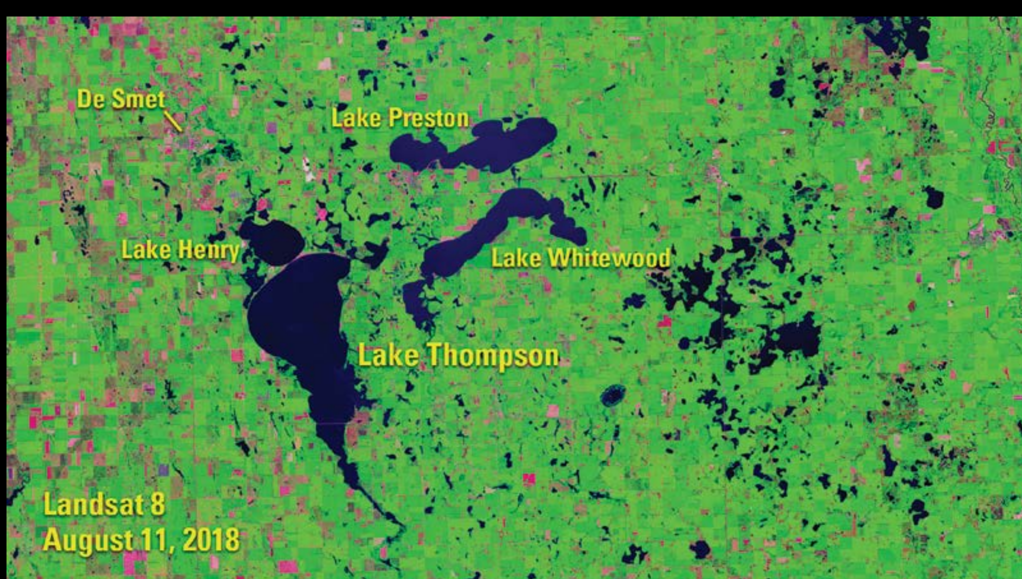
An aerial image from 1952 shows it as a wetland, with a small area of open water. Landsat began observing the area with near-infrared imaging in 1972. By the mid-1980s, the low land filled with enough water to become South Dakota's largest natural lake. There have been some fluctuations in lake levels since then, and some shoreline and shallow areas changed between dryland, marshland, and open water.

Wildlife responds to the lake's changes. Herons and egrets use the shallow water and mudflats on the lake's fringes. Pelicans, gulls, terns, and ducks thrive in the open water.

The dead trees that remained standing were perfect habitat for cormorants, eagles, and herons. Eventually, the dead trees collapsed, and the habitat changed again.

Landsat data can be used to map these changes and help managers understand the interaction between lake levels and wildlife populations.





An Overview of Chinese Earth Observing Systems

China has established itself as a major space power in the 21st century. Since the launch of their first satellite in 1970, China has demonstrated a tremendous and rapidly evolving space capability. China was the third nation to put a human in space, to have their own space station (Tiangong-1), and to have launched more than 200 satellites since 2013. Of the 200 satellites launched in the last 5 years, 60 percent were dedicated to Earth observation. Over the past 10 years, China's space program has grown at an incredible rate. In 2018 alone, China launched 22 Earth observing satellites.

Despite demonstrating substantial capabilities in the space industry, limited information is known about China's space program, which is considered to be the most complex and nontransparent in the world. The Chinese space program is not only surrounded by a high level of secrecy but is further complicated by bureaucratic structures with numerous organizations within organizations. Adding to the confusion, the Chinese have frequently restructured, renamed, and relocated these organizations all while creating new entities (fig. 27) to fulfill the needs of new programs and missions (Aliberti, 2015). Currently, the main administrative body coordinating space activities in China is the State Administration on Science, Technology and Industry for National Defense. Under this administrative body is the Chinese National Space Agency (CNSA), which is responsible for defining national space policies; administering the civilian space program; and managing the development of national space science, technology, and industry. The CNSA was established in 1993 along with the Chinese Aerospace Corporation (CAC) to separate governmental and industrial space activities. The CNSA is a liaison between the State Administration on Science, Technology and Industry for National Defense and the CAC and represents China at the international level. The CAC is a powerful internal component focused on dealing with national space matters.

The China Aerospace Science and Technology Corporation (CASC) and the China Aerospace Science and Industry Corporation are state-owned industrial groups formed in 1999 under the CAC's administration. The CASC, the main contractor of the Chinese space program, is a large-scale conglomerate of 130 companies. The CASC manages the research, design, manufacturing, and supply of space technologies and systems as well as international commercial launch services. The China Academy of Space Technology, Shanghai Academy of Spaceflight Technology, China Academy of Launch Vehicle Technology, and China Great Wall Industry Corporation are some notable subsidiaries of the CASC. The China Aerospace Science and Industry Corporation also is a huge conglomerate of aerospace companies, acting as the prime contractor for China's aerospace defense program, and specializes in manufacturing missiles and armaments.

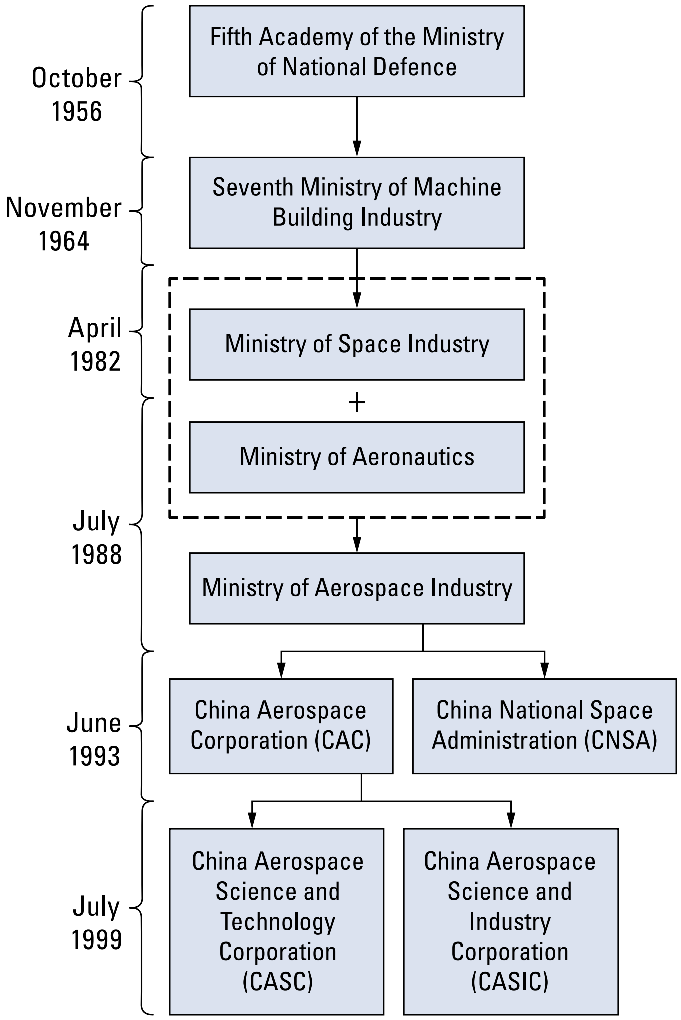


Figure 27. Evolution of Chinese space agencies [Source: Aliberti, 2015].

A few other agencies that have an important role in the Chinese space program are the China Meteorological Administration, responsible for operating China's weather satellites; the National Satellite Oceanic Application Center, responsible for the development and data processing of Chinese ocean satellites; and the National Remote Sensing Center of China, responsible for planning and policy making on remote sensing technology and its industrialization.

China's space budget is secretive, with no published records. According to reports by Euroconsult (2013), 0.042 percent of China's budget is dedicated to space endeavors. This percentage is relatively low compared to the United States (0.5 percent); however, the parity in purchasing power—the effective spending power of that money—closely matches the U.S. budget (Aliberti, 2015). China's space budget has steadily increased since 2010 and is expected to reach $5.7 billion (U.S. dollars) in 2020 and $9.4 billion (U.S. dollars) by 2030 (see fig. 28). Although human

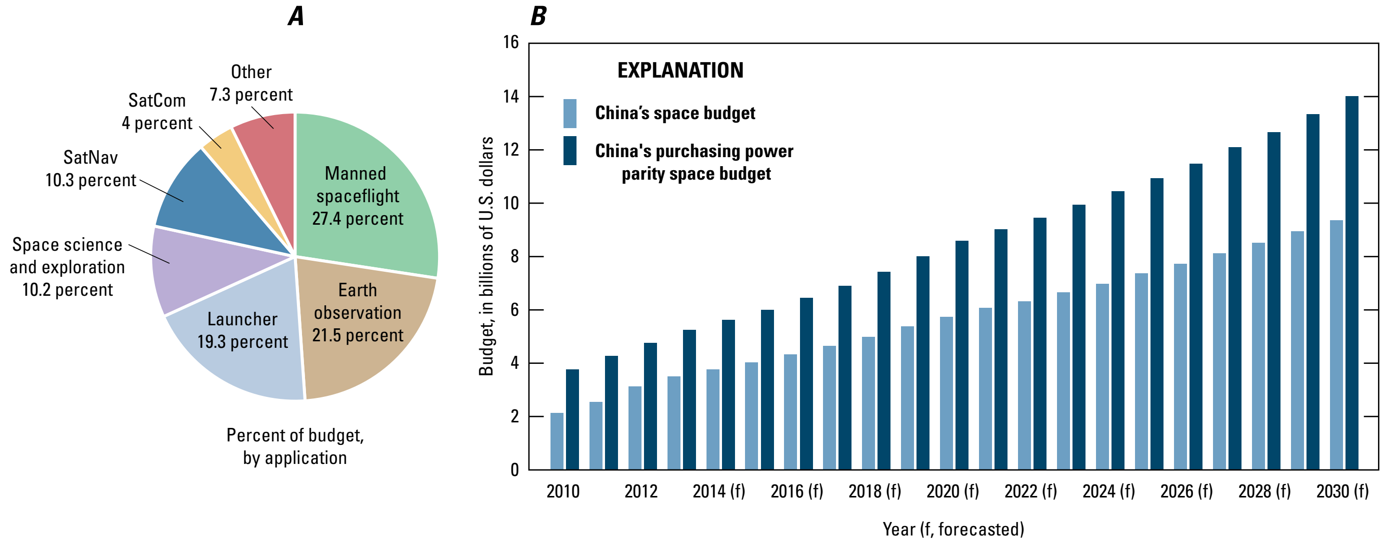


Figure 28. The pie chart on the left shows China's space budget breakdown by application [modified from Aliberti, 2015]. The graph on the right shows future trends in China's space budget [modified from Aliberti, 2015].

spaceflight accounts for the highest allocation in China's space budget, Earth observation received the second largest share with 21.5 percent of the space budget in 2012 (Aliberti, 2015). The Chinese Earth observation systems address key areas such as weather, oceans, disaster monitoring, and land mapping. These Earth observing satellites have been launched by government and commercial agencies. Some of these Chinese Earth observing systems are detailed below.

Government/Civil Satellites

Fengyun

Fengyun (FY), meaning "wind and cloud" in Chinese, are China's series of meteorological satellites. Since the launch of FY-1A in 1988, the mission has been in continuous operation with eight satellites currently in orbit. The FY-1 and 3 series of satellites are polar orbiting, whereas the FY-2 and 4 series of satellites are in geostationary orbits. FY-1C and FY-1D carry a 10-band Multichannel Visible Infrared Scanning Radiometer with 5 bands corresponding to NOAA's Advanced Very High-Resolution Radiometer and the other 5 consisting of 4 visible bands and 1 infrared band. The FY-2 satellites carry a 4-band Stretched-Visible and Infrared Spin-Scan Radiometer. The Multichannel Visible Infrared Scanning Radiometer and Stretched-Visible and Infrared Spin-Scan Radiometer have a ground sample distance (GSD) of 1 km at nadir. FY-3 carries a 25-band Medium Resolution Spectral Imager, which has a GSD of 250 m in VNIR and 1 km in the other bands. The FY-4 satellites carry a 13-band Advanced Geostationary Radiation Imager providing a GSD of 1 km in VNIR, 2 km in shortwave infrared and midwave infrared, and 4 km in thermal infrared (Jingsong and others, 2010).

Huanjing

China's disaster monitoring satellite constellation is called Huanjing (HJ), which translates to "environment." This smallsat constellation was planned for launch in two batches. The first batch contained three satellites: HJ-1A, HJ-1B, and HJ-1C. Both HJ-1A and HJ-1B were launched in 2009, followed by HJ-1C in 2013. HJ-1A carries a VNIR hyperspectral imager with a 50-km swath and a 100-m GSD. HJ-1B carries an infrared imager with a 720-km swath and a 150-m GSD. Both HJ-1A and HJ-1B operate in SSOs and carry a common wide-view camera imaging with a 700-km swath and a 30-m GSD. HJ-1C is in a dawn-dusk orbit with SAR. The second batch (HJ-2) consists of eight satellites and is planned for launch in future years.

Haiyang

China's ocean monitoring series of satellites is called Haiyang (HY), which translates to "ocean." The first satellite of the HY series, HY-1A, was launched in 2002. The constellation is currently operational with HY-1B and HY-2A in orbit and 15 more satellites planned. The HY satellites operate in SSOs. The HY-1 satellites carry a Chinese Ocean Color and Temperature Scanner and a Coastal Zone Imager, whereas the HY-2 and 3 satellites carry radar altimeters and SARs. The Chinese Ocean Color and Temperature Scanner images the Earth in VNIR and TIR bands at a GSD of 1.1 km, and the Coastal Zone Imager images at a GSD of 250-m VNIR bands (Xingwei and Mingsen, 2015).

Ziyuan

The Ziyuan (ZY), which is Chinese for “resource,” series of satellites is dedicated to Earth resources detection and monitoring. The ZY-1 series, also known as the China-Brazil Earth Resources Satellite (CBERS), is a collaboration between Brazil’s space agency, Instituto Nacional de Pesquisas Espaciais, and China’s CNSA. A total of four satellites have been launched to date, and CBERS-4A (ZY-1 04A) is planned for launch in 2019. Each ZY-1 (CBERS) satellite carries a wide-view camera, a panchromatic and multispectral imager, and an infrared imager, each providing imagery at different ground resolutions. The data are freely available through the Instituto Nacional de Pesquisas Espaciais data portal: http://www.inpe.br/dados_abertos/. The ZY-2 and ZY-3 series of satellites are built and operated by China for civil and military purposes. An artist’s model of the currently operational CBERS-4 satellite is shown in figure 29.

Figure 29. Artist’s view of China-Brazil Earth Resources Satellite CBERS-4 [Source: Instituto Nacional de Pesquisas Espaciais].

Gaofen

Gaofen (GF), meaning “high resolution,” is known as the China High Resolution Earth Observing System. Gaofen is a constellation of high-resolution satellites launched over the past 5 years. The GF 1, GF 1-02, GF 1-03, GF 1-04, and GF 6 satellites carry the first-generation panchromatic and multispectral camera, whereas the GF 2, GF 8, and GF 9 satellites carry the second-generation panchromatic and multispectral camera, capable of imaging with submeter resolution. Unlike the other GF satellites, which operate in SSOs, GF 4 is positioned in a geostationary orbit. In addition to the panchromatic and multispectral camera, GF 3 carries a SAR instrument. GF 5 carries a hyperspectral imager in VNIR bands and a multispectral sensor like the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument on the Terra satellite (Zhang and others, 2014).

Yaogan

Yaogan is a constellation of reconnaissance satellites similar to the U.S. Department of Defense Naval Ocean Surveillance System triplet satellites. China has launched 31 Yaogan satellites into SSOs of differing altitudes. The orbits indicate that the satellites carry different payloads, some of which include electronic intelligence systems, SAR instruments, and high-resolution imagers. The timeline of Chinese Government/civil satellites is shown in figure 30.

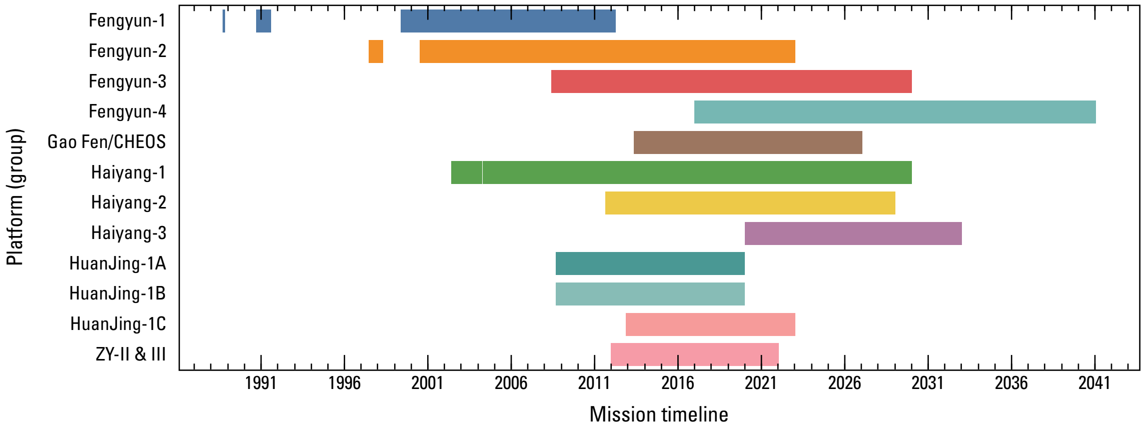


Figure 30. Timeline of Chinese Earth observing systems.

Commercial Satellites

Superview

The Superview satellite constellation by Beijing Space View Technology Co., Ltd., consists of four satellites that were launched in batches of two in 2016 and 2017. The satellites are phased 90 ° in relation to each other in an SSO, providing a revisit of 2 days for imaging any point on the Earth. They each carry a panchromatic camera with a 0.5-m GSD and a multispectral camera with a 2-m GSD. Both sensors cover a 12-km swath.

Zhuhai

Zhuhai Orbita Aerospace Science and Technology (formerly named Zhuhai Control Engineering, Ltd.) built the Zhuhai constellation of satellites with high-resolution video and hyperspectral capabilities. An additional round of satellites launched in 2018 includes 4 OHS-2 satellites capable of imaging the Earth in 5 days and 1 video satellite, OVS-2, providing video of the Earth at a 0.9-m resolution.

Jilin

The Jilin constellation of satellites, operated by Chang Guang Satellite Technology Co., Ltd., is operational with its first batch of 4 satellites—2 video, 1 optical, and 1 technology demonstration. The constellation is planned to increase to 60 satellites by 2020 and 140 satellites by 2030.

Triplesat

The Triplesat constellation of three satellites was built by Surrey Satellite Technology, Ltd. (SSTL). Twenty First Century Aerospace Technology (21AT) leases the imaging capabilities of the Triplesat-1 satellites and collects, archives, and distributes the data. The Triplesat satellites were launched in 2015 and placed in SSOs. They image the Earth at a GSD of 1 m in panchromatic and 4 m in VNIR. SSTL-S1 was launched in 2018, and the data are archived and distributed by 21AT.

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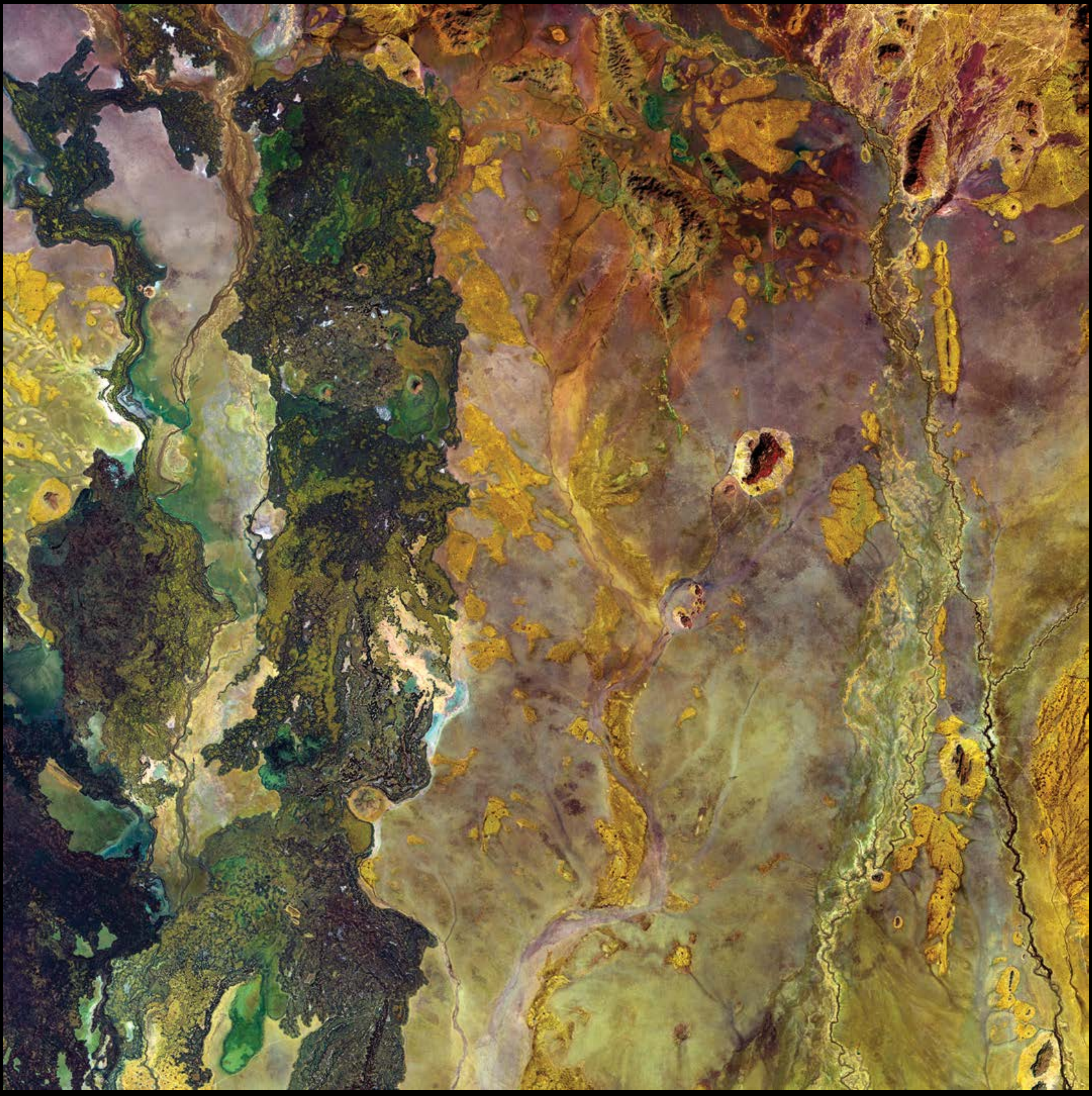

Green shades seem to be bubbling up like a lava lamp on the left side of this image from northeastern Kenya. The right side is like rusted metal. The dark green is the result of geologically recent lava flows, and the other colors are different types of soils. Even with few defined shapes, the piece has a strange beauty.

Appendix 1. Selected References

Resembling splotches of yellow and green paint, salt-encrusted seasonal lakes dot the floor of Western Australia's Shoemaker impact structure. The structure was formed about 1.7 billion years ago and is currently the oldest known impact site in Australia.

Appendix 1. Selected References

The staff in the Requirements, Capabilities, and Analysis for Earth Observation Project at the U.S. Geological Survey Earth Resources Observation and Science Center used many sources in the process of assembling the data sheets in appendix 3. Commonly, these sources provided conflicting information and the staff chose the best information available. Information obtained directly from the satellite manufacturer or associated space agency was given precedence over other sources, when available. Several satellites—particularly those still under development or from less established space agencies—had little public information available. Fields of the data sheets denoted with a "—" indicate unknown information.

The following list of references identifies the sources most frequently used to compile the information provided in appendix 3.

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Appendix 2. Recent and Future Launches

The northern end of Isla Isabela in the Galapagos looks like a seahorse with warts—with an eye painted in the ancient Egyptian style. The island was formed by the merger of six volcanoes. Wolf Volcano is the prominent one in the center; Ecuador Volcano is the one that forms the seahorse's mouth. Past volcanic flows radiate from the large craters.

Appendix 2. Recent and Future Launches

The tables below show the recent and future Earth observation satellite launches of the major space agencies identified in this circular. The launches from 2017 to 2018 are included in table 2.1, and recent launches in 2019 and planned launches beyond 2019 are shown in table 2.2.

2017–18 Launches

Table 2.1. Earth observation satellite launches of 2017–18.

[Alt. orbit, Alternate orbit; SSO, Sun-synchronous orbit; Co., company; U.S., United States; ESA, European Space Agency; GEO, geosynchronous orbit; NOAA, National Oceanic and Atmospheric Administration; UK, United Kingdom; SSTL, Surrey Satellite Technology, Ltd.; UAE, United Arab Emirates]

Launch date	Spacecraft	Orbit	Country/owner	User
1/9/2017	Jilin-1 03	SSO	China/Chang Guang Satellite Technology Co.	Commercial
2/15/2017	CARTOSAT-2D	SSO	India	Government/civil
2/15/2017	Flock-3p-88	SSO	U.S./Planet	Commercial
3/7/2017	Sentinel-2B	SSO	ESA	Government/civil
4/20/2017	Silk Road-1	SSO	China	Government/civil
6/15/2017	Nusat-3	SSO	Argentina/Satellogic	Commercial
6/15/2017	Zhuhai-1 01	SSO	China/Zhuhai Orbita Control Engineering, Ltd.	Commercial
6/15/2017	Zhuhai-1 02	SSO	China/Zhuhai Orbita Control Engineering, Ltd.	Commercial
6/23/2017	CARTOSAT-2E	SSO	India	Government/civil
7/14/2017	Landmapper-BC 1	SSO	U.S./Astro Digital	Commercial
7/14/2017	Landmapper-BC 2	SSO	U.S./Astro Digital	Commercial
7/14/2017	Kanopus-V-IK-1	SSO	Russia	Government/civil
7/14/2017	Flock-2k-48	SSO	U.S./Planet	Commercial
8/2/2017	Venµs	SSO	France	Government/civil
10/09/2017	VRSS-2	SSO	Venezuela	Government/civil
8/24/2017	FORMOSAT-5	SSO	Taiwan	Government/civil
10/9/2017	VRSS-2	SSO	Venezuela	Government/civil
10/13/2017	Sentinel-5P	SSO	ESA	Government/civil
10/31/2017	Sky Satellite-8-13	SSO	U.S./Planet	Commercial
10/31/2017	Flock-3m-4	SSO	U.S./Planet	Commercial
11/8/2017	Mohammed VI-A	SSO	Morocco	Government/civil
11/12/2017	Lemur-2-8	SSO	U.S./Spire Global	Commercial
11/18/2017	JPSS-1	SSO	U.S.	Government/civil
11/21/2017	Jilin-1 V-04-06	SSO	China/Chang Guang Satellite Technology Co.	Commercial
11/28/2017	Landmapper-BC 3	SSO	U.S./Astro Digital	Commercial
11/28/2017	Landmapper-BC 4	SSO	U.S./Astro Digital	Commercial
11/28/2017	Meteor-M N2-1	SSO	Russia	Government/civil
12/3/2017	LKW-1	SSO	China	Government/civil
12/23/2017	LKW-2	SSO	China	Government/civil
12/23/2017	GCOM-C	SSO	Japan	Government/civil
1/9/2018	SuperView-1 03	SSO	China/Superview, Ltd.	Commercial

Table 2.1. Earth Observation satellite launches of 2017–18.—Continued

[Alt. orbit, Alternate orbit; SSO, Sun-synchronous orbit; Co., company; U.S., United States; ESA, European Space Agency; GEO, geosynchronous orbit; NOAA, National Oceanic and Atmospheric Administration; UK, United Kingdom; SSTL, Surrey Satellite Technology, Ltd.; UAE, United Arab Emirates]

Launch date	Spacecraft	Orbit	Country/owner	User
1/9/2018	SuperView-1 04	SSO	China/Superview, Ltd.	Commercial
1/12/2018	Landmapper-BC 3v2	SSO	U.S./Astro Digital	Commercial
1/12/2018	CARTOSAT-2F	SSO	India	Government/civil
1/12/2018	Flock-3p’-4	SSO	U.S./Planet	Commercial
1/12/2018	Lemur-2-4	SSO	U.S./Spire Global	Commercial
1/13/2018	LKW-3	SSO	China	Government/civil
1/19/2018	Jilin-1 V-07	SSO	China/Chang Guang Satellite Technology Co.	Commercial
1/19/2018	Jilin-1 V-08	SSO	China/Chang Guang Satellite Technology Co.	Commercial
1/21/2018	Flock-2 (Dove Pioneer)	SSO	U.S./Planet	Commercial
2/1/2018	Kanopus-V N3	SSO	Russia	Government/civil
2/1/2018	Kanopus-V N4	SSO	Russia	Government/civil
2/2/2018	GomSpace Express-4A & -4B	SSO	ESA/Denmark/GomSpace	Public-private
2/2/2018	Nusat-4	SSO	Argentina/Satellogic	Commercial
2/2/2018	Nusat-5	SSO	Argentina/Satellogic	Commercial
2/22/2018	PAZ	SSO	Spain/Hisdesat	Military
3/1/2018	GOES-17	GEO	U.S./NOAA	Government/civil
3/17/2018	LKW-4	SSO	China	Government/civil
3/31/2018	Gao Fen-1 02	SSO	China	Government/civil
3/31/2018	Gao Fen-1 03	SSO	China	Government/civil
3/31/2018	Gao Fen-1 04	SSO	China	Government/civil
4/25/2018	Sentinel-3B	SSO	ESA	Government/civil
5/8/2018	Gao Fen-5	SSO	China	Government/civil
6/2/2018	Gao Fen-6	SSO	China	Government/civil
7/9/2018	PRSS-1	SSO	Pakistan	Government/civil
7/9/2018	PakTES-1A	SSO	Pakistan	Government/civil
7/12/2018	SaudiSat-5A and 5B	SSO	Saudi Arabia	Government/civil
7/31/2018	Gao Fen-11	SSO	China	Government/civil
9/7/2018	Haiyang-1C	SSO	China	Government/civil
9/15/2018	ICESAT-2	SSO	U.S.	Government/civil
9/16/2018	NOVASAR-S	SSO	UK/SSTL	Government/civil
9/16/2018	SSTL-1	SSO	UK/SSTL	Commercial
10/7/2018	SAOCOM 1A	SSO	Argentina	Government/civil
24/10/2018	Hai Yang 2B	SSO	China	Government/civil
10/29/2018	DubaiSat-3/KhalifaSat	SSO	UAE	Government/civil
11/20/2018	Mohammad VI-B	SSO	Morocco	Government/civil
11/29/2018	Blacksky Global 1	SSO	U.S./Blacksky Global	Commercial
11/29/2018	HySIS	SSO	India	Government/civil
11/29/2018	Flock-3r-16	SSO	U.S./Planet	Commercial

Table 2.1. Earth observation satellite launches of 2017–18.—Continued

[Alt. orbit, Alternate orbit; SSO, Sun-synchronous orbit; Co., company; U.S., United States; ESA, European Space Agency; GEO, geosynchronous orbit; NOAA, National Oceanic and Atmospheric Administration; UK, United Kingdom; SSTL, Surrey Satellite Technology, Ltd.; UAE, United Arab Emirates]

Launch date	Spacecraft	Orbit	Country/owner	User
12/3/2018	Flock-3s-3	SSO	U.S./Planet	Commercial
12/3/2018	Denali	SSO	U.S./Capella Space	Commercial
12/3/2018	SkySat-14, 15	SSO	U.S./Planet	Commercial
12/4/2018	Geo-KOMPSAT 2A	GEO	Republic of Korea	Government/civil
12/27/2018	GRUS-1	SSO	Japan/AxelSpace	Commercial
12/27/2018	Flock-3k-12	SSO	U.S./Planet	Commercial

2019 and Beyond

Table 2.2. Earth observation satellite launches of 2019 and beyond.

[SSO, Sun-synchronous orbit; Co., company; U.S., United States; GEO, geosynchronous orbit; ESA, European Space Agency]

Launch date	Spacecraft	Orbit	Country/owner	User
1/21/2019	Jilin-1 Hyperspectral-01 & 02	SSO	China/Chang Guang Satellite Technology Co.	Commercial
1/21/2019	Lingque-1A	SSO	China	Commercial
1/24/2019	Microsat-R	SSO	India	Government/civil
2/21/2019	EgyptSat A	SSO	Egypt	Government/civil
3/21/2019	PRISMA	SSO	Italy	Government/civil
3/27/2019	Lingque-1B	SSO	China	Commercial
4/1/2019	Flock-4a	SSO	U.S./Planet	Commercial
4/29/2019	Tianhui-2-01 A & B	SSO	China	Government/civil
5/22/2019	RISAT-2B	SSO	India	Government/civil
06/11/2019	RCM	SSO	Canada	Government/civil
06/xx/2019	CBERS-4A	SSO	China/Brazil	Government/civil
08/xx/2019	Landmapper-BC 5 & 6	SSO	U.S./Astro Digital	Commercial
10/xx/2019	Ingenio	SSO	Spain	Government/civil
2019	Blacksky Global-4	SSO	U.S./Blacksky Global	Commercial
2019	Gao Fen-7	SSO	China	Government/civil
2019	Nusat-6 to 21	SSO	Argentina/Satellogic	Commercial
2019	Jilin Video-09 to 12	SSO	China/Chang Guang Satellite Technology Co.	Commercial
2019	WorldView Scout Constellation	Mixed SSO/midlatitude	Maxar/U.S.	Commercial
2019	Sequoia	Mixed SSO/midlatitude	Maxar/U.S.	Commercial
2019	COSMO-SkyMed	SSO	Italy	Government/civil
2019	Cartosat-3	SSO	India	Government/civil
2019	Geo Imaging Satellite-1	GEO	India	Government/civil
2019	Resourcesat-3	SSO	India	Government/civil
2020	Resourcesat-3A	SSO	India	Government/civil
2020	Hai Yang 2C	SSO	China	Government/civil
2020	OceanSat-3 & 3A	SSO	India	Government/civil

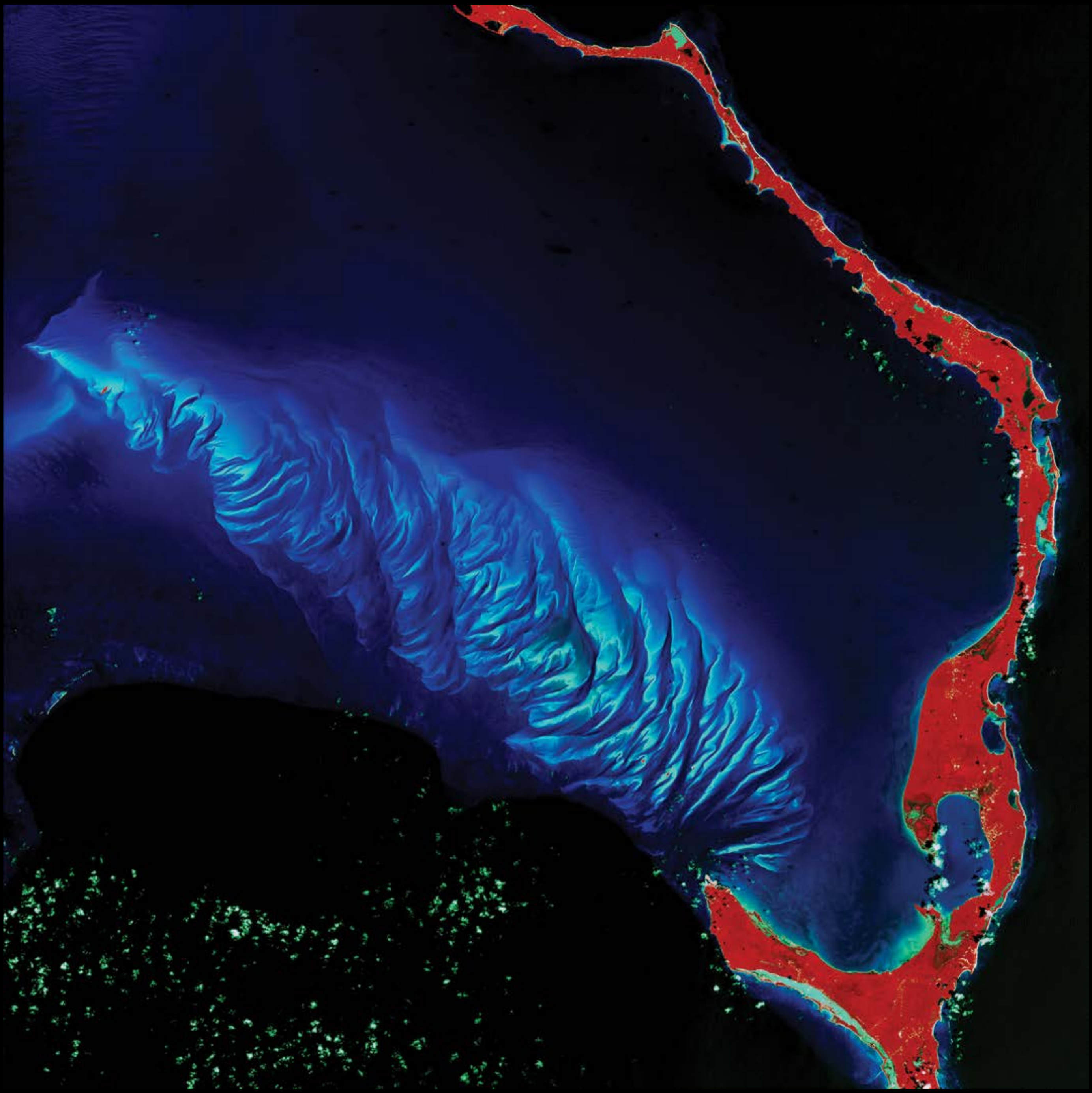
Table 2.2. Earth observation satellite launches of 2019 and beyond.—Continued

[SSO, Sun-synchronous orbit; Co., company; U.S., United States; GEO, geosynchronous orbit; Alt. orbit, Alternate orbit; ESA, European Space Agency]

Launch date	Spacecraft	Orbit	Country/owner	User
2020	Landsat-9	SSO	U.S.	Government/civil
2020	RISAT-1A	SSO	India	Government/civil
2020	Jilin-1 02A	SSO	China/Chang Guang Satellite Technology Co.	Commercial
2020	GCOM-C2	SSO	Japan	Government/civil
2020	Flock	SSO	U.S./Planet	Commercial
2020	EnMAP	SSO	Germany	Government/civil
2020	Geo-KOMPSAT 2B	GEO	Republic of Korea	Government/civil
2020	Kompsat-6	SSO	Republic of Korea	Government/civil
2020	CARTOSAT-3A	SSO	India	Government/civil
2020	Hai Yang 3A	SSO	China	Government/civil
2020	Amazonia-1	SSO	Brazil	Government/civil
2020	CAS500	SSO	Republic of Korea	Government/civil
2020	GOES-T	GEO	U.S.	Government/civil
2020	GEO-CAPE	GEO	U.S.	Government/civil
2020	COSMO-SkyMed-2	SSO	Italy	Government/civil
2020	RISAT-2A	SSO	India	Government/civil
2020	Resourcesat-3S & 3SA	SSO	India	Government/civil
2020	SAOCOM 1B	SSO	Argentina	Government/civil
2020	HRSAT	SSO	India	Government/civil
2020	Sentinel-6A	Alt. orbit	ESA	Government/civil
2020	Sentinel-3C	SSO	ESA	Government/civil
2020	Sentinel-2C	SSO	ESA	Government/civil
2021	Sentinel-2D	SSO	ESA	Government/civil
2021	JPSS-2	SSO	U.S.	Government/civil
2021	WorldView Legion Constellation	Mixed SSO/midlatitude	Maxar/U.S.	Commercial
2021	CBERS-5	SSO	China/Brazil	Government/civil
2021	RISAT-1B	SSO	India	Government/civil
2021	Kompsat-7	SSO	Republic of Korea	Government/civil
2021	Resurs-P N4	SSO	Russia	Government/civil
2021	Resurs-P N5	SSO	Russia	Government/civil
2021	Biomass	SSO	ESA	Government/Civil
2021	SWOT	SSO	U.S.	Government/civil
2021	NISAR	SSO	India/U.S.	Government/civil
2021	Sentinel-1C	SSO	ESA	Government/civil
2022	Sentinel-3D	SSO	ESA	Government/civil
2022	PACE	SSO	U.S.	Government/civil
2022	FLEX	SSO	ESA	Government/civil
2022	SABIA-Mar 1	SSO	Argentina/Brazil	Government/civil
2022	Tandem-L	SSO	Germany	Government/civil
2023	HyspIRI	SSO	U.S.	Government/civil
2023	Sentinel-1D	SSO	ESA	Government/civil

The Ganges River forms an extensive delta where it empties into the Bay of Bengal. The delta is largely covered with a swamp forest known as the Sunderbans, which is home to the Royal Bengal Tiger.

Appendix 3. Land Remote Sensing Satellite Data Sheets



The main feature here, near Eleuthera Island in the Bahamas, is the Schooner Cays shoal complex. The tidal sand ridges, parabolic bars, and intervening channels explode in a blue rhythm. The Bahamas have the third most extensive coral reef in the world. Source: Landsat 8.

1HOPSat

United States
Commercial
Future

Platform Overview

Hera System's first-generation High Optical Performance Satellites (1HOPSat) will be high-resolution, multispectral satellites for monitoring change. The 1HOPSat satellites are being developed within the Hera Systems company, based in San Jose, California. The 1HOPSat satellites are based on a 12U cubesat envelope. Their high-altitude airborne testing program is scheduled to begin late 2018 with initial launches to follow in 2019. The constellation is designed to consist of 50 satellites. With broad daily coverage, the constellation is proposed to enable data-purchasing organizations to monitor Earth changes at any location on the globe.

[Abbreviations in tables: —, no data; GSD, ground sample distance; km, kilometer; m, meter]

Launch date	2020 (planned)
Platform owner	Hera Systems
Altitude	—
Orbit period	—
Inclination	—
Crossing time	—
Nadir repeat	—
Design lifetime	—
Status	Development
System website	http://www.herasys.com/

Artistic rendering of 1HOPSat in orbit [Source: Hera Systems Inc., 2019, used with permission].

Sensor Information

	1HOPSat Imager
GSD (m)	1
Swath (km)	—
Data portal	—

1HOPSat Imager

The imager aboard the 1HOPSat satellites will provide 1 m ground sample distance (GSD) imagery with 8 bands. The 1-m GSD imagery will be sold for $1.00 per square kilometer.

ALOS-2

Japan
Civil/Government
Operational

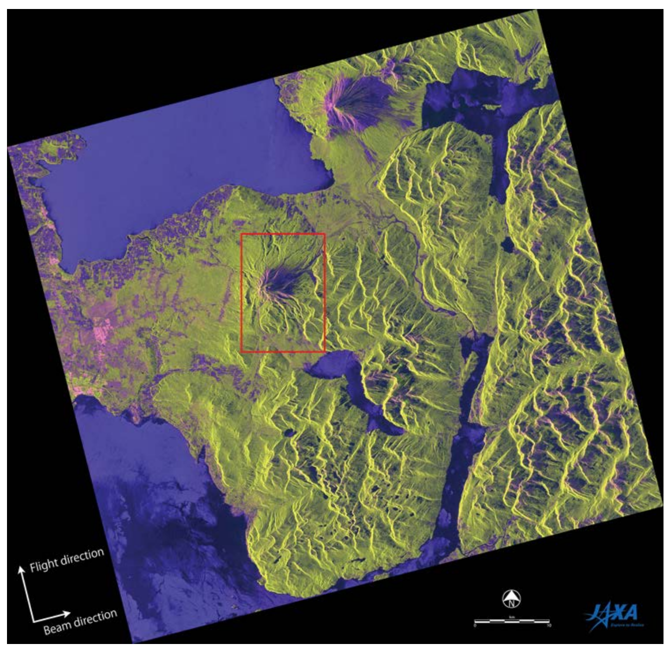
Platform Overview

Advanced Optical Satellite (ALOS)-2 is a follow-on Synthetic Aperture Radar (SAR) satellite of the ALOS mission launched in 2014 by the Japan Aerospace Exploration Agency (JAXA) on an H-IIA launch vehicle from Tanegashima Space Center for Earth resources monitoring. This is the second satellite in the ALOS mission. The ALOS-2 satellite was developed by Mitsubishi Electric Corporation (MELCO) for JAXA. It carries an advanced L-band radar to continue observations of the ALOS Phased Array type L-band SAR (PALSAR). While imaging with SAR, ALOS-2 uses a Compact Infrared Camera (CIRC) to aid the detection of wildfires.

Artistic rendering of ALOS-2 in orbit [Source: JAXA, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; —, no data; GSD, ground sample distance; m, meter; TIR, thermal infrared; H, horizontal; V, vertical]

Launch date	05/24/2014
Design lifetime	5 years
Platform owner	JAXA
Altitude	628 km
Orbit period	97.26 min
Inclination	97.9°
Crossing time	12:00 DN
Nadir repeat	—
Status	Operational
System website	http://www.eorc.jaxa.jp/ALOS-2/en/about/overview.htm



PALSAR-2 image over Mt. Calbuco volcano region, Chile [Source: JAXA, used with permission].

Sensor Information

	PALSAR	CIRC
GSD (m)	3–100 (selectable)	200
Swath (km)	25–350 (selectable)	—
Data portal	https://www.asf.alaska.edu/sar-data/palsar/	

ALOS-2—Continued

Japan
Civil/Government
Operational

PALSAR

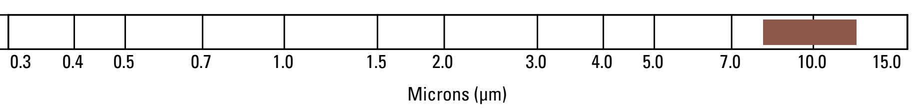
The Phases Array L-band Synthetic Aperture Radar-2 (PALSAR-2) is a proven design by MELCO used on ADEOS and ALOS-1. PALSAR-2 operates based on Active Array Phased Technology (APAA), allowing various observation modes in single, dual, full, and compact polarizations. PALSAR operates in the L-band with a selectable frequency of 1,236.5 MHz (λ = 24.2 cm), 1,257.5 MHz (λ = 23.8 cm), or 1,278.5 MHz (λ = 23.4 cm). The sensor can cover a wide range of incidence angles from 8 to 70 degrees.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
Spotlight	Single	HH, HV, VV	25 x 25	3 x 1
Stripmap (ultra-fine)	Single	HH, HV, VV	50	3
	Dual	HH/HV, VV/VH		
Stripmap (high-sensitive)	Single	HH, HV, VV	50	6
	Dual	HH/HV, VV/VH		
	CP	Circular, 45° linear		
	Quad	HH/HV/VV/VH	30	
Stripmap (fine)	Single	HH, HV, VV	70	10
	Dual	HH/HV, VV/VH		
	CP	Circular, 45° linear		
	Quad	HH/HV/VV/VH	30	
ScanSAR	Single	HH, HV, VV	350	100
	Dual	HH/HV, VV/VH		

CIRC

The Compact Infrared Camera (CIRC) is a single band thermal infrared demonstration instrument of JAXA developed as a COTS product by MELCO. CIRC provides infrared imagery for wildfire detection. The resolution of CIRC is less than 200 m at nadir.

Band	Lower	Center	Upper	GSD (m)
TIR	8.000	10.000	12.000	200



ALOS-3

Japan
Civil/Government
Future

Platform Overview

ALOS-3 is an Earth-resource-monitoring high-resolution, hyper-and multispectral satellite of the ALOS by JAXA series planned for launch in 2019. This is the third satellite in the ALOS mission. The ALOS-3 satellite is being developed by Mitsubishi Electric Corporation (MELCO) for JAXA based on the ALOS-2 bus with some modifications. It carries an advanced Panchromatic Remote-Sensing Instrument for Stereo Mapping-2 (PRISM-2) and Hyperspectral and multispectral imager (HISUI) sensors for high- and medium-resolution land imaging, respectively.

Artistic rendering of ALOS-3 in orbit [Source: JAXA, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; —, no data; Pan, panchromatic; NIR, near-infrared; TIR, thermal infrared; Hyper, hyperspectral]

Launch date	2020 (Planned)
Design lifetime	7 years
Platform owner	JAXA
Altitude	669 km
Orbit period	98.12 min
Inclination	98.06°
Crossing time	10:30 DN
Nadir repeat	35 days
Status	Development
System website	http://global.jaxa.jp/projects/sat/alos3/

Sensor Information

	PRISM-2	HISUI
GSD (m)	0.8	5, 30
Swath (km)	50	90, 30
Data portal	—	

JACIE

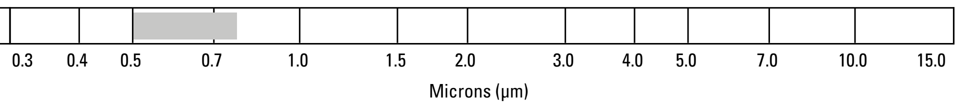
ALOS-3—Continued

Japan
Civil/Government
Future

PRISM-2

The PRISM-2 is a proven design by MELCO used on ALOS-1. The instrument will acquire stereo pair images from two telescopes for stereo mapping and digital surface models (DSMs). PRISM-2 will be able to collect high-resolution images with high geolocation accuracy without ground control points. PRISM-2 data will be commercially available.

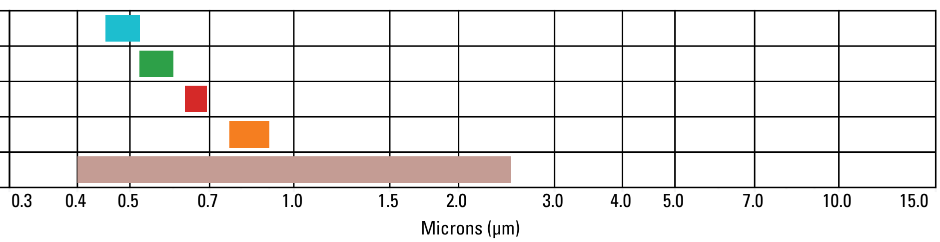
Band	Lower	Center	Upper	GSD (m)
Pan	0.500	0.635	0.770	0.8



HISUI

The HISUI has heritage of the ASTER sensor flown on board the Terra satellite. The HISUI sensor is a combination of hyperspectral and multispectral sensors operating together to achieve better spatial and spectral data. The hyperspectral imager has 185 bands. HISUI data will be commercially available.

Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	5
Green	0.520	0.560	0.600	5
Red	0.630	0.660	0.690	5
NIR	0.760	0.830	0.900	5
Hyper	0.400	1.450	2.500	30



ALOS-4

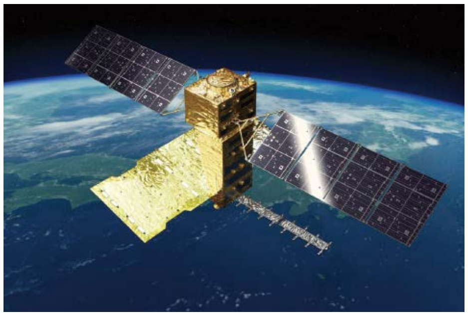
Japan
Civil/Government
Future

Platform Overview

Advanced Optical Satellite (ALOS)-4 is a synthetic aperture radar (SAR) satellite under development by the Japan Aerospace Exploration Agency (JAXA) for Earth resources monitoring. It is the fourth satellite of the ALOS mission and is designed to replace ALOS-2. The ALOS-4 platform is being developed by Mitsubishi Electric Corporation (MELCO). ALOS-4 carries the Phased Array L-band Synthetic Aperture Radar-3 (PALSAR-3) instrument to continue observations of the ALOS PALSAR instruments. ALOS-4 will also carry a Space based Automatic Identification System Experiment (SPAISE3) receiver to monitor oceans for ships.

[Abbreviations in tables: km, kilometer; min, minute; —, no data; GSD, ground sample distance; m, meter]

Launch date	2020 (Planned)
Design lifetime	7 years
Platform owner	JAXA
Altitude	628 km
Orbit period	97.26 min
Inclination	—
Crossing time	—
Nadir repeat	—
Status	Development
System website	http://global.jaxa.jp/projects/sat/alos4/



Artistic rendering of ALOS-4 in orbit [Source: JAXA, used with permission].

Sensor Information

	PALSAR-3
GSD (m)	1–10 (selectable)
Swath (km)	35–700 (selectable)
Data portal	—

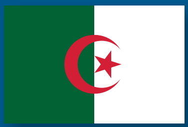
PALSAR-3

The PALSAR-3 instrument is a proven design by MELCO used on ADEOS, ALOS-1, and ALOS-2. PALSAR-3 uses Active Array Phased Technology (APAA), allowing various observation modes in single, dual, full, and compact polarizations. The instrument operates in the L-band, which has a center frequency of 1.5 GHz (λ = 20.0 cm). The angle of incidence is 8–70 degrees.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
Stripmap	—	—	100–200	3, 6, 10
ScanSAR	—	—	700	25
Spotlight	—	—	35 x 35	1 x 3

AlSat-1B

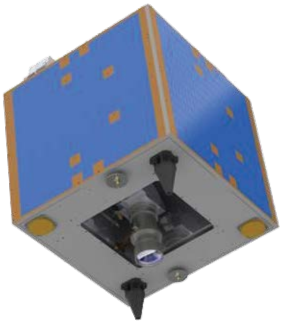
Algeria
Civil/Government
Operational



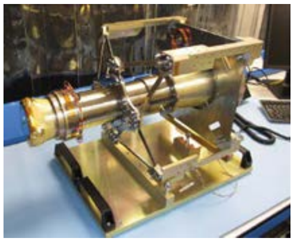
Platform Overview

Algeria Satellite-1B (AlSat-1B) is a medium-resolution, panchromatic, and multispectral microsatellite launched in 2016 on the Polar Satellite Launch Vehicle. Its primary mission is to ensure the continuity of the national coverage provided by AlSat-1 and the collective coverage of the Disaster Monitoring Constellation (DMC).

AlSat-1B was built by Surrey Satellite Technology Limited (SSTL) and the Algerian Space Agency (ASAL), with ASAL's engineers undertaking the integration and test phases in Algeria. The microsatellite is based on the SSTL-100 platform. VNIR imagery is captured at 24 m resolution by the Algerian Imager Telescope (ALITE) and is used by the Algerian Government.



Artistic rendering of AlSat-1B [Source: ASAL, used with permission].



ALITE sensor model [Source: ASAL, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; —, no data; Pan, panchromatic; NIR, near infrared]

Launch date	9/26/2016
Platform owner	ASAL
Altitude	690 km
Orbit period	97.7 min
Inclination	98.2°
Crossing time	10:30 AN
Nadir repeat	5 days
Design lifetime	5 years
Status	Operational
System website	http://www.asal.dz/Alsat-1B.php

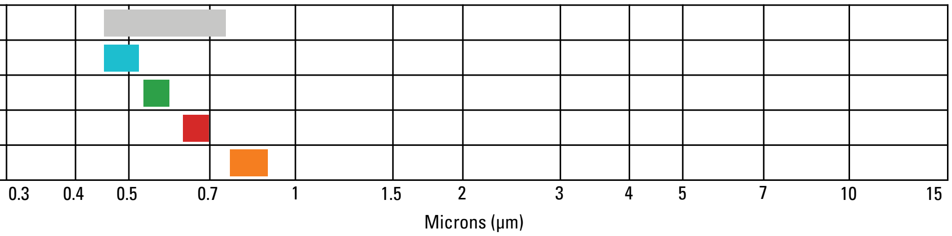
Sensor Information

	ALITE
GSD (m)	12, 24
Swath (km)	140
Data portal	—

ALITE

The ALITE aboard AlSat-1B is a new design developed by SSTL and ASAL. By combining the 24 m multispectral data and the 12 m panchromatic data, AlSat-1B can capture 12 m enhanced multispectral images.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.598	0.745	12
Blue	0.450	0.485	0.520	24
Green	0.530	0.560	0.590	24
Red	0.625	0.660	0.695	24
NIR	0.760	0.825	0.890	24



AlSat-2A and 2B

Algeria
Civil/Government
Operational

Platform Overview

AlSat-2A and AlSat-2B are high-resolution, panchromatic, and multispectral satellites for Earth observation. AlSat-2A was launched in 2010 aboard the Polar Satellite Launch Vehicle (PSLV)-C15 followed by AlSat-2B in 2016 aboard the PSLV-C35 launch vehicle. AlSat-2 is the first satellite system to use the AstroSat-100 (AS-100) platform, which was based on the Myriade platform from the French National Center for Space Studies (CNES).

Algerian Space Agency (ASAL) signed an agreement with European Aeronautics Defense and Space (EADS) Astrium SAS to design and build the two AlSat-2 satellites. AlSat-2B was successfully integrated by ASAL's engineers in Algeria. AlSat-2A and 2B carry the New AstroSat Optical Modular Instrument (NAOMI) sensor for high-resolution imaging.

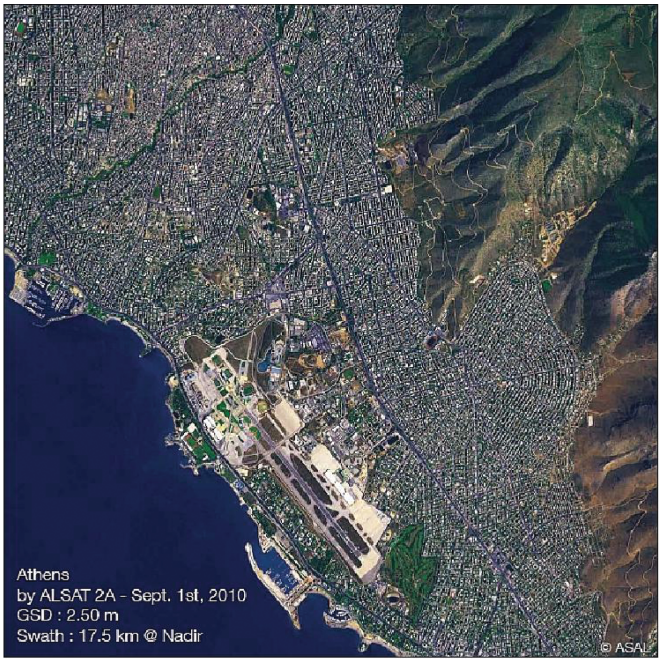
Artistic rendering of AlSat-2A in orbit [Source: Airbus DS, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; AN, ascending node; GSD, ground sample distance; m, meter; —, no data; Pan, panchromatic; NIR, near infrared]

	AlSat-2A	AlSat-2B
Launch date	7/12/2010	9/26/2016
Design lifetime	5 years	
Platform owner	ASAL	
Altitude	670 km	720 km
Orbit period	98 min	99.19 min
Inclination	98.23°	98.1°
Crossing time	9:30 DN	8:45 AN
Nadir repeat	14 days	2 days
Status	Operational	
System website	http://www.asal.dz/Alsat-2A.php	http://www.asal.dz/Alsat-2B.php

Sensor Information

	NAOMI
GSD (m)	1.5, 6
Swath (km)	17.5
Data portal	—



Athens, Greece, captured by AlSat-2A [Source: ASAL, used with permission].

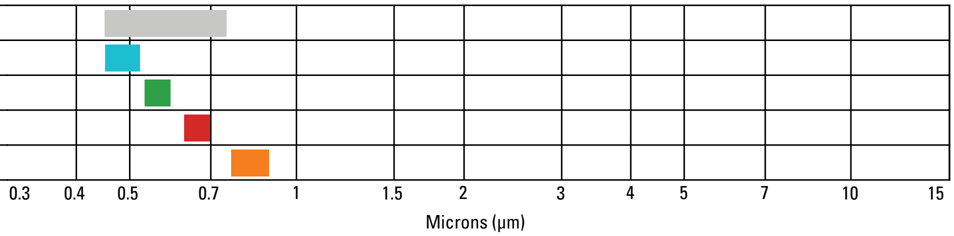
AlSat-2A and 2B—Continued

Algeria
Civil/Government
Operational

NAOMI

The NAOMI sensor is a high-resolution imager developed by EADS Astrium SAS for AlSat-2. The pushbroom imager has four visible and near infrared bands and a panchromatic band. Data are for use by the Algerian government.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.598	0.745	1.5
Blue	0.450	0.485	0.520	6
Green	0.530	0.560	0.590	6
Red	0.625	0.660	0.695	6
NIR	0.760	0.825	0.890	6

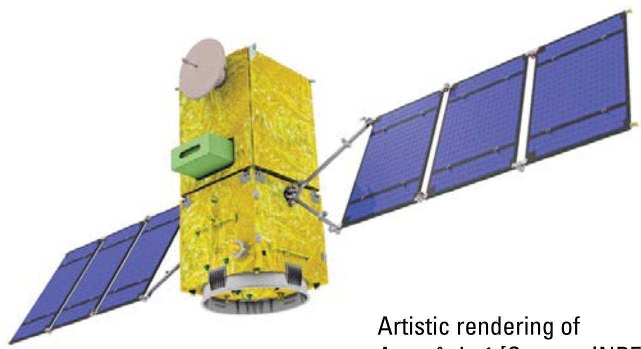


Amazônia 1

Brazil
Civil/Government
Future

Platform Overview

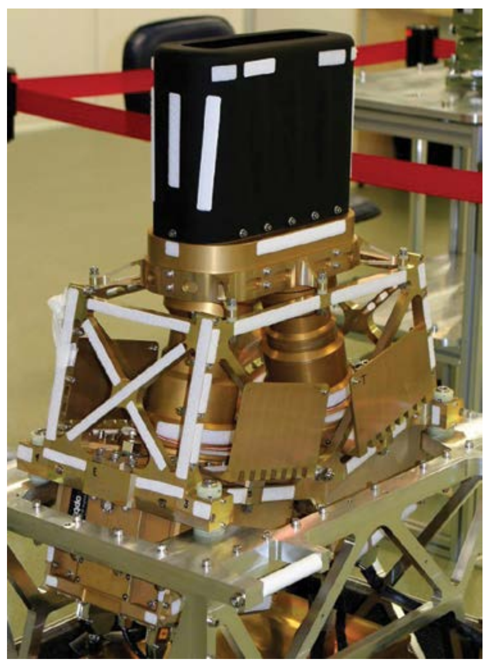
Amazônia 1 is a medium-resolution multispectral satellite to be launched in late 2020 by National Institute of Space Research (INPE) for monitoring deforestation, especially in the Amazon region. Amazônia 1 is the first satellite to be completely designed, integrated, and tested in Brazil. The satellite utilizes the Multi-Mission Platform (PMM) designed by the Brazilian Space Agency (AEB). Amazônia 1 will carry the Wide Field Imager (WFI)-2 sensor for medium-resolution land imaging.



Artistic rendering of Amazônia 1 [Source: INPE].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; —, no data; NIR, near infrared]

Launch date	2020 (Planned)
Design lifetime	2 years
Platform owner	INPE
Altitude	752 km
Orbit period	99.9 min
Inclination	98.4°
Crossing time	10:30 DN
Nadir repeat	26 days
Status	Development
System website	http://www3.inpe.br/amazonia-1/



WFI-2 sensor model [Source: INPE].

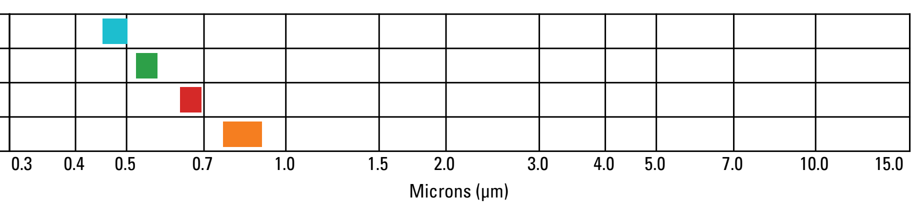
Sensor Information

	WFI-2
GSD (m)	60
Swath (km)	740
Data portal	—

WFI-2

The WFI-2 is the same sensor as the WFI sensors aboard the China–Brazil Earth Resources Satellites; however, since they are at different altitudes, the resolutions are different.

Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.475	0.500	60
Green	0.520	0.545	0.570	60
Red	0.630	0.660	0.690	60
NIR	0.760	0.830	0.900	60



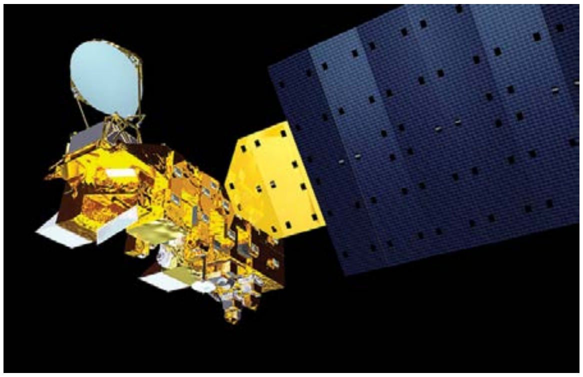
Aqua

United States
Civil/Government
Operational

Platform Overview

Aqua is a moderate-resolution multispectral satellite launched in 2002 by the National Aeronautics and Space Administration (NASA) on a Delta-II rocket from Vandenberg Air Force Base for Earth resources monitoring. Formerly named Earth Observing System (EOS) PM, signifying its afternoon crossing time, Aqua is the second satellite in the EOS mission.

The Aqua satellite was built by Northrop Grumman Corp. based on their modular, standardized T330 bus for NASA. Aqua carries six instruments: Atmospheric Infra-Red Sounder (AIRS), Advanced Microwave Sounding Unit (AMSU), Clouds and the Earth's Radiant Energy System (CERES), Moderate-Resolution Imaging Spectroradiometer (MODIS), Advanced Microwave Scanning Radiometer for EOS (AMSR-E), and Humidity Sounder for Brazil (HSB). For this compendium of land remote sensing satellites, only MODIS details are provided.



Artistic rendering of Aqua in orbit [Source: NASA].

[Abbreviations in tables: km, kilometers; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meters; CA, coastal aerosol; NIR, near infrared; SWIR, shortwave infrared, MWIR, midwave infrared; WV, water vapor; TIR, thermal infrared]

Launch date	5/4/2002
Design lifetime	6 years
Platform owner	NASA
Altitude	705 km
Orbit period	98.8 min
Inclination	98.2°
Crossing time	13:30 AN
Nadir repeat	16 days
Status	Operational
System website	https://aqua.nasa.gov/

MODIS image of northwest Australia showing forest fires [Source: NASA].

Sensor Information

	MODIS
GSD (m)	250, 500, 1,000
Swath (km)	2,230
Data portal	https://earthexplorer.usgs.gov/ https://glovis.usgs.gov/app

Aqua—Continued

United States
Civil/Government
Operational

MODIS

The MODIS sensor is a proven design built by NASA Goddard Space Flight Center (GSFC) and is a heritage of Radiation Sounder (HIRS), Landsat Thematic Mapper (TM), and Coastal Zone Color Scanner (CZCS). MODIS, which is on board the Terra and Aqua satellites, is a 36-band spectroradiometer measuring visible and infrared radiation. The MODIS sensors are widely regarded as among the best calibrated imaging instruments in space. MODIS data are freely available.

Band	Lower	Center	Upper	GSD (m)
CA	0.405	0.413	0.420	1,000
CA	0.438	0.443	0.448	1,000
Blue	0.459	0.469	0.479	500
Blue	0.483	0.488	0.493	1,000
Blue	0.526	0.531	0.536	1,000
Green	0.545	0.555	0.565	500
Green	0.546	0.551	0.556	1,000
Red	0.620	0.645	0.670	250
Red	0.662	0.667	0.672	1,000
Red	0.673	0.678	0.683	1,000
NIR	0.743	0.748	0.753	1,000
NIR	0.841	0.859	0.876	250
NIR	0.862	0.870	0.877	1,000
NIR	0.890	0.905	0.920	1,000
NIR	0.915	0.940	0.965	1,000
NIR	0.931	0.936	0.941	1,000
NIR	1.230	1.240	1.250	500
Cirrus	1.360	1.375	1.390	1,000
SWIR 1	1.628	1.640	1.652	500
SWIR 2	2.105	2.130	2.155	500
MWIR	3.660	3.750	3.840	1,000
MWIR	3.929	3.959	3.989	1,000
MWIR	4.020	4.050	4.080	1,000
MWIR	4.433	4.466	4.498	1,000
MWIR	4.482	4.516	4.549	1,000
WV-1	6.535	6.715	6.895	1,000
WV-2	7.175	7.325	7.475	1,000
TIR	8.400	8.550	8.700	1,000
TIR	9.580	9.730	9.880	1,000
TIR	10.780	11.030	11.280	1,000
TIR	11.770	12.020	12.270	1,000
TIR	13.185	13.335	13.485	1,000
TIR	13.485	13.635	13.785	1,000
TIR	13.785	13.935	14.085	1,000
TIR	14.085	14.235	14.385	1,000

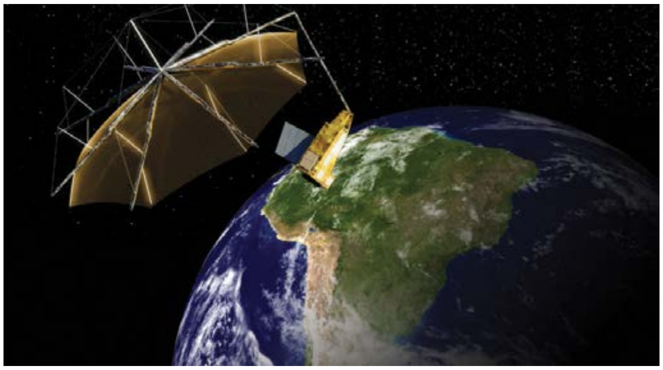
JACIE

Biomass

European Space Agency
Civil/Government
Future

Platform Overview

Biomass is a low-resolution Synthetic Aperture Radar (SAR) satellite to be launched in 2021 to determine the amount of biomass and carbon stored in forests. Biomass will be ESA's seventh Earth Explorer. The satellite will be built by Airbus Defense and Space. Biomass will carry the P-SAR sensor for low-resolution radar data.



Artistic rendering of Biomass in orbit [Source: Airbus DS, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; —, no data]

Launch date	2021 (Planned)
Platform owner	ESA
Altitude	660 km
Orbit period	97.93 min
Inclination	97.97°
Crossing time	6:00 AN
Nadir repeat	17 days
Design lifetime	5 years
Status	Development
System website	http://www.esa.int/Our_Activities/Observing_the_Earth/The_Living_Planet_Programme/Earth_Explorers/Future_missions/Biomass

Sensor Information

	P-SAR
GSD (m)	200
Swath (km)	—
Data portal	—

P-SAR

The P-band SAR instrument will be built by Airbus DS. Harris Corporation has been selected to provide the 12-m reflector and boom assembly, a major component of the instrument. P-SAR will operate in the P-band at 435 MHz (λ = 68.9 cm). The angle of incidence will be 23–35 degrees. Details of the beam modes are not yet available.

Beam mode	Polarization	Nominal swath width (km)	Approximate resolution (m)
—	—	—	—

RCA-EO; USGS EROS Center
47914 252nd St.
Sioux Falls, SD 57198
eccoe@usgs.gov

Capella 1/Denali

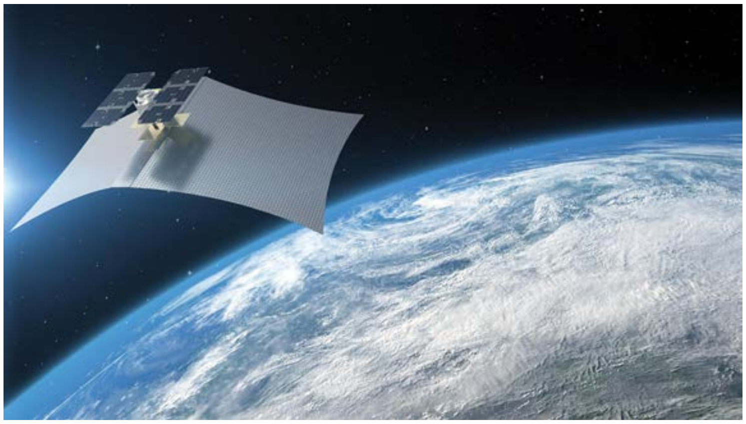
United States
Commercial
Operational

Platform Overview

Capella 1 is a synthetic aperture radar (SAR) satellite launched in 2018 by Capella Space for commercial use. The satellite was built on a 12U cubesat. The satellite is planned to be a part of a 36-satellite constellation.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; —, no data; GSD, ground sample distance; m, meter]

Launch date	12/03/2018
Platform owner	Capella Space
Altitude	575 km
Orbit period	96.16 min
Inclination	97.68°
Crossing time	10:30 DN
Nadir repeat	—
Design lifetime	—
Status	Operations
System website	https://www.capellaspace.com/



Capella 1 SAR satellite. [Source: Capella Space, used with permission].

Sensor Information

	SAR
GSD (m)	0.5
Swath (km)	7
Data portal	—

SAR

The X-band (9.4–9.9 gigahertz) SAR sensor will provide cloud-free data, which will be commercially available. Beam mode details are shown in the table.

Beam mode	Polarization	Nominal swath width (km)	Approximate resolution (m)
SPOT	Single HH, VV	5 km	0.3 × 0.5
SITE	Single HH, VV	5 km	0.5 × 0.5
STRIP	Single HH, VV	5 km	1.0 × 7.0
SCAN	Single HH, VV	7 km	2.5 × 1.7

JACIE

Cartosat-1

India
Civil/Government
Operational

Platform Overview

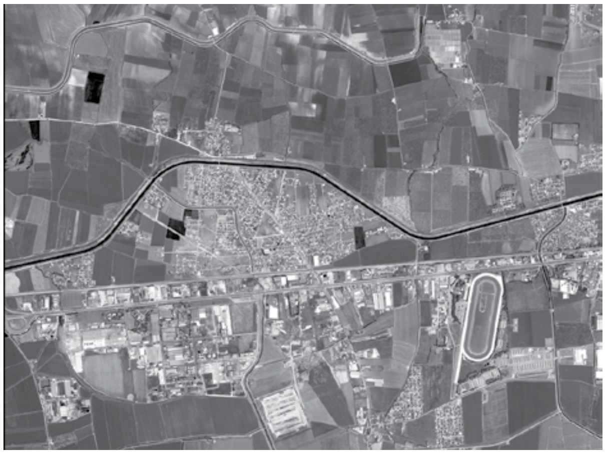
Cartosat-1 is a high-resolution satellite launched in 2005 by the Indian Space Research Organization (ISRO) on Polar Satellite Launch Vehicle (PSLV) C-5 from Satish Dhawan Space Center (SDSC) for Earth resources monitoring. This is the first mission in the Cartosat series and a part of the Indian Remote Sensing Satellite (IRS) series.

The Cartosat series was designed and built by ISRO and uses the IRS-1 bus and two panchromatic cameras. Panchromatic imagery is gathered on a global scale to provide stereo pairs required for generating digital elevation models (DEMs), ortho image products, and value-added products for various GIS applications.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; Pan, panchromatic; GSD, ground sample distance; m, meter; Pan, panchromatic]

Launch date	5/5/2005
Platform owner	ISRO
Altitude	618 km
Orbit period	97 min
Inclination	97.87°
Crossing time	10:30 DN
Nadir repeat	126 days
Design lifetime	7 years
Status	Operational
System website	https://nrsc.gov.in/CARTOSAT-1

Artistic rendering of Cartosat-1
[Source: ISRO, used with permission].



Cartosat-1 imagery of Adana, Turkey
[Source: ISRO, used with permission].

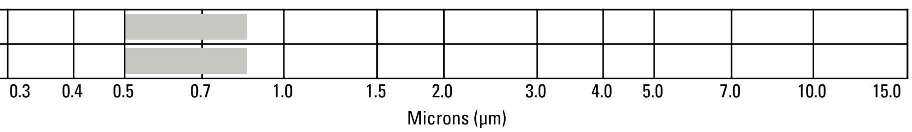
Sensor Information

	PAN-FORE	PAN-AFT
GSD (m)	2.45	2.19
Swath (km)	29.42	26.24
Data portal	http://uops.nrsc.gov.in:33333/ImgeosUops/FinalImgeosUops/FinalImgeosUops.html	

PAN-FORE and PAN-AFT

The panchromatic camera system aboard Cartosat-1 is a design from ISRO. The Pan Cam is a set of two imagers, one looking forward (PAN-FORE) and other aft (PAN-AFT) of the satellite with a combined swath of about 30 km. Both sensors acquire images at a resolution of 2.5 m with a time difference of about 52 seconds.

Band	Lower	Center	Upper	GSD (m)
Pan	0.500	0.675	0.850	2.19
Pan	0.500	0.675	0.850	2.45



Cartosat-2, -2A, and -2B

India
Civil/Government
Operational

Platform Overview

Model of Cartosat-2 [Source: ISRO, used with permission].

Cartosat-2, -2A, and -2B are high-resolution satellites launched in 2007, 2008, and 2010, respectively, by the Indian Space Research Organization (ISRO) on Polar Satellite Launch Vehicle (PSLV) from Satish Dhawan Space Center (SDSC) for Earth resources monitoring. These missions continue the Cartosat series that has been in continual operation since the launch of Cartosat-1 in 2005.

The Cartosat-2, -2A, and -2B satellites were designed and built by ISRO and use the Indian Remote Sensing Satellite (IRS)-1 bus and two panchromatic cameras. Panchromatic imagery is gathered on a global scale to provide stereo pairs required for generating digital elevation models (DEMs), Ortho Image products, and value-added products for various GIS applications.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; Pan, panchromatic; GSD, ground sample distance; m, meter]

	Cartosat-2	Cartosat-2A	Cartosat-2B
Launch date	10/1/2007	4/28/2008	7/12/2010
Design lifetime	5 years		
Platform owner	ISRO		
Altitude	635 km		
Orbit period	97.4 min		
Inclination	97.87°		
Crossing time	9:30 DN		
Nadir repeat	5 days		
Status	Operational		
System website	https://www.isro.gov.in/Spacecraft/cartosat-2-0		

A 1-meter panchromatic Cartosat-2 image of Bangalore, India [Source: ISRO, used with permission].

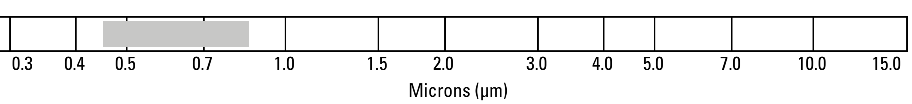
Sensor Information

	PAN
GSD (m)	0.8
Swath (km)	9.6
Data portal	http://uops.nrsc.gov.in:33333/ImgeosUops/FinalImgeosUops/FinalImgeosUops.html

PAN

The Panchromatic Camera (PAN) is a design from ISRO. The camera is a nadir-pointing pushbroom CCD instrument observing in the spectral range of 0.5–0.85 µm with a swath of 9.6 km providing a ground sample distance of less than 1 m at nadir.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.650	0.850	0.8



JACIE

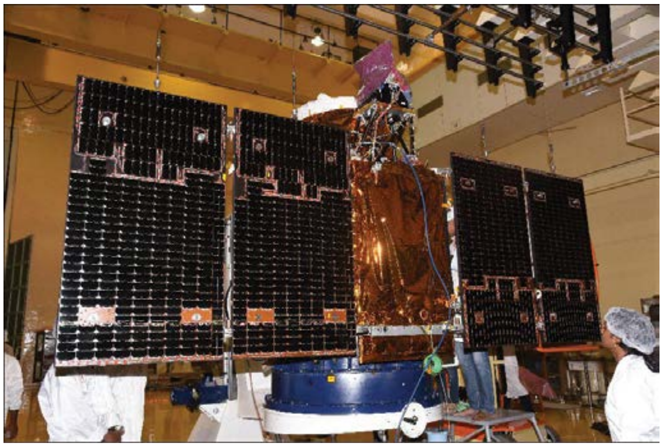
Cartosat-2C, -2D, -2E, and -2F

India
Civil/Government
Operational/Future

Platform Overview

Cartosat-2C, -2D, -2E, and -2F are high-resolution satellites launched between 2016 and 2018 by the Indian Space Research Organization (ISRO) on a Polar Satellite Launch Vehicle (PSLV) from Satish Dhawan Space Center (SDSC) for Earth resources monitoring. These missions continue the Cartosat series that has been in continual operation since the launch of Cartosat-1 in 2005.

The Cartosat-2C, -2D, -2E, and -2F satellites were designed and built by ISRO and use the Indian Remote Sensing Satellite (IRS)-1 bus and two imagers: a high-resolution multispectral camera and a panchromatic imager. Imagery in panchromatic and visible and near infrared bands is gathered on a global scale for cartographic applications.



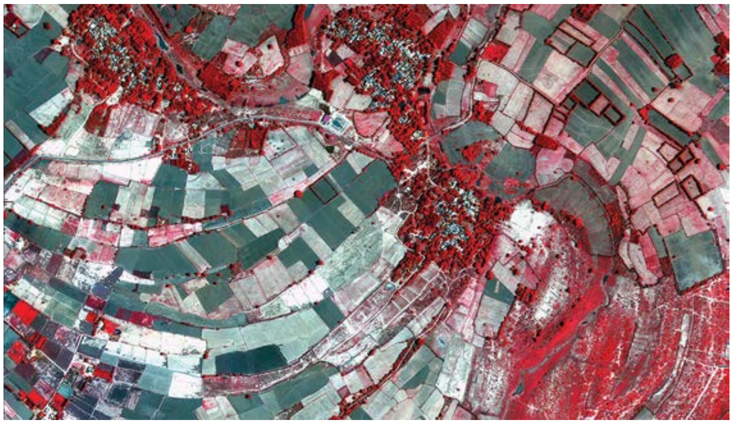
Cartosat-2E undergoing solar panel deployment test [Source: ISRO, used with permission].

[Abbreviations in tables: km, kilometer; ; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; NIR, near infrared; Pan, panchromatic]

	Cartosat-2C	Cartosat-2D	Cartosat-2E	Cartosat-2F
Launch date	6/22/2016	2/15/2017	6/23/2017	1/12/2018
Design lifetime	5 years			
Platform owner	ISRO			
Altitude	500 km			
Orbit period	97.4 min			
Inclination	97.87°			
Crossing time	9:30 DN			
Nadir repeat	5 days			
Status	Operational			
System website	https://www.isro.gov.in/Spacecraft/cartosat-2-series-satellite-2			

Sensor Information

	HRMS	PAN
GSD (m)	2	0.65
Swath (km)	10	9.6
Data portal	http://uops.nrsc.gov.in:33333/ImgeosUops/FinalImgeosUops/FinalImgeosUops.html	



Multispectral Cartosat-2 imagery of Bhidaurya, Uttar Pradesh, India [Source: ISRO, used with permission].

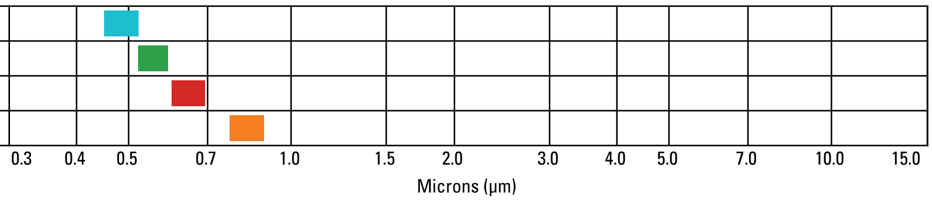
Cartosat-2C, -2D, -2E, and -2F—Continued

India
Civil/Government
Operational/Future

HRMS

The High Resolution multispectral (HRMS) sensor is a design by ISRO. The four-channel radiometer has a 10-km swath width at a ground sample distance (GSD) of 2 m in multispectral mode.

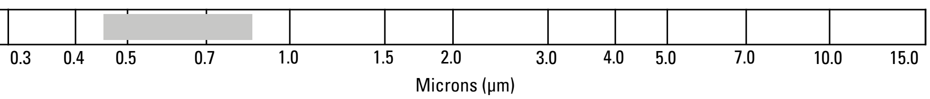
Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	2
Green	0.520	0.555	0.590	2
Red	0.600	0.645	0.690	2
NIR	0.770	0.830	0.890	2



PAN

The Panchromatic Imager (PAN) was built by ISRO and has a similar swath to the previous Cartosat-2 satellites but with higher revisit capability. It provides panchromatic imagery at a GSD of 0.65 m for stereoscopic applications.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.650	0.850	0.65



JACIE

Cartosat-3

India
Civil/Government
Future

Platform Overview

Cartosat-3 is a high-resolution multispectral satellite planned to be launched in 2019 on a Polar Satellite Launch Vehicle (PSLV) for Earth resources monitoring. This mission continues the Cartosat series that has been in continual operation since the launch of Cartosat-1 in 2005. Cartosat-3 is being developed by ISRO and carries the multispectral imager (MSI) and panchromatic (PAN) sensor for high-resolution imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; —, no data; GSD, ground sample distance; m, meter;Pan, panchromatic; NIR, near infrared]

Launch date	2019 (Planned)
Design lifetime	5 years
Platform owner	ISRO
Altitude	450 km
Orbit period	93.58 min
Inclination	97.9°
Crossing time	10:30 DN
Nadir repeat	—
Status	Development
System website	—

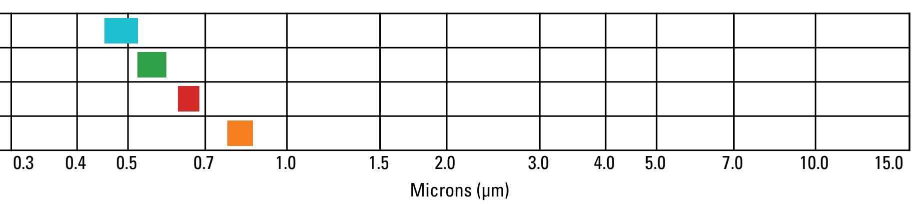
Sensor Information

	MSI	PAN
GSD (m)	1.14	0.28
Swath (km)	16	16
Data portal	—	

MSI

Details of the MSI are not yet known. The sensor will have four bands with a ground sample distance (GSD) of approximately 1 m, an improvement from Cartosat-2's 2-m GSD.

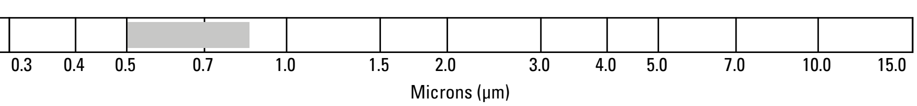
Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	1.14
Green	0.520	0.555	0.590	1.14
Red	0.620	0.650	0.680	1.14
NIR	0.770	0.815	0.860	1.14



PAN

The PAN imager has an improved 0.28-m GSD compared to Cartosat-2's 0.65-m GSD.

Band	Lower	Center	Upper	GSD (m)
Pan	0.500	0.675	0.850	0.28



CAS500-1 and -2

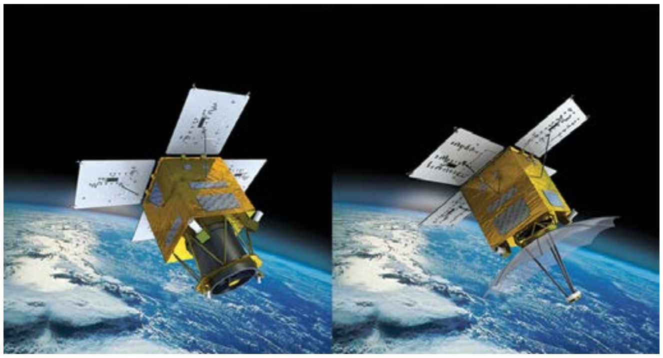
South Korea
Civil/Government/Commercial
Future

Platform Overview

CAS500-1 and -2 are high-resolution panchromatic and multispectral satellites to be launched in 2020 for Earth observation. The first satellite, CAS500-1, is being developed by the Korean Aerospace Research Institute (KARI). The medium-sized platform is designed to be easily commercialized to reduce cost. CAS500-2 will be developed by domestic industry and utilize the technology developed for CAS500-1. CAS500 satellites will carry the Advanced Earth Imaging Sensor System (AEISS-C) sensor for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; —, no data; GSD, ground sample distance; m, meter]

	CAS500-1	CAS500-2
Launch date	2020 (Planned)	
Design lifetime	4 years	
Platform owner	KARI	
Altitude	500 km	
Orbit period	94.62 min	
Inclination	—	
Crossing time	—	
Nadir repeat	—	
Status	Development	
System website	—	



Artistic renderings of CAS500-1 and -2 in orbit [Source: KARI, used with permission].

Sensor Information

	AEISS-C
GSD (m)	0.5, 2
Swath (km)	12
Data portal	—

AEISS-C

The AEISS-C is based on the AEISS sensors aboard Kompsat-3 and -3A. Detailed spectral information is not available.

JACIE

CBERS-4

China, Brazil
Civil/Government
Operational

JACIE

Platform Overview

The China–Brazil Earth Resources Satellite (CBERS)-4 is a high-resolution multispectral satellite launched in 2014 by the Chinese National Space Agency/National Institute of Space Research (CNSA/INPE) on a Chang Zheng 4B rocket from Taiyuan Satellite Launch Center for Earth resources monitoring. This is the fifth satellite in the CBERS mission. The CBERS-4 satellite was designed and built by Chinese Academy for Space Technology (CAST)/INPE and uses the Phoenix-Eye 1 bus. CBERS-4 carries four sensors: Infrared Multispectral Scanner (IRMSS), Multispectral Camera (MUXCam), Panchromatic and Multispectral Camera (PANMUX), and Wide Field Imager (WFI) for medium-resolution land imaging.

Artistic rendering of CBERS-4 in orbit [Source: INPE].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; AN, ascending node; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near infrared; SWIR, shortwave infrared; TIR, thermal infrared]

Launch date	12/7/2014
Design lifetime	3 years
Platform owner	INPE/CNSA
Altitude	778 km
Orbit period	100.26 min
Inclination	98.5°
Crossing time	10:30 DN
Nadir repeat	26 days
Status	Operational
System website	http://www.cbers.inpe.br/

Sensor Information

	IRMSS	MUX	PANMUX	WFI
GSD (m)	40, 80	20	5, 10	64
Swath (km)	120		60	866
Data portal	http://www.dgi.inpe.br/CDSR/			

CBERS-4 image of Brasilia [Source: INPE].

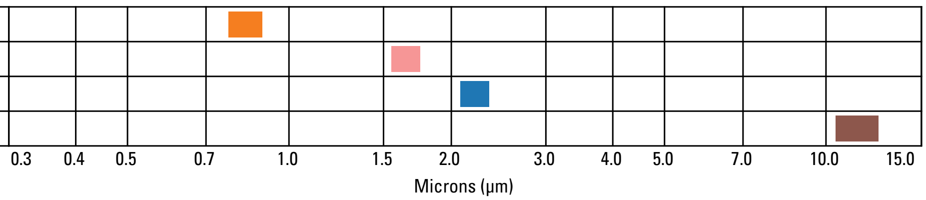
CBERS-4—Continued

China, Brazil
Civil/Government
Operational

IRMSS

The IRMSS sensor is a proven design from CNSA used on CBERS-1 and -2. This sensor on CBERS-4 offers an improvement in the spatial resolution with a ground sample distance (GSD) of 40 m in shortwave infrared and 80 m in thermal infrared. The swath and the spectral bands remain the same as the previous versions. IRMSS data are freely available.

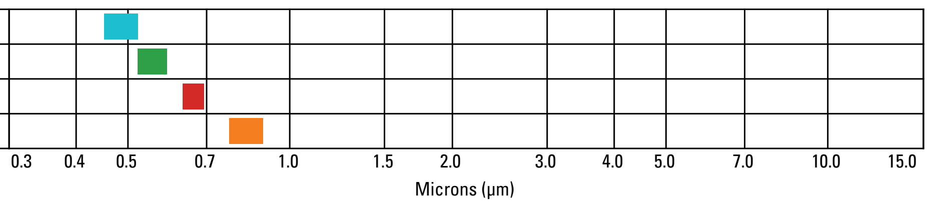
Band	Lower	Center	Upper	GSD (m)
NIR	0.770	0.830	0.890	40
SWIR 1	1.550	1.650	1.750	40
SWIR 2	2.080	2.215	2.350	40
TIR	10.400	11.450	12.500	80



MUX

The MUXCam was developed by INPE in Brazil. It is the same design used on previous satellites in the CBERS series. MUX data are freely available.

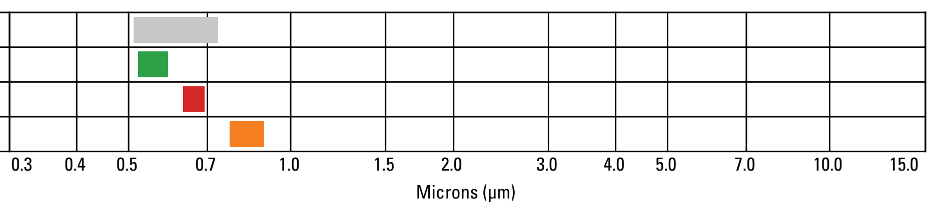
Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	20
Green	0.520	0.555	0.590	20
Red	0.630	0.660	0.690	20
NIR	0.770	0.830	0.890	20



PANMUX

The PANMUX is a three-band visible and near infrared and panchromatic camera designed by INPE. PANMUX data are freely available.

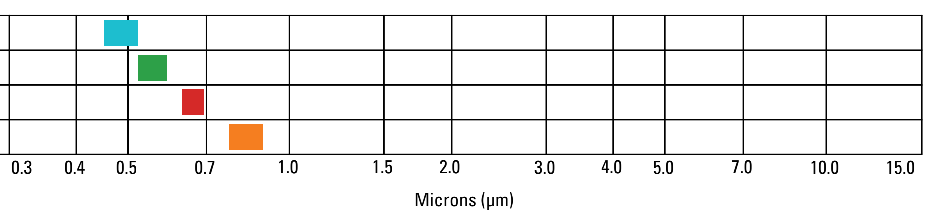
Band	Lower	Center	Upper	GSD (m)
Pan	0.510	0.620	0.730	5
Green	0.520	0.555	0.590	10
Red	0.630	0.660	0.690	10
NIR	0.770	0.830	0.890	10



WFI

The WFI is a proven design by INPE flown on previous CBERS satellites. The sensor adds blue and green bands and an improved resolution of 64 m. The swath width is reduced to 690 km, and the operational capability remains the same. WFI data are freely available.

Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	64
Green	0.520	0.555	0.590	64
Red	0.630	0.660	0.690	64
NIR	0.770	0.830	0.890	64



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CBERS-4A

China, Brazil
Civil/Government
Future


Platform Overview

China–Brazil Earth Resources Satellite (CBERS)-4A is a multiresolution multispectral satellite to be launched in 2019 by the Chinese National Space Agency/National Institute of Space Research (CNSA/INPE) on a Chang Zheng 4B rocket from Taiyuan Satellite Launch Center for Earth resources monitoring. This mission continues the CBERS mission that has been in continual operation since the launch of CBERS-1 in 1999.

The CBERS-4A satellite is being designed and built by CAST/INPE and uses the Phoenix-Eye 1 bus. CBERS-4A carries the Multispectral Camera (MUXCam) and Wide Field Imager (WFI) sensors for medium-resolution land imaging and the Wide Swath Panchromatic and Multispectral camera (WPM) sensor for high-resolution land imaging.

Artistic rendering of CBERS-4 in orbit [Source: INPE].

[Abbreviations in tables: km, kilometer; min, minute; DN, descending node; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near infrared]

Launch date	2019 (Planned)
Platform owner	CNSA/INPE
Altitude	629 km
Orbit period	97.3 min
Inclination	97.9°
Crossing time	10:30 DN
Nadir repeat	31 days
Design lifetime	5 years
Status	Development
System website	http://www.cbers.inpe.br/lancamentos/cbers04a.php

Sensor Information

	MUX	WPM	WFI
GSD (m)	16	2, 8	55
Swath (km)	90	90	690
Data portal	http://www.inpe.br/dados_abertos/		

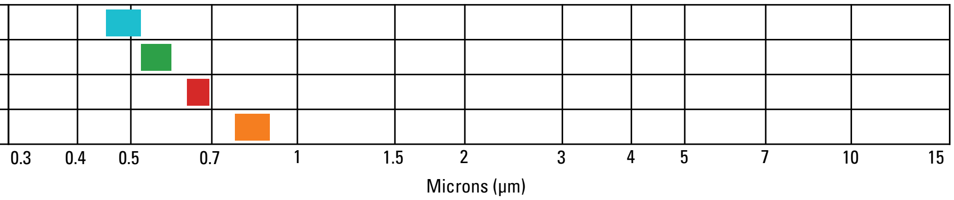
CBERS-4A—Continued

China, Brazil
Civil/Government
Future


MUXCam

The MUXCam is being developed by INPE in Brazil. It is a multispectral radiometer with nadir viewing, capable of imaging the entire Earth every 31 days. It provides a swath width of 90 km. MUX data are freely available.

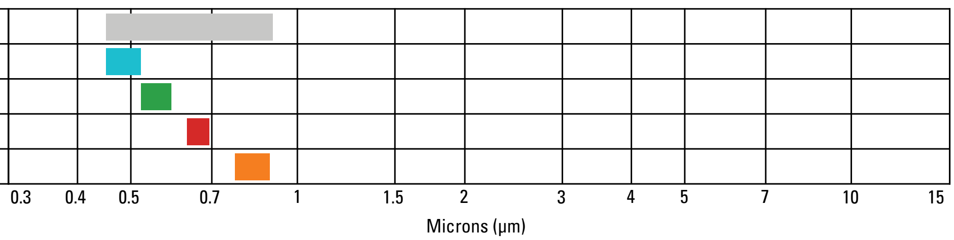
Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	16
Green	0.520	0.555	0.590	16
Red	0.630	0.660	0.690	16
NIR	0.770	0.830	0.890	16



WPM

The WPM is a four-band visible and near infrared and panchromatic camera designed by INPE. WPM data are freely available.

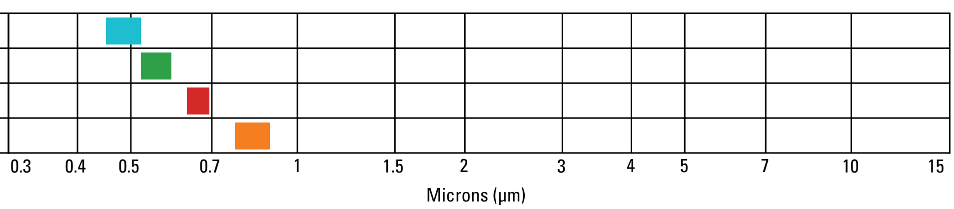
Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.675	0.900	2
Blue	0.450	0.485	0.520	8
Green	0.520	0.555	0.590	8
Red	0.630	0.660	0.690	8
NIR	0.770	0.830	0.890	8



WFI

The WFI is a proven design by INPE flown on previous CBERS satellites. The sensor adds blue and green bands with an improved resolution of 55 m. The swath width and the operational capability remain the same as previous CBERS WFI sensors. WFI data are freely available.

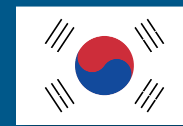
Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	55
Green	0.520	0.555	0.590	55
Red	0.630	0.660	0.690	55
NIR	0.770	0.830	0.890	55



JACIE

COMS

South Korea
Civil/Government
Future



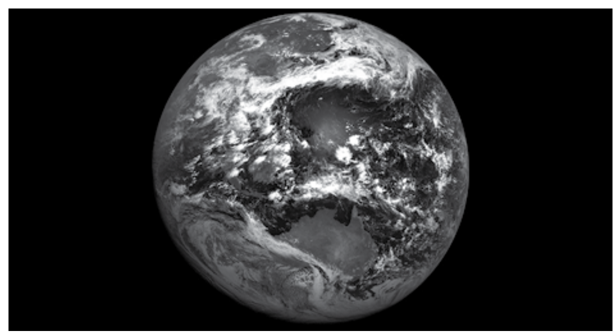
Platform Overview

The Communication, Ocean and Meteorological Satellite (COMS), also known as GEO-KOMPSAT-1, is a low-resolution, multispectral, geostationary satellite launched in 2010 by the Korean Aerospace Research Institute (KARI) on an Ariane-5ECA launch vehicle for meteorology, ocean observation, and communications. COMS was Korea's first geostationary satellite, was designed and built by Airbus for KARI, and was based on the Eurostar-3000 bus. COMS carries the Geostationary Ocean Color Imager (GOCI) and Meteorological Imager (MI) sensors for multiresolution land imaging.

Artistic rendering of COMS in orbit [Source: KARI, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; —, no data; GSD, ground sample distance; m, meter; CA, coastal aerosol; Pan, panchromatic; NIR, near infrared; MWIR, midwave infrared; TIR, thermal infrared]

Launch date	6/27/2010
Design lifetime	7 days
Platform owner	KARI
Altitude	36,000 km
Orbit period	24 hours
Inclination	0°
Crossing time	—
Nadir repeat	—
Status	Operational
System website	https://www.kari.re.kr/eng/sub03_02_02.do



COMS imagery of Earth [Source: KARI, used with permission].

Sensor Information

	GOCI	MI
GSD (m)	500	1,000; 4,000
Swath (km)	2,500	—
Data portal	—	

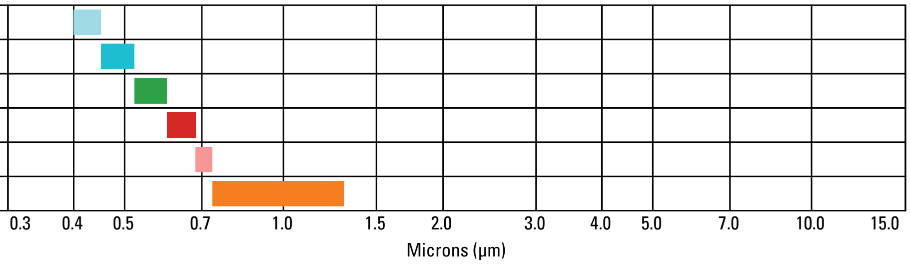
COMS—Continued

South Korea
Civil/Government/
Future

GOCI

The GOCI was the first sensor to measure ocean data from a geostationary orbit.

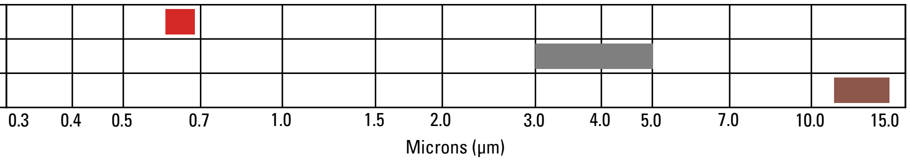
Band	Lower	Center	Upper	GSD (m)
CA	0.400	0.425	0.450	500
Blue	0.450	0.485	0.520	500
Green	0.520	0.560	0.600	500
Red	0.600	0.640	0.680	500
Red Edge	0.680	0.705	0.730	500
NIR	0.730	1.015	1.300	500



MI

The MI is an off-the-shelf sensor from the U.S company ITT Inc.

Band	Lower	Center	Upper	GSD (m)
Red	0.600	0.640	0.680	1,000
MWIR	3.000	4.000	5.000	4,000
TIR	11.000	12.500	14.000	4,000



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COSMO-SkyMed-1 to -4

Italy
Civil/Government
Operational

JACIE

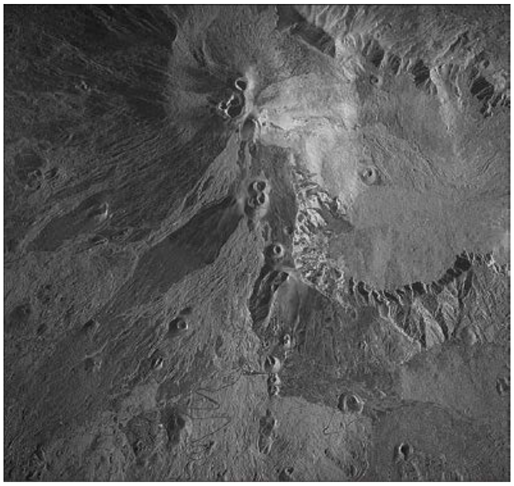
Platform Overview

The COnstellation of small Satellites for Mediterranean basin Observation (COSMO-SkyMed) satellites are multiresolution Synthetic Aperture Radar (SAR) satellites for Earth observation. The four satellites were launched on Delta-7420-10C launch vehicles. The COSMO-SkyMed (CSK) satellites are based on the Piattaforma Riconfigurabile Italiana Multi-Applicativa (PRIMA) bus. The satellites are identical, and all carry the synthetic aperture radar (SAR-2000) instrument for high-resolution radar data.

Artistic rendering of a COSMO-SkyMed satellite in orbit [Source: ASI, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; H, horizontal; V, vertical]

	CSK-1	CSK-2	CSK-3	CSK-4
Launch date	6/8/2007	12/9/2007	10/25/2008	11/6/2010
Platform owner	ASI			
Altitude	620 km			
Orbit period	97.1 min			
Inclination	97.8°			
Crossing time	6:00 AN			
Nadir repeat	16 days			
Design lifetime	5 years			
Status	Operational			
System website	http://www.e-geos.it/cosmo-skymed.html			



Summit of Mount Etna captured by COSMO-SkyMed [Source: ASI, used with permission].

Sensor Information

	SAR-2000
GSD (m)	1—600 (selectable)
Swath (km)	10—200 (selectable)
Data portal	http://catalog.e-geos.it/

SAR-2000

The SAR-2000 instrument was developed and built by Thales Alenia Space Italia. The SAR instrument operates in the X-band at 9.6 GHz ($\lambda = 3.1$ cm). The angle of incidence is 18–59.5 degrees. SAR-2000 data are commercially available.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
Spotlight	Single	HH, VV	10	1
Stripmap Himage	Single	HH, HV, VH, VV	40	5
Stripmap Ping Pong	Alternating	HH/VV, HH/HV, VV/VH	30	20
ScanSAR Wide Region	Single	HH, HV, VH, VV	100	30
ScanSAR Huge Region	Single	HH, HV, VH, VV	200	100

CryoSat-2

European Space Agency
Civil/Government
Operational

Platform Overview

CryoSat-2 is a low-resolution radar altimeter satellite launched in 2010 on a Dnepr launch vehicle for monitoring ice thickness. CryoSat-2 replaces CryoSat, which was lost because of a launch failure in 2005. CryoSat-2 was built and integrated by European Aeronautics Defense and Space Astrium. CryoSat-2 carries the SAR Interferometer Radar Altimeter (SIRAL) sensor for low-resolution altimetry data.

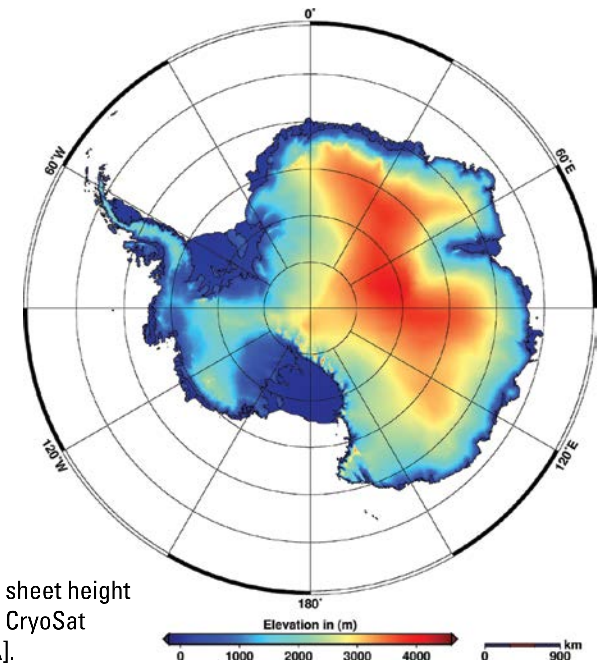
Artistic rendering of CryoSat-2 in orbit [Source: ESA].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; —, no data; GSD, ground sample distance; m, meter]

Launch date	4/8/2010
Platform owner	ESA
Altitude	717 km
Orbit period	100 min
Inclination	92°
Crossing time	—
Nadir repeat	—
Design lifetime	3.5 years
Status	Operational
System website	http://www.esa.int/Our_Activities/Observing_the_Earth/CryoSat

Sensor Information

	SIRAL
GSD (m)	250
Swath (km)	15
Data portal	https://earth.esa.int/web/guest/-/how-to-access-cryosat-data-6842



Antarctic ice sheet height measured by CryoSat [Source: ESA].

SIRAL

The SIRAL instrument was designed and developed by Thales Alenia Space. SIRAL is of Poseidon-2 heritage and was based on existing equipment. The sensor operates in the Ku-band at 13.575 GHz (λ = 2.21 cm). SIRAL data are freely available.

Beam mode	Polarization	Nominal swath width (km)	Approximate resolution (m)
LRM (Low Resolution Mode)	—	—	—
SARM (Synthetic Aperture Radar Mode)	—	—	—
SARIn (SAR Interferometric)	—	—	—

CSG-1 and -2

Italy
Civil/Government
Future

Platform Overview

CSG-1 and -2 (COSMO-SkyMed Second Generation) are high-resolution synthetic aperture radar (SAR) satellites to be launched in 2018/2019 and 2020, respectively, by the Italian Space Agency (ASI) for civil and defense use. The CSG satellites provide continuity of the COSMO-SkyMed (CSK) first generation satellites. The CSG satellites are being built by Thales Alenia Space, use the PRIMA bus, and will carry the CSG-SAR sensor for high-resolution radar data.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; —, no data; GSD, ground sample distance; m, meter; H, horizontal; V, vertical]

	CSG-1	CSG-2
Launch date	2019 (Planned)	2020 (Planned)
Design lifetime	7 years	
Platform owner	ASI	
Altitude	620 km	
Orbit period	97.1 min	
Inclination	97.8°	
Crossing time	6:00 AN	
Nadir repeat	16 days	
Status	Development	
System website	—	

Sensor Information

	CSG-SAR
GSD (m)	0.8–6 (selectable)
Swath (km)	10–200 (selectable)
Data portal	—

CSG-SAR

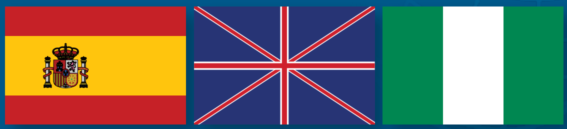
The CSG-SAR sensor is based on the SAR sensor aboard the CSK satellites. CSG-SAR provides improved capabilities and data continuity for the CSK constellation. CSG-SAR operates in the X-band at 9.6 GHz (λ = 3.12 cm). The angle of incidence is unavailable. Data are expected to be commercially available.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
Spotlight-2A	Single	HH, HV, VV, VH	10 x 10	0.8 x 0.8
Spotlight-2B	Dual	HH/HV, VV/VH	10 x 10	1 x 1
Stripmap	Single	HH, HV, VV, VH	40 x 2500	3 x 3
	Dual	HH/HV, VV/VH		
Pingpong	Burst dual	HH/HV, VV/VH	30 x 2500	5 x 20
Quadpol	Quad	HH/HV/VV/VH	15 x 2500	3 x 3
ScanSAR-1	Dual	HH/HV, VV/VH	100 x 2500	4 x 20
ScanSAR-2	Dual	HH/HV, VV/VH	200 x 2500	6 x 20

JACIE

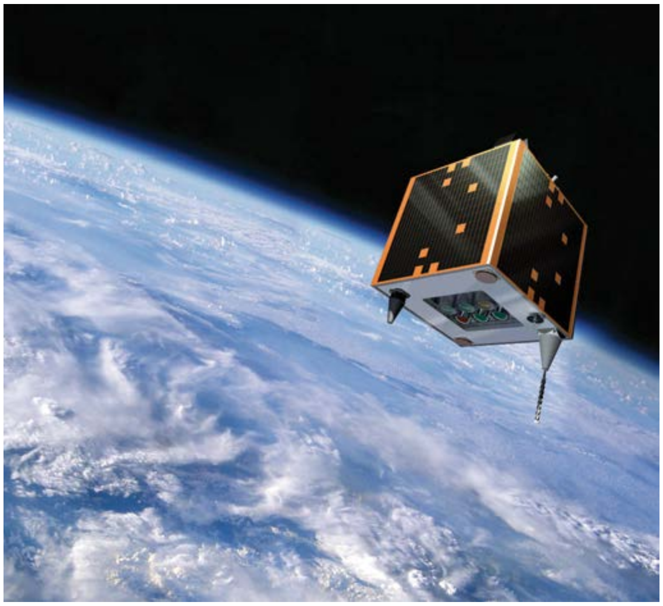
Deimos-1, UK-DMC-2, NigeriaSat-X

Spain, United Kingdom, Nigeria
Civil/Government
Operational



Platform Overview

The second generation of Disaster Monitoring Constellation (DMC) satellites, Deimos-1, UK-DMC-2, and NigeriaSat-X, provide medium-resolution, multispectral imagery. (NigeriaSat-2 is also a part of the DMC second generation but is described elsewhere in this document.) Deimos-1 and UK-DMC-2 were launched together in 2009 on a Dnepr-1 launch vehicle for disaster monitoring. NigeriaSat-X was launched with NigeriaSat-2 in 2011 on a Dnepr-1 launch vehicle. These three satellites were intended to provide continuity to the first generation of the DMC with enhanced imaging capabilities. The satellites were built by Surrey Satellite Technology, Ltd., (SSTL) and are of SSTL-100 heritage. These satellites carry the improved Surrey Linear Imager Multispectral 6 channels (SLIM6) sensor for medium-resolution land imaging.



Artistic rendering of Deimos-1 satellite in orbit [Source: Urthecast, used with permission].

[Abbreviations in tables: —, no data; km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; NIR, near infrared; m, meter; °, degree]

	Deimos-1	UK-DMC-2	NigeriaSat-X
Launch date	7/29/2009	7/29/2009	8/17/2011
Design lifetime	5 years	—	—
Platform owner	Deimos Imaging SL	SSTL	Nigerian National Space Research and Development Agency
Altitude	661 km	686 km	680 km
Orbit period	97.7 min	97.7 min	98 min
Inclination	98°	98.13°	98.25°
Crossing time	10:30 AN	10:30 AN	10:15 AN
Nadir repeat	5 days	—	—
Status	Operational	Operational	Operational
System website	https://www.deimos-imaging.com/satellites#1	http://www.sst-us.com/missions/uk-dmc-2--launched-2009	http://nasrda.gov.ng/en/

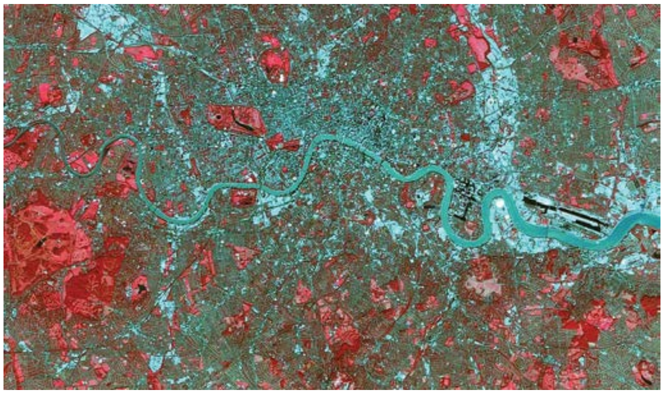
JACIE

Deimos-1, UK-DMC-2, NigeriaSat-X—Continued

Spain, United Kingdom, Nigeria
Civil/Government
Operational

Sensor Information

GSD (m)	22
Swath (km)	650
Data Portal	http://www.dmcii.com/

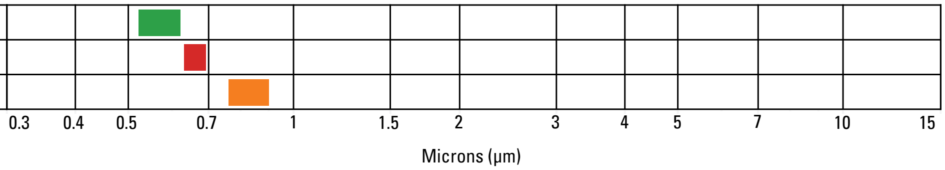


London, UK-DMC Constellation, UK-DMC2 image. [Source: Airbus DS, 2011, used with permission].

SLIM6 (22 meters)

The SLIM6 sensing element flown on the DMC second-generation satellites is an improved model of the first SLIM6 sensor. The ground sample distance was improved from 32 m to 22 m while maintaining the same swath width by using longer dimension arrays. The signal-to-noise ratio (SNR) was also improved in this generation of SLIM6 imagers. The SLIM6-22 imagers can image in 8-bit or 10-bit quantization, although the higher quantization limits the potential swath length of collectible data. SLIM6 data are commercially available.

Band	Lower	Center	Upper	GSD (m)
Green	0.520	0.570	0.620	22
Red	0.630	0.660	0.690	22
NIR	0.760	0.830	0.900	22



Deimos-2

Spain
Commercial
Operational

Platform Overview

Deimos-2 is a high-resolution, multispectral minisatellite launched in 2014 on a Dnepr-1 launch vehicle for Earth observation. Deimos-2 follows on the Deimos-1 mission, providing enhanced resolution and agility.

The satellite was built by Deimos Satellite Systems of Spain and Satrec Initiative (SI) of Korea. Deimos-2 utilizes SI's SpaceEye-1 platform (also known as SI-300) and is nearly identical to DubaiSat-1. Deimos-2 carries the High Resolution Advanced Imaging System (HiRAIS) sensor for high-resolution pan and VNIR imaging.

Deimos-2 satellite [Source: UrtheCast, used with permission].

[Abbreviations in tables: km, kilometer; AN, ascending node; min, minute; °, degree; GSD, ground sample distance; m, meter; Pan, panchromatic]

Launch date	6/19/2014
Design lifetime	10 years
Platform owner	Deimos Imaging
Altitude	620 km
Orbit period	97.3 min
Inclination	98°
Crossing time	10:30 AN
Nadir repeat	5 days
Status	Operational
System website	https://www.deimos-imaging.com/

Image of Stade de France captured by Deimos-2 satellite [Source: UrtheCast, used with permission].

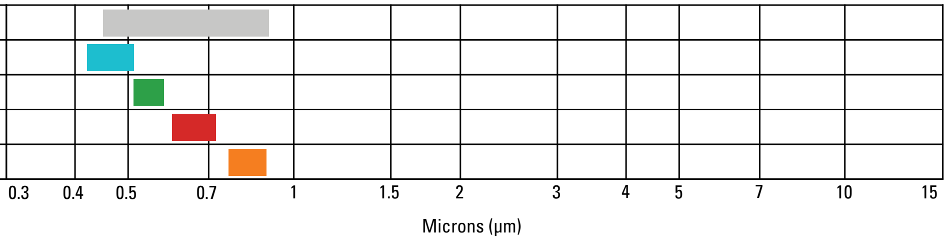
Sensor Information

GSD (m)	1, 4
Swath (km)	12
Data portal	https://www.deimos-imaging.com/catalogue

HiRAIS

The HiRAIS aboard Deimos-2 is a proven design with substantial heritage with DubaiSat-1 and 2. The sensor was designed and developed by SI in Korea. HiRAIS data are commercially available.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.675	0.900	1
Blue	0.420	0.465	0.510	4
Green	0.510	0.545	0.580	4
Red	0.600	0.660	0.720	4
NIR	0.760	0.825	0.890	4



DubaiSat-1

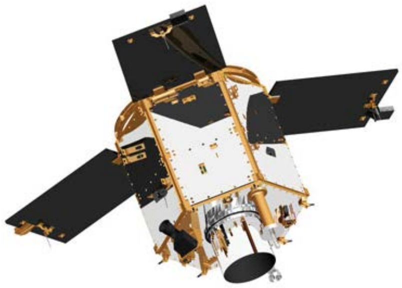
United Arab Emirates
Civil/Government
Operational

Platform Overview

DubaiSat-1 is a high-resolution multispectral satellite launched in 2009 by the Mohammed Bin Rashid Space Center (MBRSC) on a Dnepr rocket for Earth resources monitoring. This mission is the first satellite of the DubaiSat series. The DubaiSat-1 satellite was designed and built by Satrec Initiative Co. for the MBRSC and uses the SI-200 bus. DubaiSat-1 carries the DubaiSat Medium Aperture Camera (DMAC) sensor for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near-infrared]

Launch date	7/29/2009
Design lifetime	5 years
Platform owner	MBRSC
Altitude	680 km
Orbit period	97.7 min
Inclination	98.13°
Crossing time	10:30 AN
Nadir repeat	8 days
Status	Operational
System website	https://mbrsc.ae/en/page/dubai-sat-1



Artistic rendering of DubaiSat-1 [Source: Satrec Initiative, used with permission].

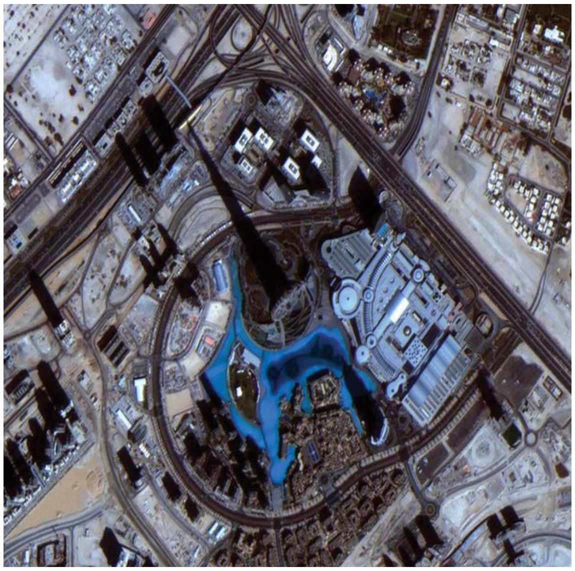


Image of Burj Khalifa, Dubai, captured by DubaiSat-1 [Source: MBRSC, used with permission].

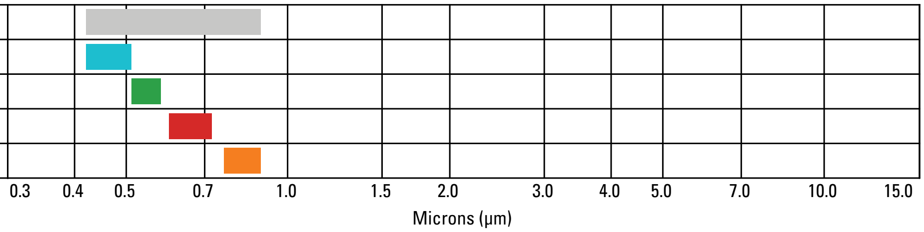
Sensor Information

	DMAC
GSD (m)	2.5, 5
Swath (km)	20.1
Data portal	—

DMAC

The DMAC is an optical pushbroom type camera imaging the Earth in visible and near infrared bands.

Band	Lower	Center	Upper	GSD (m)
Pan	0.420	0.655	0.890	2.5
Blue	0.420	0.465	0.510	5
Green	0.510	0.545	0.580	5
Red	0.600	0.660	0.720	5
NIR	0.760	0.825	0.890	5



DubaiSat-2

United Arab Emirates
Civil/Government
Operational

Platform Overview

DubaiSat-2 is a high-resolution multispectral satellite launched in 2013 by the Mohammed Bin Rashid Space Center (MBRSC) on a Dnepr rocket from Dombarovsky for Earth resources monitoring. This mission continues the DubaiSat series that has been in continual operation since the launch of DubaiSat-1 in 2009.

The DubaiSat-2 satellite was designed and built by Satrec Initiative Co. for the MBRSC and uses the SI-300 bus. DubaiSat-2 carries the High Resolution Advanced Imaging System (HiRAIS) sensor for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree: DN, descending node; —, no data; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near infrared]

Launch date	11/21/2013
Design lifetime	5 years
Platform owner	MBRSC
Altitude	600 km
Orbit period	96.69 min
Inclination	97.81°
Crossing time	10:30 DN
Nadir repeat	—
Status	Operational
System website	https://mbrsc.ae/en/page/dubai-sat-2

Artistic rendering of DubaiSat-2 in orbit [Source: MBRSC, used with permission].

Image of Abu Dhabi, United Arab Emirates, by DubaiSat-2 [Source: MBRSC, used with permission].

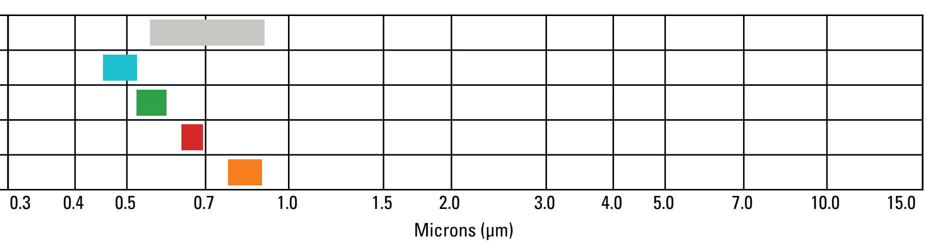
Sensor Information

	HiRAIS
GSD (m)	1, 4
Swath (km)	12
Data portal	https://mbrsc.ae/en/page/dubai-sat-2

HiRAIS

The HiRAIS is an improved version of the DMAC sensor flown on DubaiSat-1. The sensor offers a major improvement in image quality with a larger mirror diameter. The spectral bands, ground sample distance, swath width, and operating model remain the same as previous members of the DubaiSat family. HiRAIS data are gathered for paying customers only on a pre-paid, pre-scheduled basis.

Band	Lower	Center	Upper	GSD (m)
Pan	0.550	0.725	0.900	1
Blue	0.450	0.485	0.520	4
Green	0.520	0.555	0.590	4
Red	0.630	0.660	0.690	4
NIR	0.770	0.830	0.890	4



EnMAP

Germany
Civil/Government
Future

Platform Overview

Environmental Mapping and Analysis Program (EnMAP) is medium-resolution hyperspectral minisatellite to be launched in 2019 on a Polar Satellite Launch Vehicle for monitoring the condition of Earth's surface and the changes affecting it. EnMAP is based on the OHB-System of SAR-Lupe heritage. The bus of the system is referred to as LEOBus-1000. EnMAP will carry the Hyperspectral Imager (HSI) sensor for medium-resolution hyperspectral land imaging.

Artistic rendering of EnMAP in orbit [Source: DLR].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; —, no data; Hyper, hyperspectral]

Launch date	2020 (Planned)
Design lifetime	5 years
Platform owner	German Aerospace Center (DLR)
Altitude	643 km
Orbit period	97 min
Inclination	98°
Crossing time	11:00 AN
Nadir repeat	21 days
Status	Development
System website	http://www.enmap.org/

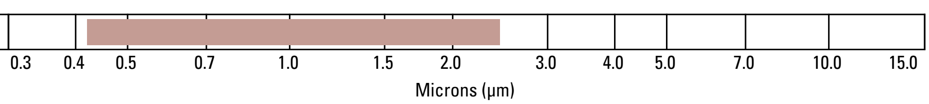
Sensor Information

	HSI
GSD (m)	30
Swath (km)	30
Data portal	—

HSI

The HSI sensor on EnMAP is a hyperspectral imager in visible and near infrared (VNIR) and shortwave infrared (SWIR). The imagery is acquired in 228 bands sampled at 5 nm in VNIR and at 10 nm in SWIR.

Band	Lower	Center	Upper	GSD (m)
Hyper	0.420	1.435	2.450	30



FLEX

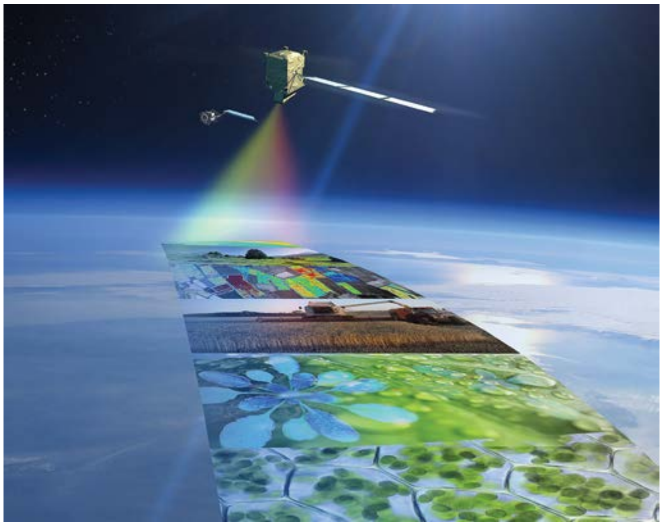
European Space Agency
Civil/Government
Future

Platform Overview

The Fluorescence Explorer (FLEX) is a European Space Agency (ESA) high-resolution imaging spectrometer satellite to be launched in 2022 for mapping vegetation fluorescence. FLEX was selected as the eighth Earth Explorer mission in 2015 and carries the FLuORescence Imaging Spectrometer (FLORIS) sensor for low-resolution land imaging, with an expected 500–800-nm spectral range.

[Abbreviations in tables: km, kilometer; —, no data; GSD, ground sample distance; m, meter; NIR, near-infrared]

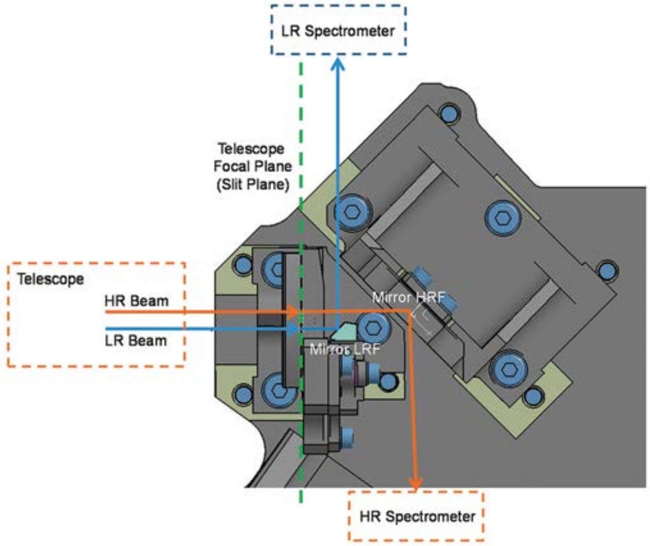
Launch date	2022 (Planned)
Design lifetime	5 years
Platform owner	ESA
Altitude	815 km
Orbit period	—
Inclination	—
Crossing time	—
Nadir repeat	—
Status	Planned
System website	https://earth.esa.int/web/guest/missions/esa-future-missions/flex



Artistic rendering of FLEX in orbit [Source: ESA].

Sensor Information

	FLORIS
GSD (m)	300
Swath (km)	150
Data portal	—



FLORIS sensor illustration [Source: ESA].

JACIE

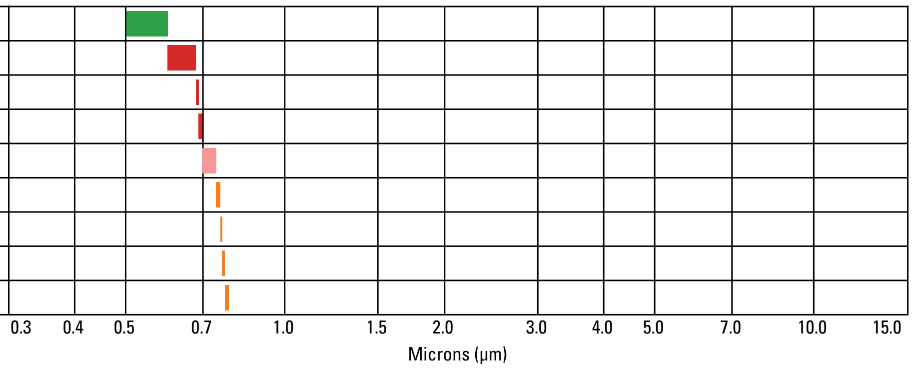
FLEX—Continued

European Space Agency
Civil/Government
Future

FLORIS

FLORIS, a pushbroom hyperspectral imager, will measure vegetation fluorescence in visible and near infrared (VNIR) at medium spatial resolution over a swath of 150 km. The imaging spectrometer has two modules—one has very high spectral resolution (0.3 nm) with two oxygen absorption bands (O2A and O2B, shown as NIR here) and the other has lower spectral resolution (3 nm) for atmospheric and vegetation parameters.

Band	Lower	Center	Upper	GSD (m)
Green	0.500	0.550	0.600	300
Red	0.600	0.639	0.677	300
Red	0.677	0.682	0.686	300
Red	0.686	0.692	0.697	300
Red Edge	0.697	0.719	0.740	300
NIR	0.740	0.748	0.755	300
NIR	0.755	0.757	0.759	300
NIR	0.759	0.764	0.769	300
NIR	0.769	0.775	0.780	300



GEO-CAPE

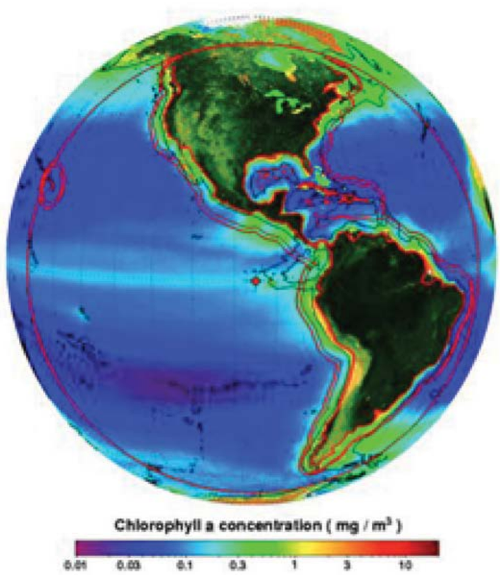
United States
Civil/Government
Future

Platform Overview

The GEOstationary Coastal and Air Pollution Events (GEO-CAPE) mission is planned to be launched in 2020 to measure tropospheric trace gases and aerosols, coastal ocean phytoplankton, water quality, and biogeochemistry. GEO-CAPE will be in a geostationary orbit near 95–100 degrees west to cover North and South America and their coasts. Specific sensors for GEO-CAPE have not yet been selected.

[Abbreviations in table: —, no data; km, kilometer; °, degree]

Launch date	2020 (Planned)
Design lifetime	—
Platform owner	NASA
Altitude	35,786 km
Orbit period	24 hours
Inclination	0°
Crossing time	NA
Nadir repeat	NA
Status	Operational
System website	https://geo-cape.larc.nasa.gov/

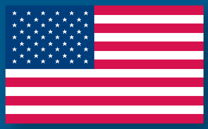


Geostationary view from 95° W for the GEO-CAPE coastal ecosystem sensor overlain on the SeaWiFS chlorophyll-*a* mission composite [Source: NASA].

JACIE

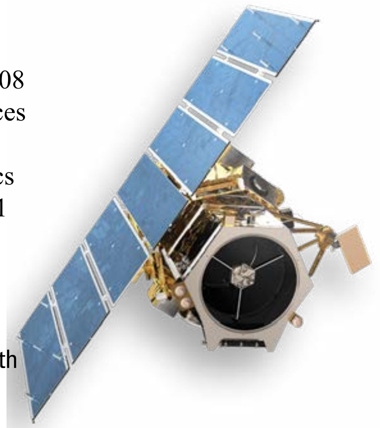
GeoEye-1

United States
Commercial
Operational



Platform Overview

GeoEye-1 is a high-resolution panchromatic and multispectral satellite launched in 2008 on a Delta-II launch vehicle from Vandenberg Air Force Base for commercial Earth resources monitoring. DigitalGlobe acquired GeoEye Inc. in 2013, adding GeoEye-1 to their constellation of commercial satellites. GeoEye-1 was designed and developed at General Dynamics in the United States and uses the SA-200HP bus of Coriolis and SWIFT heritage. GeoEye-1 carries the GeoEye Imaging System (GIS) for high-resolution land imaging.



Artistic rendering of GeoEye-1 [Source: MAXAR Technologies, 2019, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; —, no data; GSD, ground sample distance; m, meter; NIR, near infrared]

Launch date	9/6/2008
Design lifetime	7 years
Platform owner	DigitalGlobe
Altitude	681 km
Orbit period	98 min
Inclination	98.12°
Crossing time	10:30 DN
Nadir repeat	—
Status	Operational
System website	https://www.digitalglobe.com/about/our-constellation/

GeoEye-1 image of Monopoli, Italy [Source: MAXAR Technologies, 2019, used with permission].

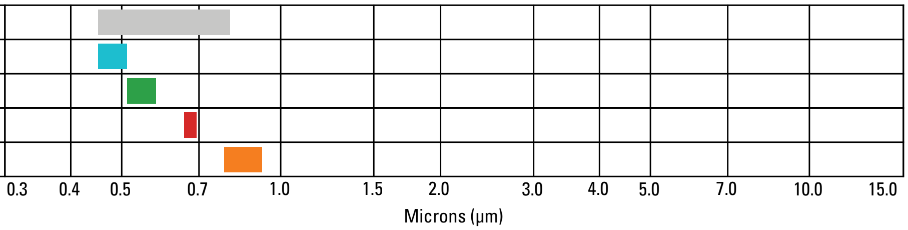
Sensor Information

	GIS
GSD (m)	0.41, 1.65
Swath (km)	15.3
Data portal	https://www.digitalglobe.com/products/collection-request

GIS

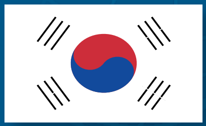
The GIS sensor is a pushbroom-style CCD imager. The sensor was designed and developed by ITT in the United States and delivered to General Dynamics for integration. GIS data are commercially available.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.625	0.800	0.41
Blue	0.450	0.480	0.510	1.65
Green	0.510	0.545	0.580	1.65
Red	0.655	0.673	0.690	1.65
NIR	0.780	0.850	0.920	1.65



GEO-KOMPSAT-2A

South Korea
Civil/Government
Operational



Platform Overview

GEO-KOMPSAT-2A is a low-resolution, multispectral, geostationary satellite launched in 2018 by the Korean Aerospace Research Institute (KARI) on an Ariane-5ECA launch vehicle for meteorological monitoring. GEO-KOMPSAT-2A provides continuity for the Meteorological Imager aboard COMS. The platform used by GEO-KOMPSAT-2A is developed and built by KARI. GEO-KOMPSAT-2A carries the Advanced Meteorological Imager (AMI) sensor for low-resolution meteorological imaging.

Artistic rendering of GEO-KOMPSAT-2A in orbit [Source: KARI, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; GSD, ground sample distance; m, meter; —, no data; NIR, near infrared; SWIR, shortwave infrared; MWIR, midwave infrared; TIR, thermal infrared]

Launch date	12/4/2018
Design lifetime	10 years
Platform owner	KARI
Altitude	35,786 km
Orbit period	24 hours
Inclination	0°
Crossing time	NA
Nadir repeat	NA
Status	Operational
System website	https://www.kari.re.kr/eng/sub03_02_02.do

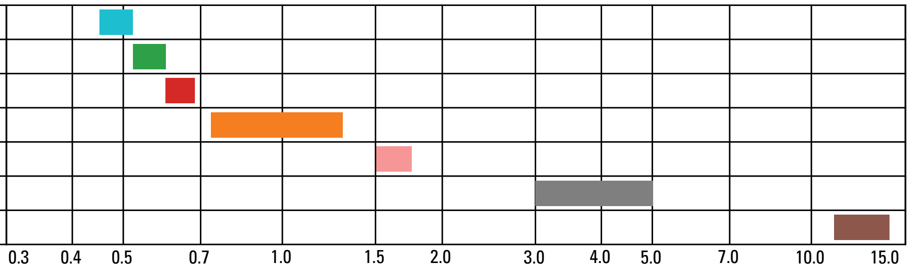
Sensor Information

	AMI
GSD (m)	500; 1,000; 2,000
Swath (km)	—
Data portal	—

AMI

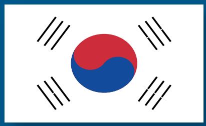
The AMI was developed by ITT Inc. in the United States. AMI is based on the Advanced Baseline Imager (ABI) flown on GOES-R. AMI has improved spectral, temporal, and spatial resolution compared to the imager aboard COMS.

Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	1,000
Green	0.520	0.560	0.600	1,000
Red	0.600	0.640	0.680	500
NIR	0.730	1.015	1.300	1,000
SWIR 1	1.500	1.625	1.750	2,000
MWIR	3.000	4.000	5.000	2,000
TIR	11.000	12.500	14.000	2,000



GEO-KOMPSAT-2B

South Korea
Civil/Government
Future



Platform Overview

GEO-KOMPSAT-2B is a low-resolution, multispectral, geostationary satellite to be launched in 2019 by the Korean Aerospace Research Institute (KARI) on an Ariane-5ECA launch vehicle for ocean monitoring. GEO-KOMPSAT-2B provides continuity for the GOCI sensor aboard COMS. The platform used by GEO-KOMPSAT-2B is being developed and built by KARI. GEO-KOMPSAT-2B will carry the Global Ocean Color Imager—II (GOCI-II) sensor for low-resolution ocean imaging.

Artistic rendering of GEO-KOMPSAT-2B in orbit [Source: KARI, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; GSD, ground sample distance; m, meter; —, no data; NIR, near infrared]

Launch date	2020 (Planned)
Design lifetime	10 years
Platform owner	KARI
Altitude	35,786 km
Orbit period	24 hours
Inclination	0°
Crossing time	NA
Nadir repeat	NA
Status	Development
System website	https://www.kari.re.kr/eng/sub03_02_02.do

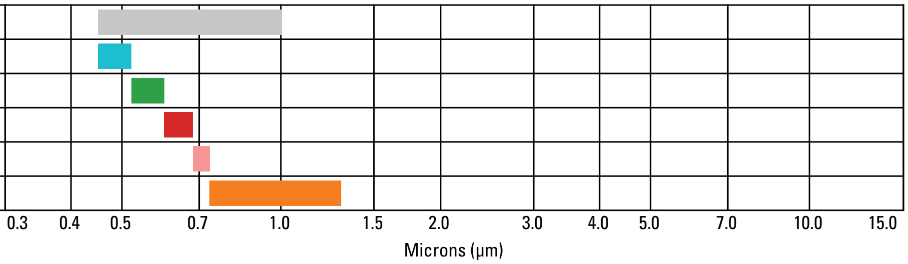
Sensor Information

	GOCI-II
GSD (m)	250
Swath (km)	—
Data portal	—

GOCI-II

The Global Ocean Color Imager–II (GOCI-II) was developed by Airbus DS. GOCI-II has improved spectral, temporal, and spatial resolution compared to the imager aboard the Communication, Oceanography and Meteorological Satellite (COMS).

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.725	1.000	250
Blue	0.450	0.485	0.520	250
Green	0.520	0.560	0.600	250
Red	0.600	0.640	0.680	250
Red Edge	0.680	0.705	0.730	250
NIR	0.730	1.015	1.300	250



GISAT

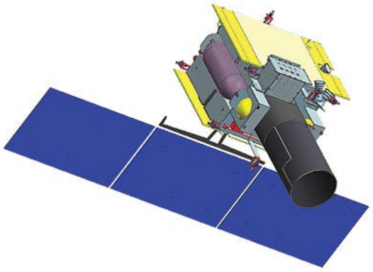
India
Civil/Government
Future

Platform Overview

GEO Imaging Satellite (GISAT) is a multiresolution geostationary satellite to be launched in 2019 on a Geo Stationary Launch Vehicle (GSLV) Mark-2A for continuous observation of India and quick monitoring of natural hazards and disasters. GISAT is based on the Indian Space Research Organization (ISRO) I-1K (I-1000) bus and carries the high resolution multispectral visible and near infrared (HRMX-VNIR) for medium-resolution land imaging and the high resolution multispectral thermal infrared (HRMX-TIR), hyperspectral shortwave infrared (HySI-SWIR), and hyperspectral visible ansd near infrared (HySI-VNIR) sensors for low-resolution land imaging.

[Abbreviations in tables: km, kilometer; °, degree; —, no data; GSD, ground sample distance; m, meter; NIR, near-infrared; SWIR, shortwave infrared; TIR, thermal infrared]

Launch date	2019 (Planned)
Design lifetime	7 years
Platform owner	ISRO
Altitude	36,000 km
Orbit period	24 hours
Inclination	0°
Crossing time	—
Nadir repeat	—
Status	Development
System website	—



3-Dimensional model of GISAT [Source: ISRO, used with permission].

Sensor Information

	HRMX-TIR	HRMS-VNIR	HySI-SWIR	HySI-VNIR
GSD (m)	1,500	50	320	192
Swath (km)	—	—	—	—
Data portal	—			

HRMX-TIR

The HRMX-TIR sensor has three bands in the TIR spectral range. The ground sample distance (GSD) is 1.5 km. Spectral information details are not yet available.

HRMX-VNIR

The HRMX-VNIR sensor has four bands in the VNIR spectral range. The GSD is 50 m. Spectral information details are not yet available.

HySI-SWIR

The HySI-SWIR sensor has 60 bands in the SWIR spectral range. The GSD is 320 m. Spectral information details are not yet available.

HySI-VNIR

The HySI-SWIR sensor has 60 bands in the VNIR spectral range. The GSD is 192 m. Spectral information details are not yet available.

JACIE

GOES-16, -17, -T, and -U

United States
Civil/Government
Operational/Future

Platform Overview

The third-generation Geostationary Operational Environmental Satellites (GOES-16, -17, -T, and -U), commonly referred to as the GOES-R series, are low-resolution multispectral satellites for environmental monitoring. GOES-16 and -17 were launched in 2016 and 2018, respectively. GOES-T and -U are planned to be launched in 2020 and 2024, respectively. This mission continues the GOES series that has been in continual operation since the launch of GOES-1 in 1984. The GOES satellites have been built by NOAA and NASA. Lockheed Martin Space Systems Company was selected to build the third-generation spacecraft. The bus is based on the A2100 bus. The GOES-R satellites carry the Advanced Baseline Imager (ABI) sensor for low-resolution land imaging.

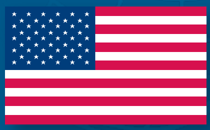
Artistic rendering of a GOES-R satellite in orbit [Source: Lockheed Martin, used with permission].

[Abbreviations in tables: km, kilometer; NA, not applicable; min, minute; °, degree; GSD, ground sample distance; m, meters; —, no data; NIR, near infrared; SWIR, shortwave infrared; MWIR, midwave infrared; TIR, thermal infrared]

	GOES-16	GOES-17	GOES-T	GOES-U
Launch date	11/19/2016	3/1/2018	2020 (Planned)	2024 (Planned)
Design lifetime	10 years			
Platform owner	NOAA			
Altitude	35,786 km			
Orbit period	24 hours			
Inclination	0°			
Crossing time	NA			
Nadir repeat	NA			
Status	Operational	In-orbit checkout	Development	
System website	https://www.goes-r.gov/			

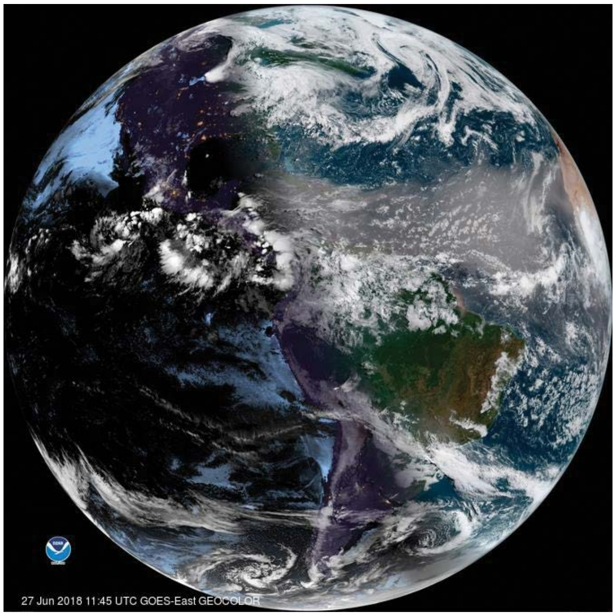
GOES-16, -17, -T, and -U—Continued

United States
Civil/Government
Operational/Future



Sensor Information

	ABI
GSD (m)	500; 1,000; 2,000
Swath (km)	—
Data portal	https://www.ngdc.noaa.gov/stp/satellite/goes-r.html

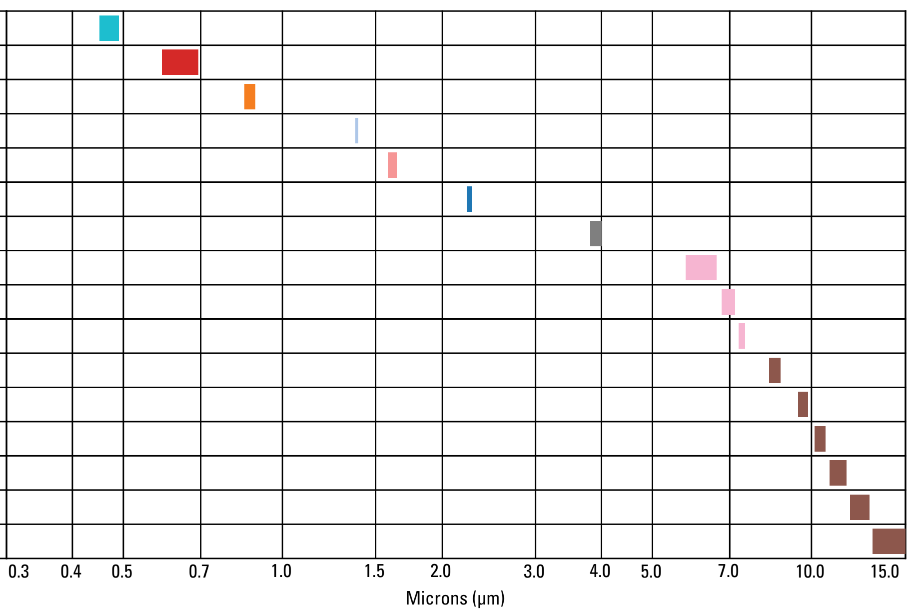


GOES-16 image of Earth [Source: NOAA].

ABI

The ABI was designed and developed by ITT Inc. ABI greatly improved on the imager flown on the second-generation GOES satellites, featuring more spectral bands (16), faster imaging cycles, and higher spatial resolution. ABI data are freely available.

Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.470	0.490	1,000
Red	0.590	0.640	0.690	500
NIR	0.846	0.866	0.885	1,000
Cirrus	1.371	1.379	1.386	2,000
SWIR 1	1.580	1.610	1.640	1,000
SWIR 2	2.225	2.250	2.275	2,000
MWIR	3.800	3.900	4.000	2,000
WV	5.770	6.185	6.600	2,000
WV	6.750	6.950	7.150	2,000
WV	7.240	7.340	7.440	2,000
TIR	8.300	8.500	8.700	2,000
TIR	9.420	9.610	9.800	2,000
TIR	10.100	10.350	10.600	2,000
TIR	10.800	11.200	11.600	2,000
TIR	11.800	12.300	12.800	2,000
TIR	13.000	14.000	15.000	2,000



GOMX-4A and -4B

Denmark
Commercial
Operational

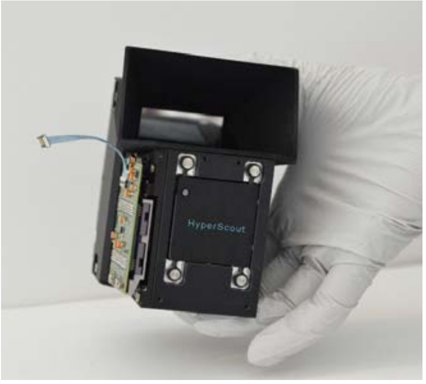
Platform Overview

GOMX-4A and -4B are medium-resolution hyperspectral satellites launched in 2018 on a Long March 2D from Jiquan launch center, China, to demonstrate constellation capability, intersatellite link, and station keeping; and for Earth resources monitoring. The GOMX-4 6U cubesats were designed and built by GomSpace as a part of their flight demonstration mission series. GomSpace partnered with the Danish Defense Acquisition and Logistics Organization (DALO), the Technical University of Denmark (TUD), and the European Space Agency (ESA). The two satellites are linked by the inter satellite link (ISL) system. GOMX-4A carries an Automatic Identification System (AIS) maritime tracking sensor with a 70-mm NanoCamera for monitoring arctic ice and maritime applications. GOMX-4B carries the HyperScout sensor for medium-resolution hyperspectral land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; —, no data; Hyper, Hyperspectral]

Launch date	2/2/2018
Design lifetime	3 years
Platform owner	GomSpace
Altitude	500 km
Orbit period	94.6 min
Inclination	97.32°
Crossing time	15:00 DN
Nadir repeat	5 days
Status	Operational
System website	https://gomspace.com/gomx-4.aspx https://hyperscout.nl/

Artistic rendering of the GOMX-4 satellites in orbit [Source: GomSpace, used with permission].



HyperScout sensor [Source: COSINE Measurement Systems (https://cosine.nl), used with permission].

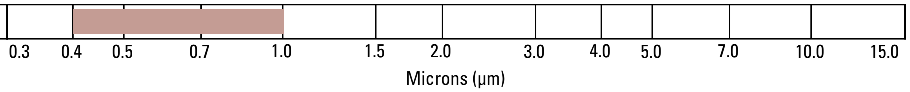
Sensor Information

	HyperScout
GSD (m)	70
Swath (km)	200
Data portal	—

HyperScout

The HyperScout sensor built by COSINE Measurement Systems in the Netherlands, is the first hyperspectral sensor for nanosatellites. It has 45 visible and near infrared (VNIR) bands with a spectral resolution of 15 nm. The aim of this demonstration mission is to assess the quality of data acquired and consequent suitability to applications like crop water management, fire monitoring, and land use and change. HyperScout sensor is now available for purchase as a COTS component from COSINE.

Band	Lower	Center	Upper	GSD (m)
Hyper	0.400	0.700	1.000	70



JACIE

HRSAT 1A, 1B, 1C

India
Civil/Government
Future

Platform Overview

HRSAT 1A, 1B, and 1C are high-resolution multispectral satellites to be launched in 2020 by the Indian Space Research Organization (ISRO) for Earth observation. Limited information currently (2018) is available. The HRSAT satellites carry a multispectral camera (MX) and a panchromatic camera (PAN) for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; —, no data; GSD, ground sample distance; m, meter; Hyper, Hyperspectral]

	HRSAT 1A	HRSAT 1B	HRSAT 1C
Launch date	2020 (Planned)		
Design lifetime	—		
Platform owner	ISRO		
Altitude	660 km		
Orbit period	97.94 min		
Inclination	98.02°		
Crossing time	9:30 DN		
Nadir repeat	—		
Status	Development		
System website	—		

Sensor Information

	MX	PAN
GSD (m)	2, 4	1
Swath (km)	15	20
Data portal	—	

PAN and MX

The HRSAT carries a panchromatic and multispectral imager (four bands). The visible bands have a 2-m ground sample distance (GSD) and the infrared band has a 4-m GSD. Detailed spectral information is not available at this time.

JACIE

HyspIRI Mission Concept

United States
Civil/Government
Future

Platform Overview

The Hyperspectral Infrared Imager (HyspIRI) mission concept is for a medium-resolution hyperspectral and multispectral satellite estimated to be launched in 2023 by the National Aeronautics and Space Administration (NASA) for the study of Earth surface biology, geology, and natural disaster monitoring. HyspIRI currently (2018) is still in conceptual development. HyspIRI is expected to carry the visible shortwave infrared (VSWIR) and thermal infrared (TIR) sensors for medium resolution land imaging, roughly 60-m spatial resolution.

Artistic rendering of HyspIRI in orbit [Source: NASA].

[Abbreviations in tables: km, kilometer; —, no data; °, degree; DN, descending node; GSD, ground sample distance; m, meter; Hyper, hyperspectral; MWIR, midwave infrared; TIR, thermal infrared]

Launch date	2023 (Planned)
Platform owner	NASA
Altitude	626 km
Orbit period	—
Inclination	98°
Crossing time	11:00 DN
Nadir repeat	19 days
Design lifetime	3 years
Status	Concept
System website	https://hyspiri.jpl.nasa.gov/

Sensor Information

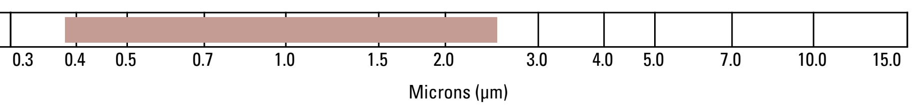
	VSWIR	TIR
GSD (m)	60	
Swath (km)	185	
Data portal	—	

JACIE

VSWIR

The VSWIR Imaging Spectrometer is a hyperspectral imager with a wide spectral range.

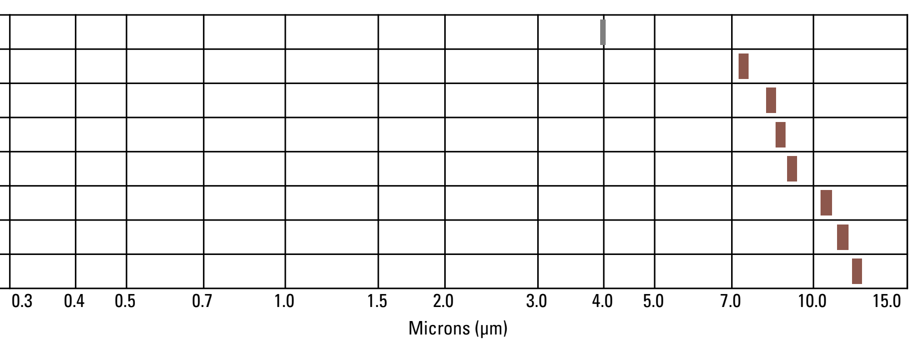
Band	Lower	Center	Upper	GSD (m)
Hyper	0.380	1.445	2.510	60



TIR

The TIR is a multispectral infrared imager with a wide swath operating in the thermal part of the spectrum.

Band	Lower	Center	Upper	GSD (m)
MWIR	3.940	3.982	4.024	60
TIR	7.190	7.350	7.509	60
TIR	8.107	8.279	8.450	60
TIR	8.455	8.628	8.801	60
TIR	8.894	9.074	9.254	60
TIR	10.258	10.528	10.798	60
TIR	11.060	11.330	11.600	60
TIR	11.790	12.050	12.310	60

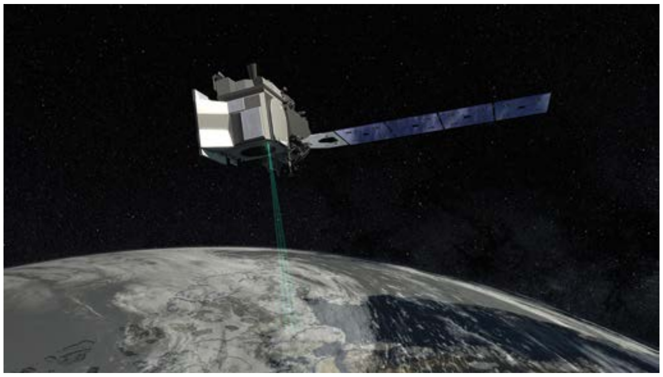


ICESat-2

United States
Civil/Government
Operational

Platform Overview

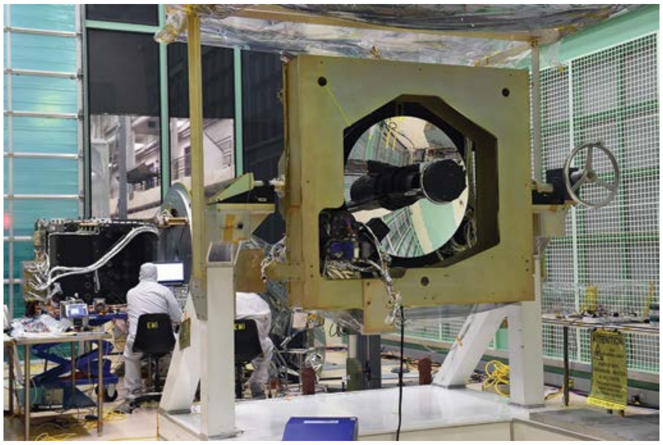
The Ice, Cloud, and land Elevation Satellite–2 (ICESat-2) is a high-precision laser altimeter satellite launched by the National Aeronautics and Space Administration (NASA) on a Delta-II launch vehicle from Vandenberg Air Force Base in California. ICESat-2's primary mission is to collect precise measurements of the heights of the Earth's ice, vegetation, land surface, water, and clouds. This mission continues and improves on the observations of the original ICESat satellite (and Operation IceBridge annual polar data collection aircraft campaigns). The ICESat-2 spacecraft bus was built by Orbital ATK and uses the LEOStar-3 bus used on Landsat 8 and GeoEye-1. ICESat-2 carries the Advanced Topographic Laser Altimeter System (ATLAS).



Artistic rendering of ICESat-2 in orbit [Source: NASA].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; —, no data; GSD, ground sample distance; m, meter]

Launch date	09/15/2018
Design lifetime	3 years
Platform owner	NASA
Altitude	500 km
Orbit period	94.6 min
Inclination	92°
Crossing time	—
Nadir repeat	91 days
Status	Commissioning
System website	https://icesat-2.gsfc.nasa.gov/



ATLAS instrument model [Source: NASA].

Sensor Information

	ATLAS
GSD (m)	0.7 (along track)
Swath (km)	6
Data portal	—

ATLAS

The ATLAS is a new design from NASA's Goddard Space Flight Center (GSFC). Unlike the original ICESat's Geoscience Laser Altimeter System (GLAS), which used millions of photons to measure a single data point, ATLAS measures very few photons—a few dozen at most. The instrument has a vertical resolution of 4 mm. ATLAS splits its laser into nine beams and samples approximately every 70 cm on the ground. The laser has a frequency of 532 nm (visible green).

JACIE

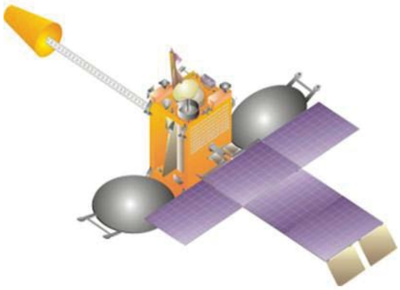
INSAT-3A

India
Civil/Government
Operational

Platform Overview

The Indian National Satellite–3A (INSAT-3A) is a low-resolution multispectral satellite launched in 2003 on an Ariane-5 launch vehicle from Kourou, French Guiana, by the Indian Space Research Organization (ISRO) for meteorological monitoring. INSAT-3A is in a geostationary orbit at 93.5 degrees east. The satellite is based on the I-3000 bus. INSAT-3A carries the Very High-Resolution Radiometer (VHRR) sensor and a CCD Camera for meteorological monitoring.

[Abbreviations in tables: km, kilometer; °, degree; NA, not applicable; GSD, ground sampling distance; m, meters; —, no data; NIR, near infrared; TIR, thermal infrared]



3-Dimensional model of INSAT-3A [Source: ISRO, used with permission].

Launch date	4/9/2003
Design lifetime	12 years
Platform owner	ISRO
Altitude	35,786 km
Orbit period	24 hours
Inclination	0°
Crossing time	NA
Nadir repeat	NA
Status	Operational
System website	https://www.isro.gov.in/Spacecraft/insat-3a

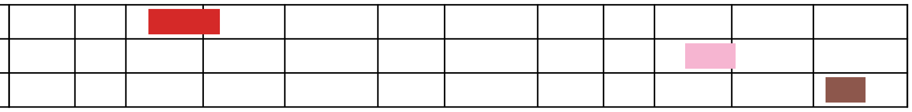
Sensor Information

	VHRR	CCD Camera
GSD (m)	2,000; 8,000	1,000
Swath (km)	—	—
Data portal	https://mosdac.gov.in/content/Mission/insat-3a	

VHRR

The VHRR sensor is identical to the VHRR sensor flown on Kalpana-1. The sensor can operate in Full scan mode with a 33-minute repeat; Normal scan mode with a 23-minute repeat; or Sector scan mode, which can scan an area three times in 23 minutes.

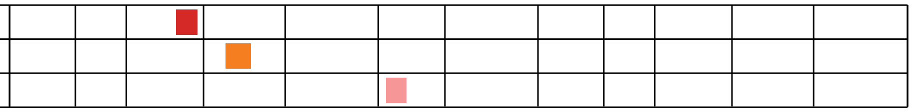
Band	Lower	Center	Upper	GSD (m)
VIS	0.550	0.650	0.750	2,000
WV	5.700	6.400	7.100	8,000
TIR	10.500	11.500	12.500	8,000



CCD Camera

The CCD camera is an experimental sensor for meteorological monitoring as well as vegetation mapping. The CCD camera was first introduced on INSAT-2E. Bands 1 and 2 provide vegetation index data and band 3 is used to measure snow cover.

Band	Lower	Center	Upper	GSD (m)
Red	0.620	0.650	0.680	1,000
NIR	0.770	0.815	0.860	1,000
SWIR 1	1.550	1.620	1.690	1,000



Data compiled by the USGS National Land Imaging Program's Requirements Capabilities and Analysis for Earth Observation (RCA-EO) project. JACIE is a collaboration between U.S. Federal agencies NASA, NGA, NOAA, USDA, and USGS. For more information see: https://www.usgs.gov/land-resources/eros/calval/jacie

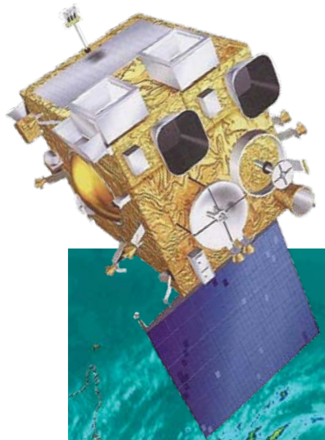
For Joint Agency Commercial Imagery Evaluation (JACIE) sensor performance information see: https://www.usgs.gov/land-resources/eros/calval/jacie

RCA-EO; USGS EROS Center
47914 252nd St.
Sioux Falls, SD 57198
eccoe@usgs.gov

INSAT-3D and -3DR

India
Civil/Government
Operational

Platform Overview

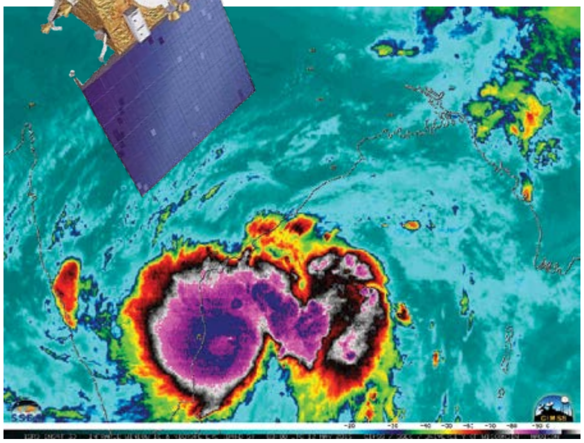


Artistic rendering of INSAT-3D [Source: ISRO, used with permission].

The Indian National Satellite–3D (INSAT-3D) is a low-resolution multispectral satellite launched in 2013 by the Indian Space Research Organization (ISRO) on an Ariane-5 launch vehicle from Kourou, French Guiana, for meteorological monitoring. This mission continues the INSAT-3 series of satellites with improved capabilities. INSAT-3D is in a geostationary orbit at 82 degrees east. INSAT-3DR was launched in 2016 featuring similar instruments. INSAT-3DR is in a geostationary orbit at 72 degrees east. INSAT-3D and -3DR carry the Multispectral Imager (MSI) for meteorological monitoring.

[Abbreviations in tables: km, kilometer; °, degree; GSD, ground sample distance; m, meter; —, no data; VIS, Visible; SWIR, shortwave infrared; MWIR, midwave infrared; TIR, thermal infrared]

	INSAT-3D	INSAT-3DR
Launch date	7/25/2013	9/8/2016
Design lifetime	7.7 years	10 years
Platform owner	ISRO	
Altitude	35,786 km	
Orbit period	24 hours	
Inclination	0°	
Crossing time	NA	
Nadir repeat	NA	
Status	Operational	
System website	https://www.isro.gov.in/Spacecraft/insat-3d	https://www.isro.gov.in/Spacecraft/insat-3dr



INSAT-3D data of Cyclone Roanu, Indian ocean [Source: University of Wisconsin].

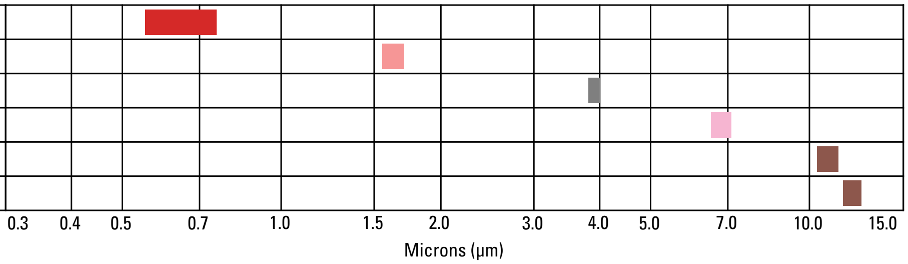
Sensor Information

	MSI
GSD (m)	1,000; 4,000; 8,000
Swath (km)	—
Data portal	https://www.mosdac.gov.in/

MSI

The MSI is an improved version of the Very High-Resolution Radiometer (VHRR) flown on Kalpana-1 and INSAT-3A. The imager includes three new bands: shortwave infrared, midwave infrared, and an additional thermal infrared band. The spatial resolution is also improved.

Band	Lower	Center	Upper	GSD (m)
VIS	0.550	0.650	0.750	1,000
SWIR 1	1.550	1.625	1.700	1,000
MWIR	3.800	3.900	4.000	4,000
WV	6.500	6.800	7.100	8,000
TIR	10.300	10.800	11.300	4,000
TIR	11.500	12.000	12.500	4,000



JACIE

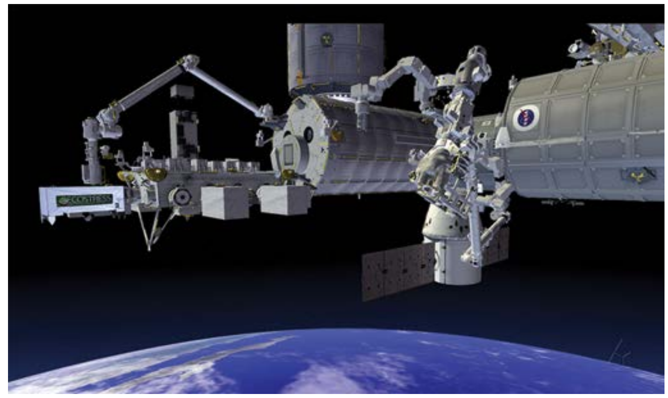
ISS JEM-EF/Kibo

Japan
Civil/Government
Operational

Platform Overview

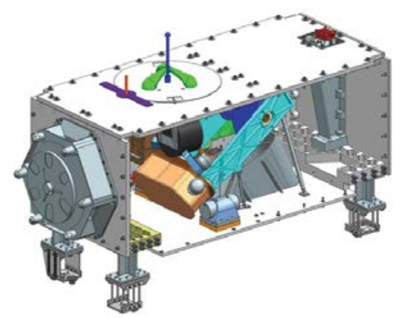
The Japanese Experiment Module Exposed Facility (JEM-EF) is a part of JEM (referred to as Kibo in Japan), launched in 2009 by the Japan Aerospace Exploration Agency (JAXA) on STS-127 with an emphasis on Earth observation instruments. JEM-EF will host the ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) sensor.

[Abbreviations in tables: —, no data; km, kilometer; min, minute; °, degree; GSD, ground sample distance; m, meter; SWIR, shortwave infrared; TIR, thermal infrared]



Artistic rendering of the ISS JEM-EF module with ECOSTRESS attached [Source: NASA].

Launch date	7/15/2009
Design lifetime	—
Platform owner	JAXA
Altitude	407 km
Orbit period	93 min
Inclination	51.6°
Crossing time	—
Nadir repeat	—
Status	Operational
System website	https://www.nasa.gov/mission_pages/station/research/experiments/JEM-EF.html



3-Dimensional model of ECOSTRESS [Source: NASA].

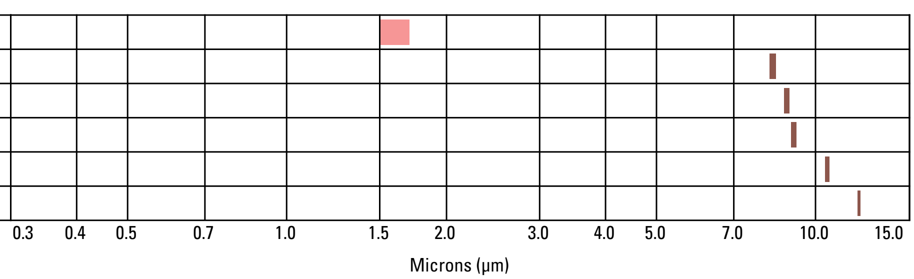
ECOSTRESS

The ECOSTRESS payload was launched to ISS in June 2018 on a Falcon 9 launch vehicle and installed on July 5, 2018. ECOSTRESS's central mission is to study the terrestrial biosphere, vegetation water use, and agricultural dynamics. ECOSTRESS is an implementation of the existing Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR) developed by NASA. ECOSTRESS data will be freely available.

Sensor Information

	ECOSTRESS
GSD (m)	38
Swath (km)	384
Data portal	—

Band	Lower	Center	Upper	GSD (m)
SWIR 1	1.500	1.600	1.700	38
TIR	8.180	8.280	8.380	38
TIR	8.690	8.790	8.890	38
TIR	8.960	9.060	9.160	38
TIR	10.400	10.500	10.600	38
TIR	11.950	12.035	12.120	38



ISS MUSES

United States
Civil/Government
Operational

Platform Overview

The Multiple User System for Earth Sensing (MUSES) is a commercially operated multiuser facility aboard the International Space Station (ISS) launched in June 2017 on a SpaceX Falcon 9 launch vehicle. MUSES was developed by Teledyne Brown Engineering. The facility is mounted on the starboard side of the ISS. MUSES currently hosts the DLR Earth Sensing Imaging Spectrometer (DESIS) sensor.

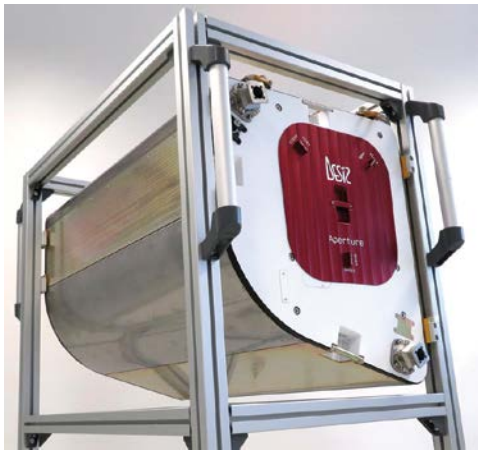
[Abbreviations in tables: —, no data; km, kilometer; min, minute; °, degree; GSD, ground sample distance; m, meter; Hyper, hyperspectral]

Launch date	6/3/2017
Design lifetime	—
Platform owner	NASA
Altitude	407 km
Orbit period	93 min
Inclination	51.6°
Crossing time	—
Nadir repeat	—
Status	Operational
System website	https://www.nasa.gov/mission_pages/station/research/experiments/1282.html

MUSES pointing platform [Source: NASA].

Sensor Information

	DESIS
GSD (m)	30
Swath (km)	57
Data portal	—

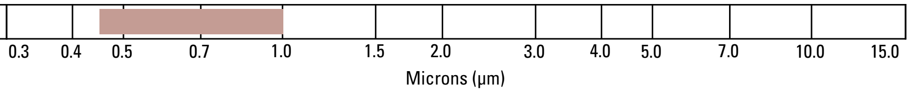


DESIS sensor model [Source: DLR].

DESIS

The DESIS sensor was launched from Cape Canaveral, Florida, on June 29, 2018, as part of the SpaceX CRS-15 logistics flight to the ISS. DESIS was placed in the MUSES facility on the ISS for environmental monitoring. DESIS is a hyperspectral imager with as many as 235 bands built and designed by DLR and Teledyne Brown Engineering. DESIS data are commercially available through Teledyne.

Band	Lower	Center	Upper	GSD (m)
Hyper	0.450	0.725	1.000	30



ISS Zvezda

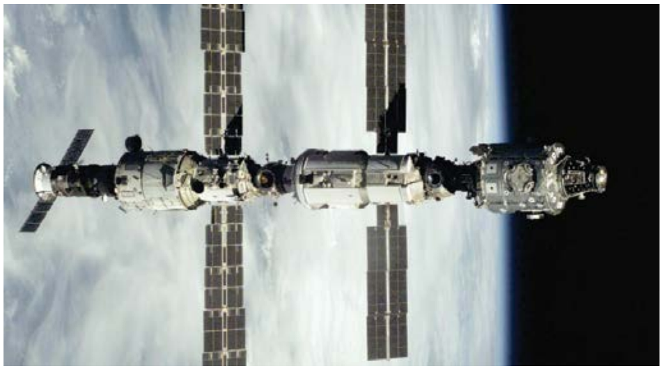
Russia
Civil/Government
Operational

Platform Overview

The Zvezda Service Module aboard the International Space Station (ISS) was launched in 2000 on a Russian Proton rocket. Zvezda is a Russian contribution to the ISS. It provides living quarters, life support systems, electrical power distribution, data processing systems, flight control systems, and propulsion systems. Zvezda currently hosts the Iris and Theia sensors.

[Abbreviations in tables: —, no data; km, kilometer; min, minute; °, degree; GSD, ground sample distance; m, meter; NIR, near infrared]

Launch date	7/12/2000
Design lifetime	—
Platform owner	Roscosmos
Altitude	407 km
Orbit period	93 min
Inclination	51.6°
Crossing time	—
Nadir repeat	—
Status	Operational
System website	https://www.nasa.gov/mission_pages/station/structure/elements/sm.html



Artistic rendering of the Zvezda service module (on the left) [Source: NASA].

Sensor Information

	Theia	Iris
GSD (m)	5	1
Swath (km)	50	—
Data portal	https://www.urthecast.com/data/	

Iris sensor on the International Space Station [Source: Urthecast, used with permission].

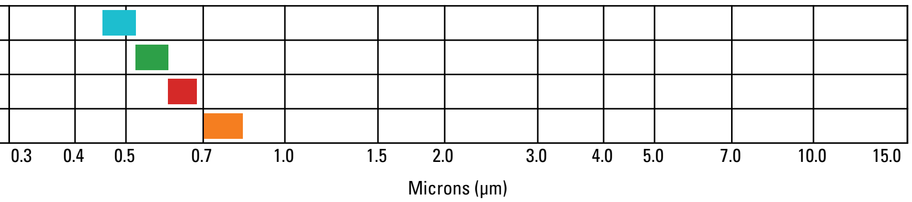
ISS Zvezda—Continued

Russia
Civil/Government
Operational

Theia

The Medium Resolution Camera (MRC) payload aboard the Zvezda module on the ISS is called Theia. Theia was launched with Iris in 2013 on the Progress M-21M cargo spacecraft. Theia was built by RAL Space for UrtheCast Inc. and is essentially a modified version of RALCam-3RAL. The Theia sensor stopped operations in 2017.

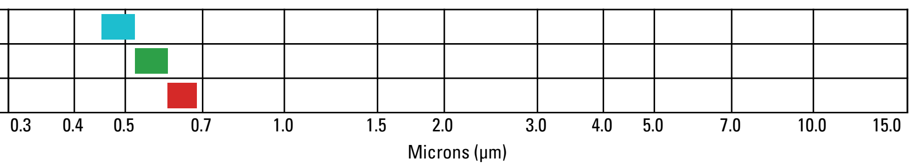
Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	5
Green	0.520	0.560	0.600	5
Red	0.600	0.640	0.680	5
NIR	0.700	0.765	0.830	5



Iris

The High-Resolution Camera (HRC) payload aboard the Zvezda module on the ISS is called Iris. Iris was launched with Theia in 2013 on the Progress M-21M cargo spacecraft. Iris was built by RAL Space for UrtheCast Inc. The Iris sensor stopped operations in 2017.

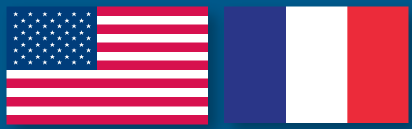
Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	1
Green	0.520	0.560	0.600	1
Red	0.600	0.640	0.680	1



JACIE

Jason-2 (OSTM)

United States, France
Civil/Government
Operational



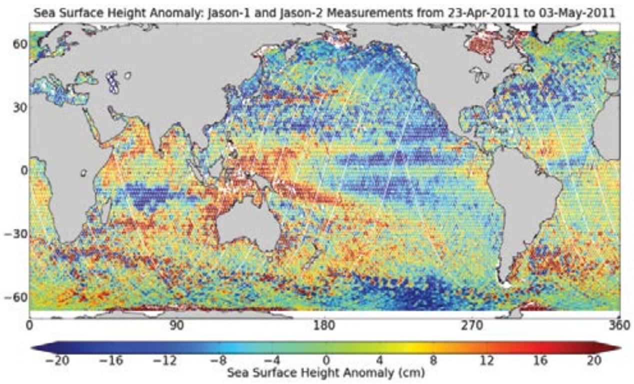
Platform Overview

Jason-2, also known as the Ocean Surface Topography Mission (OSTM), is a radar altimeter satellite launched in 2008 on a Delta-II launch vehicle from Vandenberg Air Force Base in California for oceanic observation. This mission is a follow-on to Jason-1 with a collaboration between the National Aeronautics and Space Administration (NASA) and French National Center for Space Research (CNES). Thales Alenia Space was the prime contractor for the spacecraft, which uses the Proteus bus. Jason-2 carries the Poseidon-3 instrument for collecting altimetry data.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; —, no data; GSD, ground sample distance; m, meter]

Launch date	6/20/2008
Design lifetime	5 years
Platform owner	NASA, CNES
Altitude	1,336 km
Orbit period	112.38 min
Inclination	66.04°
Crossing time	—
Nadir repeat	10 days
Status	Operational
System website	https://www.nasa.gov/mission_pages/ostm/main/

Artistic rendering of Jason-2 in orbit [Source: NASA].



Jason-1 and -2 data [Source: NASA].

Sensor Information

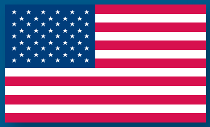
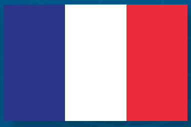
	Poseidon-3
GSD (m)	—
Swath (km)	—
Data portal	—

Poseidon-3

The Poseidon-3 instrument is a proven design by Thales Alenia Space based on the Poseidon-2 instrument used on Jason-1. Poseidon-3 is a dual-frequency radar altimeter and operates in the C-band at 5.3 GHz (λ = 5.66 cm) and Ku-band at 13.575 GHz (λ = 2.21 cm).

Jason-3

United States, France
Civil/Government
Operational

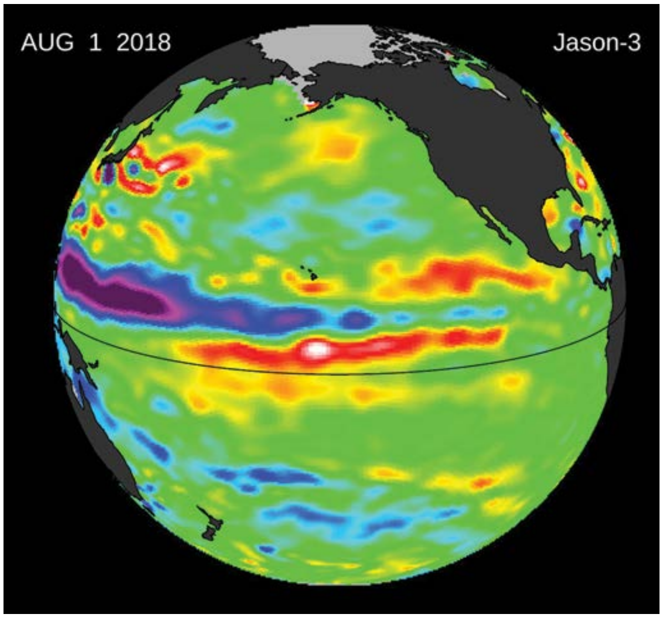
Platform Overview

Jason-3 is a radar altimeter satellite launched in January 2016 on a Falcon 9 launch vehicle from Vandenberg Air Force Base in California for oceanic observation. This mission is a follow-on to Jason-2 with a collaboration between the National Aeronautics and Space Administration (NASA) and French National Center for Space Research (CNES). Thales Alenia Space was the prime contractor for the spacecraft and, like Jason-2, uses the Proteus bus. Jason-3 carries the Poseidon-3B instrument for collecting altimetry data.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; —, no data; GSD, ground sample distance; m, meter]

Launch date	1/17/2016
Design lifetime	5 years
Platform owner	NASA, CNES
Altitude	1,336 km
Orbit period	112.38 min
Inclination	66.04°
Crossing time	—
Nadir repeat	10 days
Status	Operational
System website	https://sealevel.jpl.nasa.gov/missions/jason3/

Artistic rendering of Jason-3 in orbit [Source: NASA].



Sea surface data acquired by Jason-3 [Source: NASA].

Sensor Information

	Poseidon-3B
GSD (m)	—
Swath (km)	—
Data portal	—

Poseidon-3B

The Poseidon-3B instrument is a proven design by Thales Alenia Space based on the Poseidon-3 instrument used on Jason-2. Poseidon-3B modestly improves on Poseidon-3 and operates in the C-band at 5.3 GHz (λ = 5.66 cm) and Ku-band at 13.575 GHz (λ = 2.21 cm).

JACIE

Kalpana-1

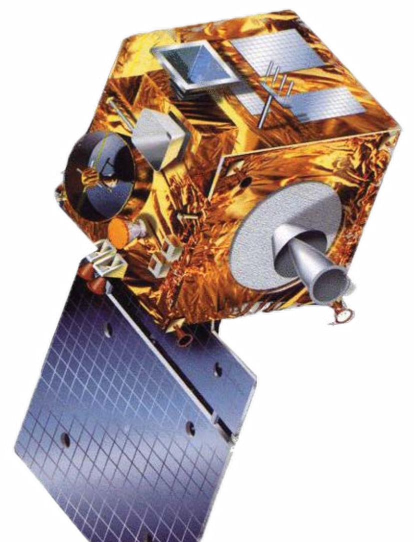
India
Civil/Government
Operational

Platform Overview

Kalpana-1, formerly known as Meteorological Satellite–1 (MetSat-1), is a low-resolution multispectral satellite launched in 2002 on a Polar Satellite Launch Vehicle (PSLV) from SDSC-SHAR for meteorological monitoring. This mission was a low-cost solution to continue the Very High-Resolution Radiometer (VHRR) data provided by INSAT-2B, which had to be retired in 2000 when it ran out of fuel, and INSAT-2E, which failed in 1999. Kalpana-1 is in a geostationary orbit at 74.1 degrees east. The satellite platform was developed by the Indian Space Research Organization (ISRO) using the newly developed I-1000 bus. Kalpana-1 carries the VHRR sensor for meteorological monitoring.

[Abbreviations in tables: km, kilometer; °, degree; NA, not applicable; GSD, ground sample distance; m, meter; VIS, visible; WV, water vapor; TIR, thermal infrared]

Launch date	9/12/2002
Design lifetime	7 years
Platform owner	ISRO
Altitude	35,786 km
Orbit period	24 hours
Inclination	0°
Crossing time	NA
Nadir repeat	NA
Status	Operational
System website	https://www.isro.gov.in/Spacecraft/kalpana-1



Artistic rendering of Kalpana-1 [Source: ISRO, used with permission].

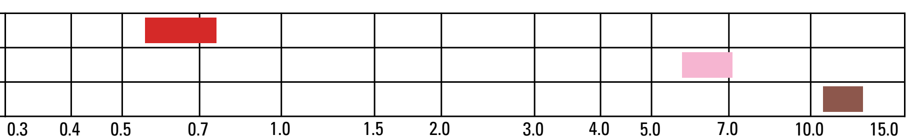
Sensor Information

	VHRR
GSD (m)	2,000; 8,000
Swath (km)	—
Data portal	https://mosdac.gov.in/content/Mission/kalpana-1

VHRR

The VHRR sensor is a modified version of the VHRR imagers flown on the INSAT-2 satellites. The sensor can operate in Full scan mode with a 33-minute repeat; Normal scan mode with a 23-minute repeat; or Sector scan mode, which can scan an area three times in 23 minutes.

Band	Lower	Center	Upper	GSD (m)
VIS	0.550	0.650	0.750	2,000
WV	5.700	6.400	7.100	8,000
TIR	10.500	11.500	12.500	8,000



KazEOSat-1

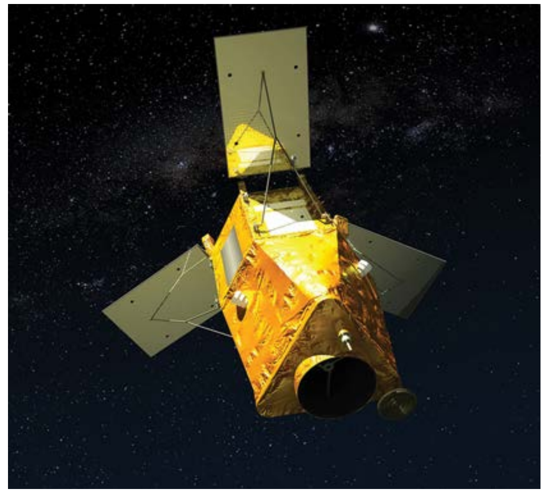
Kazakhstan
Civil/Government
Operational

Platform Overview

The Kazakhstan Earth Observation Satellite–1 (KazEOSat-1) is a high-resolution multispectral satellite launched in 2014 on a Vega launch vehicle from the Guiana Space Center, French Guiana, for Earth observation. KazEOSat-1 is part of a two-satellite Earth observation system. The Kazakhstan National Space Agency, Kazcosmos, charged the Joint-Stock Company National Company Kazakhstan Gharysh Sapary (JSC KGS) with the development of the satellite system. KazEOSat-1 was built by Airbus and uses the AstroSat-250 bus with SPOT-6 and SPOT-7 heritage. KazEOSat-1 carries the New AstroSat Optical Modular Instrument (NAOMI) sensor for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; —, no data; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near infrared]

Launch date	4/30/2014
Design lifetime	7.25 years
Platform owner	Kazcosmos
Altitude	759 km
Orbit period	100.0 min
Inclination	98.54°
Crossing time	10:30 DN
Nadir repeat	—
Status	Operational
System website	—



Artistic rendering of KazEOSat-1 [Source: Airbus DS, used with permission].

Sensor Information

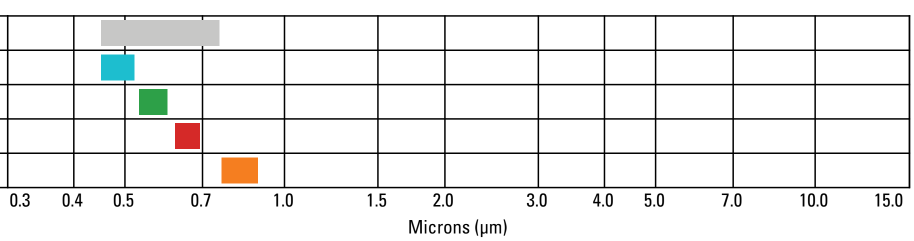
	NAOMI
GSD (m)	1, 4
Swath (km)	10
Data portal	—

KazEOSat-1 image of Singapore [Source: Airbus DS, used with permission].

NAOMI

The NAOMI sensor is a proven design from Airbus used on AlSat-2, SSOT, VNREDSat-1A, SPOT-6, and SPOT-7.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.600	0.750	1
Blue	0.450	0.485	0.520	4
Green	0.530	0.565	0.600	4
Red	0.620	0.655	0.690	4
NIR	0.760	0.825	0.890	4



Data compiled by the USGS National Land Imaging Program's Requirements Capabilities and Analysis for Earth Observation (RCA-EO) project. JACIE is a collaboration between U.S. Federal agencies NASA, NGA, NOAA, USDA, and USGS. For more information see: https://www.usgs.gov/land-resources/eros/calval/jacie

For Joint Agency Commercial Imagery Evaluation (JACIE) sensor performance information see: https://www.usgs.gov/land-resources/eros/calval/jacie

RCA-EO; USGS EROS Center
47914 252nd St.
Sioux Falls, SD 57198
eccoe@usgs.gov

KazEOSat-2

Kazakhstan
Civil/Government
Operational

Platform Overview

The Kazakhstan Earth Observation Satellite–2 (KazEOSat-2) is a medium-resolution multispectral satellite launched in 2014 on a Dnepr-1 launch vehicle from the Yasny Cosmodrome in the Dombarovsky region of Russia for Earth observation. KazEOSat-2 is part of a two-satellite Earth observation system. The Kazakhstan National Space Agency, Kazcosmos, charged the Joint-Stock Company National Company Kazakhstan Gharysh Sapary (JSC KGS) with the development of the satellite system. KazEOSat-2 was built by Surrey Satellite Technology, Ltd., (SSTL) and uses the SSTL-159 bus with Bejing-1 and RapidEye heritage. KazEOSat-2 carries the Kazakh Earth Imaging System (KEIS) for medium-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; NIR, near infrared]

Launch date	6/19/2014
Design lifetime	7 years
Platform owner	Kazcosmos
Altitude	630 km
Orbit period	97.31 min
Inclination	98°
Crossing time	10:30 AN
Nadir repeat	—
Status	Operational
System website	—

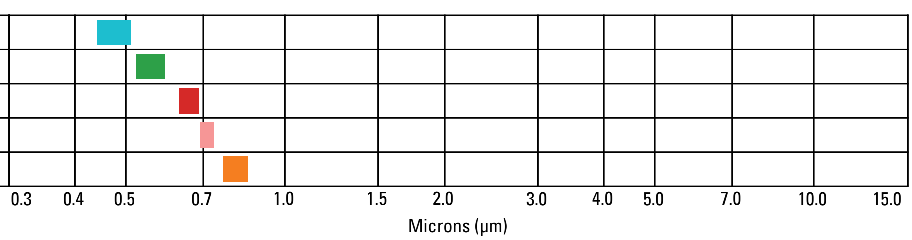
Sensor Information

	KEIS
GSD (m)	6.5
Swath (km)	78
Data portal	—

KEIS

The KEIS was developed by Jena-Optronik GmbH (JOP) and is of RapidEye heritage. The instrument is also referred to as the Jena-Optronik Spaceborne Scanner-56 (JSS-56) or the Multispectral Imager (MSI).

Band	Lower	Center	Upper	GSD (m)
Blue	0.440	0.475	0.510	6.5
Green	0.520	0.555	0.590	6.5
Red	0.630	0.658	0.685	6.5
Red Edge	0.690	0.710	0.730	6.5
NIR	0.760	0.805	0.850	6.5



KhalifaSat

United Arab Emirates
Civil/Government
Operational

Platform Overview

Khalifasat (formerly known as DubaiSat-3) is a high-resolution, multispectral satellite launched in 2018 onboard Japan's H-IIA rocket by the United Arab Emirates (UAE) Mohammed bin Rashad Space Centre (MBRSC) on Japan's H-IIA rocket for Earth resources monitoring. This mission continues the DubaiSat series that has been in continual operation since the launch of DubaiSat-1 in 2009. Where DubaiSat-1 and DubaiSat-2 were built in cooperation with the South Korean satellite manufacturer Satrec Initiative, KhalifaSat is the first satellite developed entirely by MBRSC. KhalifaSat was designed and built by MBRSC and uses the SI-300 bus heritage of Dubaisat-2. KhalifaSat carries the KhalifaSat Camera System (KHCS) for high-resolution imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; —, no data; GSD, ground sample distance; Pan, panchromatic; NIR, near infrared; m, meter]

Launch date	10/15/2018
Platform owner	MBRSC
Altitude	613 km
Orbit period	96.96 min
Inclination	98.13°
Crossing time	—
Nadir repeat	6 days
Design lifetime	5 years
Status	Operational
System website	http://khalifasat-thejourney.com/

Image captured by Khalifasat on November 5, 2018 over Palm Jumeirah in Dubai, United Arab Emirates [Source: MBRSC, used with permission].

Sensor Information

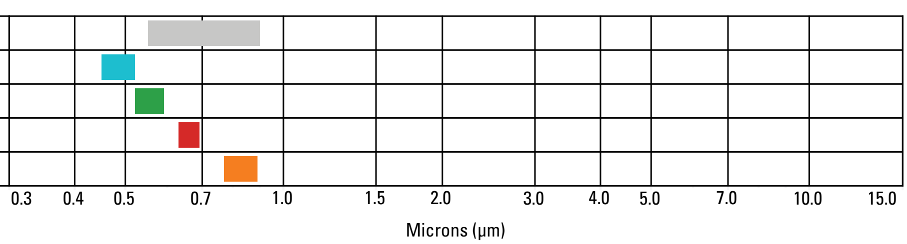
	KHCS
GSD (m)	0.75, 3
Swath (km)	12
Data portal	—

JACIE

KHCS

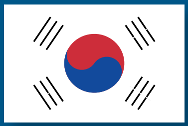
The KHCS is an improved version of the heritage HiRAIS pushbroom sensor previously flown on Dubaisat-2 and provides imagery in VNIR bands. The KHCS offers a major improvement in resolution and downlink capability. The four spectral bandwidths and the 12-kilometer (km) swath width are the same as DubaiSat-2, although resolution is improved to a GSD of 0.75 meter (m) in Panchromatic and 3 m in multispectral mode. Data are collected at a radiometric resolution of 10 bits.

Band	Lower	Center	Upper	GSD (m)
Pan	0.550	0.725	0.900	0.75
Blue	0.450	0.485	0.520	3
Green	0.520	0.555	0.590	3
Red	0.630	0.660	0.690	3
NIR	0.770	0.830	0.890	3



Kompsat-2

South Korea
Civil/Government
Operational



Platform Overview

Kompsat-2 is a high-resolution multispectral satellite launched in 2006 by the Republic of Korea on a Rockot-KM launch vehicle from Plesetsk, Russia, for Earth resources monitoring. This mission continues the Kompsat series that has been in operation since the launch of Kompsat-1 in 1999. The Kompsat-2 satellite was designed and built by the Korean Aerospace Research Institute (KARI) and uses the TRW bus of Kompsat-1 heritage. Kompsat-2 carries the Multispectral Camera (MSC) for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near infrared]

Launch date	7/28/2006
Design lifetime	3 years
Platform owner	KARI
Altitude	685 km
Orbit period	98.46 min
Inclination	98.13°
Crossing time	10:50 AN
Nadir repeat	28 days
Status	Operational
System website	https://www.kari.re.kr/eng/sub03_02_01.do

Artistic rendering of Kompsat-2 in orbit [Source: KARI, used with permission].

Kompsat-2 image of Sydney, Australia [Source: KARI, used with permission].

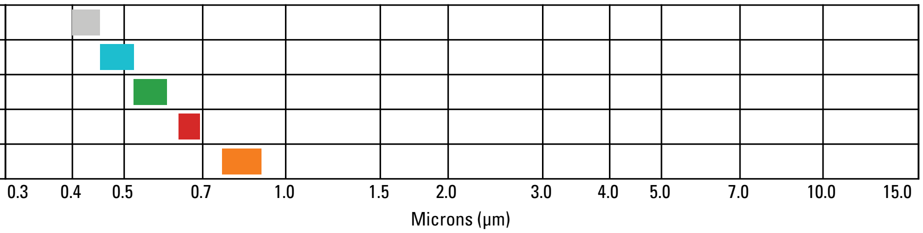
Sensor Information

	MSC
GSD (m)	1, 4
Swath (km)	15
Data portal	https://earth.esa.int/web/guest/-/kompsat-2-msc-bundle-5683

MSC

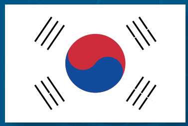
The MSC is a design from KARI built in cooperation with Electro Optics Industries (ELOP) and OHB-Systems. MSC provides global imagery with a revisit of 1 day.

Band	Lower	Center	Upper	GSD (m)
Pan	0.400	0.425	0.450	1
Blue	0.450	0.485	0.520	4
Green	0.520	0.560	0.600	4
Red	0.630	0.660	0.690	4
NIR	0.760	0.830	0.900	4



Kompsat-3

South Korea
Civil/Government
Operational



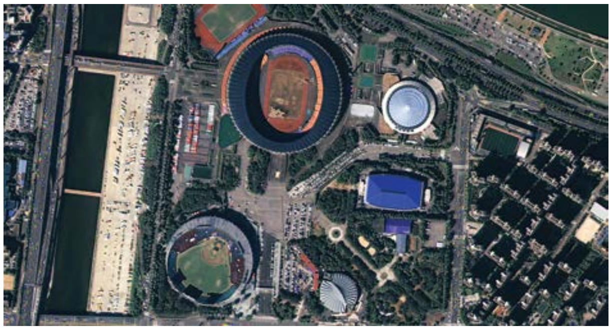
Platform Overview

Artistic rendering of Kompsat-3 in orbit [Source: KARI, used with permission].

Kompsat-3 is a high-resolution multispectral satellite launched in 2012 by the Republic of Korea on the H-IIA launch vehicle from Tanegashima Space Center of the Japan Aerospace Exploration Agency (JAXA) for Earth resources monitoring. This mission continues the Kompsat series that has been in operation since the launch of Kompsat-1 in 1999. The Kompsat-3 satellite was designed and built by the Korean Aerospace Research Institute (KARI). It is the first satellite of Korea with submeter resolution. Kompsat-3 carries the Advanced Earth Imaging Sensor System (AEISS) sensor for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; —, no data; Pan, panchromatic; NIR, near infrared]

Launch date	5/17/2012
Design lifetime	4 years
Platform owner	KARI
Altitude	685 km
Orbit period	98.5 min
Inclination	98.13°
Crossing time	13:30 AN
Nadir repeat	28 days
Status	Operational
System website	https://www.kari.re.kr/eng/sub03_02_01.do



Kompsat-3 image of PyeongChang Olympic Stadium, South Korea [Source: KARI, used with permission].

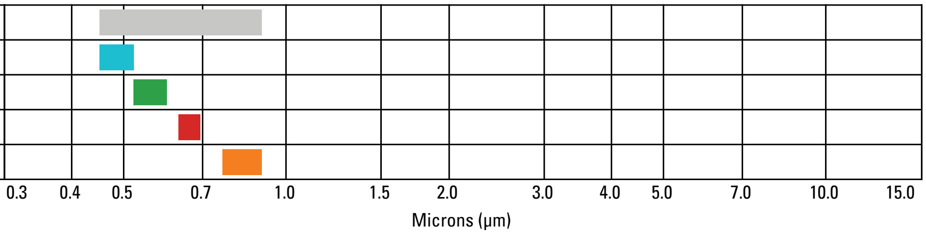
Sensor Information

	AEISS
GSD (m)	0.7, 2.8
Swath (km)	15
Data portal	—

AEISS

The AEISS is a pushbroom-style imager designed by KARI with support from European Aeronautics Defense and Space Astrium.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.675	0.900	0.7
Blue	0.450	0.485	0.520	2.8
Green	0.520	0.560	0.600	2.8
Red	0.630	0.660	0.690	2.8
NIR	0.760	0.830	0.900	2.8



Kompsat-3A

South Korea
Civil/Government
Operational

Platform Overview

Kompsat-3A is a high-resolution multispectral satellite launched in 2015 by the Republic of Korea on a Dnepr-1 vehicle from the Dombarovsky launch site in Russia for Earth resources monitoring. This mission continues the Kompsat series that has been in operation since the launch of Kompsat-1 in 1999. The Kompsat-3A satellite was designed and built by the Korean Aerospace Research Institute (KARI) and uses the TRW bus similar to Kompsat-3 design. It carries the improved Advanced Earth Imaging Sensor System-A (AEISS-A) sensor for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; AN, ascending node; GSD, ground sample distance; m, meter; —, no data; Pan, panchromatic; NIR, near infrared]

Launch date	3/25/2015
Design lifetime	4 years
Platform owner	KARI
Altitude	528 km
Orbit period	95.21 min
Inclination	97.51°
Crossing time	13:30 AN
Nadir repeat	28 days
Status	Operational
System website	https://www.kari.re.kr/eng/sub03_02_01.do

Artistic rendering of Kompsat-3A in orbit [Source: KARI, used with permission].

Imagery of Dubai International Airport, United Arab Emirates, captured by Kompsat-3A [Source: KARI, Distribution (SI Imaging Services, Republic of Korea), 2019, all rights reserved, used with permission].

Sensor Information

	AEISS-A	IIS
GSD (m)	0.55, 2.2	5.5
Swath (km)	12	
Data portal	—	

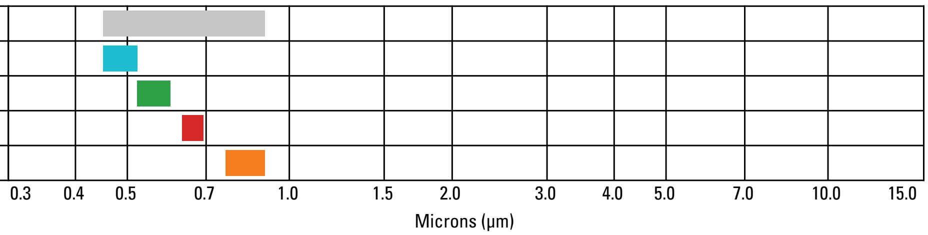
Kompsat-3A—Continued

South Korea
Civil/Government
Operational

AEISS-A

The AEISS-A is a design from KARI built with support from European Aeronautics Defense and Space Astrium on the heritage of AEISS.

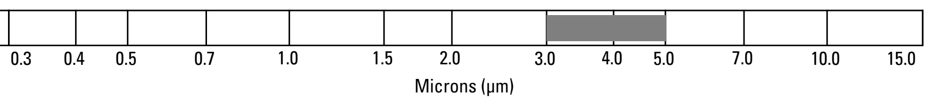
Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.675	0.900	0.55
Blue	0.450	0.485	0.520	2.2
Green	0.520	0.560	0.600	2.8
Red	0.630	0.660	0.690	2.8
NIR	0.760	0.830	0.900	5.5



IIS

The Infrared Imaging System (IIS) on Kompsat-3A was built by AIM Infrarot-Module GmbH (AIM) in Heilbronn, Germany.

Band	Lower	Center	Upper	GSD (m)
MWIR	3.000	4.000	5.000	5.5



Kompsat-5

South Korea
Civil/Government
Operational

Platform Overview

Kompsat-5 is a high-resolution synthetic aperture radar (SAR) satellite launched in 2013 by the Republic of Korea on a Dnepr-1 vehicle from the Dombarovsky launch site in Russia for Earth resources monitoring. This mission continues the Kompsat series that has been in operation since the launch of Kompsat-1 in 1999. Kompsat-5 is also called a GIS, Ocean and Land management, Disaster and Environment monitoring (GOLDEN) mission. The Kompsat-5 satellite was designed and built by the Korean Aerospace Research Institute (KARI) with the support of private industries in Korea. Kompsat-5 carries the Corea SAR Instrument (COSI) sensor for high-resolution SAR data.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter;—, no data; H, horizontal, V, vertical]

Launch date	8/22/2013
Design lifetime	5 years
Platform owner	KARI
Altitude	550 km
Orbit period	95.78 min
Inclination	97.6°
Crossing time	6:00 AN
Nadir repeat	28 days
Status	Operational
System website	https://www.kari.re.kr/eng/sub03_02_01.do

Artistic rendering of Kompsat-5 [Source: ESA].

Kompsat-5 image of Abu Dhabi, United Arab Emirates [Source: KARI, Distribution (SI Imaging Services, Republic of Korea), 2019, all rights reserved, used with permission].

Sensor Information

	COSI
GSD (m)	1–20 (selectable)
Swath (km)	5–100 (selectable)
Data portal	—

COSI

The COSI is a design by Thales Alenia Space for KARI. It provides high-resolution imagery in X-band at 9.66 GHz (λ = 3.1 cm). The angle of incidence is 20–55 degrees.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
High Resolution (HR)	Single	HH, HV, VH, VV	5	1
Standard (ST)	Single	HH, HV, VH, VV	30	3
Wideswath (WS)	Single	HH, HV, VH, VV	100	20

Kompsat-6

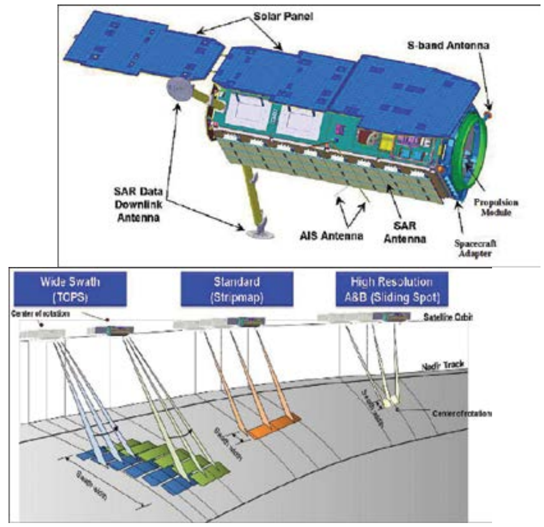
South Korea
Civil/Government
Future

Platform Overview

Kompsat-6 is an all-weather, high-resolution synthetic aperture radar (SAR) satellite scheduled for launch in 2020 by the Republic of Korea on an Angara 1.2 launch vehicle from Plesetsk Cosmodrome in Russia for Earth resources monitoring. This mission continues the Kompsat series that has been in continuous operation since the launch of Kompsat-1 in 1999. The Kompsat-6 satellite is being built by LIG Nex1 Co., Ltd., of Korea and Airbus Defense and Space for the Korean Aerospace Research Institute (KARI). Kompsat-6 will carry the X-SAR sensor for high-resolution SAR data.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; —, no data; H, horizontal; V, vertical]

Launch date	2020 (Planned)
Design lifetime	5 years
Platform owner	KARI
Altitude	505 km
Orbit period	94.71 min
Inclination	97.6°
Crossing time	6:00 AN
Nadir repeat	11 days
Status	Development
System website	https://www.kari.re.kr/eng/sub03_02_01.do



Illustrations showing the Kompsat-6 on-orbit configuration and beam mode [Source: KARI, used with permission].

Sensor Information

	X-SAR
GSD (m)	0.5–20 (selectable)
Swath (km)	5–100 (selectable)
Data portal	—

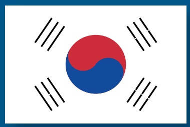
X-SAR

The X-band SAR is a multimode instrument built by Airbus that operates at 9.66 GHz (λ = 3.1 cm). The angle of incidence is 20–60 degrees.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
High Resolution-A	Single	HH, HV, VV, VH	5	0.5
	Dual	HH/HV, VV/VH		
	Quad	HH/HV/VV/VH		
High Resolution-B	Single	HH, HV, VV, VH	10	1
	Dual	HH/HV, VV/VH		
	Quad	HH/HV/VV/VH		
Standard	Single	HH, HV, VV, VH	30	3
	Dual	HH/HV, VV/VH		
	Quad	HH/HV/VV/VH		
Wide Swath	Single	HH, HV, VV, VH	100	20
	Dual	HH/HV, VV/VH		
	Quad	HH/HV/VV/VH		

Kompsat-7

South Korea
Civil/Government
Future



Platform Overview

Kompsat-7 is a high-resolution multispectral satellite scheduled for launch in 2021 by the Republic of Korea for Earth resources monitoring. This mission continues the Kompsat series that has been in continual operation since the launch of Kompsat-1 in 1999. The Kompsat-7 satellite is being built by an undisclosed Korean company using the Korean technologies for by the Korean Aerospace Research Institute (KARI). Kompsat-7 carries the improved Advanced Earth Imaging Sensor System-High Resolution (AEISS-HR) sensor for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; —, no data; AN, ascending node; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near infrared; MWIR, midwave infrared]

Launch date	2021 (Planned)
Design lifetime	4 years
Platform owner	KARI
Altitude	685 km
Orbit period	98.5 min
Inclination	—
Crossing time	10:50 AN
Nadir repeat	28 days
Status	Planned
System website	https://www.kari.re.kr/eng/sub03_02_01.do

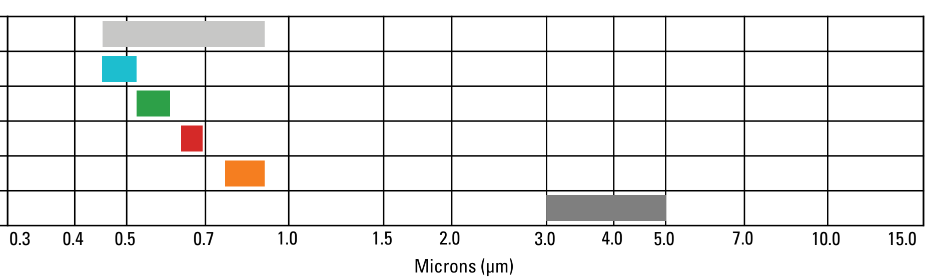
Sensor Information

	AEISS-HR
GSD (m)	0.3, 1.2, 4
Swath (km)	—
Data portal	—

AEISS-HR

AEISS-HR is a high-resolution multispectral imager on Kompsat-7 built by Korea. It is an improvement to the AEISS sensor flown on previous Kompsats. The GSD is improved to 30 cm in panchromatic, 1.2 m in visible and near infrared, and 4 m in infrared.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.675	0.900	0.3
Blue	0.450	0.485	0.520	1.2
Green	0.520	0.560	0.600	1.2
Red	0.630	0.660	0.690	1.2
NIR	0.760	0.830	0.900	4
MWIR	3.000	4.000	5.000	4



Landmapper-BC 3 v2

United States
Commercial
Operational/Future

Platform Overview

The Landmapper-BC satellites are medium-resolution, multispectral satellites for commercial Earth observation. Astro Digital plans to have a constellation of 8 to 12 Landmapper-BC satellites to provide daily imaging of all Earth land areas. Landmapper 1 and 2 failed shortly after their July 2017 launch. Landmapper 3 and 4 were lost due to a launch failure in November 2017. Landmapper-BC 3 v2 was successfully launched in January 2018. At least eight more Landmapper-BC satellites are planned. The Landmapper-BC satellites are based on the Perseus-O satellites developed at Canopus System Inc. The system captures medium-resolution imagery that is commercially available.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; —, no data; DN, descending node; GSD, ground sample distance; m, meter; NIR, near infrared]

Artistic rendering of Landmapper-BC satellite [Source: Astro Digital, used with permission].

Launch date	1/14/2018
Platform owner	Astro Digital Inc.
Design lifetime	5 years
Altitude	650 km
Orbit period	97.7 min
Inclination	97.98°
Crossing time	10:00 DN
Nadir repeat	—
Status	Operational
System website	https://www.astrodigital.com/

Sensor Information

	Landmapper-BC Imager
GSD (m)	22
Swath (km)	220
Data portal	https://www.astrodigital.com/api/

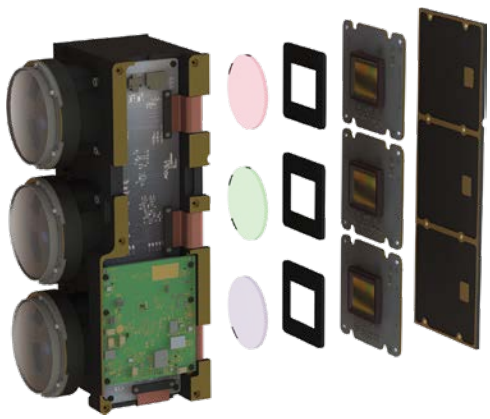
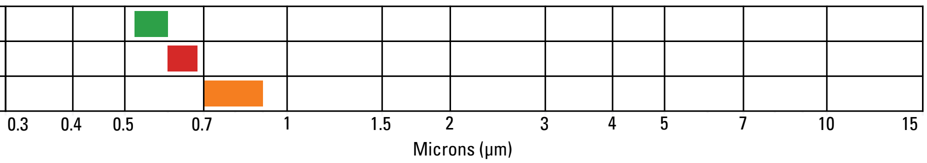


Image of Landmapper-BC imager [Source: Astro Digital, used with permission].

Landmapper-BC Imager

The imager consists of three separate cameras for green, red, and NIR bands similar to the SLIM6 imager used on the DMC systems. These bands are used to calculate the productivity of plants and estimate crop yields.

Band	Lower	Center	Upper	GSD (m)
Green	0.520	0.560	0.600	22
Red	0.600	0.640	0.680	22
NIR	0.700	0.800	0.900	22



Landsat 7

United States
Civil/Government
Operational

Platform Overview

Landsat 7 is a medium-resolution multispectral satellite launched in 1999 by the National Aeronautics and Space Administration (NASA) and U.S. Geological Survey (USGS) on a Delta-II rocket from Vandenberg Air Force Base for Earth resources monitoring. This mission continues the Landsat series that has been in continual operation since the launch of Landsat 1 in 1972. The Landsat 7 satellite was designed and built by Lockheed Martin Missiles and Space for NASA and uses the TIROS-N bus. Landsat 7 carries the Enhanced Thematic Mapper Plus (ETM+) sensor for medium-resolution land imaging.

Artistic rendering of Landsat 7 in orbit [Source: NASA].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near infrared; SWIR, shortwave infrared; TIR, thermal infrared]

Launch date	4/15/1999
Platform owner	USGS/NASA
Altitude	705 km
Orbit period	98.98 min
Inclination	98.2°
Crossing time	10:00 DN
Nadir repeat	16 days
Design lifetime	5 years
Status	Operational
System website	https://landsat.usgs.gov/landsat-7

Landsat 7 imagery of Seattle, Washington [Source: NASA].

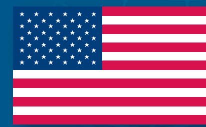
Sensor Information

	ETM+
GSD (m)	15, 30, 60
Swath (km)	185
Data portal	https://earthexplorer.usgs.gov/ https://glovis.usgs.gov/app

JACIE

Landsat 7—Continued

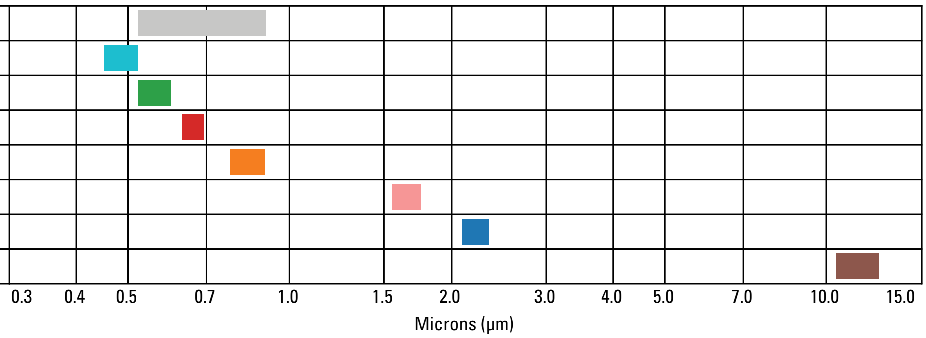
United States
Civil/Government
Operational



ETM+

The ETM+ sensor was built by Hughes Santa Barbara Remote Sensing. This sensor was an improvement to the Thematic Mapper (TM) sensor on previous Landsat satellites with the addition of a 15 m resolution panchromatic band and a 60 m resolution thermal band replacing the 120 m band of TM. The 185 km swath width is maintained from the TM sensor. The operational model is to continually map the Earth, gathering as much data as practical on every orbit. ETM+ data are freely available.

Band	Lower	Center	Upper	GSD (m)
Pan	0.520	0.710	0.900	15
Blue	0.450	0.485	0.520	30
Green	0.520	0.560	0.600	30
Red	0.630	0.660	0.690	30
NIR	0.775	0.838	0.900	30
SWIR 1	1.550	1.650	1.750	30
SWIR 2	2.090	2.220	2.350	30
TIR	10.400	11.450	12.500	60



Data compiled by the USGS National Land Imaging Program's Requirements Capabilities and Analysis for Earth Observation (RCA-EO) project. JACIE is a collaboration between U.S. Federal agencies NASA, NGA, NOAA, USDA, and USGS. For more information see: https://www.usgs.gov/land-resources/eros/calval/jacie

For Joint Agency Commercial Imagery Evaluation (JACIE) sensor performance information see: https://www.usgs.gov/land-resources/eros/calval/jacie

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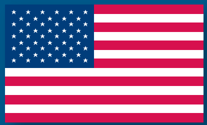
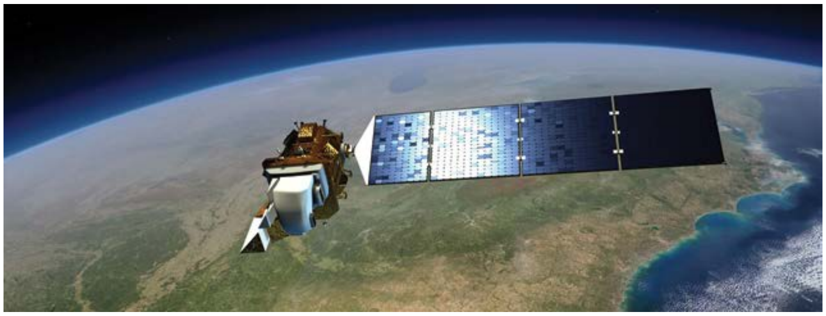
Landsat 8 and 9

United States
Civil/Government
Operational/Future



Platform Overview



Artistic rendering of Landsat 8 in orbit [Source: NASA].

The Landsat 8 and 9 medium-resolution satellites continue the ongoing Landsat data record collected continuously since 1972 with the launch of the Earth Resources Technology Satellite (ERTS), later renamed Landsat 1. Landsat 8, launched in 2013, will be joined by Landsat 9 following its planned 2020 launch date. Together they will provide continuous synoptic coverage of the Earth's land areas with a combined 8-day repeat. The Landsat program is managed jointly by National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS). NASA is responsible for procuring, integrating, and launching each mission, and providing on-orbit verification of performance. The USGS provides science and operational data user requirements during mission formulation and, following on-orbit verification of performance, is responsible for operations, data reception, archiving, and distribution for the remaining life of the mission.

The Landsat 8 satellite bus was designed and built by Orbital Sciences for NASA and uses the LEOStar-3 bus with the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) sensors. The Landsat 9 bus is being built by Northrup Grumman/Orbital ATK using modestly improved OLI-2 and TIRS-2 sensors.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; Pan, panchromatic, CA, coastal aerosol; NIR, near infrared; SWIR, short wave infrared; TIR, thermal infrared]

	Landsat 8	Landsat 9
Launch date	2/11/2013	December 2020 (planned)
Platform owner	NASA/USGS	
Altitude	705 km	
Orbit period	98.98 min	
Inclination	98.2°	
Crossing time	10:00 DN	
Nadir repeat	16 days	
Design lifetime	5 years	
Status	Operational	Development
System website	https://landsat.usgs.gov/landsat-8	https://landsat.usgs.gov/landsat-9-mission

Landsat 8 OLI image of Netherland's coast showing flower fields [Source: NASA].

Sensor Information

	OLI	TIRS
GSD (m)	15, 30	100
Swath (km)	185	
Data portal	https://earthexplorer.usgs.gov/	https://glovis.usgs.gov/app

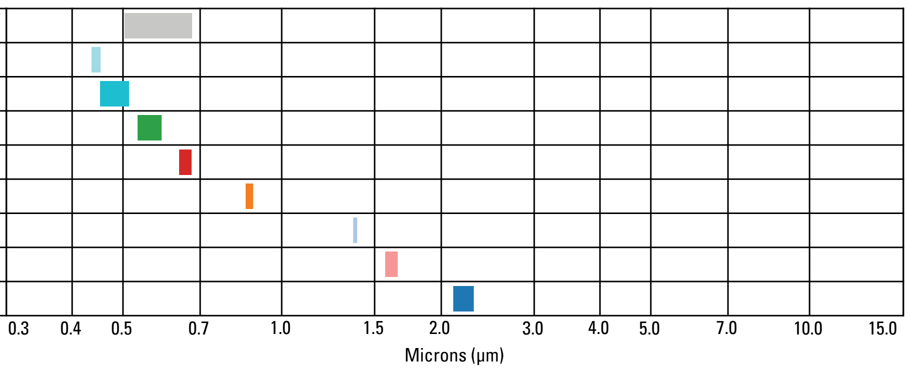
Landsat 8 and 9—Continued

United States
Civil/Government
Operational/Future

OLI

The OLI sensor aboard Landsat 8 and 9 was built by Ball Aerospace Technology Corp. based on technologies proven in the Advanced Land Imager (ALI) aboard Earth Observing-1 (EO-1). The OLI sensor in Landsat 8 and 9 adds a coastal aerosol band as well as a cirrus band to complement the bands on the ETM+ sensor on Landsat 7. The 185 km swath width is maintained from previous Landsat TM and ETM+ sensors. The operational model is to continually map the Earth, gathering as much sunlit land imagery as practical on every orbit. The 12 bit radiometric resolution of Landsat 8 is being increased to 14 bits with Landsat 9. OLI data are freely available.

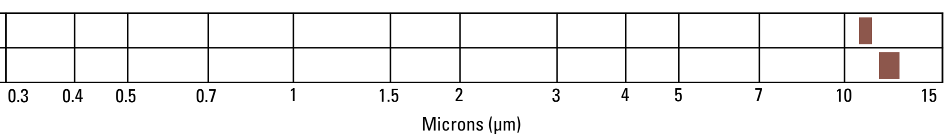
Band	Lower	Center	Upper	GSD (m)
Pan	0.503	0.590	0.676	15
CA	0.435	0.443	0.451	30
Blue	0.452	0.482	0.512	30
Green	0.533	0.562	0.590	30
Red	0.637	0.655	0.673	30
NIR	0.851	0.865	0.879	30
Cirrus	1.363	1.374	1.384	30
SWIR 1	1.566	1.609	1.651	30
SWIR 2	2.107	2.204	2.300	30



TIRS

The TIRS is a new design built by NASA Goddard Space Flight Center (GSFC). The GSD of 100 m is provided with two spectral bands in the thermal infrared region. Landsat 9 will also carry a second-generation TIRS instrument of similar specifications and enhanced reliability. The 12-bit radiometric resolution of Landsat 8 is being increased to 14 bits with Landsat 9. TIRS data are freely available.

Band	Lower	Center	Upper	GSD (m)
TIR	10.600	10.895	11.190	100
	11.500	12.005	12.510	100



Mohammed VI-A and -B

Morocco
Civil/Government
Operational

Platform Overview

Mohammed VI-A and -B are high-resolution, multispectral, and panchromatic satellites for mapping and land surveying developed by Royal Center for Remote Sensing (CRTS) in Morocco. Mohammed VI-A was launched in 2017 on a Vega launch vehicle. Mohammed VI-B was launched in 2018. The Mohammed VI satellite platforms were designed and built by Airbus and use the AstroSat-1000 bus. The Mohammed VI satellites carry the High-Resolution Imager (HiRI) sensor for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN,descending node; —, no data; GSD, ground sample distance; m, meter; NIR, near infrared]

	Mohammed VI-A	Mohammed VI-B
Launch date	11/8/2017	11/20/2018
Design lifetime	5 years	
Platform owner	CRTS	
Altitude	630 km	
Orbit period	97.5 min	
Inclination	98°	
Crossing time	10:30 DN	
Nadir repeat	—	
Status	Operational	
System website	—	

Artistic rendering of Pleiades satellite (identical to Mohammed-VIA satellite) in orbit [Source: CNES, used with permission].

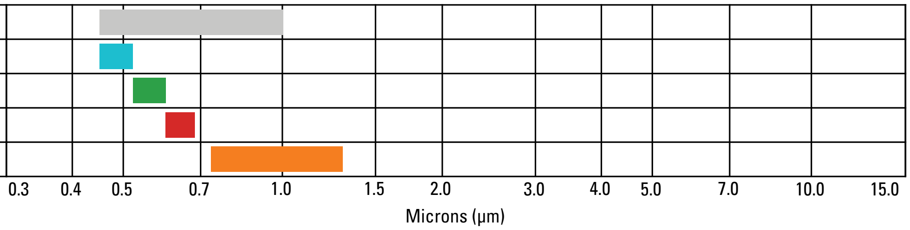
Sensor Information

	HiRI
GSD (m)	0.7, 2.8
Swath (km)	—
Data portal	—

HiRI

The HiRI aboard the Mohammed VI satellites was developed and built by Thales Alenia Space and is of Pleiades HiRI heritage.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.725	1.000	0.7
Blue	0.450	0.485	0.520	2.8
Green	0.520	0.560	0.600	2.8
Red	0.600	0.640	0.680	2.8
NIR	0.730	1.015	1.300	2.8



NigeriaSat-2

Nigeria
Commercial
Operational

Platform Overview

NigeriaSat-2 is a high-resolution, multispectral, and panchromatic imaging minisatellite launched alongside NigeriaSat-X in 2011 on a Dnepr-1 launch vehicle for Earth observation and disaster monitoring. NigeriaSat-2 is based on the newly developed SSTL-300 bus. The Nigerian National Space Research and Development Agency (NASRDA), in partnership with Surrey Satellite Technology, Ltd., (SSTL), built the satellite. NigeriaSat-2 carries the Very High-Resolution Imager (VHRI) and the Medium Resolution Imager (MRI) for land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near infrared]

Launch date	8/17/2011
Platform owner	NASRDA
Altitude	715 km
Orbit period	99.8 min
Inclination	98.24°
Crossing time	10:30 AN
Nadir repeat	5 days
Design lifetime	7.5 years
Status	Operational
System website	http://nasrda.gov.ng/en/

Sensor Information

	VHRI	MRI
GSD (m)	2.5, 5	32
Swath (km)	20	300
Data portal	http://www.dmcii.com/	

Salvador, State of Bahia, Brazil—NigeriaSat-2 satellite. [Source: NASRDA, 2014, all rights reserved, supplied by DMCii, used with permission].

JACIE

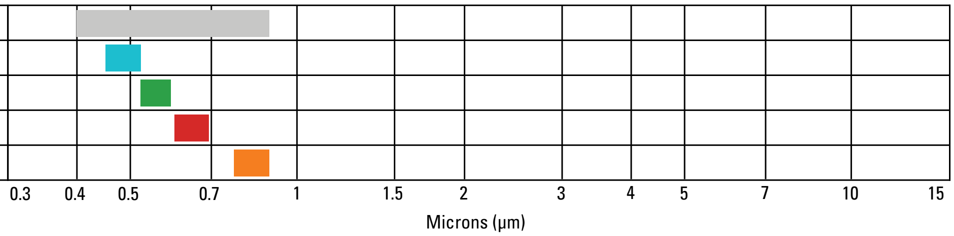
NigeriaSat-2—Continued

Nigeria
Commercial
Operational

VHRI

The VHRI was built by SSTL and is of CMT (China Mapping Telescope flown on Bejing-1) heritage. The VHRI is essentially a scaled-up version of CMT, giving it a wider aperture. The VHRI data are commercially available.

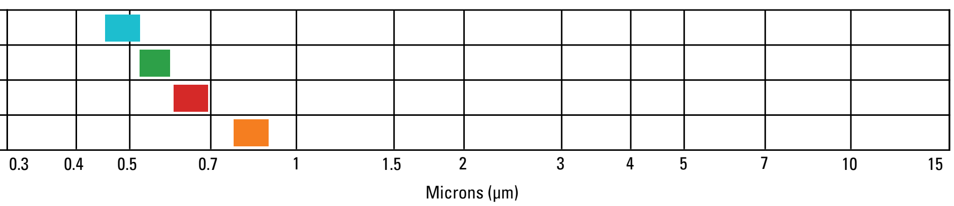
Band	Lower	Center	Upper	GSD (m)
Pan	0.400	0.645	0.890	2.5
Blue	0.450	0.485	0.520	5
Green	0.520	0.555	0.590	5
Red	0.600	0.645	0.690	5
NIR	0.770	0.830	0.890	5



MRI

The MRI is based on the SLIM6 sensor flown on NigeriaSat-1. The MRI provides continuity with DMC data and has one-half the swath width of SLIM6 and an additional spectral band (four total). NigeriaSat-2's swath can be artificially widened by taking advantage of the satellite's agility. The MRI data are commercially available.

Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	32
Green	0.520	0.555	0.590	32
Red	0.600	0.645	0.690	32
NIR	0.770	0.830	0.890	32



Data compiled by the USGS National Land Imaging Program's Requirements Capabilities and Analysis for Earth Observation (RCA-EO) project. JACIE is a collaboration between U.S. Federal agencies NASA, NGA, NOAA, USDA, and USGS. For more information see: https://www.usgs.gov/land-resources/eros/calval/jacie

For Joint Agency Commercial Imagery Evaluation (JACIE) sensor performance information see: https://www.usgs.gov/land-resources/eros/calval/jacie

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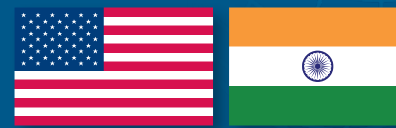
NISAR

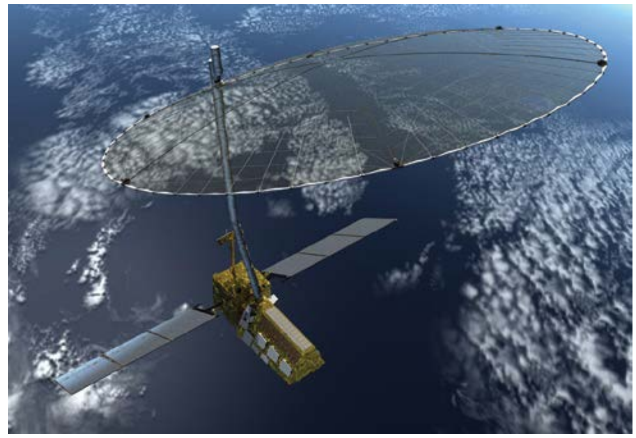
United States, India
Civil/Government
Future



Platform Overview

The NASA ISRO Synthetic Aperture Radar satellite (NISAR) is planned to be launched in 2021 on the Indian Space Research Organization's (ISRO) Geo Stationary Launch Vehicle (GSLV)-II for Earth resource monitoring, disaster planning, and infrastructure monitoring. The NISAR satellite is being built jointly by NASA's Jet Propulsion Laboratory (JPL) and ISRO. ISRO is designing the I-3K (I-3000) bus, which has been used on geostationary satellites previously. NISAR will carry the L-band and S-band polarimetric synthetic aperture radar sensors for collection of high-resolution SAR data.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; km, kilometer; —, no data; H, horizontal; V, vertical]



Artistic rendering of NISAR in orbit [Source: NASA].

Launch date	2021 (Planned)
Platform owner	NASA/IRSO
Altitude	747 km
Orbit period	98.5 min
Inclination	98.4°
Crossing time	6:00 DN
Nadir repeat	12 days
Design lifetime	3 years
Status	Development
System website	https://nisar.jpl.nasa.gov/

Sensor Information

	L-band	S-band
GSD (m)	3–24 (selectable)	3–48 (selectable)
Swath (km)	240 (selectable)	
Data portal	—	

L-band / S-band

The L-band SAR and S-band instruments aboard NISAR are new instruments designed and built by ISRO and JPL. The SAR systems employ an innovation called SweepSAR—developed jointly with the German Space Agency (DLR)—which allows the instruments to provide wide area coverage and fine spatial resolution at the same time. The L-band instrument operates at 1.257 GHz (λ = 23.85 cm). The S-band instrument operates at 3.2 GHz (λ = 9.37 cm). The angle of incidence for both instruments is 33–47 degrees. Data will be freely available.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
S-band	Single	HH, VV	—	—
	Dual	HH/HV, VV/VH		
	Compact	RH/RV		
	Quasi-Quad	HH/HV, VH/VV		
L-band	Single	HH, VV	—	—
	Dual	HH/HV, VV/VH		
	Compact	RH/RV		
	Quad	HH/HV/VH/VV		

JACIE

ÑuSat-1 to -8

Argentina
Commercial
Operational/Future

JACIE

Platform Overview

The Aleph-1 constellation of ÑuSat satellites consists of multiresolution multispectral satellites for commercial Earth imaging. The first five satellites (ÑuSat-1 to -5) were launched between 2016 and early 2018. ÑuSat-6 to -8 are planned to be launched in 2018. The ÑuSat satellites are developed, built, and operated by Satellogic, headquartered in Buenos Aires, Argentina. The satellites carry the Panchromatic (PAN) and Multispectral Imager (MSI) for high-resolution land imaging and the Hyperspectral Imager (HIS) and Thermal Infrared Imager (TIR) for medium-resolution land imaging.

Artistic rendering of a ÑuSat in orbit [Source: Satellogic, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; —, no data; GSD, ground sample distance; m, meter; NIR, near-infrared; TIR, thermal infrared; Hyper, hyperspectral]

	Ñ-1	Ñ-2	Ñ-3	Ñ-4	Ñ-5	Ñ-6	Ñ-7	Ñ-8
Launch date	5/30/2016		6/15/17	2/2/2018		2019 (Planned)		
Design lifetime	3 years							
Platform owner	Satellogic							
Altitude	500 km							
Orbit period	94.62 min							
Inclination	97.5°							
Crossing time	10:30 AN							
Nadir repeat	—							
Status	Operational					Development		
System website	https://www.satellogic.com/							

Sensor Information

	PAN	MSI	HSI	TIR
GSD (m)	1	1	30	90
Swath (km)	5	5	150	92
Data portal	https://www.satellogic.com/data-streams			

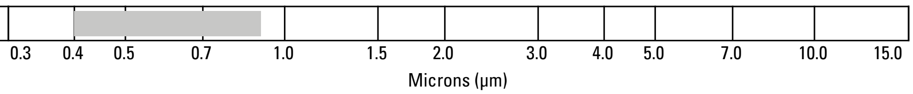
ÑuSat-1 to -8—Continued

Argentina
Commercial
Operational/Future

PAN

PAN data are commercially available from Satellogic.

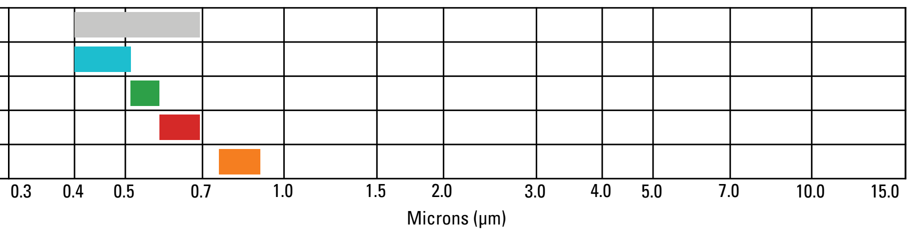
Band	Lower	Center	Upper	GSD (m)
Pan	0.400	0.650	0.900	1.00



MSI

MSI data are commercially available from Satellogic.

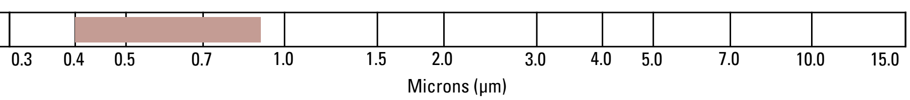
Band	Lower	Center	Upper	GSD (m)
Pan	0.400	0.545	0.690	1.00
Blue	0.400	0.455	0.510	1.00
Green	0.510	0.545	0.580	1.00
Red	0.580	0.635	0.690	1.00
NIR	0.750	0.825	0.900	1.00



HSI

HSI data are commercially available from Satellogic.

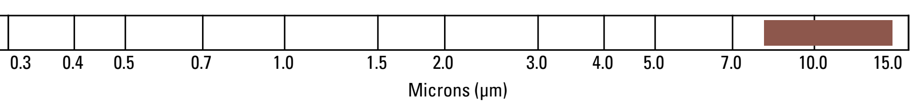
Band	Lower	Center	Upper	GSD (m)
Hyper	0.400	0.650	0.900	30.00



TIR

TIR data are commercially available from Satellogic.

Band	Lower	Center	Upper	GSD (m)
TIR	8.000	11.000	14.000	90.00



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OceanSat-2

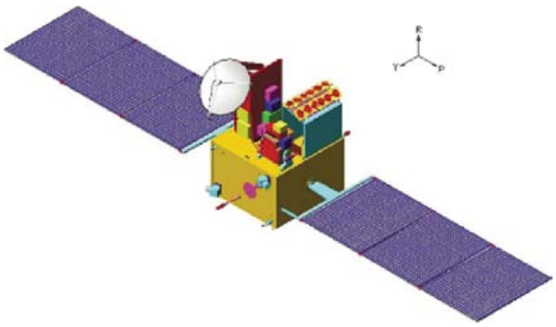
India
Civil/Government
Operational

Platform Overview

OceanSat-2 is a low-resolution multispectral satellite launched in 2009 on a Polar Satellite Launch Vehicle (PSLV) from Satish Dhawan Space Center (SDSC) for ocean monitoring. This mission is a follow-on to OceanSat-1, which was launched in 1999. OceanSat-2 was designed and built by the Indian Space Research Organization (ISRO) and uses the proven Indian Remote-sensing Satellite (IRS) bus. OceanSat-2 carries the Ocean Color Monitor–2 (OCM-2) sensor for low-resolution ocean imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; CA, coastal aerosol; NIR, near infrared]

Launch date	9/23/2009
Design lifetime	5 years
Platform owner	ISRO
Altitude	720 km
Orbit period	99.31 min
Inclination	98.28°
Crossing time	12:00 AN
Nadir repeat	2 days
Status	Operational
System website	https://www.isro.gov.in/Spacecraft/oceansat-2



3-Dimensional model of OceanSat-2 [Source: ISRO, used with permission].

OceanSat-2 image of the Irrawaddy River Delta, Bay of Bengal [Source: ISRO, used with permission].

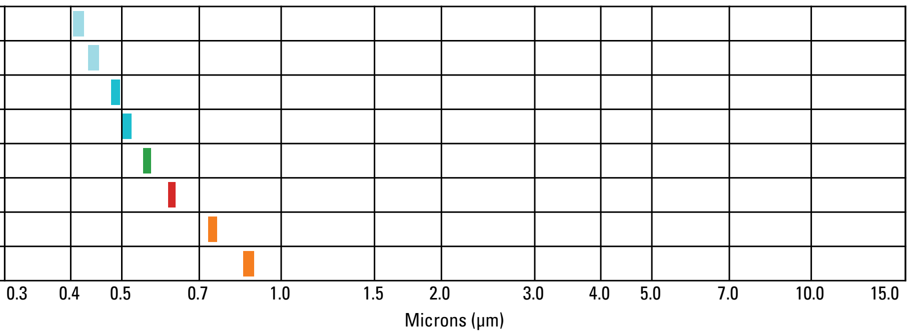
OCM-2

The OCM-2 sensor is a modestly improved version of the OCM sensor flown on OceanSat-1. OCM-2 is nearly identical to the original OCM sensor. One of the few changes is that bands 6 and 7 are slightly shifted. The ground sample distance and swath width remain the same as OCM. OCM-2 data are commercially available.

Sensor Information

	OCM-2
GSD (m)	360
Swath (km)	1,440
Data portal	http://uops.nrsc.gov.in:33333/ImgeosUops/FinalImgeosUops/FinalImgeosUops.html

Band	Lower	Center	Upper	GSD (m)
CA	0.404	0.414	0.424	360
CA	0.431	0.441	0.451	360
Blue	0.476	0.486	0.496	360
Blue	0.500	0.510	0.520	360
Green	0.546	0.556	0.566	360
Red	0.610	0.620	0.630	360
NIR	0.725	0.740	0.755	360
NIR	0.845	0.865	0.885	360

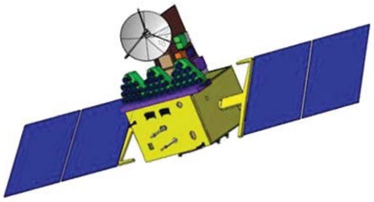


OceanSat-3 and -3A

India
Civil/Government
Future

Platform Overview

OceanSat-3 and -3A are low-resolution multispectral satellites planned to be launched in 2019 and 2020, respectively, on Polar Satellite Launch Vehicles (PSLVs) from the Satish Dhawan Space Center (SDSC) for ocean monitoring. OceanSat-3 and -3A are being designed and built by the Indian Space Research Organization (ISRO) and will use the proven Indian Remote-sensing Satellite (IRS) bus. These missions will provide continuity for users of OCM data. OceanSat-3 and -3A also have an additional thermal sensor. The OceanSat series of satellites has been operational since the launch of OceanSat-1 in 1999. OceanSat-3 carries the Ocean Color Monitor–3 (OCM-3) sensor and the Sea Surface Temperature Monitor–1 (SSTM-1) sensor for low-resolution ocean imaging.



3-Dimensional model of OceanSat-3 [Source: ISRO, used with permission].

[Abbreviations in tables: —, no data; GSD, ground sample distance; m, meter; km, kilometer; CA, coastal aerosol; NIR, near infrared; TIR, thermal infrared]

	OceanSat-3	OceanSat-3A
Launch date	2019 (Planned)	2020 (Planned)
Design lifetime	—	
Platform owner	ISRO	
Altitude	—	
Orbit period	—	
Inclination	—	
Crossing time	—	
Nadir repeat	—	
Status	—	
System website	—	

Sensor Information

	OCM-3	SSTM-1
GSD (m)	360	1,080
Swath (km)	1,400	
Data portal	https://www.isro.gov.in/Spacecraft/oceansat-2	

JACIE

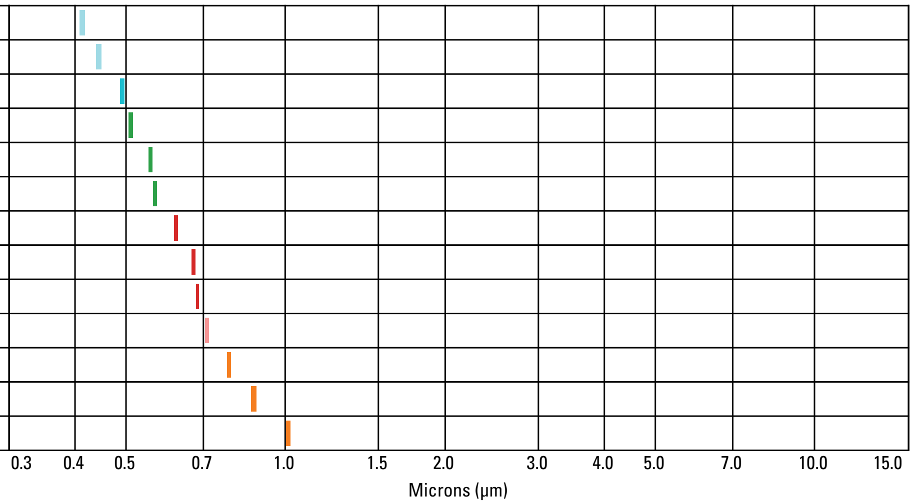
OceanSat-3 and -3A—Continued

India
Civil/Government
Future

OCM-3

The OCM-3 sensor is an improved version of the OCM-2 sensor flown on OceanSat-2. OCM-3 has five additional bands. The GSD and swath width remain nearly the same as OCM-2. OCM-3 data will be commercially available.

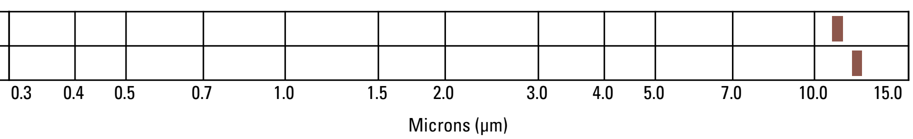
Band	Lower	Center	Upper	GSD (m)
CA	0.407	0.412	0.417	360
CA	0.438	0.443	0.448	360
Blue	0.485	0.490	0.495	360
Green	0.505	0.510	0.515	360
Green	0.550	0.555	0.560	360
Green	0.561	0.566	0.571	360
Red	0.615	0.620	0.625	360
Red	0.665	0.670	0.675	360
Red	0.677	0.681	0.685	360
Red Edge	0.705	0.710	0.715	360
NIR	0.775	0.780	0.785	360
NIR	0.860	0.870	0.880	360
NIR	1.000	1.010	1.020	360



SSTM-1

The SSTM-1 sensor is a new sensor introduced to the OceanSat series of satellites. SSTM-1 adds two thermal bands to OceanSat-3's capabilities. SSTM-1 data will be commercially available.

Band	Lower	Center	Upper	GSD (m)
TIR	10.750	11.000	11.250	1,080
TIR	11.750	12.000	12.250	1,080



PACE

United States
Civil/Government
Future

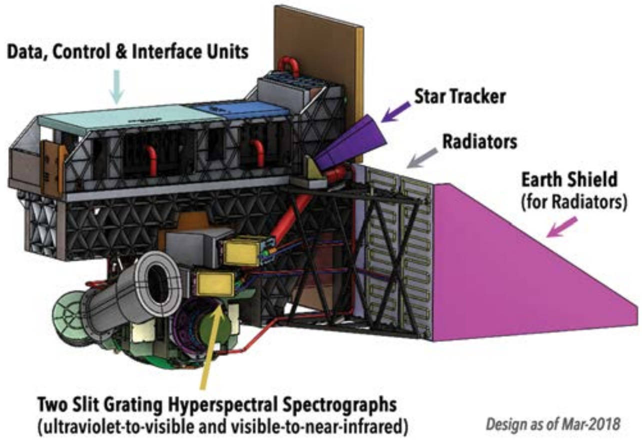
Platform Overview

The Plankton, Aerosol, Cloud, ocean Ecosystem satellite (PACE) is a low-resolution, wide swath hyperspectral satellite to be launched in 2022 for measuring atmospheric and hydrologic characteristics. PACE will extend and improve NASA's satellite observation records of global ocean biogeochemistry, aerosols, and clouds. PACE is being developed by NASA's GSFC and carries the hyperspectral Ocean Color Instrument (OCI) optical spectrometer sensor for low-resolution imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; —, no data; UV, ultraviolet; CA, coastal aerosol; NIR, near infrared; SWIR, short wave infrared]

Launch date	2022 (planned)
Platform owner	NASA
Altitude	676.5 km
Orbit period	98 min
Inclination	98°
Crossing time	13:00 AN
Nadir repeat	2 days
Design lifetime	3 years
Status	Development
System website	https://pace.oceansciences.org/

Artistic rendering of The Plankton, Aerosol, Cloud, ocean Ecosystem satellite (PACE) in orbit [Source: NASA].



Artistic rendering of the Ocean Color Instrument (OCI) [Source: NASA].

Sensor Information

	OCI
GSD (m)	1,000, 4,000
Swath (km)	2,000
Data portal	—

JACIE

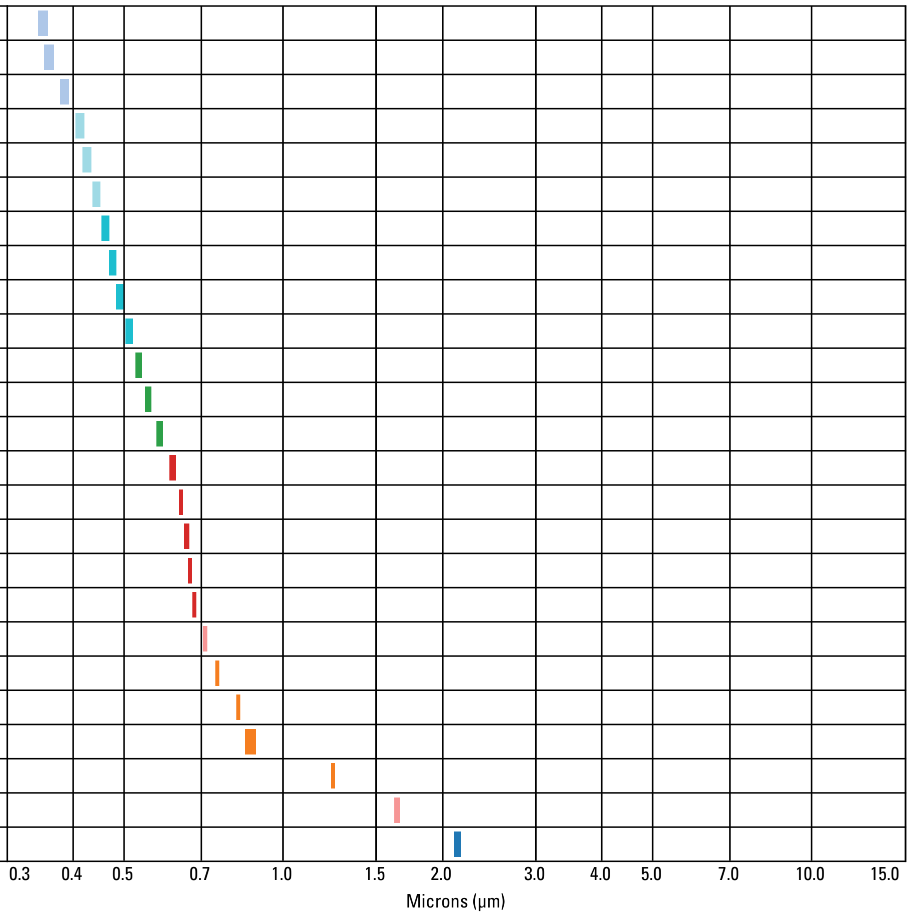
PACE—Continued

United States
Civil/Government
Future

OCI

The OCI aboard PACE was built by Goddard Space Flight center based on a long heritage of NASA technology development and flight programs. The OCI takes advantage of advancements made developing previous instruments such as ORCA, CZCS, SeaWiFS, VIIRS, and MODIS. The satellite also uses a polarimeter for calibration. OCI data will be freely available.

Band	Lower	Center	Upper	GSD (m)
UV	0.343	0.350	0.358	1,000
UV	0.353	0.360	0.368	1,000
UV	0.378	0.385	0.393	1,000
CA	0.405	0.412	0.420	1,000
CA	0.418	0.425	0.433	1,000
CA	0.436	0.443	0.451	1,000
Blue	0.453	0.460	0.468	1,000
Blue	0.468	0.475	0.483	1,000
Blue	0.483	0.490	0.498	1,000
Blue	0.503	0.510	0.518	1,000
Green	0.525	0.532	0.540	1,000
Green	0.548	0.555	0.563	1,000
Green	0.576	0.583	0.591	1,000
Red	0.610	0.617	0.625	1,000
Red	0.635	0.640	0.645	1,000
Red	0.648	0.655	0.663	1,000
Red	0.660	0.665	0.670	1,000
Red	0.673	0.678	0.683	4000
Red Edge	0.703	0.710	0.718	1,000
NIR	0.743	0.748	0.753	1,000
NIR	0.813	0.820	0.828	1,000
NIR	0.845	0.865	0.885	1,000
NIR	1.230	1.240	1.250	1,000
SWIR 1	1.620	1.640	1.660	1,000
SWIR 2	2.105	2.130	2.155	1,000



PeruSat-1

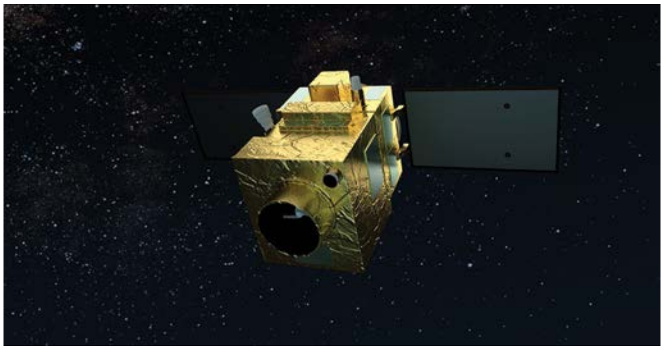
Peru
Civil/Government
Operational

Platform Overview

PeruSat-1 is a high-resolution multispectral satellite launched in 2016 by the Peruvian Space Agency (CONIDA) on a Vega launcher from Kourou, French Guiana, for Earth resources monitoring. The PeruSat-1 satellite was designed and built by Airbus Defense and Space and uses the Astro-Bus-S satellite bus, a smaller version of the Astrobus-5000. PeruSat-1 carries the New AstroSat Optical Modular Instrument (NAOMI) sensor for civil and military applications.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; —, no data; DN, descending node; GSD, ground sample distance; m, meter; Pan, panchromatic]

Launch date	9/16/2016
Design lifetime	10 years
Platform owner	CONIDA
Altitude	695 km
Orbit period	98.64 min
Inclination	98.3°
Crossing time	—
Nadir repeat	—
Status	Operational
System website	https://www.airbus.com/space/earth-observation/perusat.html



Artistic rendering of PeruSat-1 [Source: Airbus DS, used with permission].

PeruSat-1 image of Cuajone, a large copper mine in Peru [Source: Airbus DS, used with permission].

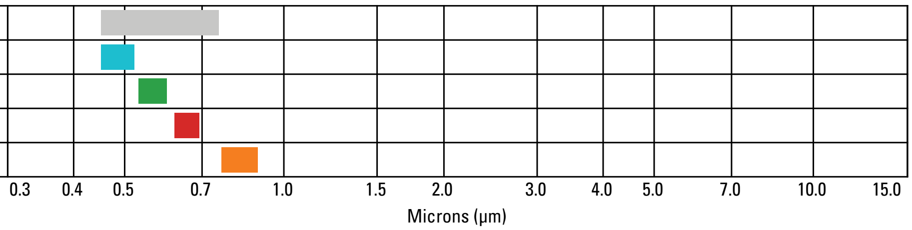
NAOMI

The NAOMI sensor is a proven design from Airbus used on the Alsat-2, SPOT-6, SPOT-7, and VNREDSat-1A satellites. This sensor provides an improved resolution of 0.7 m in panchromatic and 2 m in visible and near infrared bands. The swath width and operational capability remain the same as the previous versions of the sensor.

Sensor Information

	NAOMI
GSD (m)	0.7, 2
Swath (km)	60
Data portal	—

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.600	0.750	0.7
Blue	0.450	0.485	0.520	2
Green	0.530	0.565	0.600	2
Red	0.620	0.655	0.690	2
NIR	0.760	0.825	0.890	2



Planet's Mission-1

United States
Commercial
Operational

JACIE

Platform Overview

Mission-1 is a high-resolution multispectral satellite constellation built, launched, and operated by Planet for Earth observation. Dove-1 and -2 were launched in 2013 as technology demonstration satellites followed by the Flocks. Flocks 1a, 1b, 1c, 1d, 1d', 2e, and 2e' (about 115 satellites) were launched into an orbit similar to ISS, whereas Flocks 2p, 3p, 3m, 2k, and Dove Pioneer (about 180 satellites) were launched into an SSO orbit. The operational Flock satellites carry multispectral imagers that together can image the Earth daily in the visible and near-infrared parts of the spectrum.

Flock satellite [Source: Planet Labs Inc., used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; —, no data; DN, descending node; GSD, ground sample distance; m, meter; NIR, near infrared]

Constellation	Flock-1a	Flock-1b	Flock-1c	Flock-1d	Flock-1d′	Flock-1e	Flock-2e	Flock-2e′
Launch date	1/9/2014	7/13/2014	6/19/2014	10/28/2014	1/9/2015	4/13/2015	12/6/2015	3/23/2016
Design lifetime	1 year	1 year	2 years	2 years	2 years	2 years	3 years	3 years
Platform owner	Planet							
Altitude	420 km							
Orbit period	92.96 min							
Inclination	52°							
Crossing time	—	—	—	—	—	—	—	—
Nadir repeat	—	—	—	—	—	—	—	—
Status	Retired	Retired	Retired	Launch failure	Retired	Retired	Retired	Retired
System website	https://www.planet.com							

Constellation	Flock-2p	Flock-3p	Flock-3m	Flock-2k	Dove Pioneer
Launch date	6/22/2016	2/15/2017	10/31/2017	7/14/2017	1/21/2018
Design lifetime	3 years	3 years	3 years	3 years	3 years
Platform owner	Planet				
Altitude	475 km				
Orbit period	94.1 min				
Inclination	97.3˚				
Crossing time	10:30 DN				
Nadir repeat	1 day				
Status	Operational				
System website	https://www.planet.com				

Planet's Mission-1—Continued

United States
Commercial
Operational

Sensor Information

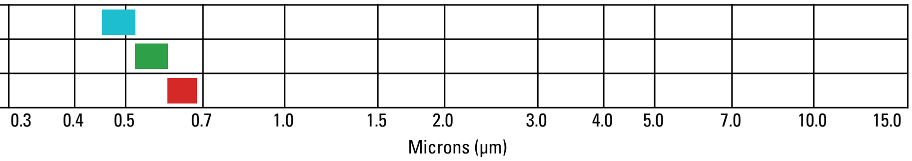
	PS-1	PS-2
GSD (m)	2.7	4
Swath (km)	20	24
Data portal	https://www.planet.com/products/planet-imagery/	

Image of Pamplona, Spain, by Dove satellite. [Source: Planet Labs Inc., used with permission].

PLANET SCOPE-1

The Planet Scope-1 (PS-1) is a three-band multispectral imager used on early Flock satellites (1a–1e). PS-1 images the Earth in the visible spectrum, providing imagery daily at a ground sample distance (GSD) of 2.7 m. Data are available to customers by way of Planet's commercial portal.

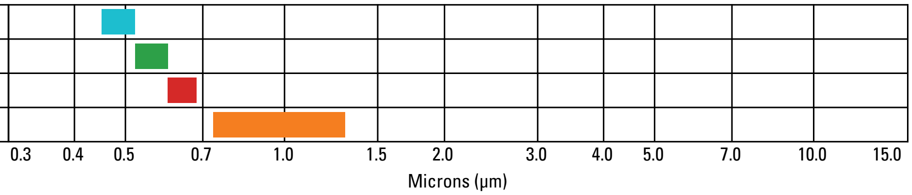
Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	2.7
Green	0.520	0.560	0.600	2.7
Red	0.600	0.640	0.680	2.7



PLANET SCOPE-2

The Planet Scope-2 (PS-2) is an improved version of the PS-1 carried by second generation flock satellites (2e–2k). PS-2 images the Earth in four bands (3 visible, 1 near infrared) providing imagery daily at a GSD of 4 m. Data are available to customers by way of Planet's commercial portal.

Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	4
Green	0.520	0.560	0.600	4
Red	0.600	0.640	0.680	4
NIR	0.730	1.015	1.300	4



JACIE

Pleiades-HR (1A and 1B)

France
Civil/Government
Operational

JACIE

Platform Overview

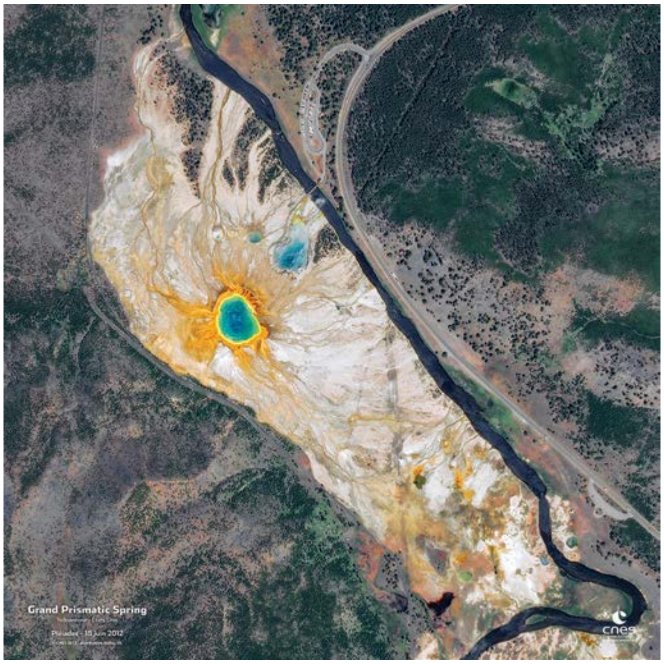
The Pleiades-HR constellation of high-resolution multispectral satellites consists of Pleiades-1A and Pleiades-1B launched in 2011 and 2012, respectively, by the National Center for Space Studies (CNES) on Soyuz ST launchers from Kourou, French Guiana, for intelligence and Earth resources monitoring. This mission is completely funded by CNES and has been in continual operation since 2011.

The Pleiades-HR series of satellites were designed and built by Airbus for CNES and use the Astrosat-1000 bus and a High-Resolution Imager (HiRI). Imagery in visible and near infrared is gathered for civil and military applications.

Artistic rendering of Pleiades-1A in orbit [Source: CNES/ill/DUCROS David, 2018, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; Pan, Panchromatic; NIR, near infrared]

	Pleiades-1A	Pleiades-1B
Launch date	12/17/2011	12/1/2012
Platform owner	CNES	
Altitude	694 km	
Orbit period	98.6 min	
Inclination	98.2°	
Crossing time	10:30 DN	
Nadir repeat	26 days	
Design lifetime	5 years	
Status	Operational	
System website	https://pleiades.cnes.fr/en/PLEIADES/index.htm	



Grand Prismatic Spring in Yellowstone National Park [Source: CNES/Distribution Airbus DS, 2012, used with permission].

Sensor Information

	HiRI
GSD (m)	0.7,2.8
Swath (km)	20
Data portal	https://www.intelligence-airbusds.com/pleiades/

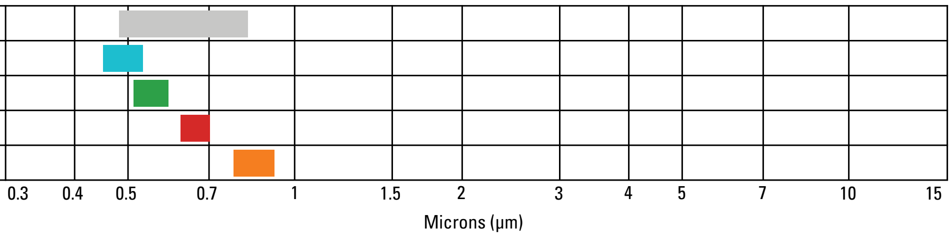
Pleiades-HR (1A and 1B)—Continued

France
Civil/Government
Operational

HiRI

The HiRI sensor aboard the Pleiades-HR (1A and 1B) satellites is a design from Thales Alenia Space-France (TAS-F). The GSD of 2.8 m in visible and near infrared and 0.7 m in Pan with a swath width of 20 km is provided on a global and targeted basis. Data are available to customers through Airbus's commercial portal.

Band	Lower	Center	Upper	GSD (m)
Pan	0.480	0.650	0.820	0.7
Blue	0.450	0.490	0.530	2.8
Green	0.510	0.550	0.590	2.8
Red	0.620	0.660	0.700	2.8
NIR	0.775	0.845	0.915	2.8



PRISMA

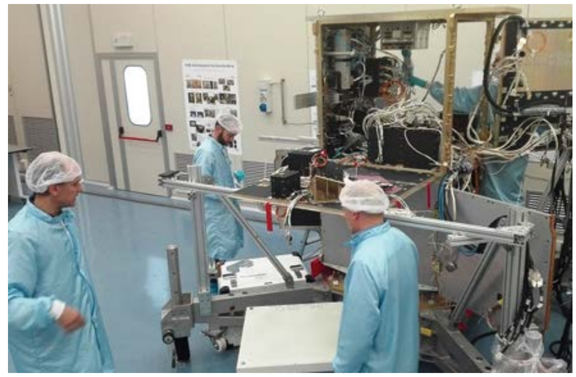
Italy
Civil/Government
Operational

Platform Overview

The Hyperspectral Precursor of the Application Mission (PRISMA) is a medium-resolution hyperspectral satellite launched March 2019 by ASI on a Vega launcher for environmental monitoring. PRISMA was developed at Carlo Gavazzi Space (CGS) of Milan, Italy. The satellite is based on a minisatellite bus of MITA heritage. PRISMA carries a hyperspectral sensor for medium-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; km, kilometer; —, no data; Pan, panchromatic; Hyper, hyperspectral]

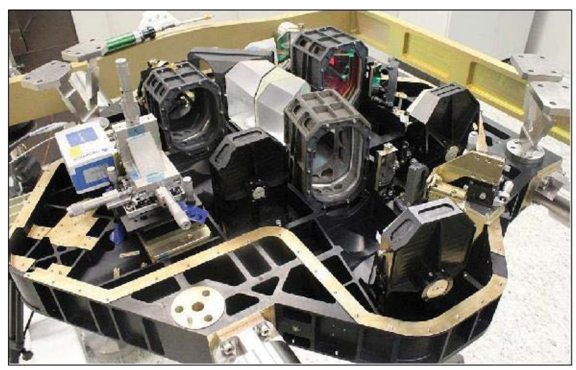
Launch date	03/21/2019
Design lifetime	5 years
Platform owner	ASI
Altitude	615 km
Orbit period	97 min
Inclination	97.84°
Crossing time	10:30 DN
Nadir repeat	29 days
Status	Commissioning
System website	http://prisma-i.it/



PRISMA satellite in development [Source: ASI, used with permission].

Sensor Information

	PRISMA
GSD (m)	5, 30
Swath (km)	30
Data portal	—

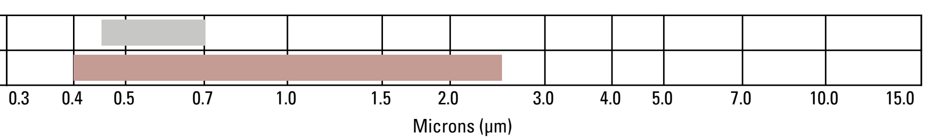


Prototype model of the PRISMA sensor [Source: ASI, used with permission].

PRISMA

The hyperspectral sensor is primarily being developed by Selex ES of Campi Bisenzio, Italy. The imager has approximately 250 bands. The instrument is based on the prism spectrometer concept.

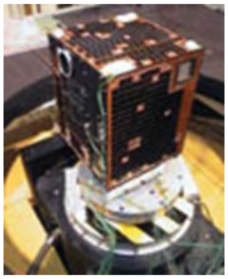
Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.575	0.700	5
Hyper	0.400	1.450	2.500	30



PROBA-1

European Space Agency
Civil/Government
Operational

Platform Overview



Proba-1 during vibration tests [Source: ESA].

Project for On-Board Autonomy-1 (PROBA-1) is a medium-resolution hyperspectral satellite launched by the European Space Agency (ESA) in 2001 on a Polar Satellite Launch Vehicle (PSLV) for technology demonstration and Earth observation. This is the first satellite in the PROBA series manufactured by Verhaert Space NV along with 18 other contractors. Proba-1 was followed by Proba-2 and Proba-V, currently in operation. Proba-3 is under development. Proba-1 carries the Compact High-Resolution Imaging Spectrometer (CHRIS) for medium-resolution hyperspectral imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; Hyper, hyperspectral]

Launch date	10/22/2001
Design lifetime	1 year
Platform owner	ESA
Altitude	621 km
Orbit period	96.97 min
Inclination	97.9°
Crossing time	10:30 DN
Nadir repeat	7 days
Status	Operational
System website	http://www.esa.int/Our_Activities/Observing_the_Earth/Proba-1/Overview

CHRIS's image of Ardennes, Belgium [Source: ESA].

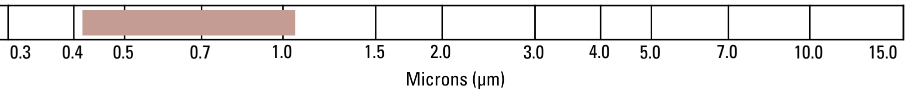
Sensor Information

	CHRIS
GSD (m)	18
Swath (km)	14
Data portal	https://earth.esa.int/web/guest/-/proba-chris-level-1a-1488

CHRIS

The CHRIS instrument is a hyperspectral sensor designed to image the Earth in 19 visible and near infrared (VNIR) bands at a ground sample distance (GSD) of 18 m. CHRIS can be reconfigured to provide 63 bands at a GSD of 34 m and 150 bands at a lower GSD. Data are available for free at https://earth.esa.int/web/guest/-/proba-chris-level-1a-1488.

Band	Lower	Center	Upper	GSD (m)
Hyper	0.415	0.733	1.050	18



PROBA-V

European Space Agency
Civil/Government
Operational

Platform Overview

Project for On-Board Autonomy-V (PROBA-V) is a medium-resolution multispectral satellite launched by the European Space Agency (ESA) in 2013 on a Vega launcher for Earth observation. This is the third satellite in the PROBA series manufactured by QinetiQ Space Belgium. Proba-V will be followed by Proba-3. Proba-V carries a Vegetation Instrument (VI) for low-resolution vegetation monitoring.

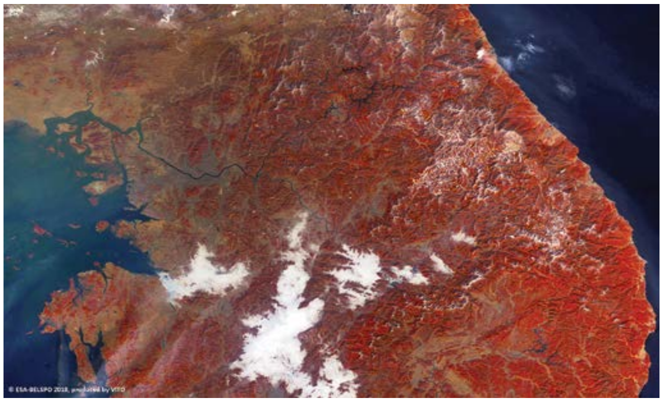
[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; —, no data; GSD, ground sample distance; m, meter; NIR, near infrared; SWIR, shortwave infrared]

Launch date	05/07/2013
Design lifetime	2.5 years
Platform owner	ESA
Altitude	820 km
Orbit period	101 min
Inclination	98.73˚
Crossing time	11:00 DN
Nadir repeat	—
Status	Operational
System website	https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/proba-v

Artistic rendering of Proba-V satellite in orbit [Source: ESA].

Sensor Information

	VI
GSD (m)	100
Swath (km)	2,250
Data portal	http://proba-v.vgt.vito.be/en/product-access

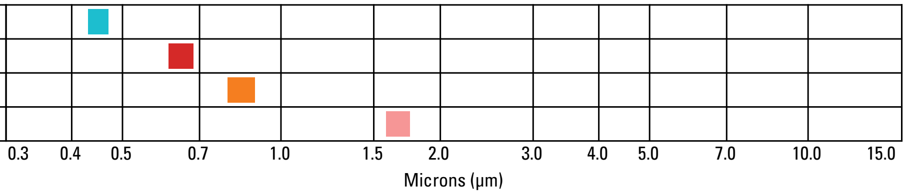


Proba-V image of South Korea (ESA) [Source: ESA].

VEGETATION INSTRUMENT

The VI sensor on PROBA-V is intended to extend the dataset of the Spot-4 and -5 instruments. With a swath width of 2,250 km, VI images the Earth in visible, near infrared, andshortwave infrared wavelengths providing a ground sample distance of 100 m. Data are available for free.

Band	Lower	Center	Upper	GSD (m)
Blue	0.430	0.450	0.470	100
Red	0.610	0.645	0.680	100
NIR	0.790	0.840	0.890	100
SWIR 1	1.580	1.665	1.750	300



RADARSAT Constellation Mission

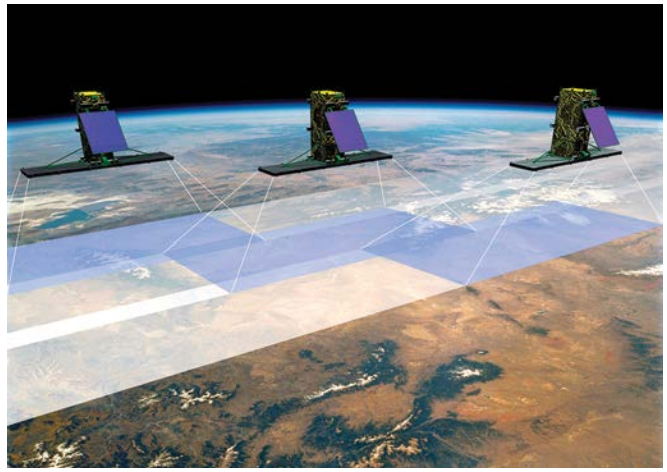
Canada
Civil/Government
Future

Platform Overview

The RADARSAT Constellation Mission (RCM) will consist of three small high-resolution synthetic aperture radar (SAR) satellites to be launched in early 2019 by Canadian Space Agency and MDA for Earth observation. The RCM satellites will operate in tandem with RADARSAT-2, significantly improving revisit. The RCM satellite bus is based on the Magellan MAC-200 bus designed by Bristol Aerospace. The bus is also referred to as the Canadian Smallsat Bus. The RCM satellites will carry the SAR sensor for high-resolution SAR data.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; —, no data; H, horizontal; V, vertical]

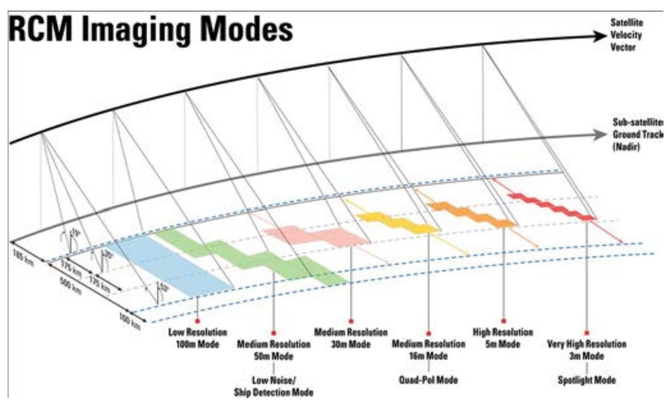
Launch date	06/11/2019
Design lifetime	7 years
Platform owner	CSA / MDA
Altitude	500 km
Orbit period	96.4 min
Inclination	97.74°
Crossing time	6:00 DN
Nadir repeat	12 days
Status	Planned
System website	http://www.asc-csa.gc.ca/eng/satellites/radarsat/default.asp



Artistic rendering of RADARSAT Constellation Mission satellites in orbit [Source: MDA/NASA, used with permission].

Sensor Information

	SAR
Resolution (m)	1–100 (selectable)
Swath (km)	14–500 (selectable)
Data portal	—



RADARSAT Constellation imaging modes [Source: CSA].

JACIE

RADARSAT Constellation Mission—Continued

Canada
Civil/Government
Future

SAR

The SAR instrument aboard the RCM satellites is derived from RADARSAT-2's SAR instrument. The ground sample distance will be the same, and the size of the antenna will be decreased. The SAR instrument operates in the C-band at 5.405 GHz (λ = 5.5 cm). The angle of incidence is 19–53 degrees. SAR data are available through MDA.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
Low Resolution	Single	HH, VV, HV, VH	500	100 x 100
	Dual	HH/HV, VV/VH, HH/VV, Compact		
Medium Resolution 50 m	Single	HH, VV, HV, VH	350	50 x 50
	Dual	HH/HV, VV/VH, HH/VV, Compact		
Medium Resolution 30 m	Single	HH, VV, HV, VH	125	30 x 30
	Dual	HH/HV, VV/VH, HH/VV, Compact		
Medium Resolution 16 m	Single	HH, VV, HV, VH	30	16 x 16
	Dual	HH/HV, VV/VH, HH/VV, Compact		
High Resolution	Single	HH, VV, HV, VH	30	5 x 5
	Dual	HH/HV, VV/VH, HH/VV, Compact		
Very High Resolution 3 m	Single	HH, VV, HV, VH	20	3 x 3
	Dual	HH/HV, VV/VH, HH/VV, Compact		
Low Noise	Single	HH, VV, HV, VH	350	100 x 100
	Dual	HH/HV, VV/VH, Compact		
Ship Detection	Single	HH, VV, HV, VH	350	Variable
	Dual	HH/HV, VV/VH, Compact		
Spotlight	Single	HH, VV, HV, VH	14 [5 km in azimuth]	1 x 3
	Dual	HH/HV, VV/VH, Compact		
Quad-Polarization	Quad	HH/HV/VH/VV	20	9 x 9

Data compiled by the USGS National Land Imaging Program's Requirements Capabilities and Analysis for Earth Observation (RCA-EO) project. JACIE is a collaboration between U.S. Federal agencies NASA, NGA, NOAA, USDA, and USGS. For more information see: https://www.usgs.gov/land-resources/eros/calval/jacie

For Joint Agency Commercial Imagery Evaluation (JACIE) sensor performance information see: https://www.usgs.gov/land-resources/eros/calval/jacie

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RADARSAT-2

Canada
Civil/Government
Operational

Platform Overview

RADARSAT-2 is a high-resolution synthetic aperture radar (SAR) satellite launched in 2007 on a Soyuz launch vehicle by the Canadian Space Agency (CSA) for Earth observation. RADARSAT-2 operated in tandem with RADARSAT-1 (before RADARSAT-1's retirement). RADARSAT-2 was designed and built by MDA. Alenia Spazio was subcontracted to build the bus, which was designed on PRIMA, a bus originally designed for the Italian Space Agency. RADARSAT-2 carries the SAR instrument for high-resolution SAR data.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; H, horizontal; V, vertical]

Launch date	12/14/2007
Platform owner	CSA/MDA
Altitude	798 km
Orbit period	100.7 min
Inclination	98.6°
Crossing time	6:00 DN
Nadir repeat	24 days
Design lifetime	7 years
Status	Operational
System website	http://www.asc-csa.gc.ca/eng/satellites/radarsat2/default.asp

Artistic rendering of RADARSAT-2 in orbit [Source: MDA/NASA, used with permission].

Montreal, Quebec, captured by RADARSAT-2 [Source: MDA, used with permission].

Sensor Information

	SAR
GSD (m)	1–100 (selectable)
Swath (km)	18–530 (selectable)
Data portal	http://www.asc-csa.gc.ca/eng/satellites/radarsat2/order-contact.asp

Data compiled by the USGS National Land Imaging Program's Requirements Capabilities and Analysis for Earth Observation (RCA-EO) project. JACIE is a collaboration between U.S. Federal agencies NASA, NGA, NOAA, USDA, and USGS. For more information see: https://www.usgs.gov/land-resources/eros/calval/jacie

For Joint Agency Commercial Imagery Evaluation (JACIE) sensor performance information see: https://www.usgs.gov/land-resources/eros/calval/jacie

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RADARSAT-2—Continued

Canada
Civil/Government
Operational

SAR

The SAR instrument aboard RADARSAT-2 is very similar in design to the SAR instrument aboard RADARSAT-1. The new SAR instrument has improved resolution. The SAR instrument operates in the C-band at 5.405 GHz (λ = 5.5 cm). The angle of incidence is 10–60 degrees. SAR data are available through MDA.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
Fine	Single	HH, HV, VH, VV	50	8
	Dual	HH/HH, HH/HV, HV/HH, HV/HV		
Wide Fine	Single	HH, HV, VH, VV	150	8
	Dual	HH/HH, HH/HV, HV/HH, HV/HV		
Standard	Single	HH, HV, VH, VV	100	25
	Dual	HH/HH, HH/HV, HV/HH, HV/HV		
Wide	Single	HH, HV, VH, VV	150	25
	Dual	HH/HH, HH/HV, HV/HH, HV/HV		
ScanSAR Narrow	Single	HH, HV, VH, VV	300	50
	Dual	HH/HH, HH/HV, HV/HH, HV/HV		
ScanSAR Wide	Single	HH, HV, VH, VV	500	100
	Dual	HH/HH, HH/HV, HV/HH, HV/HV		
Ocean Surveillance	Single Dual	HH, HV, VH, VV	530	Variable
		HH/HH, HH/HV, HV/HH, HV/HV		
Fine Quad-Pol	Polarimetric	Alt. HV / HV	25 50	12
Wide Fine Quad-Pol	Polarimetric	Alt. HV / HV		12
Standard Quad-Pol	Polarimetric	Alt. HV / HV	25 50	25
Wide Standard Quad-Pol	Polarimetric	Alt. HV / HV		25
Extended High	Single	HH	75	25
Extended Low	Single	HH	170	60
Spotlight	Single	HH, HV, VH, VV	18	1
Ultra-Fine	Single	HH, HV, VH, VV	20	3
Wide Ultra-Fine	Single	HH, HV, VH, VV	50	3
Extra-Fine	Single	HH, HV, VH, VV	125	5
Multi-Look Fine	Single	HH, HV, VH, VV	50	8
Wide Multi-Look Fine	Single	HH, HV, VH, VV	90	8
Ship Detection	Single	HH, HV, VH, VV	450	Variable

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RASAT

Turkey
Civil/Government
Operational

Platform Overview

RASAT is a medium-resolution, panchromatic, and multispectral satellite launched in 2011 by TUBITAK-UZAY on a Dnepr-1 launch vehicle from the Yasny/Dombarovsky launch site for Earth observation. RASAT was designed and built in Turkey by Space Technologies Research Institute-Tubitak and is of BILSAT heritage (Turkey's previous satellite). RASAT carries the Optical Imaging System (OIS) sensor for medium-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; —, no data; GSD, ground sample distance; m, meter; Pan, panchromatic]

Launch date	8/17/2011
Design lifetime	3 years
Platform owner	TUBITAK-UZAY
Altitude	700 km
Orbit period	98 min
Inclination	98.25°
Crossing time	10:30 AN
Nadir repeat	—
Status	Operational
System website	http://uzay.tubitak.gov.tr/en/uydu-uzay/rasat

Artistic rendering of RASAT in orbit [Source: TUBITAK-UZAY, used with permission].

Sensor Information

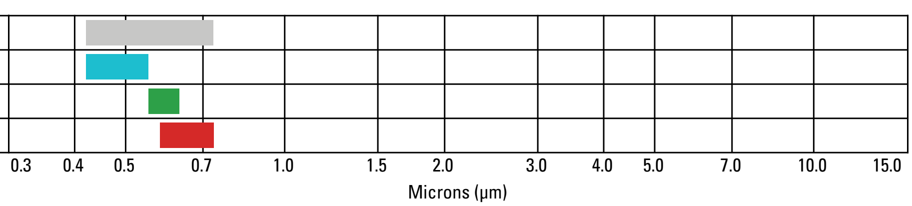
	OIS
GSD (m)	7.5, 15
Swath (km)	30
Data portal	—

RASAT image of the Colima volcano in Mexico [Source: TUBITAK-UZAY, used with permission].

OIS

The OIS aboard RASAT is a pushbroom-style imager. OIS was designed and developed by Satrec Initiative (SI) in Korea and is a variant of their Earth Observing System-A (EOS-A).

Band	Lower	Center	Upper	GSD (m)
Pan	0.420	0.575	0.730	7.5
Blue	0.420	0.485	0.550	15
Green	0.550	0.590	0.630	15
Red	0.580	0.655	0.730	15



JACIE

ResourceSat-2 and -2A

India
Civil/Government
Operational

JACIE

Platform Overview

ResourceSat-2 is a medium- and high-resolution satellite launched in 2011 on the Polar Satellite Launch Vehicle (PSLV)-C16 launch vehicle. ResourceSat-2 carries the same sensing elements as ResourceSat-1 (launched in October 2003) and provides continuity for the mission. The objectives of the ResourceSat mission are to provide remote sensing data services to global users, focusing on data for integrated land and water resources management.

ResourceSat-2A is identical to ResourceSat-2 and was launched in 2016 on the PSLV-C36 launch vehicle for continuity of data and improved temporal resolution. The two satellites (ResourceSat-2 and ResourceSat-2A) operating in tandem improved the revisit capability from 5 days to 2-3 days.

The ResourceSat-2 platform is of IRS-1C/1D-P3 heritage and was built by the Indian Space Research Organization (ISRO). ResourceSat-2 and 2A carry the Advanced Wide Field Sensor (AWiFS), the Linear Imaging Self Scanning Sensor–III (LISS-3), and the Linear Imaging Self Scanning Sensor–IV (LISS-4) for medium-resolution imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; NIR, near infrared; SWIR, short wave infrared]

	RS-2	RS-2A
Launch date	4/20/2011	12/7/2016
Platform owner	ISRO	
Altitude	817 km	
Orbit period	101.35 min	
Inclination	98.78°	
Crossing time	10:30 DN	
Nadir repeat	24 days	
Design lifetime	5 years	
Status	Operational	
System website	https://www.isac.gov.in/earth-observation/html/resourcesat-2.jsp	

ResourceSat-2 satellite in clean room [Source: ISRO, used with permission].

ResourceSat-2 LISS-3 imagery over Chesapeake Bay and Delaware Bay, United States [Source: USGS].

Sensor Information

	AWiFS	LISS-3	LISS-4
GSD (m)	56	23.5	5.8
Swath (km)	740	141	70
Data Portal	https://nrsc.gov.in/		

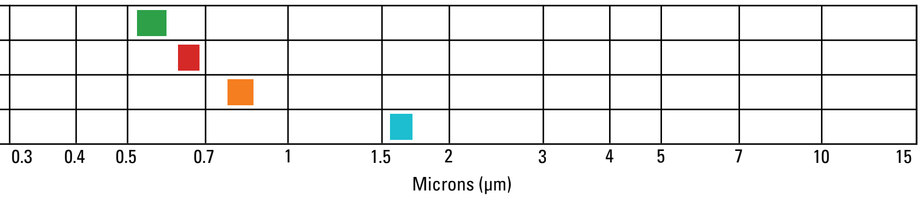
ResourceSat-2 and -2A—Continued

India
Civil/Government
Operational

AWiFS

The AWiFS aboard ResourceSat-2 and 2A is identical to the AWiFS sensor on ResourceSat-1. The data quantization for all sensors is now 10 bits. AWiFS data are available for purchase.

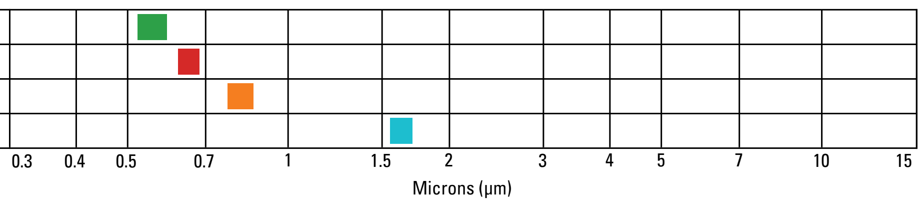
Band	Lower	Center	Upper	GSD (m)
Green	0.520	0.555	0.590	56
Red	0.620	0.650	0.680	56
NIR	0.770	0.815	0.860	56
SWIR 1	1.550	1.625	1.700	56



LISS-3

The LISS-3 aboard ResourceSat-2 and 2A is identical to the LISS-3 sensor on ResourceSat-1. The data quantization for all sensors is now 10 bits. LISS-3 data are available for purchase.

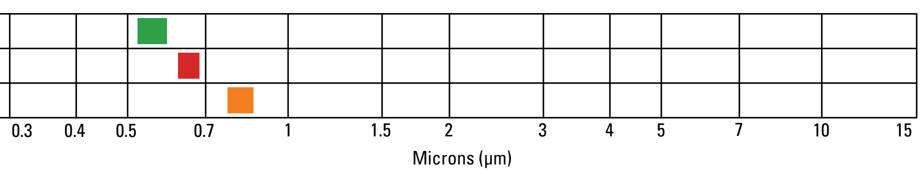
Band	Lower	Center	Upper	GSD (m)
Green	0.520	0.555	0.590	23.5
Red	0.620	0.650	0.680	23.5
NIR	0.770	0.815	0.860	23.5
SWIR 1	1.550	1.625	1.700	23.5



LISS-4

The LISS-4 aboard ResourceSat-2 and 2A is based on the LISS-4 sensor on ResourceSat-1 and has an increased swath of 70 km. The data quantization for all sensors is now 10 bits. LISS-4 data are available for purchase.

Band	Lower	Center	Upper	GSD (m)
Green	0.520	0.555	0.590	5.8
Red	0.620	0.650	0.680	5.8
NIR	0.770	0.815	0.860	5.8



ResourceSat-3 and -3A

India
Civil/Government
Future

Platform Overview

ResourceSat-3 and -3A are medium-resolution wide swath satellites to be launched in 2019 and 2020, respectively, for advanced land and water resources management by the Indian Space Research Organization (ISRO). ResourceSat-3 and -3A will provide continuity of the ResourceSat program and enhanced capabilities. ResourceSat-3 and -3A will carry the Advanced Linear Imaging Self Scanning Sensor-III (ALISS) and Atmospheric Correction (ATCOR) sensor for medium- and high-resolution land imaging, respectively.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; —, no data; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near infrared; SWIR, shortwave infrared]

	RS-3	RS-3A
Launch date	Sept. 2019 (Planned)	Aug. 2020 (Planned)
Platform owner	ISRO	
Altitude	795 km	
Orbit period	101 min	
Inclination	97.91°	
Crossing time	10:30 DN	
Nadir repeat	11 days	
Design lifetime	5 years	
Status	Development	
System website	—	

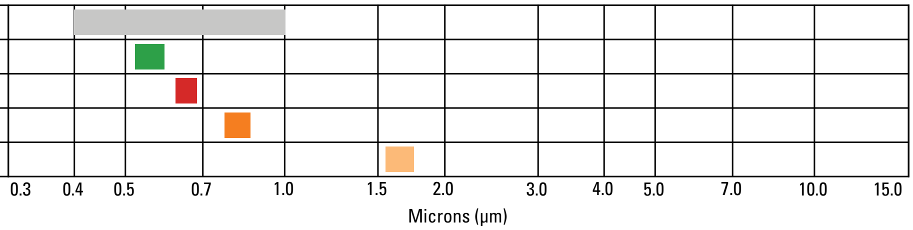
Sensor Information

	ALISS	ATCOR
GSD (m)	20	240
Swath (km)	925	
Data portal	—	

ALISS

The ALISS-3 sensor is an improvement upon the LISS-3 sensor flown on previous ResourceSat missions. ALISS-3 has visible and near infrared (VNIR) and shortwave infrared (SWIR) bands with improved 20-m ground sample distance and a 925-km swath. ALISS data will be commercially available.

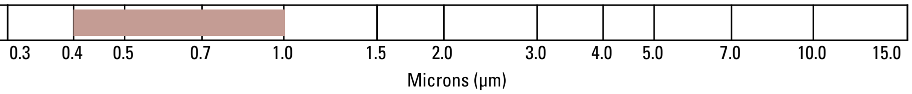
Band	Lower	Center	Upper	GSD (m)
Pan	0.400	0.700	1.000	20
Green	0.520	0.555	0.590	20
Red	0.620	0.650	0.680	20
NIR	0.770	0.815	0.860	20
SWIR1	1.550	1.650	1.750	20



ATCOR

The ATCOR sensor is a new hyperspectral sensing element that will operate in VNIR bands. ATCOR is intended to improve the quality of the data products. ATCOR data will be commercially available.

Band	Lower	Center	Upper	GSD (m)
Hyper	0.400	0.700	1.000	240



ResourceSat-3S and -3SA

India
Civil/Government
Future

Platform Overview

ResourceSat-3S and -3SA are high-resolution, multispectral, and panchromatic Earth imaging satellites to be launched in 2019 and 2020 by the Indian Space Research Organization (ISRO) for generating improved digital elevation models (DEMs). ResourceSat-3S and -3SA will be used for stenographic mapping with improved resolution. ResourceSat-3S and -3SA will carry the Advanced Panchromatic (APAN) and Linear Self-Scanner (LISS-V) sensors for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; —, no data; NIR, near-infrared]

	RS-3S	RS-3SA
Launch date	May 2019 (Planned)	Jan. 2020 (Planned)
Platform owner	ISRO	
Altitude	633 km	
Orbit period	97.5 min	
Inclination	98.89°	
Crossing time	10:30 DN	
Nadir repeat	48 days	
Design lifetime	5 years	
Status	Development	
System website	—	

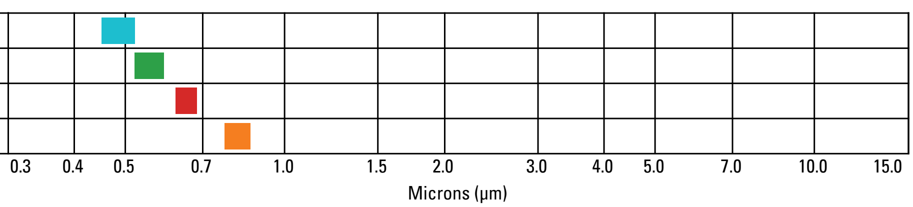
Sensor Information

	LISS-V	APAN
GSD (m)	2.5	1.5
Swath (km)	60	
Data portal	—	

LISS-V

The LISS-V sensor is an improvement on the LISS-4 sensor flown on previous ResourceSat missions. LISS-V has visible and near infrared (VNIR) bands with improved 2.5 m ground sample distance.

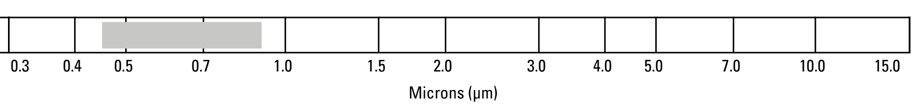
Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	2.5
Green	0.520	0.555	0.590	2.5
Red	0.620	0.650	0.680	2.5
NIR	0.770	0.815	0.860	2.5



APAN

The APAN sensor is a new high-resolution, panchromatic imager for sharpening. Both sensors have a narrowed swath of 60 km.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.675	0.900	1.5



Data compiled by the USGS National Land Imaging Program's Requirements Capabilities and Analysis for Earth Observation (RCA-EO) project. JACIE is a collaboration between U.S. Federal agencies NASA, NGA, NOAA, USDA, and USGS. For more information see: https://www.usgs.gov/land-resources/eros/calval/jacie

For Joint Agency Commercial Imagery Evaluation (JACIE) sensor performance information see: https://www.usgs.gov/land-resources/eros/calval/jacie

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RISAT-1, -1A, and -1B

India
Civil/Government
Operational/Future

Platform Overview

The Radar Imaging Satellite (RISAT)-1 is a multiresolution Synthetic Aperture Radar (SAR) satellite launched in 2012 by the Indian Space Research Organization (ISRO) on a Polar Satellite Launch Vehicle (PSLV) from Satish Dhawan Space Center for Earth resources monitoring. RISAT-1A and RISAT-1B are copies of RISAT-1 and are planned for launch in 2018/2019 and 2021, respectively. The RISAT-1 satellites carry the RISAT-SAR instrument for measuring radar data.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; H, horizontal; V, vertical]

	RISAT-1	RISAT-1A	RISAT-1B
Launch date	4/26/2012	2020 (Planned)	March 2021 (Planned)
Design lifetime	5 years		
Platform owner	ISRO		
Altitude	536 km		
Orbit period	95.49 min		
Inclination	97.55°		
Crossing time	6:00 AN		
Nadir repeat	25 days		
Status	Operational	Development	
System website	https://www.isro.gov.in/Spacecraft/risat-1		

RISAT-1 main structure [Source: ISRO, used with permission].

Sensor Information

	RISAT-SAR
GSD (m)	0.67–55 (selectable)
Swath (km)	10–223 (selectable)
Data portal	http://uops.nrsc.gov.in:33333/ImgeosUops/FinalImgeosUops/FinalImgeosUops.html

RISAT-1 image of the Chambal river, Madhya Pradesh [Source: ISRO, used with permission].

RISAT-1, -1A, and -1B—Continued

India
Civil/Government
Operational/Future

RISAT-SAR

The RISAT-SAR instrument was built by ISRO's Space Applications Center and uses dual receivers. RISAT-SAR operates in the C-band at 5.35 GHz (λ = 5.60 cm). The angle of incidence is 12–55 degrees.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
High Resolution Spotlight (HRS)	Single	HH, HV, VH, VV	10 x 10	1 x 0.67
	Dual	HH/HV, VV/VH		
	Circular	CP/VH		
Fine Resolution Stripmap-1 (FRS-1)	Single	HH, HV, VH, VV	25	3 x 2
	Dual	HH/HV, VV/VH		
	Circular	CP/VH		
Fine Resolution Stripmamp-2 (FRS-2)	Circular	CP/VH	25	3 x 4
	Quad	HH/HV/VV/VH		9 x 4
Medium Resolution ScanSAR (MRS)	Single	HH, HV, VH, VV	115	21–23 x 8
	Dual	HH/HV, VV/VH		
	Circular	CP/VH		
Coarse Resolution ScanSAR (CRS)	Single	HH, HV, VH, VV	223	41–55 x 8
	Dual	HH/HV, VV/VH		
	Circular	CP/VH		

RISAT-2 and -2A

India
Civil/Government
Operational/Future

JACIE

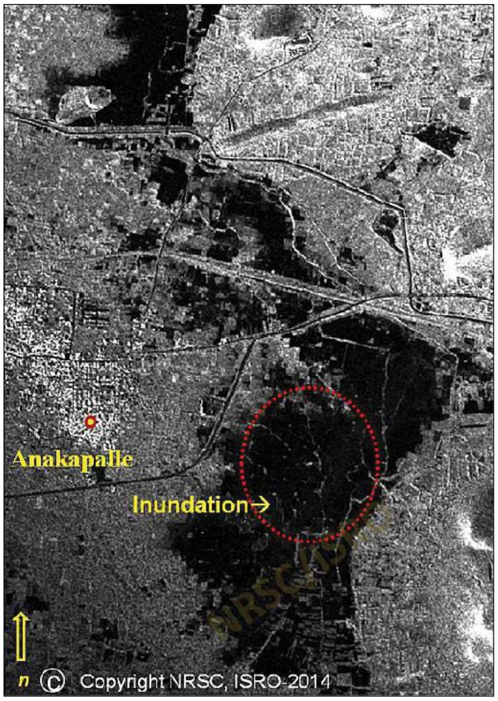
Platform Overview

RISAT-2 is a multiresolution synthetic aperture radar (SAR) satellite launched in 2009 by the Indian Space Research Organization (ISRO) on a Polar Satellite Launch Vehicle (PSLV) launch vehicle from Satish Dhawan Space Center (SDSC) for Earth resources monitoring. RISAT-2 was designed and built by Israel Aerospace Industries, Ltd., (IAI/MBT) and uses the OptSat-2000 platform of TecSAR bus heritage. ISRO purchased RISAT-2 when RISAT-1 was delayed. A larger, more capable model of the satellite, RISAT-2A, is planned to be launched in 2020. RISAT-2B is planned for launch in May 2019 on the PSLV C-46 mission. RISAT-2 carries the X-SAR instrument for measuring SAR data.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; —, no data; GSD, ground sample distance; m, meter; H, horizontal; V, vertical]

	RISAT-2	RISAT-2A
Launch date	4/20/2009	2020 (Planned)
Design lifetime	5 years	
Platform owner	ISRO	
Altitude	548 km	
Orbit period	95.61 min	
Inclination	41.21°	
Crossing time	—	
Nadir repeat	14 days	
Status	Operational	Development
System website	https://nrsc.gov.in/RISAT-2	

Artistic rendering of RISAT-2 [Source: ISRO, used with permission].



RISAT-2 image of Anakapalle, Vishakapatnam district, Andhra Pradesh [Source: ISRO, used with permission].

Sensor Information

	X-SAR
GSD (m)	1–8 (selectable)
Swath (km)	10–120 (selectable)
Data portal	—

RISAT-2 and -2A—Continued

India
Civil/Government
Operational/Future

X-SAR

The X-band SAR (X-SAR) instrument was built by Elta Systems, Ltd., of Ashdod, Israel, and has heritage of the X-SAR instrument flown on TecSAR. X-SAR operates in the X-band at 9.59 GHz (λ = 3.13 cm). The angle of incidence is 20–45 degrees.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
Spotlight mode	Single	HH, HV, VH, VV	—	<1
Super Stripmap (mosaic) mode	Single	HH, HV, VH, VV	—	1.8
Stripmap mode	Single	HH, HV, VH, VV	—	3
Wide coverage ScanSAR mode	Single	HH, HV, VH, VV	—	8

JACIE

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SABIA-Mar 1 and 2

Argentina, Brazil
Civil/Government
Future

Platform Overview

SABIA-Mar 1 is a low-resolution multispectral satellite to be launched in 2022 to study the sea and coasts. The Argentinian National Space Activities Commission (CONAE) partnered with the Brazilian space agency (AEB) to form a constellation of two ocean satellites. CONAE is fully responsible for SABIA-Mar 1 and AEB is responsible for SABIA-Mar 2. Investigación Aplicada (INVAP) is the primary contractor for the development of SABIA-Mar 1. SABIA-Mar 1 will carry two primary sensors, visible-near infraredInfrard (VIS-NIR) and near infrared-shortwave infrared (NIR-SWIR), for ocean color monitoring. The mission also includes a high-sensitivity panchromatic camera (H-PAN) and a thermal infrared(TIR) sensor for measuring ocean temperature as a secondary payload.

[Abbreviations in tables: —, no data; km, kilometer; min, minute; °, degree; GSD, ground sample distance; m, meter]

	SABIA-Mar 1	SABIA-Mar 2
Launch date	2022 (Planned)	—
Design lifetime	5 years	
Platform owner	CONAE, AEB	
Altitude	702 km	
Orbit period	98.81 min	
Inclination	98.19°	
Crossing time	22:20 AN	
Nadir repeat	4 days	
Status	Development	Planned
System website	http://www.conae.gov.ar/index.php/espanol/introduccion-sace	

Sensor Information

	VIS-NIR	NIR-SWIR	TIR
GSD (m)	200, 800	400, 800	400
Swath (km)	—	—	—
Data portal	—		

VIS-NIR

The VIS-NIR sensor will have 11 bands between 412 nm and 865 nm (visible to near-infrared) to study ocean color and coasts. The sensor will provide 800-m ground sample distance (GSD) data over oceans and 200-m GSD data over coasts. Detailed spectral information is not yet available.

NIR-SWIR

The NIR-SWIR sensor will have six bands between 750 nm and 1600 nm (near-infrared to shortwave infrared) to study ocean color and coasts. The sensor will provide 800-m GSD data over oceans and 400-m GSD data over coasts. Detailed spectral information is not yet available.

TIR

The TIR sensor will have two bands centered at 11 µm and 12 µm (thermal infrared) for measuring sea surface temperature. The sensor will provide 400-m GSD data globally. Detailed spectral information is not yet available.

H-PAN

No information is available currently.

SARAL

India, France
Civil/Government
Operational

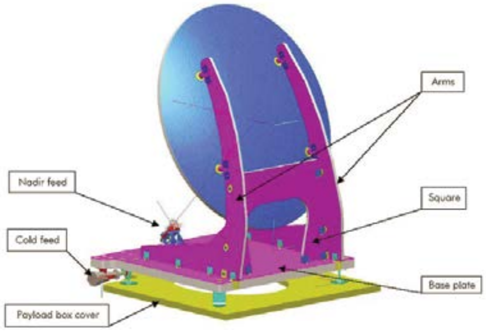
Platform Overview

SARAL is a radar altimeter satellite launched in 2013 by the Indian Space Research Organization (ISRO) on a Polar Satellite Launch Vehicle (PSLV)—C20 launch vehicle from Satish Dhawan Space Center, Sriharikota, India, for oceanographic studies. SARAL is complementary to Jason-2 and will improve sea surface height mapping. The SARAL mission is a collaboration with French National Center for Space Studies (CNES). ISRO developed a new bus for SARAL, referred to as Indian MiniSatellite-2 (IMS-2), and a Payload Instrument Module (PIM). SARAL carries the Altimeter in Ka band (AltiKa) instrument, which measures radar data.

Artistic rendering of SARAL in orbit [Source: CNES/ill/SATTLER Oliver, 2010, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; —, no data]

Launch date	2/25/2013
Design lifetime	5 years
Platform owner	ISRO/CNES
Altitude	800 km
Orbit period	100.6 min
Inclination	98.54°
Crossing time	6:00 AN
Nadir repeat	35 days
Status	Operational
System website	https://www.isro.gov.in/Spacecraft/saral https://altika-saral.cnes.fr/en/



3-Dimensional model of the AltiKa instrument aboard SARAL [Source: CNES, 2016, used with permission].

Sensor Information

	AltiKa
GSD (m)	—
Swath (km)	—
Data portal	—

AltiKa

The AltiKa was designed and built by CNES and is of Poseidon (flown on the Jason missions) heritage. The altimeter operates in the Ka-band at 35.75 GHz ($\lambda = 0.84$ cm). The AltiKa instrument also includes a bi-frequency radiometer that operates at 23.8 GHz ($\lambda = 1.26$ cm) and 37 GHz ($\lambda = 0.81$ cm).

JACIE

Sentinel-1

European Space Agency
Civil/Government
Operational/Future

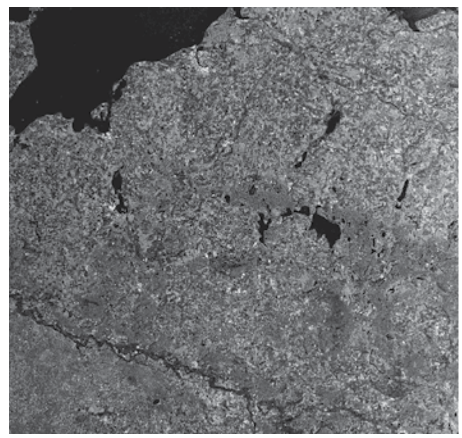
Platform Overview

Sentinel-1 is European Space Agency's (ESA) all-weather, day-and-night radar imaging mission for land and ocean services. Sentinel-1A was launched in 2014, followed by Sentinel-1B in 2016. Two more Sentinel-1 satellites (C and D) are planned to be launched in 2021 and 2023, respectively, to extend the Sentinel-1 mission at least until the end of 2030. The Sentinel-1 satellites are built by Thales Alenia Space Italia (TAS-I) and are based on the Piattaforma Italiana Multi Applicativa (PRIMA) bus of TAS-I, of COSMO-SkyMed and RADARSAT-2 heritage, with a mission-specific payload module. The satellites carry the C-Synthetic Aperture Radar (C-SAR) sensor for medium-resolution SAR data.

Artistic rendering of Sentinel-1 in orbit [Source: ESA].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter; H, horizontal; V, vertical]

	Sentinel-1A	Sentinel-1B	Sentinel-1C	Sentinel-1D
Launch date	4/3/2014	4/25/2016	2021 (Planned)	2023 (Planned)
Platform owner	ESA			
Altitude	786 km			
Orbit period	100.7 min			
Inclination	98.5°			
Crossing time	10:30 AN			
Nadir repeat	10 days			
Design lifetime	7.25 years			
Status	Operational		Development	
System website	https://scihub.copernicus.eu/			



The Alps between Munich and Bozen captured by Sentinel-1A [Source: DLR].

Sensor Information

Mode	C-SAR
GSD (m)	5–40
Swath (km)	80–400
Data portal	https://scihub.copernicus.eu/

C-SAR

The C-SAR is designed and developed by EADS Astrium GmbH of Germany. The center frequency of the C-band is 5.405 GHz (λ = 5.5 cm). The angle of incidence is 20–46 degrees. C-SAR data are freely available.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
Stripmap Mode (SM)	Dual	HH/HV, VV/VH	80	5 x 5
Interferometric Wide Swath Mode (IW)	Dual	HH/HV, VV/VH	250	5 x 20
Extra Wide Swath Mode (EW)	Dual	HH/HV, VV/VH	400	20 x 40
Wave Mode (WV)	Single	HH, VV	20 x 20	5 x 5

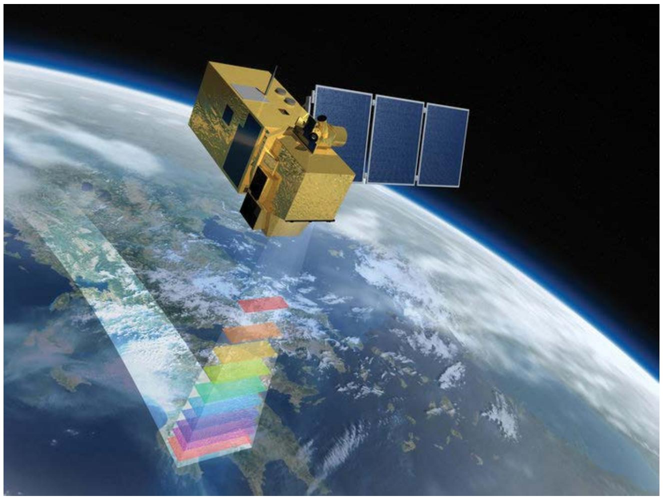
Sentinel-2

European Space Agency
Civil/Government
Operational/Future

Platform Overview

Sentinel-2 is a high-resolution, multispectral Earth imaging mission by European Space Agency (ESA) with high revisit capability. Sentinel-2A was launched in 2015 and followed by Sentinel-2B in 2017. Sentinel-2C and Sentinel-2D are under construction and will be ready for launch in 2020/2021.

The Sentinel-2 satellites are built by Airbus Defense and Space and use the AstroBus-L bus, a standard modular European Cooperation for Space Standards (ECSS) compatible satellite platform. The Sentinel-2 satellites carry the Multispectral Imager (MSI) for medium-resolution land imaging.



Artistic rendering of Sentinel-2A satellite in orbit [Source: ESA].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; Pan, panchromatic, CA, coastal aerosol; NIR, near infrared; SWIR, short wave infrared]

	Sentinel-2A	Sentinel-2B	Sentinel-2C	Sentinel-2D
Launch date	6/23/2015	3/7/2017	2020 (planned)	2021 (planned)
Platform owner	ESA			
Altitude	786 km			
Orbit period	100.7 min			
Inclination	98.5°			
Crossing time	10:30 DN			
Nadir repeat	10 days			
Design lifetime	7.25 years			
Status	Operational		Development	
System website	https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2			

JACIE

Sentinel-2—Continued

European Space Agency
Civil/Government
Operational/Future

Sensor Information

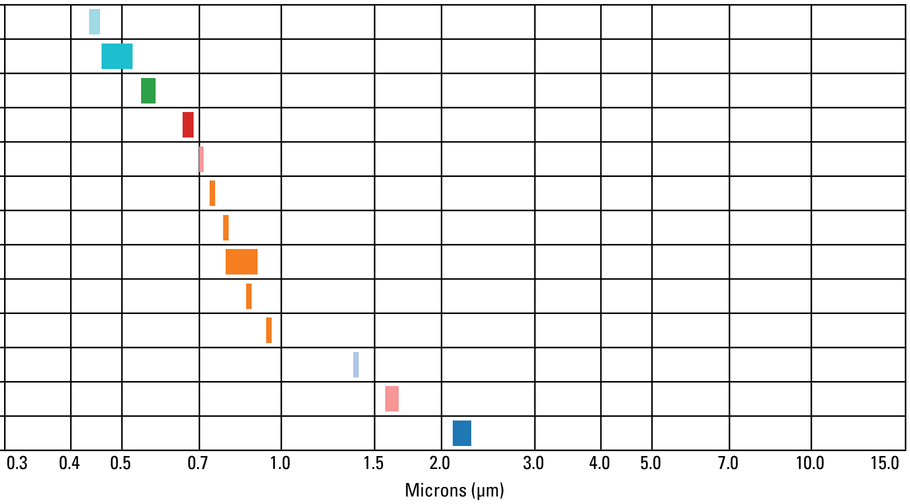
	MSI
GSD (m)	10, 20, 60
Swath (km)	290
Data portal	https://scihub.copernicus.eu/

Satellite image of Amsterdam, Netherlands, captured by Sentinel-2B [Source: ESA].

MSI

The MSI aboard Sentinel-2 is a new pushbroom sensor with visible and near infrared and shortwave infrared bands. Onboard calibration bands in combination with ground targets ensure high-quality radiometric performance.

Band	Lower	Center	Upper	GSD (m)
CA	0.433	0.443	0.453	60
Blue	0.458	0.490	0.523	10
Green	0.542	0.560	0.578	10
Red	0.650	0.665	0.681	10
Red Edge	0.698	0.705	0.713	20
NIR	0.733	0.740	0.748	20
NIR	0.773	0.783	0.793	20
NIR	0.785	0.842	0.900	10
NIR	0.855	0.865	0.875	20
NIR	0.935	0.945	0.955	60
Cirrus	1.365	1.380	1.395	60
SWIR 1	1.565	1.610	1.655	20
SWIR 2	2.100	2.190	2.280	20



Sentinel-3

European Space Agency
Civil/Government
Operational/Future

Platform Overview

Sentinel-3 is a multi-instrument mission to measure sea-surface topography, sea- and land-surface temperature, ocean color, and land color with high accuracy and reliability. Sentinel-3A was launched in 2016 followed by Sentinel-3B in 2018. Sentinel-3C and Sentinel-3D are planned to follow, extending the mission at least until 2030.

The Sentinel-3 satellites are built by Thales Alenia Space-France (TAS-F) and are based on a new generation of avionics for the TAS-F low earth orbit (LEO) platform. Sentinel-3 carries the Ocean and Land Color Instrument (OLCI), Sea and Land Surface Temperature Radiometer (SLSTR), and SAR Radar Altimeter (SRAL) sensing elements. Data are available to the public for free.

Artistic rendering of Sentinel-3 in orbit [Source: ESA].

[Abbreviations in tables: ESA, European Space Agency; km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; CA, coastal aerosol; NIR, near infrared; SWIR, short wave infrared; MWIR, mid wave infrared; TIR, thermal infrared]

	Sentinel-3A	Sentinel-3B	Sentinel-3C	Sentinel-3D
Launch date	4/16/2016	4/25/2018	2020 (planned)	2022 (planned)
Platform owner	ESA			
Altitude	814 km			
Orbit period	100 min			
Inclination	98.65°			
Crossing time	10:00 DN			
Nadir repeat	27 days			
Design lifetime	7.5 years			
Status	Operational		Development	
System website	https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-3			

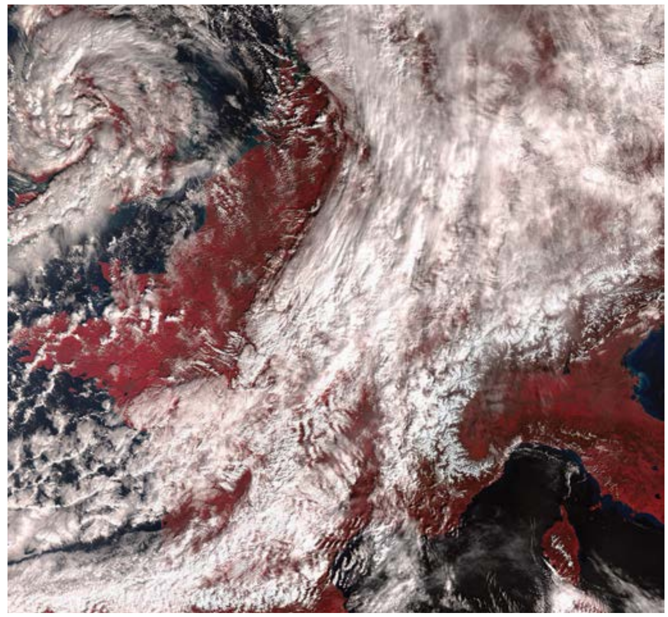
JACIE

Sentinel-3—Continued

European Space Agency
Civil/Government
Operational/Future

Sensor Information

	OLCI	SLSTR	SRAL
GSD (m)	300	500/1,000	300
Swath (km)	1,270	1,675	1,270
Data portal	https://scihub.copernicus.eu/		

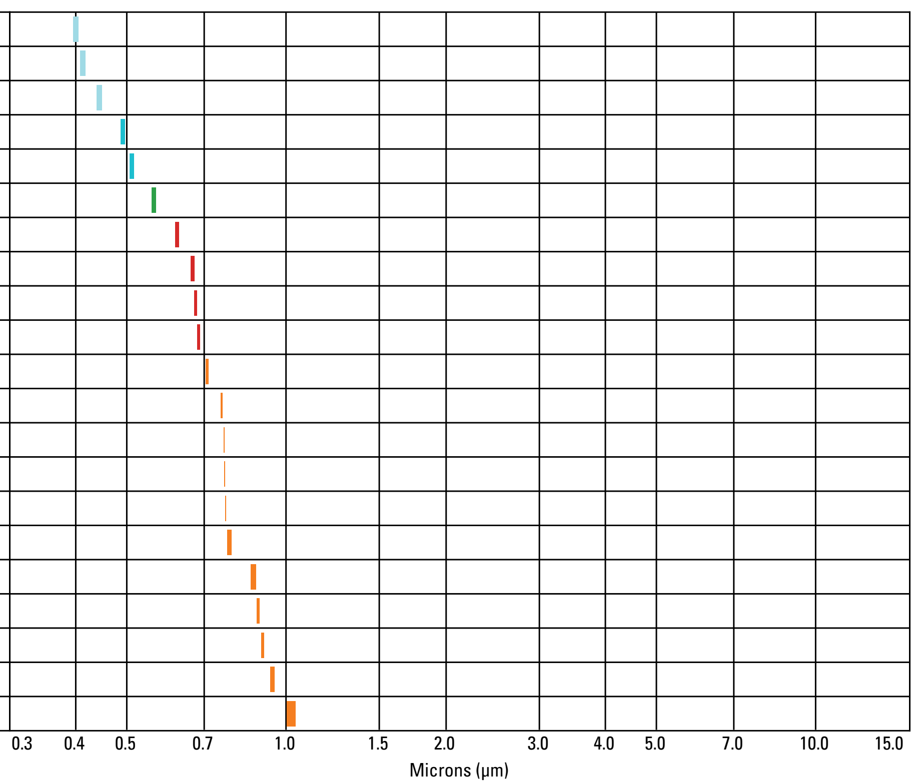


Europe captured by Sentinel-3B [Source: ESA].

OLCI

The OLCI is of the European Space Agency's medium-spectral resolution, imaging spectrometer of MERIS heritage (flown on Envisat). The field of view is tilted toward the west 12 degrees from the sun to minimize the sunglint effect over the ocean and increase the effective swath.

Band	Lower	Center	Upper	GSD (m)
CA	0.395	0.400	0.405	300
CA	0.408	0.413	0.418	300
CA	0.438	0.443	0.448	300
Blue	0.485	0.490	0.495	300
Blue	0.505	0.510	0.515	300
Green	0.555	0.560	0.565	300
Red	0.615	0.620	0.625	300
Red	0.660	0.665	0.670	300
Red	0.670	0.674	0.678	300
Red	0.678	0.681	0.685	300
NIR	0.703	0.708	0.713	300
NIR	0.750	0.754	0.758	300
NIR	0.760	0.761	0.763	300
NIR	0.763	0.764	0.766	300
NIR	0.766	0.768	0.769	300
NIR	0.771	0.779	0.786	300
NIR	0.855	0.865	0.875	300
NIR	0.880	0.885	0.890	300
NIR	0.895	0.900	0.905	300
NIR	0.930	0.940	0.950	300
NIR	1.000	1.020	1.040	300



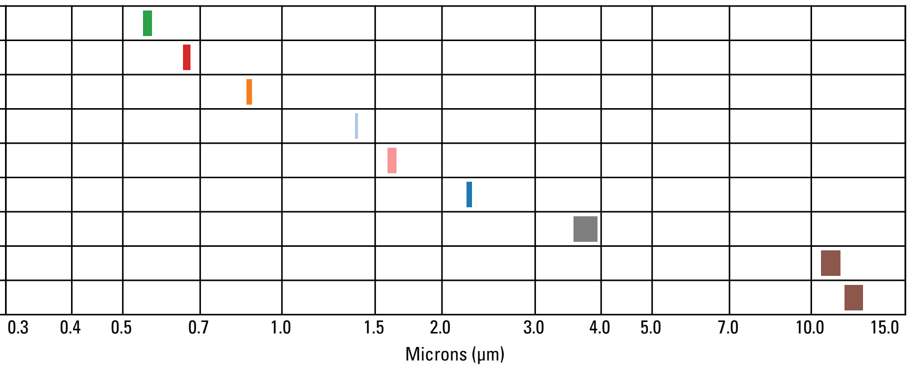
Sentinel-3—Continued

European Space Agency
Civil/Government
Operational/Future

SLSTR

The SLSTR is an upgraded and advanced version of the Advanced Along-Track Scanning Radiometer (AATSR) instrument flown on Envisat, offering a wider swath, more bands, and greater resolution. The wider swath allows for shorter revisit time. Two dedicated channels were added for fire and high temperature events monitoring at 1 km resolution, and two SWIR bands were added to improve cloud and aerosol detection.

Band	Lower	Center	Upper	GSD (m)
Green	0.545	0.555	0.565	500
Red	0.649	0.659	0.669	500
NIR	0.855	0.865	0.875	500
Cirrus	1.368	1.375	1.383	500
SWIR 1	1.580	1.610	1.640	500
SWIR 2	2.225	2.250	2.275	500
MWIR	3.550	3.740	3.930	1,000
TIR	10.400	10.850	11.300	1,000
TIR	11.500	12.000	12.500	1,000



SRAL

The SAR Radar Altimeter (SRAL) instrument has strong heritage of the instrument techniques implemented on the Poseidon-3 altimeter on Jason-2, SAR Interferometer Radar Altimeter (SIRAL) on CryoSat-2, and Altimeter in Ka-band (AltiKa) on the SRAL mission of ISRO and CNES. SRAL is the core instrument of the topographic payload.

Sentinel-6

European Space Agency
Civil/Government
Future

Platform Overview

Sentinel-6, also known as Jason Continuity of Service (Jason-CS), is a radar altimeter satellite of the European Space Agency (ESA), intended to ensure continuity with Jason-3. Sentinel-6 is a partnership between the ESA, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), French National Center for Space Studies (CNES), European Commission (EC), National Aeronautics and Space Administration (NASA), and National Oceanic and Atmospheric Administration (NOAA). Sentinel-6A is planned to be launched in 2020 with Sentinel-6B to be launched before the end of life of Sentinel-6A to ensure continuity of data. The two Sentinel-6 satellites are based on the CryoSat-2 heritage platform and are being built by Airbus Defense and Space in Germany. Sentinel-6 will carry the Poseidon-4 Synthetic Aperture Radar Altimeter (POS4) sensor for SAR data.

Artistic rendering of Sentinel-6 in orbit [Source: ESA].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; —, no data; GSD, ground sample distance; m, meter]

	Sentinel-6A	Sentinel-6B
Launch date	2020 (Planned)	2025 (Planned)
Platform owner	ESA	
Altitude	1366 km	
Orbit period	112 min	
Inclination	66.03°	
Crossing time	—	
Nadir repeat	9.9 days	
Design lifetime	—	
Status	Development	Planned
System website	https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-6	

Sensor Information

	POS4
GSD (m)	—
Swath (km)	—
Data portal	—

POS4

POS4 is the principle payload instrument aboard Sentinel-6. The new instrument is a collaboration between agencies, each contributing different elements. The instrument measures surface height and wind speed. The system can operate in conventional pulse-width limited (LRM) and SAR processing simultaneously. POS4 operates in the Ku-band at 13.575 GHz (λ = 2.2 cm) and the C-band at 5.3 GHz (λ = 5.7 cm). The angle of incidence and the beam modes are unavailable. The data will be freely available.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
—	—	—	—	—

Data compiled by the USGS National Land Imaging Program's Requirements Capabilities and Analysis for Earth Observation (RCA-EO) project. JACIE is a collaboration between U.S. Federal agencies NASA, NGA, NOAA, USDA, and USGS. For more information see: https://www.usgs.gov/land-resources/eros/calval/jacie

For Joint Agency Commercial Imagery Evaluation (JACIE) sensor performance information see: https://www.usgs.gov/land-resources/eros/calval/jacie

RCA-EO; USGS EROS Center
47914 252nd St.
Sioux Falls, SD 57198
eccoe@usgs.gov

SEOSat

Spain
Civil/Government
Future

Platform Overview

The Spanish System for Earth Observation Satellite (SEOSat), also known as Ingenio (Spanish for "ingenuity"), is a high-resolution multispectral satellite to be launched in 2019 by the National Institute of Aerospace Technology (INTA) for Earth observation. This is a flagship mission of the Spanish Space Strategic Plan 2007–11. The spacecraft development has been led by Airbus Defense and Space. SEOSat uses the proven AstroSat-250 bus. SEOSat carries the Primary Payload (PP) instrument for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; —, no data; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near infrared]

Launch date	2019 (Planned)
Design lifetime	7 years
Platform owner	INTA
Altitude	670 km
Orbit period	98.15 min
Inclination	98°
Crossing time	10:30 DN
Nadir repeat	38 days
Status	Development
System website	—

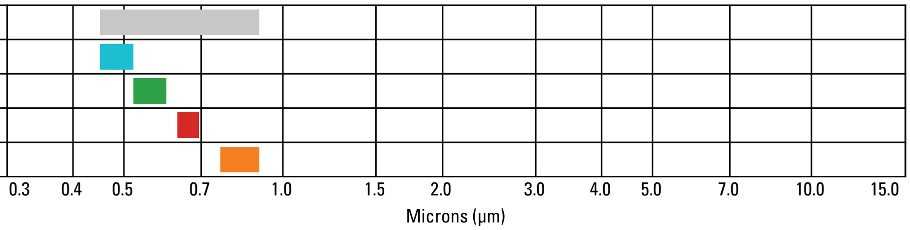
Sensor Information

	PP
GSD (m)	2.5, 10
Swath (km)	55
Data portal	—

PP

The PP instrument is a new design being developed by Sener Ingeniería y Sistemas S.A. of Spain.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.675	0.900	2.5
Blue	0.450	0.485	0.520	10
Green	0.520	0.560	0.600	10
Red	0.630	0.660	0.690	10
NIR	0.760	0.830	0.900	10



SkySat-1 to -13

United States
Commercial
Operational

Platform Overview

SkySat-1 through -13 are high-resolution, multispectral microsatellites for high revisit, high-resolution imaging. SkySat-1 and -2 were built by Skybox Imaging. Skybox Imaging (Skybox), acquired by Google, was changed to “Terra Bella” in 2016 before being acquired by Planet in 2017. Sinclair Interplanetary (SI) was contracted to develop the ST-16-star trackers for the satellites. SkySat-3 through -13 were built by Space Systems/Loral (SS/L) and were very similar in design to SkySat-1 and -2. The new SkySats feature better reaction wheels and a propulsion system, increasing agility, as well as smaller pixels. Each SkySat is equipped with a Ritchey-Chretien Cassegrain telescope. The camera provides a ground sample distance of 2 m in VNIR and 0.9 m in panchromatic bands. Data can be ordered from Planet.

SkySat-14 and -15 launched in 2018 and SkySat-16 to -21 are in development with options to add SkySat-22 to -27 to the constellation.

SkySat-1 and -2 deployed configurations [Source: Planet Labs Inc., used with permission].

SkySat-3 through -13 deployed configurations [Source: Planet Labs Inc., used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; AN, ascending node; GSD, ground sample distance; m, meter; Pan, panchromatic, NIR, near infrared]

	SS-1	SS-2	SS-3	SS-4 to -7	SS-8 to -13
Launch date	11/21/2013	7/8/2014	6/22/2016	9/16/2016	10/31/2017
Launch vehicle	Dnepr	Soyuz-2.1b/Fregat	PSLV-C34	Vega	Minotaur-C
Platform owner	Planet				
Altitude	587 km		500 km	695 km	500 km
Orbit period	96.41 min		94.6 min	98.6 min	94.6 min
Inclination	97.98°		95.3°	98.3°	95.3°
Crossing time	10:30 DN				13:30 AN
Design lifetime	6 years				
Status	Operational				
System website	https://www.planet.com/products/hi-res-monitoring/				

SkySat-1 to -13—Continued

United States
Commercial
Operational

Sensor Information

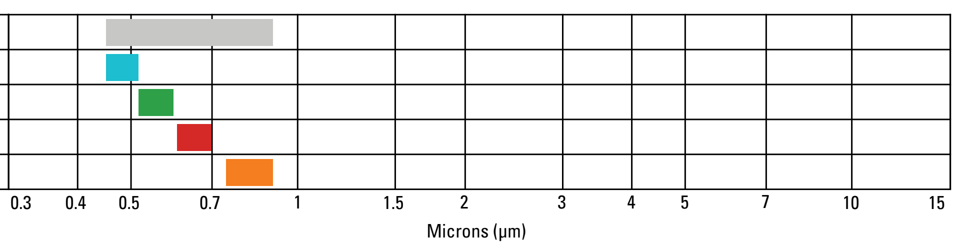
	SS-MSI
GSD (m)	0.9/2
Swath (km)	8
Data portal	https://www.planet.com/products/planet-imagery/

Skysat imagery of Rome, Italy [Source: Planet Labs Inc., used with permission].

SS-MSI

The SkySat-Multispectral Imager is an optical payload of the SkySat satellites based on a Ritchey-Chretien Cassegrain telescope design with a focal length of 3.6 m. The camera can deliver full motion video with frame rates as high as 50 Hz. SkySat data are available from Planet.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.675	0.900	0.9
Blue	0.450	0.483	0.515	2
Green	0.515	0.555	0.595	2
Red	0.605	0.650	0.695	2
NIR	0.740	0.820	0.900	2



SMAP

United States
Civil/Government
Operational

Platform Overview

The Solid Moisture Active/Passive (SMAP) satellite is a low-resolution synthetic aperture radar (SAR) satellite launched in 2015 by the National Aeronautics and Space Administration (NASA) on a Delta-II launch vehicle from Vandenberg Air Force Base in California for global soil moisture mapping. SMAP was designed by NASA's Jet Propulsion Laboratory (JPL) and has heritage of previous radar missions developed at JPL. SMAP carries a SAR sensor for measuring low-resolution radar data.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; GSD, ground sample distance; m, meter]

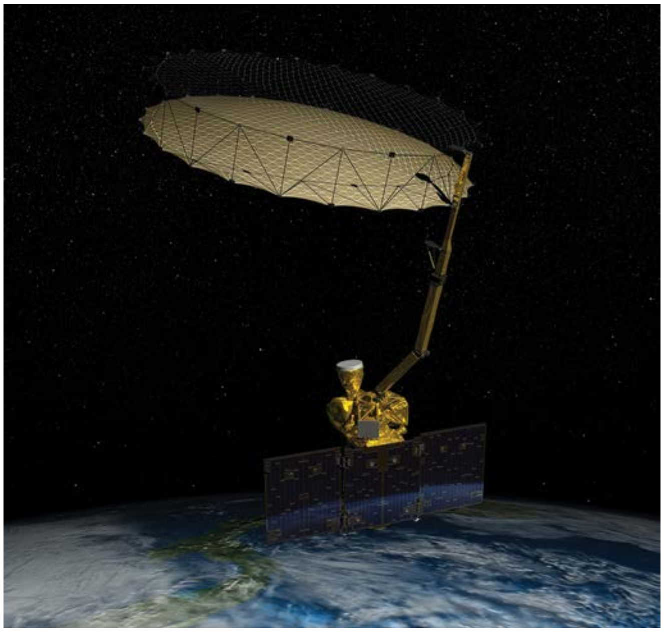
Launch date	1/31/2015
Design lifetime	3 years
Platform owner	NASA
Altitude	685 km
Orbit period	98.5 min
Inclination	98°
Crossing time	18:00 AN
Nadir repeat	8 days
Status	Operational
System website	https://smap.jpl.nasa.gov/

Sensor Information

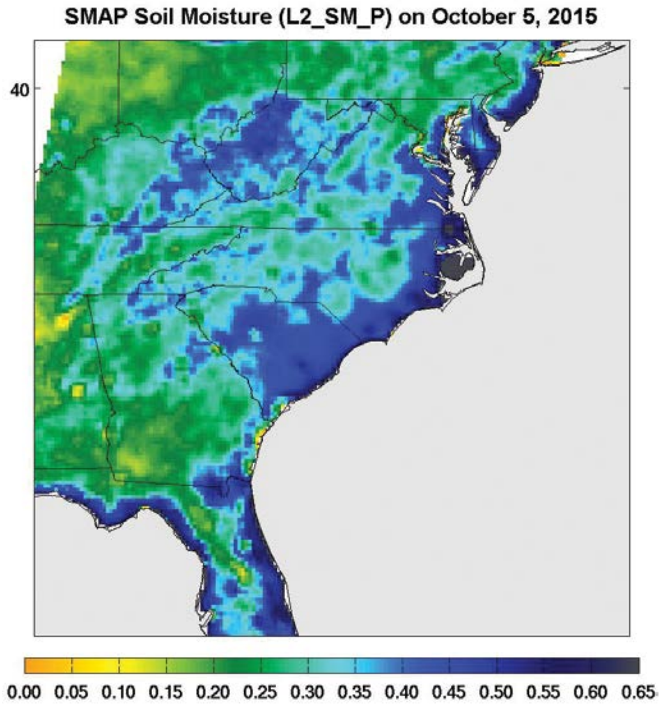
	SMAP
GSD (m)	3,000
Swath (km)	1,000
Data portal	https://www.asf.alaska.edu/smap/data-imagery/

SMAP

The SMAP instrument is a SAR developed at JPL. Astro Aerospace (a business unit of Northrop Grumman) was contracted to design the reflector boom assembly (RBA). The RBA rotates and scans the Earth conically. SMAP's SAR instrument operates in the L-band at 1,217–1,298 MHz (λ = 24.6—23.1 cm). The radiometer on board operates in the L-band at 1,400–1,427 MHz (λ = 21.4–21.0 cm). The angle of incidence is 40 degrees.



Artistic rendering of SMAP in orbit [Source: NASA].



SMAP soil moisture map of southeastern United States [Source: NASA].

SMOS

European Space Agency
Civil/Government
Operational

Platform Overview

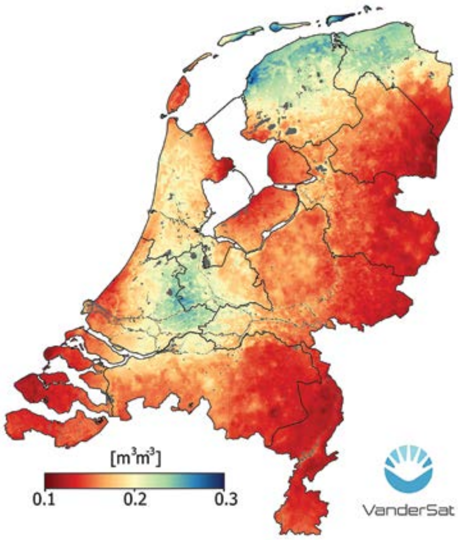
The Soil Moisture and Ocean Salinity (SMOS) satellite is a low-resolution satellite launched in 2009 on a Rockot launch vehicle for making global observations of soil moisture over land and salinity over oceans. SMOS is an Earth Explorer Opportunity mission.

SMOS utilizes the Proteus bus developed by National Center for Space Studies (CNES) and Alcatel Alenia Space and carries the Microwave Imaging Radiometer using Aperture Synthesis (MIRAS) sensor, which captures 30 km GSD imagery freely available to the public.

Artistic rendering of SMOS in orbit [Source: ESA].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; AN, ascending node; GSD, ground sample distance; m, meter]

Launch date	11/2/2009
Platform owner	ESA
Altitude	755 km
Orbit period	100 min
Inclination	98.44°
Crossing time	6:00 AN
Nadir repeat	23 days
Design lifetime	3 years
Status	Operational
System website	https://www.esa.int/Our_Activities/Observing_the_Earth/SMOS



Soil moisture in the Netherlands measured by SMOS [Source: ESA].

Sensor Information

	MIRAS
GSD (m)	30,000
Swath (km)	900
Data portal	https://smos-ds-02.eo.esa.int/oads/access/

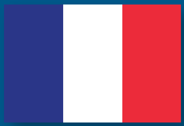
MIRAS

The MIRAS instrument was developed by European Aeronautics Defense and Space. MIRAS operates at frequencies around 1.4 GHz (L-band) to capture images of emitted microwave radiation from Earth.

MIRAS works by collecting the data via an 8-m antenna-receiver unit with 69 antenna elements called LICEFs. Each LICEF antenna weighs 190 g and is 165 mm in diameter and 19 mm high.

SPOT-6 and -7

France, Azerbaijan
Commercial
Operational



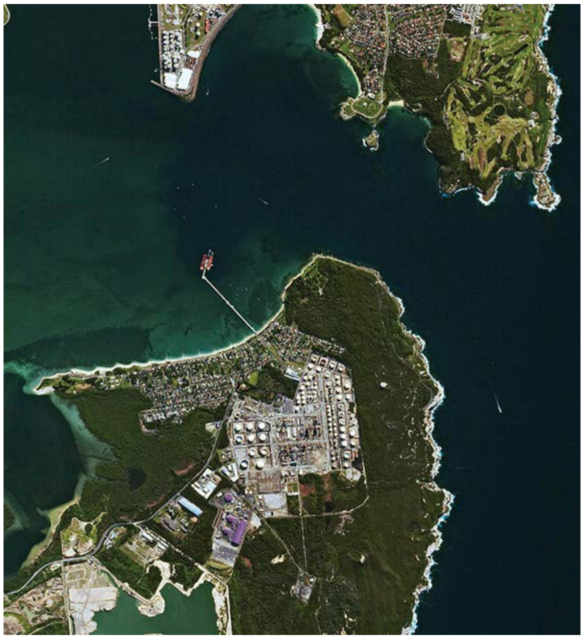
Platform Overview

SPOT-6 and -7 are high-resolution multispectral satellites launched in 2012 and 2014, respectively, by the EADS Astrium on a Polar Satellite Launch Vehicle (PSLV) from SDSC-SHAR for Earth resources monitoring. These missions continue the SPOT series that has been in continual operation since the launch of SPOT-1 in 1986. These satellites are privately owned by EADS Astrium. Azerbaijan acquired SPOT-7 and renamed it Azersky. The SPOT-6 and -7 satellites were designed and built by Airbus Defense and Space and use the AstroSat-250 bus. With a highly agile system, the satellites can provide visible and near infrared (VNIR) imagery at global scale and on a targeted basis. SPOT-6 and SPOT-7 are placed 180 degrees apart and operate with the high-resolution Pleaides-HR satellites in orbit. SPOT-6 and -7 carry the New AstroSat Optical Modular Instrument (NAOMI) sensor for high-resolution land imaging.

SPOT-7 in orbit [Source: Airbus DS, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; NIR, near-infrared]

	SPOT 6	SPOT 7
Launch date	9/9/2012	6/30/2014
Design lifetime	10 years	
Platform owner	EADS Astrium/Azercosmos	
Altitude	694 km	
Orbit period	98.6 min	
Inclination	98.2°	
Crossing time	10:00 DN	
Nadir repeat	26 days	
Status	Operational	
System website	https://www.intelligence-airbusds.com/en/191-spot-technical-information	



SPOT-7 satellite image of Sydney, Australia [Source: Airbus DS, used with permission].

Sensor Information

	NAOMI
GSD (m)	1.5, 6
Swath (km)	60
Data portal	https://www.intelligence-airbusds.com/en/147-spot-6-7-satellite-imagery

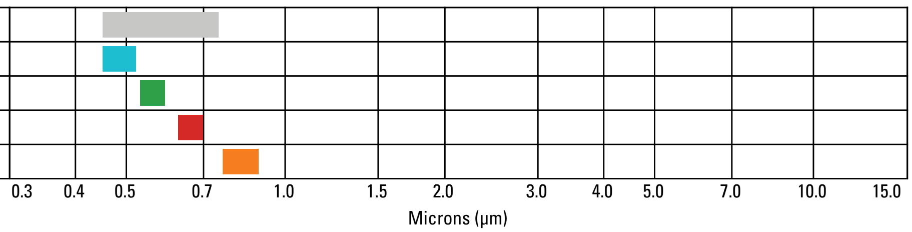
SPOT-6 and -7—Continued

France, Azerbaijan
Commercial
Operational

NAOMI

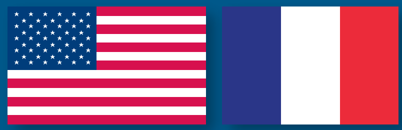
The NAOMI sensor is a proven design from Airbus used on Disaster Monitoring Constellation (DMC) satellites. The sensor aboard SPOT-6 operates with two cameras to provide greater swath width. Data are available to customers through the Airbus's commercial portal.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.598	0.745	1.5
Blue	0.450	0.485	0.520	6
Green	0.530	0.560	0.590	6
Red	0.625	0.660	0.695	6
NIR	0.760	0.825	0.890	6



SWOT

United States, France
Civil/Government
Future



Platform Overview

The Surface Water Ocean Topography (SWOT) mission is a wide-swath altimeter satellite to be launched in 2021 by the National Aeronautics and Space Administration (NASA) and French National Center for Space Studies (CNES) on a Falcon 9 launch vehicle from Vandenberg Air Force Base in California for monitoring local sea level changes along coasts. The SWOT mission is also supported by the Canadian Space Agency (CSA) and United Kingdom Space Agency (UKSA). The spacecraft bus for SWOT was provided by CNES and has heritage of technologies developed through the CNES Incitation à l'utilisation Scientifique des Images Spot (ISIS) program. SWOT carries the Ka-band Radar Interferometer (KaRIn), Jason-class Altimeter, and a Microwave Radiometer for medium-resolution imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; —, no data; GSD, ground sample distance; m, meter; H, horizontal; V, vertical]

Launch date	April 2021 (Planned)
Design lifetime	—
Platform owner	NASA/CNES
Altitude	890 km
Orbit period	102.78 min
Inclination	77.6°
Crossing time	—
Nadir repeat	21 days
Status	Development
System website	https://swot.jpl.nasa.gov/

Artistic rendering of SWOT in orbit [Source: CNES/DUCROS David, 2015, used with permission].

Sensor Information

	KaRIn
GSD (m)	5—1,000 (selectable)
Swath (km)	120 (combined)
Data portal	—

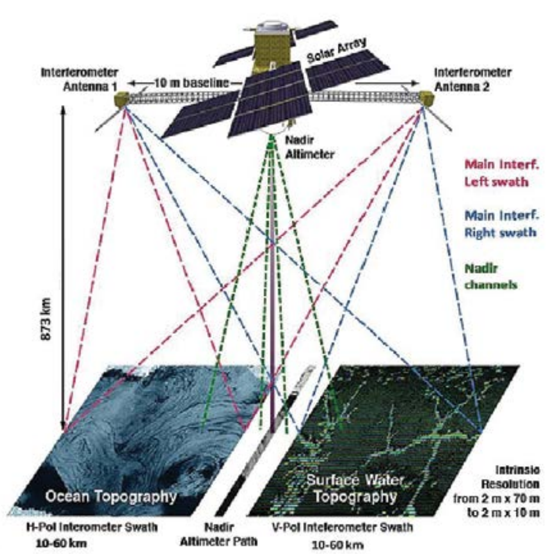


Illustration of the KaRIn instrument operation [Source: NASA].

KaRIn

KaRIn was developed at JPL and was based on heritage of ERS-1, TOPEX/Poseidon, ERS-2, Jason-1, Envisat, and Jason-2. KaRIn operates in the Ka-band at 35.75 GHz ($\lambda = 0.84$ cm).

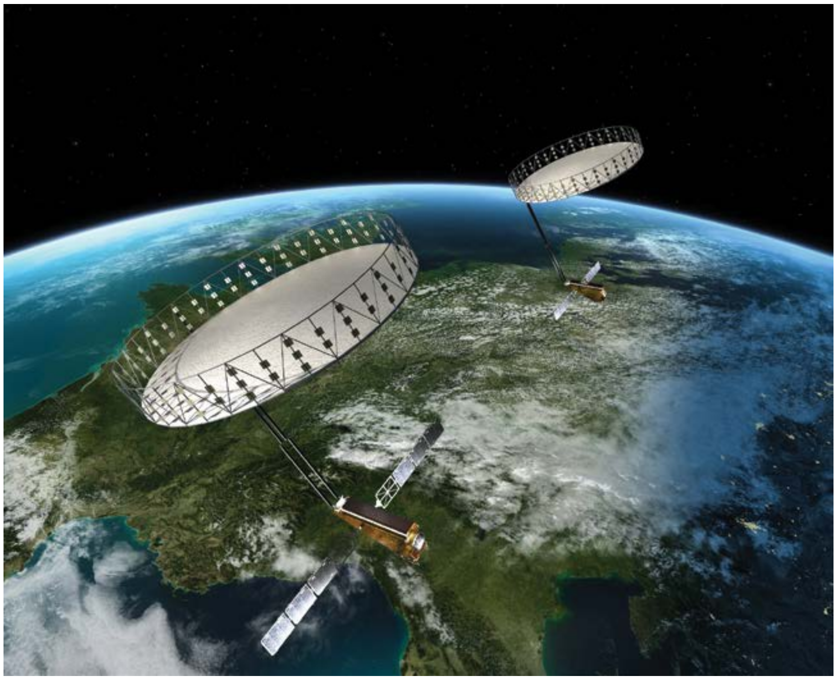
Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
Left swath	Single	HH	50	5 x 10–70
Right swath	Single	VV	50	5 x 10–70

TanDEM-L

Germany
Civil/Government
Future

Platform Overview

TanDEM-L is a multiresolution Synthetic Aperture Radar (SAR) satellite to be launched by German Aerospace Center (DLR) for creating detailed digital elevation models (DEMs). TanDEM-L is a follow-on mission to the TanDEM-X mission launched in 2010. TanDEM-L will carry an L-band Synthetic Aperture Radar (L-SAR) instrument for collecting SAR data.



Artistic rendering of TanDEM-L in orbit [Source: DLR].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; —, no data; GSD, ground sample distance; m, meter]

Launch date	2022 (Planned)
Design lifetime	10 years
Platform owner	DLR
Altitude	745 km
Orbit period	99.72 min
Inclination	98.4°
Crossing time	—
Nadir repeat	16 days
Status	Planned
System website	https://www.dlr.de/hr/en/desktopdefault.aspx/tabid-8113/

Sensor Information

	L-SAR
GSD (m)	1
Swath (km)	350
Data portal	—

L-SAR

The L-SAR instrument in the L-band has a center frequency of 1.5 GHz (λ = 20.0 cm). The angle of incidence is 26.3–47.0 degrees. Details of beam modes currently (2018) are not available.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
—	—	—	—	—

Data compiled by the USGS National Land Imaging Program's Requirements Capabilities and Analysis for Earth Observation (RCA-EO) project. JACIE is a collaboration between U.S. Federal agencies NASA, NGA, NOAA, USDA, and USGS. For more information see: https://www.usgs.gov/land-resources/eros/calval/jacie

For Joint Agency Commercial Imagery Evaluation (JACIE) sensor performance information see: https://www.usgs.gov/land-resources/eros/calval/jacie

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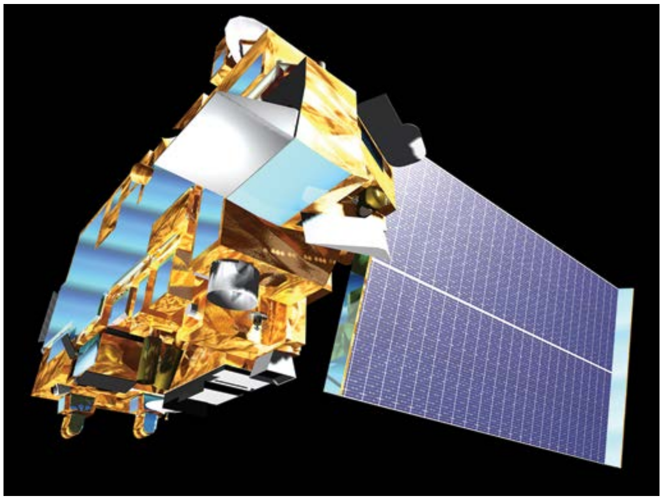
Terra

United States
Civil/Government
Operational

Platform Overview

Terra is a moderate-resolution multispectral satellite for Earth resource monitoring, launched in 1999 by National Aeronautics and Space Administration (NASA) on an Atlas Centaur II expendable launch vehicle from Vandenberg Air Force Base in California. Formerly named Earth Observing System (EOS) AM-1 signifying its morning crossing time, Terra is the flagship mission of the EOS.

The Terra satellite was built by NASA on the spacecraft bus designed by Lockheed Martin Missiles and Space (LMMS) with five instruments on board: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Clouds and Earth's Radiant Energy System (CERES), Multi-angle Imaging Spectroradiometer (MISR), Measurements of Pollution in the Troposphere (MOPITT) and Moderate Resolution Imaging Spectroradiometer (MODIS). ASTER and MODIS are the land imaging instruments included here.



Artistic rendering of Terra in orbit [Source: NASA].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; CA, coastal aerosol; NIR, near infrared; SWIR, short wave infrared; MWIR, mid wave infrared; WV, water vapor; TIR, thermal infrared]

Launch date	12/18/1999
Platform owner	NASA
Altitude	705 km
Orbit period	98.8 min
Inclination	98.3°
Crossing time	10:30 DN
Nadir repeat	16 days
Design lifetime	6 years
Status	Operational
System website	https://terra.nasa.gov/

Data compiled by the USGS National Land Imaging Program's Requirements Capabilities and Analysis for Earth Observation (RCA-EO) project. JACIE is a collaboration between U.S. Federal agencies NASA, NGA, NOAA, USDA, and USGS. For more information see: https://www.usgs.gov/land-resources/eros/calval/jacie

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Terra—Continued

United States
Civil/Government
Operational

Sensor Information

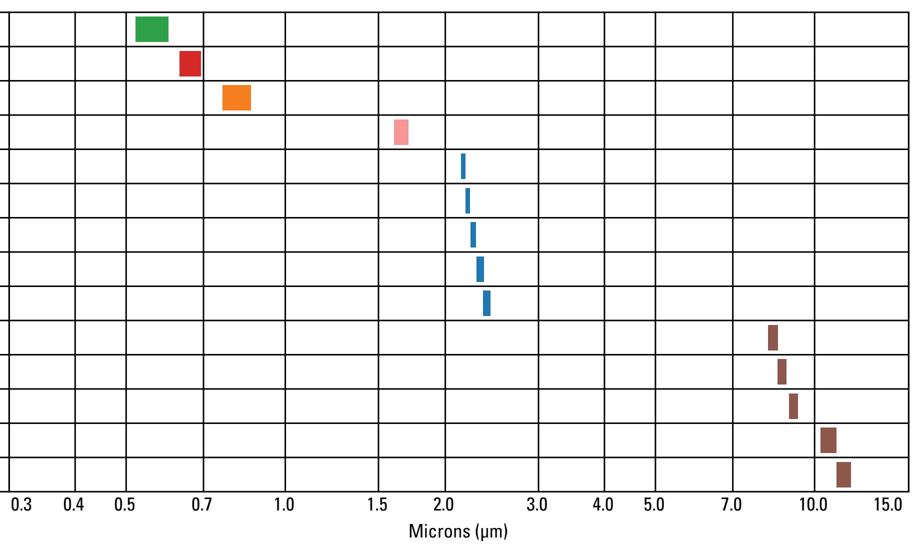
	ASTER	MODIS
GSD (m)	15/30/90	250/500/1,000
Swath (km)	60	2,230
Data portal	https://earthexplorer.usgs.gov/ https://glovis.usgs.gov/app	

ASTER image of the Andes Mountains [Source: NASA].

ASTER

The ASTER sensor is a cooperative effort between NASA and Japan's Ministry of Economy Trade and Industry (METI). ASTER on Terra captures images in 14 spectral bands from visible to thermal infrared and provides stereo capability for digital elevation modeling. The swath width is 60 km with a GSD of 15 m in visible and near infrared (VNIR), 30 m in short-wave infrared (SWIR), and 90 m in thermal infrared (TIR). Beginning in 2008, ASTER SWIR imagery began to degrade and in January of 2009 the mission managers declared that the SWIR detectors were no longer functioning and no further actions were being taken. Data are available for free download to all the customers.

Band	Lower	Center	Upper	GSD (m)
Green	0.520	0.560	0.600	15
Red	0.630	0.660	0.690	15
NIR	0.760	0.810	0.860	15
SWIR 1	1.600	1.650	1.700	30
SWIR 2	2.145	2.165	2.185	30
SWIR 2	2.185	2.205	2.225	30
SWIR 2	2.235	2.260	2.285	30
SWIR 2	2.295	2.330	2.365	30
SWIR 2	2.360	2.395	2.430	30
TIR	8.125	8.300	8.475	90
TIR	8.475	8.650	8.825	90
TIR	8.925	9.100	9.275	90
TIR	10.250	10.600	10.950	90
TIR	10.950	11.300	11.650	90



JACIE

Terra—Continued

United States
Civil/Government
Operational

MODIS

The Moderate Resolution Imaging Spectroradiometer (MODIS) is a proven design built by NASA GSFC heritage of High Resolution Infrared Radiation Sounder (HIRS), Landsat Thematic Mapper (TM) and Nimbus-7 Coastal Zone Color Scanner (CZCS). MODIS, onboard both the Terra and Aqua satellites, is a 36-band spectroradiometer measuring visible, shortwave, and thermal infrared radiation. This sensor provides a swath width of 2,300 km with a ground sample distance of 250 m (2 bands), 500 m (5 bands), and 1,000 m (29 bands). Imagery is collected in VNIR through TIR and data are available with no cost or restrictions.

Band	Lower	Center	Upper	GSD (m)
CA	0.405	0.413	0.420	1,000
CA	0.438	0.443	0.448	1,000
Blue	0.459	0.469	0.479	500
Blue	0.483	0.488	0.493	1,000
Blue	0.526	0.531	0.536	1,000
Green	0.545	0.555	0.565	500
Green	0.546	0.551	0.556	1,000
Red	0.620	0.645	0.670	250
Red	0.662	0.667	0.672	1,000
Red	0.673	0.678	0.683	1,000
NIR	0.743	0.748	0.753	1,000
NIR	0.841	0.859	0.876	250
NIR	0.862	0.870	0.877	1,000
NIR	0.890	0.905	0.920	1,000
NIR	0.915	0.940	0.965	1,000
NIR	0.931	0.936	0.941	1,000
NIR	1.230	1.240	1.250	500
Cirrus	1.360	1.375	1.390	1,000
SWIR 1	1.628	1.640	1.652	500
SWIR 2	2.105	2.130	2.155	500
MWIR	3.660	3.750	3.840	1,000
MWIR	3.929	3.959	3.989	1,000
MWIR	4.020	4.050	4.080	1,000
MWIR	4.433	4.466	4.498	1,000
MWIR	4.482	4.516	4.549	1,000
WV-1	6.535	6.715	6.895	1,000
WV-2	7.175	7.325	7.475	1,000
TIR	8.400	8.550	8.700	1,000
TIR	9.580	9.730	9.880	1,000
TIR	10.780	11.030	11.280	1,000
TIR	13.185	13.335	13.485	1,000
TIR	13.485	13.635	13.785	1,000
TIR	13.785	13.935	14.085	1,000
TIR	14.085	14.235	14.385	1,000

TerraSAR-X and TanDEM-X

Germany
Civil/Government
Operational

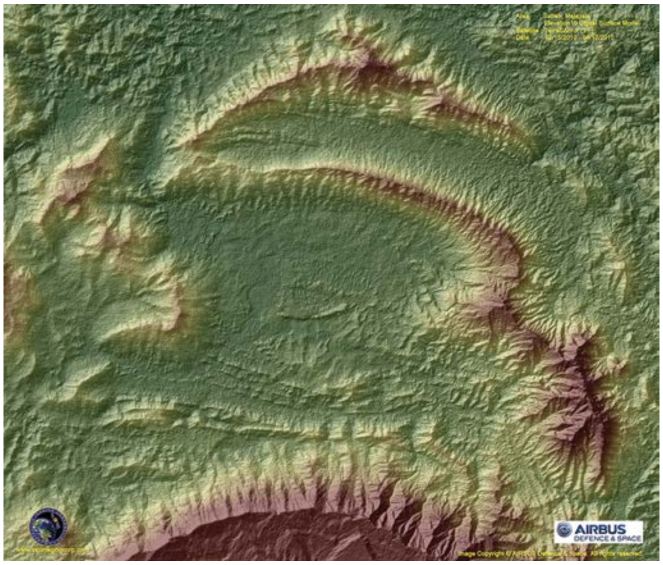
Platform Overview

TerraSAR-X (TSX) is a multiresolution Synthetic Aperture Radar (SAR) satellite launched in 2007 by the German Aerospace Center (DLR) on a Dnepr-1 launch vehicle from the Russian Cosmodrome, Baikonur, Kazakhstan, for Earth resources monitoring. TSX was built by Airbus Defense and Space GmbH and uses the proven AstroSat-1000 bus. TanDEM-X (TDX) is a follow-on mission to TerraSAR-X launched in 2010 to improve digital elevation models (DEMs). The two satellites carry identical instruments. TSX and TDX carry the TSX-SAR and TDX-SAR instruments, respectively, for collecting SAR data. Tandem-X DEM 90-m data are available free of charge for scientific purposes.

Artistic rendering of TerraSAR-X in orbit [Source: DLR].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; GSD, ground sample distance; m, meter; H, horizontal; V, vertical]

	TerraSAR-X	TanDEM-X
Launch date	6/15/2007	6/21/2010
Design lifetime	5 years	
Platform owner	DLR	
Altitude	514 km	
Orbit period	94.85 min	
Inclination	97.44°	
Crossing time	18:00 AN	
Nadir repeat	11 days	
Status	Operational	
System website	https://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10377/	



TerraSAR-X elevation data of Sabah, Malaysia [Source: Airbus DS, used with permission].

Sensor Information

	TSX-SAR
GSD (m)	1–16 (selectable)
Swath (km)	5–1500 (selectable)
Data portal	https://terrasar-x-archive.terrasar.com/

Data compiled by the USGS National Land Imaging Program's Requirements Capabilities and Analysis for Earth Observation (RCA-EO) project. JACIE is a collaboration between U.S. Federal agencies NASA, NGA, NOAA, USDA, and USGS. For more information see: https://www.usgs.gov/land-resources/eros/calval/jacie

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TerraSAR-X and TanDEM-X—Continued

Germany
Civil/Government
Operational

TSX-SAR

The TSX-SAR and TDX-SAR instruments are active phased array X-band antenna systems operating at 9.65 GHz (λ = 3.11 cm). The angle of incidence is 15–60 degrees.

Beam mode	Polarization		Nominal swath width (km)	Approximate resolution (m)
Experimental Spotlight	Singe	HH, HV, VH, VV	5 x 10	2 x 1
	Dual	—		
Spotlight HS	Singe	HH, HV, VH, VV	10 x 10	2 x 1
	Dual	—		
Spotlight SL	Singe	HH, HV, VH, VV	5 x 10	1 x 1
	Dual	—		
Stripmap	Singe	HH, HV, VH, VV	1,500 x 30	3 x 3
	Dual	—		
ScanSAR	Singe	HH, HV, VH, VV	1,500 x 100	16 x 16
	Dual	—		

JACIE

THEOS

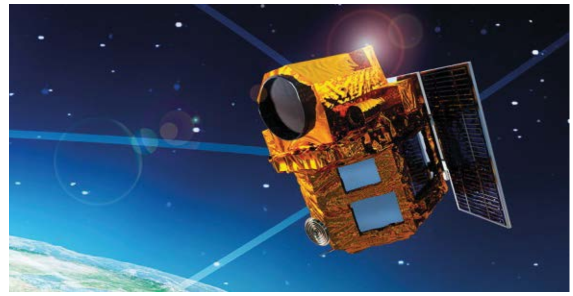
Thailand
Civil/Government
Operational

Platform Overview

Thailand Earth Observing System (THEOS) is a medium-resolution, panchromatic, and multispectral satellite launched in 2008 on a Dnepr launch vehicle from Yasny/Dombarovsky launch center by Geo-Informatics and Space Technology Development Agency (GISTDA) for Earth observation. THEOS was designed and built by European Aeronautics Defense and Space (EADS) Astrium SAS of France and utilizes the AstroSat-500 platform. The satellite is of FormoSat-2 heritage and carries the panchromatic (PAN) and multispectral (MS) sensors for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; —, no data; Pan, panchromatic; NIR, near infrared]

Launch date	10/1/2008
Design lifetime	5 years
Platform owner	GISTDA
Altitude	822 km
Orbit period	101.4 min
Inclination	98.7°
Crossing time	10:00 DN
Nadir repeat	26 days
Status	Operational
System website	https://www.gistda.or.th/main/en/node/569



Artistic rendering of THEOS in orbit [Source: GISTDA, used with permission].

Sensor Information

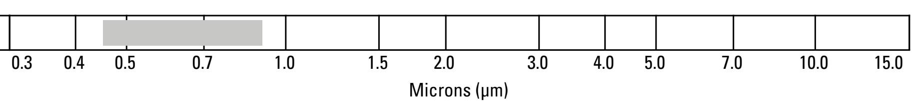
	PAN	MS
GSD (m)	2	15
Swath (km)	22	90
Data portal	—	

Sample THEOS images [Source: GISTDA, used with permission].

PAN

The PAN aboard THEOS is a pushbroom-style CCD imager.

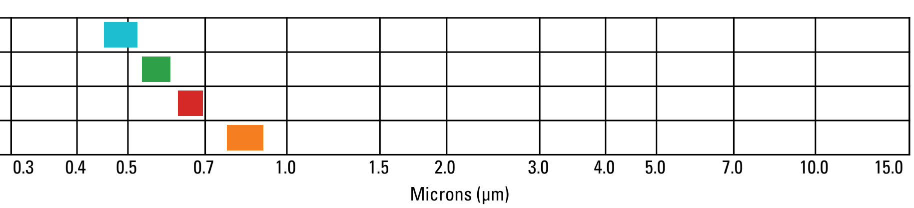
Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.675	0.900	2



MS

The MS aboard THEOS is a pushbroom-style CCD imager with four visible and near infrared bands.

Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	15
Green	0.530	0.565	0.600	15
Red	0.620	0.655	0.690	15
NIR	0.770	0.835	0.900	15



TripleSat-1 to -3 / SSTL-S1

United Kingdom, China
Commercial
Operational/Future

Platform Overview

TripleSat-1, -2, and -3 are three identical high-resolution, multispectral satellites launched in 2015 on the Polar Satellite Launch Vehicle for disaster monitoring. The TripleSat satellites form the third generation of the Disaster Monitoring Constellation (DMC). The Twenty First Century Aerospace Technology Co. (21AT) has leased 100 percent of the imaging capacity of the TripleSat constellation.

The TripleSats were designed and built by Surrey Satellite Technology (SSTL) and were based on the SSTL-300 S1 bus, building on the heritage of the SSTL-300 platform and avionics of NigeriaSat-2. The Very High-Resolution Imager-100 aboard TripleSat captures 3.2 m ground sample distance (GSD) visible and near infrared (VNIR) imagery and 0.8 m GSD panchromatic imagery available for purchase from DMCii.

TripleSat is also known as DMC-3 or Beijing-2. A fourth identical satellite, SSTL-S1, launched in 2018. The imaging capacity of SSTL-S1 is also being leased to 21AT.

Sir Martin Sweeting with DMC3/TripleSat Satellites, 2015 [Source: SSTL, used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near infrared]

	TripleSat-1 to 3	SSTL-S1-4
Launch date	7/10/2015	9/16/2018
Platform owner	DMCii	
Altitude	651 km	
Orbit period	97.7 min	
Inclination	98.1°	
Crossing time	10:30 DN	
Nadir repeat	1 day	
Design lifetime	7 years	
Status	Operational	
System website	https://www.intelligence-airbusds.com/en/8079-triplesat	

TripleSat-1 to -3 / SSTL-S1—Continued

United Kingdom, China
Commercial
Operational/Future

Sensor Information

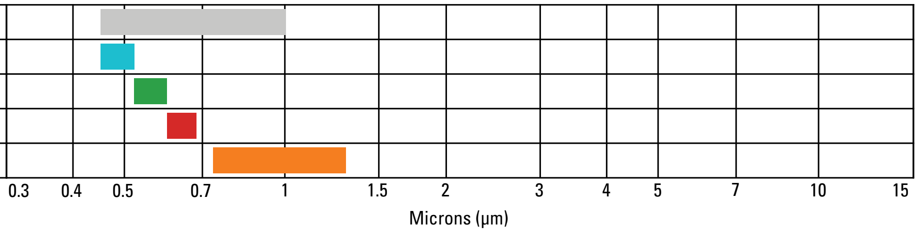
	VHRI-100
GSD (m)	0.8/3.2
Swath (km)	23.8
Data portal	http://www.21at.com.cn/en/Imagery/OnlinePortal/

A 1-meter resolution pan-sharpened image is an extract showing Sydney Airport acquired by DMC3/TripleSat satellite, 2015 [Source: SSTL, used with permission].

VHRI-100

The VHRI is a modified Newtonian telescope. VHRI-100 is the next generation of the VHRI imager flown on NigeriaSat-2. Data are available commercially through 21AT.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.725	1.000	0.8
Blue	0.450	0.485	0.520	3.2
Green	0.520	0.560	0.600	3.2
Red	0.600	0.640	0.680	3.2
NIR	0.730	1.015	1.300	3.2



JACIE

Data compiled by the USGS National Land Imaging Program's Requirements Capabilities and Analysis for Earth Observation (RCA-EO) project. JACIE is a collaboration between U.S. Federal agencies NASA, NGA, NOAA, USDA, and USGS. For more information see: https://www.usgs.gov/land-resources/eros/calval/jacie

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VENµS

France, Israel
Civil/Government
Operational

Platform Overview

The Vegetation and Environment monitoring on a New MicroSatellite mission (VENµS) is a medium-resolution superspectral satellite launched in 2017 on a Vega launch vehicle from the Guiana Space Center in Kourou, French Guiana, for Earth resources monitoring. The spacecraft was designed and developed by the French National Center for Space Studies (CNES) and Israel Aerospace Industries, Ltd., (IAI). The satellite will first operate as a science mission (VM1, VENµS Mission 1) aimed at understanding vegetation and water dynamics. The science mission is designed to operate for 2 years at an altitude of 720 km, and then the satellite will be lowered for 1 year to 410 km and operate as a technology mission (VM2, VENµS Mission 2). The technology mission aims to improve understanding of orbital dynamics and related goals and after an expected time of 6 months will continue imagery acquisition related to science mission goals (VM3, VENµS Mission 3). VENµS carries the VENµS Superspectral Camera (VSSC) for medium-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; —, no data; CA, coastal aerosol; NIR, near infrared]

Launch date	8/2/2017
Design lifetime	4.5 years
Platform owner	CNES, IAI
Altitude	720/410 km
Orbit period	99.19 min
Inclination	98.28°
Crossing time	10:30 DN
Nadir repeat	2 days
Status	Operational
System website	https://venus.cnes.fr/en/home-41

Sensor Information

	VSSC
GSD (m)	5.3/ 3.0
Swath (km)	27.56
Data portal	—

Artistic rendering of VENµS in orbit [Source: IDÉ/SARIAN Robin, 2015, used with permission].

Archipelago of Jardines de la Reina in the Caribbean Sea in Cuba seen by the satellite Venµs [Source: CNES, used with permission].

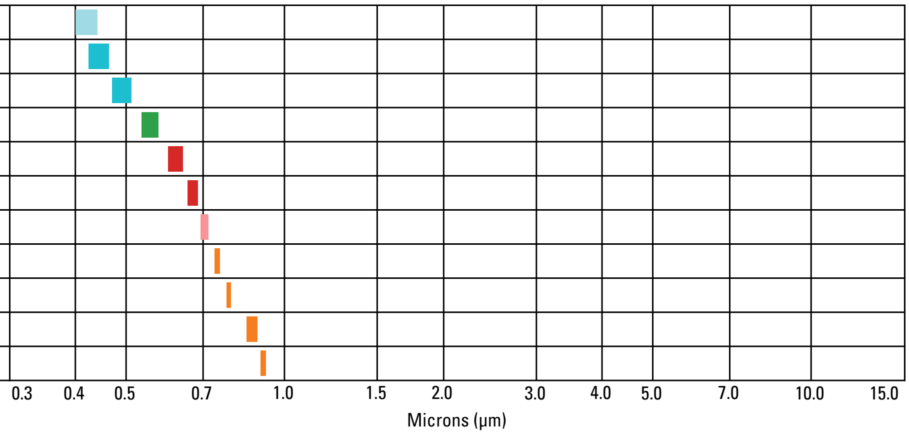
VENμS—Continued

France, Israel
Civil/Government
Operational

VSSC

The VSSC was built by Elbit Systems Electro-Optics of Rehovot, Israel (EL-OP), under contract with CNES.

Band	Lower	Center	Upper	GSD (m)
CA	0.400	0.420	0.440	5.3
Blue	0.423	0.443	0.463	5.3
Blue	0.470	0.490	0.510	5.3
Green	0.535	0.555	0.575	5.3
Red	0.600	0.620	0.640	5.3
Red	0.652	0.667	0.682	5.3
Red Edge	0.690	0.702	0.714	5.3
NIR	0.734	0.742	0.750	5.3
NIR	0.774	0.782	0.790	5.3
NIR	0.845	0.865	0.885	5.3
NIR	0.900	0.910	0.920	5.3



JACIE

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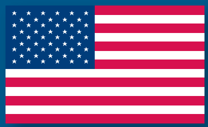
Suomi NPP, NOAA-20, JPSS-2 to -4

United States
Civil/Government
Operational/ Future



JACIE

Platform Overview

The Suomi National Polar-orbiting Partnership (NPP) is a low-resolution satellite launched in 2011 on a Delta-II rocket to serve as a gap filler between the National Oceanic and Atmospheric Administration (NOAA) Polar Operational Environmental Satellites (POES) satellites and the new NOAA Joint Polar Satellite System (JPSS) satellites and to provide continuity to the National Aeronautics and Space Administration's (NASA's) Earth Observing System (EOS) mission observations.

Artistic rendering of NOAA-20 satellite in orbit [Source: NOAA].

Nearly identical to Suomi NPP, NOAA-20 is the second satellite in the JPSS mission series. NOAA-20, designated JPSS-1 prior to launch, was launched in 2017 by NOAA on a Delta-II rocket for Earth resources monitoring. Suomi NPP and NOAA-20 were built by Ball Aerospace and Technologies Corp. for NOAA and use the BCP-2000 bus like the KEPLER and Quickbird satellites. JPSS-2, -3, and -4 will feature similar instruments and are scheduled to launch in 2021, 2026, and 2031, respectively. These satellites carry the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument for land imaging as well as several atmospheric measurement instruments.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; AN, ascending node; GSD, ground sample distance; m, meter; Pan DNB, panchromatic day night band; CA, coastal aerosol; NIR, near infrared, SWIR, short wave infrared, MWIR, mid wave infrared, TIR, thermal infrared]

	Suomi NPP	NOAA-20	JPSS-2	JPSS-3	JPSS-4
Launch date	10/28/2011	11/18/2017	2021 (planned)	2026 (planned)	2031 (planned)
Design lifetime	7 years				
Platform owner	NOAA, NASA				
Altitude	824 km				
Orbit period	101 min				
Inclination	98.74°				
Crossing time	10:30 DN	13:30 AN			
Nadir repeat	16 days	20 days			
Status	Operational	Development			
System website	http://www.jpss.noaa.gov/				

Sensor Information

	VIIRS
GSD (m)	375, 750
Swath (km)	3,000
Data Portal	https://www.nnvl.noaa.gov/view/globaldata.html

Suomi NPP, NOAA-20, JPSS-2 to -4—Continued

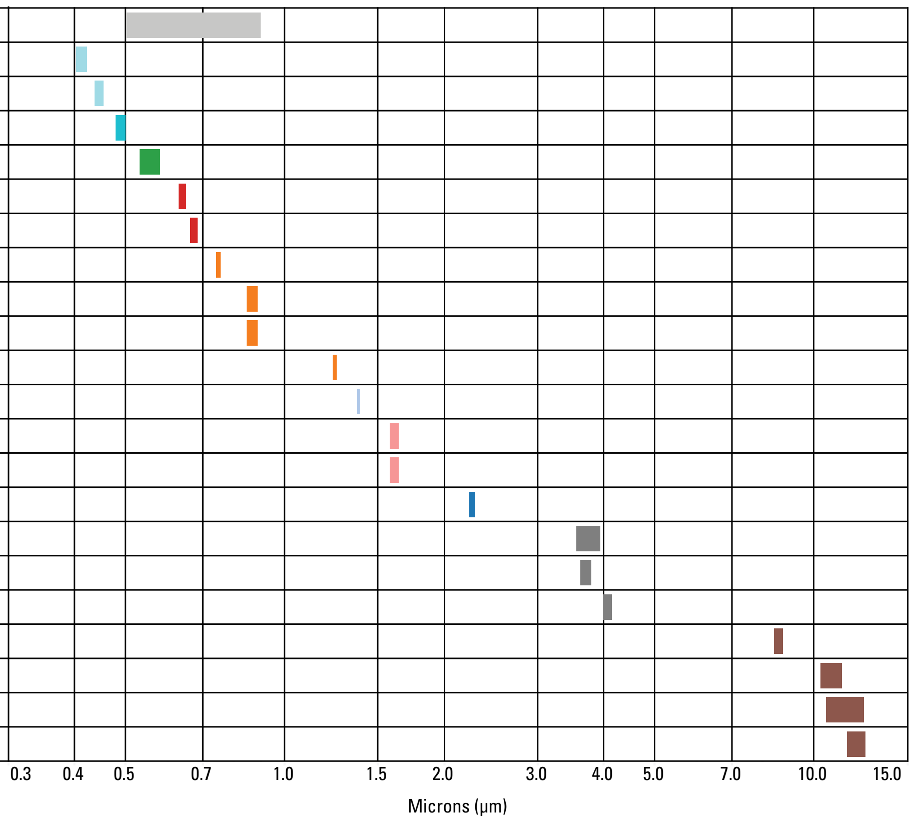
United States
Civil/Government
Operational/ Future

VIIRS

The VIIRS is a proven design from Raytheon. It combines technology developed in the MODIS and SeaWiFS sensors. The ground sample distance, swath width, and operating model remain the same as the previous version of this sensor. Data are available in two sets of records called environmental data records (ERDs) produced by NOAA, and Earth System Data Records (ESDRs) produced by NASA. VIIRS also includes a panchromatic Day/Night Band (DNB) that is capable of detailed night imaging. This DNB improves upon the heritage of similar bands aboard the Defense Meteorological Support Program (DMSP) satellites. VIIRS data are freely available.

NOAA-20 VIIRS image showing one of the largest wildfires in California history [Source: NOAA].

Band	Lower	Center	Upper	GSD (m)
Pan DNB	0.500	0.700	0.900	750
CA	0.402	0.412	0.422	750
CA	0.436	0.445	0.454	750
Blue	0.478	0.488	0.498	750
Green	0.530	0.555	0.580	750
Red	0.630	0.640	0.650	375
Red	0.662	0.672	0.682	750
NIR	0.739	0.746	0.754	750
NIR	0.846	0.865	0.885	375
NIR	0.846	0.865	0.885	750
NIR	1.230	1.240	1.250	750
Cirrus	1.371	1.378	1.386	750
SWIR 1	1.580	1.610	1.640	375
SWIR 1	1.580	1.610	1.640	750
SWIR 2	2.225	2.250	2.275	750
MWIR	3.550	3.740	3.930	750
MWIR	3.610	3.700	3.790	375
MWIR	3.973	4.050	4.128	750
TIR	8.400	8.550	8.700	750
TIR	10.263	10.763	11.263	750
TIR	10.500	11.450	12.400	375
TIR	11.538	12.013	12.488	750



JACIE

Vivid-i 1 to 5

United Kingdom
Commercial
Future

Platform Overview

Vivid-i 1 to 5 are high-resolution multispectral satellites planned to be launched in 2019 by Earth-i for commercial Earth observation. A prototype technology demonstration satellite, VividX2 (also known as Carbonite-2) was launched in January 2018. The Vivid-i satellites are being built by SSTL and are based on the SSTL-X50 platform. The Vivid-i satellites will carry the High-Resolution Imager (HRI) for high-resolution land imaging.

Artistic rendering of a Vivid-i satellite [Source: Earth-i, Ltd., used with permission].

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; —, no data]

Launch date	1/12/2018
Design lifetime	5 years
Platform owner	Earth-i
Altitude	500 km
Orbit period	94.36 min
Inclination	97.33°
Crossing time	10:30 DN
Nadir repeat	1 day
Status	Operational
System website	http://earthi.space/

A 1-meter resolution image of Dubai Airport acquired by CARBONITE-2 satellite, 2018 [Source: SSTL, used with permission].

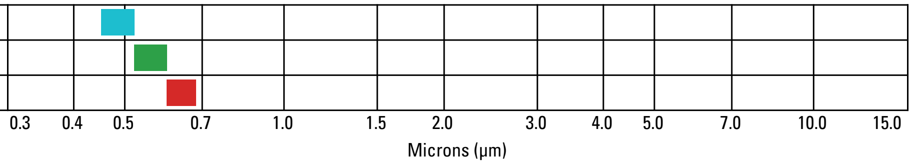
Sensor Information

	HRI
GSD (m)	0.6
Swath (km)	5
Data portal	https://earthi.space/image-data/

HRI

The HRI aboard the Vivid-i satellites is expected to be similar to the imager aboard the VividX2 prototype satellites. HRI data will be commercially available.

Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	0.6
Green	0.520	0.560	0.600	0.6
Red	0.600	0.640	0.680	0.6



JACIE

VNREDSat-1A

Vietnam
Civil/Government
Operational

Platform Overview

The Vietnamese Natural Resources, Environment and Disaster Monitoring Satellite-1A (VNREDSat-1A) is a high-resolution, multispectral satellite designed for natural resource, environment, and disaster monitoring. It was launched on a Vega launch vehicle in 2013.

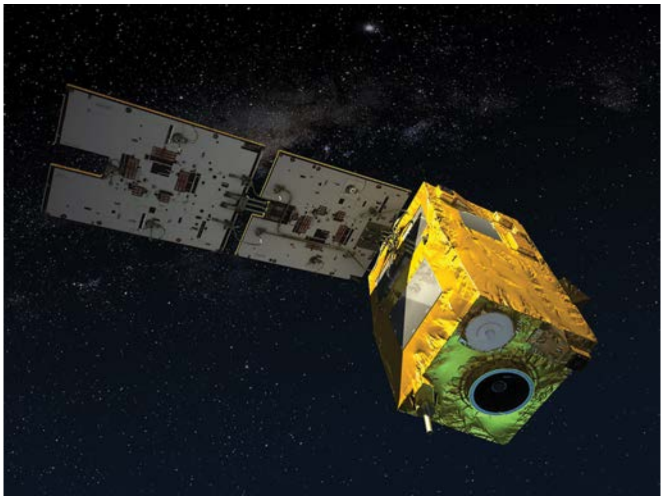
VNREDSat-1A was developed and built by European Aeronautic Defence and Space Company (EADS) Astrium and is based on the AstroSat-100 bus. It is operated by the Vietnam Academy of Science and Technology (VAST) and is the first Earth Observation satellite for Vietnam. The satellite carries the New AstroSat Optical Modular Instrument (NAOMI), which provides 2.5 m ground sample distance (GSD) panchromatic and 10m GSD multispectral imagery available freely to the public.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; —, no data; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near infrared]

Launch date	5/7/2013
Platform owner	STI-VAST
Altitude	704 km
Orbit period	98.85 min
Inclination	98.7°
Crossing time	10:30 DN
Nadir repeat	—
Design lifetime	5 years
Status	Operational
System website	http://www.sti.vast.ac.vn/en/

Sensor Information

	NAOMI
GSD (m)	2.5/10
Swath (km)	17.5
Data portal	http://datacube.vn/



Artistic rendering of VNREDSat-1A [Source: Airbus DS, used with permission].

VNREDSat-1 imagery [Source: Airbus DS, used with permission].

JACIE

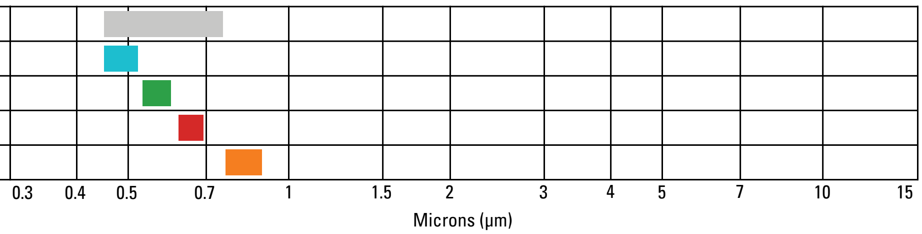
VNREDSat-1A—Continued

Vietnam
Civil/Government
Operational

NAOMI

The NAOMI sensor aboard VNREDSat-1A is based on the instruments of the same name aboard AlSat-2, SSOT, and SPOT-6.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.600	0.750	2.5
Blue	0.450	0.485	0.520	10
Green	0.530	0.565	0.600	10
Red	0.620	0.655	0.690	10
NIR	0.760	0.825	0.890	10



VRSS-1

Venezuela
Civil/Government
Operational

Platform Overview

The Venezuelan Remote Sensing Satellite-1 (VRSS-1) is a medium-resolution multispectral satellite launched on a Long March 2D rocket from Jiquan Launch Area. This is the first Earth observing mission for Venezuela, mainly used for resource investigation and urban planning. VRSS-1 was designed and manufactured by China Academy of Space (CAST) for Bolivarian Agency for Space Activities (ABAE) based on the CAST 2000 platform. VRSS-1 carries the Panchromatic and Multispectral Camera (PMC) and Wide-swath Multispectral Camera (WMC) for high- and medium-resolution land imaging, respectively.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; —, no data; NIR, near infrared]

Launch date	9/29/2012
Design lifetime	5 years
Platform owner	ABAE
Altitude	640 km
Orbit period	97.5 min
Inclination	98°
Crossing time	10:30 DN
Nadir repeat	4 days
Status	Operational
System website	http://www.abae.gob.ve/web/VRSS-1.php

Sensor Information

	PMC	WMC
GSD (m)	2.5, 10	16
Swath (km)	57	370
Data portal	—	

JACIE

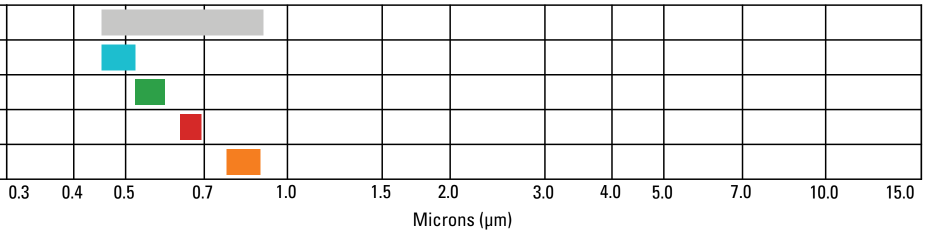
VRSS-1—Continued

Venezuela
Civil/Government
Operational

PMC

The PMC is a set of two imagers with time-delay integration capability (TDI). The combined swath width of both imagers is 57 km.

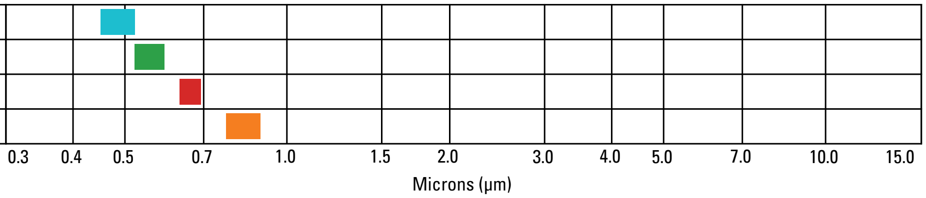
Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.675	0.900	2.5
Blue	0.450	0.485	0.520	10
Green	0.520	0.555	0.590	10
Red	0.630	0.660	0.690	10
NIR	0.770	0.830	0.890	10



WMC

The WMC is like PMC with two imagers operating with TDI capability.

Band	Lower	Center	Upper	GSD (m)
Blue	0.450	0.485	0.520	16
Green	0.520	0.555	0.590	16
Red	0.630	0.660	0.690	16
NIR	0.770	0.830	0.890	16



VRSS-2

Venezuela
Civil/Government
Operational

Platform Overview

The Venezuelan Remote Sensing Satellite-2 (VRSS-2) is a high-resolution multispectral satellite launched in 2017 on a Long March 2D rocket from Jiquan Launch Area. This is the second Earth observing mission for Venezuela, mainly used for resource investigation and urban planning. VRSS-2 was designed and manufactured by China Great Wall Industry Corporation (CGWIC) for Bolivarian Agency for Space Activities (ABAE) based on the CAST 2000 platform. VRSS-2 carries the Panchromatic and Multispectral Camera (PMC)-2 and Infrared Camera (IRC) sensors for high- and medium-resolution land imaging, respectively.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; —, no data; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near infrared; SWIR, shortwave infrared]

Launch date	10/9/2017
Design lifetime	5 years
Platform owner	ABAE
Altitude	645 km
Orbit period	97.62 min
Inclination	98°
Crossing time	—
Nadir repeat	—
Status	Operational
System website	http://www.abae.gob.ve/web/VRSS-2.php

Sensor Information

	PMC-2	**IRC**
GSD (m)	1, 4	30, 60
Swath (km)	30	30
Data portal	—	

JACIE

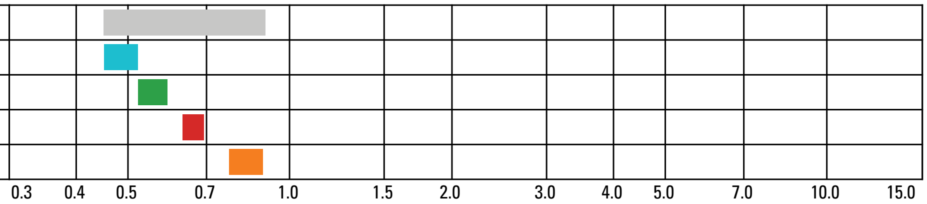
VRSS-2—Continued

Venezuela
Civil/Government
Operational

PMC-2

The PMC-2 is a proven design based on PMC from VRSS-1. PMC-2 has an improved GSD of 4 m for visible and near infrared and 1 m for panchromatic bands.

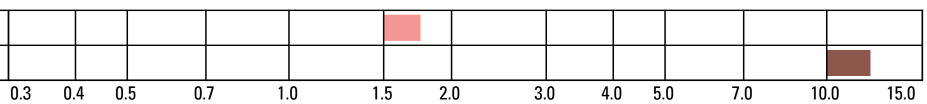
Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.675	0.900	1
Blue	0.450	0.485	0.520	4
Green	0.520	0.555	0.590	4
Red	0.630	0.660	0.690	4
NIR	0.770	0.830	0.890	4



IRC

The IRC is a new design with a capability of observing in the SWIR and TIR parts of the spectrum.

Band	Lower	Center	Upper	GSD (m)
SWIR 1	1.500	1.625	1.750	30
TIR	10.000	11.000	12.000	60

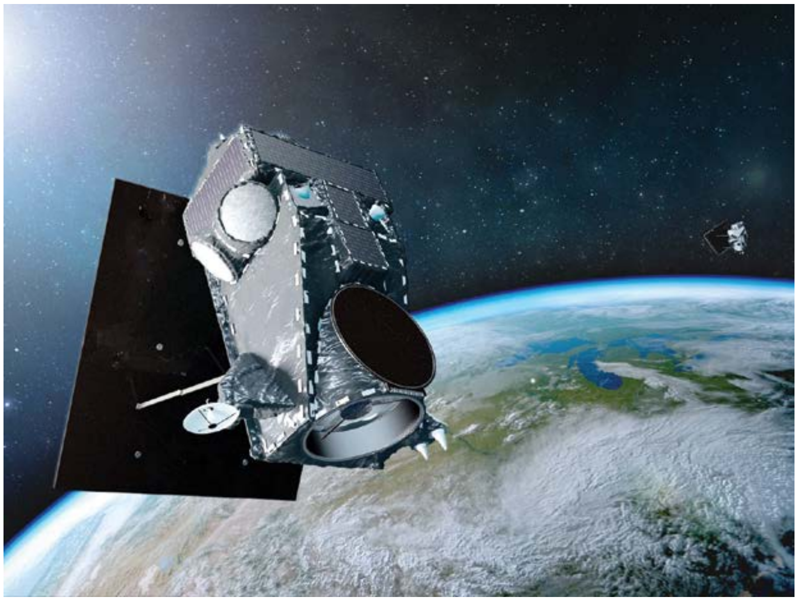


WorldView Legion

United States
Commercial
Future

Platform Overview

The WorldView Legion constellation of high-resolution, panchromatic, and multispectral satellites are planned to be launched in 2021 by DigitalGlobe for commercial Earth observation. The satellites will have a mix of mid-latitude and sun-synchronous orbits. In conjunction with the WorldView Scout satellites, DigitalGlobe will have the ability to image regions of Earth as many as 40 times daily. DigitalGlobe announced the new six-satellite constellation shortly after being acquired by MDA in 2017.



Artistic rendering of a WorldView Legion satellite in orbit [Source: MAXAR Technologies, 2019, used with permission].

[Abbreviations in tables: —, no data; GSD, ground sample distance; ~, approximately; m, meter; km, kilometer]

Launch date	2021 (Planned)
Design lifetime	—
Platform owner	DigitalGlobe
Altitude	—
Orbit period	—
Inclination	—
Crossing time	—
Nadir repeat	—
Status	Planned
System website	https://www.digitalglobe.com/

Sensor Information

	WVLI
GSD (m)	~0.35–0.50
Swath (km)	—
Data portal	—

WorldView Legion Imager (WVLI)

The imager aboard the WorldView Legion satellites will have a ground sample distance of approximately 0.35 to 0.50 m. Spectral information details are unavailable at this time. Data will be commercially available.

JACIE

WorldView Scout

United States
Commercial
Future

JACIE

Platform Overview

The WorldView Scout constellation of high-resolution panchromatic and multispectral satellites are planned to be launched in 2019 for commercial Earth observation. The satellites will have mid-latitude orbits. In conjunction with the WorldView Legion satellites, DigitalGlobe will have the ability to image regions of Earth as many as 40 times daily. DigitalGlobe and Saudi Arabia's King Abdul Aziz City for Science and Technology Space Research Institute (KACST SRI) have announced a partnership for building and operating the WorldView Scout constellation.

[Abbreviations in tables: —, no data; GSD, ground sample distance; m, meter; ~, approximately; km, kilometer]

Launch date	2019 (Planned)
Design lifetime	—
Platform owner	DigitalGlobe/KACST SRI
Altitude	—
Orbit period	—
Inclination	—
Crossing time	—
Nadir repeat	—
Status	Development
System website	https://www.digitalglobe.com/

Sensor Information

	WVSI
GSD (m)	~0.8
Swath (km)	—
Data portal	—

WorldView Scout Imager

The imager aboard the WorldView Scout satellites will have a ground sample distance of approximately 0.8 m. Spectral information details are unavailable at this time.

WorldView-1

United States
Commercial
Operational

Platform Overview

WorldView-1 (WV-1) is a high-resolution panchromatic satellite launched in 2007 by DigitalGlobe on a Delta-II launch vehicle from Vandenberg Air Force Base for commercial Earth resources monitoring. The WV-1 satellite was designed and built by Ball Aerospace and Technologies Corporation (BATC) in the United States and utilizes the BCP-5000 bus. WV-1 carries the WorldView-60 (WV-60) camera for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; —, no data; GSD, ground sample distance; m, meter; Pan, panchromatic]

Launch date	9/18/2007
Design lifetime	7.5 years
Platform owner	DigitalGlobe
Altitude	496 km
Orbit period	94.6 min
Inclination	97.2°
Crossing time	10:30 DN
Nadir repeat	—
Status	Operational
System website	https://www.digitalglobe.com/about/our-constellation

Artistic rendering of WorldView-1 [Source: MAXAR Technologies, 2019, used with permission].

WorldView-1 image of Stratolaunch in Mojave, California [Source: MAXAR Technologies, 2019, used with permission].

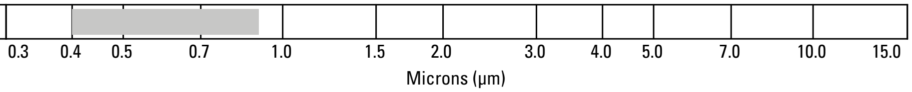
Sensor Information

	WV-60
GSD (m)	0.5
Swath (km)	18
Data portal	—

WV-60

The WV-60 aboard WV-1 was designed and developed by BATC and is of QuickBird heritage. The camera captures high-resolution panchromatic imagery.

Band	Lower	Center	Upper	GSD (m)
Pan	0.400	0.650	0.900	0.5



JACIE

Data compiled by the USGS National Land Imaging Program's Requirements Capabilities and Analysis for Earth Observation (RCA-EO) project. JACIE is a collaboration between U.S. Federal agencies NASA, NGA, NOAA, USDA, and USGS. For more information see: https://www.usgs.gov/land-resources/eros/calval/jacie

For Joint Agency Commercial Imagery Evaluation (JACIE) sensor performance information see: https://www.usgs.gov/land-resources/eros/calval/jacie

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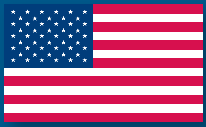
WorldView-2

United States
Commercial
Operational



Platform Overview

WorldView-2(WV-2) is a high-resolution multispectral satellite launched in 2009 by DigitalGlobe on a Delta 7920 from Vandenberg Air Force Base for Earth resources monitoring. This mission continues the WV series that has been in continual operation since the launch of WorldView-1 in 2007. The WorldView-2 satellite was designed and built by Ball Aerospace for DigitalGlobe and uses the BCP-5000 bus. WorldView-2 carries the WorldView-110 camera for high-resolution land imaging.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; —, no data; GSD, ground sample distance; m, meter; Pan, panchromatic; CA, coastal aerosol; NIR, near infrared]

Launch date	10/8/2009
Design lifetime	10–12 years
Platform owner	DigitalGlobe
Altitude	770 km
Orbit period	100.2 min
Inclination	97.8°
Crossing time	10:30 DN
Nadir repeat	—
Status	Operational
System website	https://www.digitalglobe.com/about/our-constellation

At right: Artistic rendering of WorldView-2 [Source: MAXAR Technologies, 2019, used with permission]. Below: WorldView-2 image of Indian Wells Tennis Garden in Indian Wells, California [Source: MAXAR Technologies, 2019, used with permission].

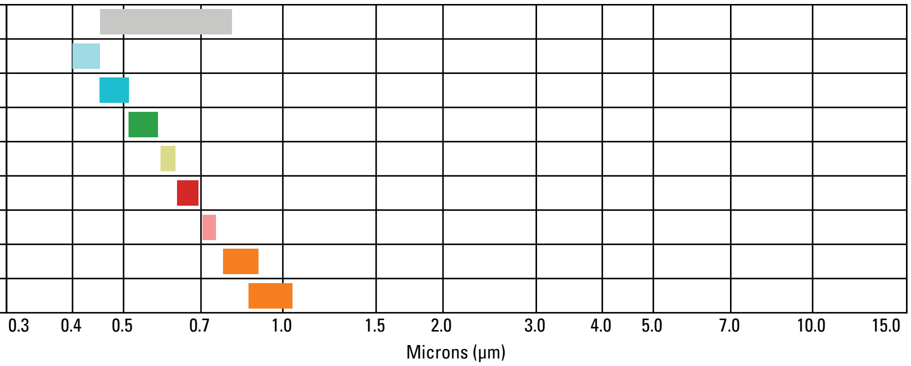
Sensor Information

	WorldView-110
GSD (m)	0.46, 1.85
Swath (km)	16
Data portal	https://discover.digitalglobe.com/

WorldView-110

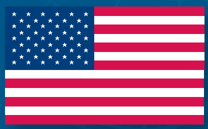
The WV-110 camera was newly designed and built by ITT Exelis. The new design adds a yellow and red-edge band that previous WV satellites did not have. Data are available to customers through DigitalGlobe's commercial portal.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.625	0.800	0.46
CA	0.400	0.425	0.450	1.85
Blue	0.450	0.480	0.510	1.85
Green	0.510	0.545	0.580	1.85
Yellow	0.585	0.605	0.625	1.85
Red	0.630	0.660	0.690	1.85
Red Edge	0.705	0.725	0.745	1.85
NIR	0.770	0.833	0.895	1.85
NIR	0.860	0.950	1.040	1.85



WorldView-3

United States
Commercial
Operational



Platform Overview

WorldView-3 (WV-3) is a high-resolution multispectral satellite launched in 2014 by the DigitalGlobe on an Atlas V from Vandenberg Air Force Base in California for Earth resource monitoring. WV-3 provides significant technical improvements to previous WorldView satellites, including spectral bands, GSD, and swath.

The WV-3 satellite was designed and built by Lockheed Martin for the DigitalGlobe Corporation using the BCP-5000 bus with the WorldView-3 Imager and the Clouds, Aerosols, Vapors, Ice and Snow (CAVIS) sensor. The high-resolution WV-3 Imager is the main instrument, with the CAVIS providing additional data on obscurants and other atmospheric effects used in data production.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; GSD, ground sample distance; m, meter; CA, coastal aerosol; NIR, near infrared; SWIR, short wave infrared; MWIR, mid wave infrared]

Launch date	8/13/2014
Platform owner	Digital Globe/MDA
Altitude	620 km
Orbit period	97 min
Inclination	97.9°
Crossing time	10:30 DN
Nadir repeat	5 days
Design lifetime	7.25 years
Status	Operational
System website	http://worldview3.digitalglobe.com/

Artistic rendering of WorldView-3 in orbit [Source: MAXAR Technologies, 2019, used with permission].

WorldView-3 image of Beijing Daxing International Airport, Beijing, China [Source: MAXAR Technologies, 2019, used with permission].

Sensor Information

	CAVIS	WV-3 Imager
GSD (m)	30	0.31/1.24/3.7
Swath (km)	13.1	
Data portal	https://www.digitalglobe.com/products/collection-request	

JACIE

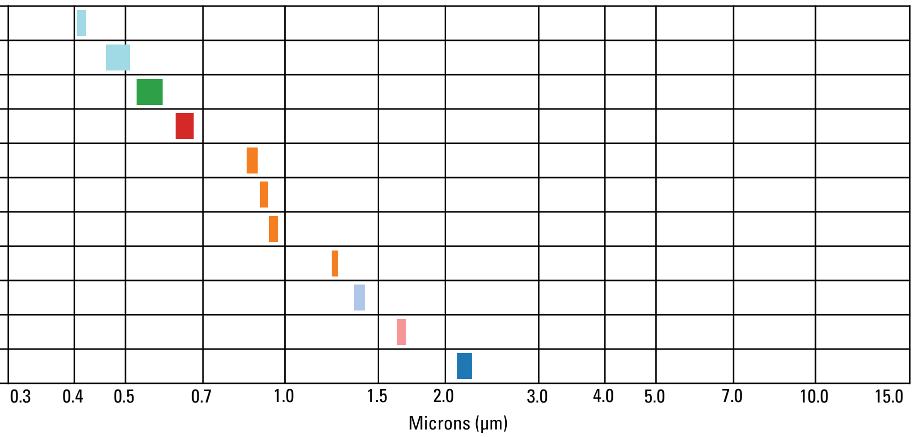
WorldView-3—Continued

United States
Commercial
Operational

CAVIS

The CAVIS instrument on WV-3 provides 12 spectral bands at 30 m ground sample distance (GSD) to improve atmospheric corrections and image production. Data from this sensor are not generally available outside of Digital Globe.

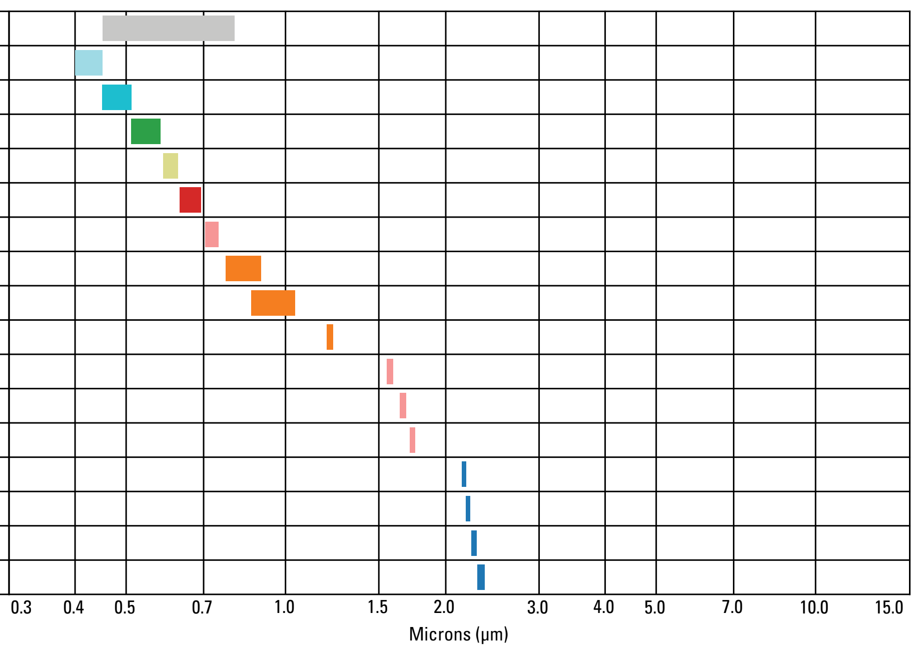
Band	Lower	Center	Upper	GSD (m)
CA	0.405	0.413	0.420	30
CA	0.459	0.484	0.509	30
Green	0.525	0.555	0.585	30
Red	0.620	0.645	0.670	30
NIR	0.845	0.865	0.885	30
NIR	0.897	0.912	0.927	30
NIR	0.930	0.948	0.965	30
NIR	1.220	1.236	1.252	30
Cirrus	1.350	1.380	1.410	30
SWIR 1	1.620	1.650	1.680	30
SWIR 2	2.105	2.175	2.245	30



WV-3 Imager

The Imaging sensor aboard WV-3 was built by ITT Exelis. The WV-3 Imager provides the same eight visible and near infrared (VNIR) bands as WV-2 and adds eight shortwave infrared (SWIR) bands. The GSD is improved to 31 cm for panchromatic data, 1.2 m in VNIR, and images at a GSD of 3.7 m in SWIR; however, terms of its licensing as of 2018 require Digital Globe to resample the SWIR data to 7.5 m effective GSD. DigitalGlobe is working with the U.S. Government to revise this restriction so that SWIR data can be distributed at its 3.7 m native resolution.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.625	0.800	0.31
CA	0.400	0.425	0.450	1.24
Blue	0.450	0.480	0.510	1.24
Green	0.510	0.545	0.580	1.24
Yellow	0.585	0.605	0.625	1.24
Red	0.630	0.660	0.690	1.24
Red Edge	0.705	0.725	0.745	1.24
NIR	0.770	0.833	0.895	1.24
NIR	0.860	0.950	1.040	1.24
NIR	1.195	1.210	1.225	3.7
SWIR 1	1.550	1.570	1.590	3.7
SWIR 1	1.640	1.660	1.680	3.7
SWIR 1	1.710	1.730	1.750	3.7
SWIR 2	2.145	2.165	2.185	3.7
SWIR 2	2.185	2.205	2.225	3.7
SWIR 2	2.235	2.260	2.285	3.7
SWIR 2	2.295	2.330	2.365	3.7



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WorldView-4

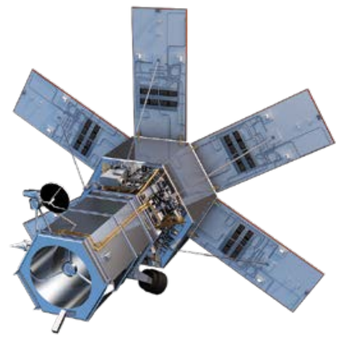
United States
Commercial
Failed

Platform Overview

WorldView-4 is a high-resolution, panchromatic, and multispectral satellite launched in 2016 on an Atlas-V launch vehicle from Vandenberg Air Force Base for commercial Earth resources monitoring. After DigitalGlobe's acquisition of GeoEye Inc. in 2013, the development of GeoEye-2 was accelerated and the satellite was renamed WorldView-4. WorldView-4 was designed and developed by Lockheed Martin Space Systems in the United States and uses the LM-900. WorldView-4 carries the SpaceView™ 110 sensor for high-resolution land imaging. The satellite suffered a gyro failure in early January 2019, ending its operations.

[Abbreviations in tables: km, kilometer; min, minute; °, degree; DN, descending node; —, no data; GSD, ground sample distance; m, meter; Pan, panchromatic; NIR, near infrared]

Launch date	11/11/2016
Design lifetime	7 years
Platform owner	DigitalGlobe
Altitude	617 km
Orbit period	97 min
Inclination	97.97°
Crossing time	10:30 DN
Nadir repeat	—
Status	Retired
System website	https://www.digitalglobe.com/about/our-constellation/



Artistic rendering of WorldView-4 [Source: MAXAR Technologies, 2019, used with permission].

Sensor Information

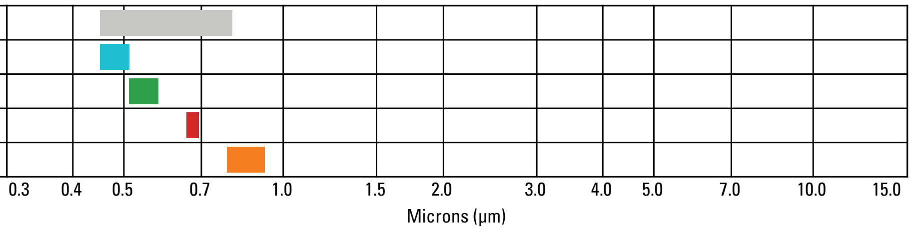
	SpaceView™ 110
GSD (m)	0.31, 1.24
Swath (km)	13.1
Data portal	https://www.digitalglobe.com/products/collection-request

WorldView-4 image of Houston, Texas [Source: MAXAR Technologies, 2019, used with permission].

SpaceView™ 110

The SpaceView™ 110 camera aboard WorldView-4 was designed and developed by ITT Inc. in the United States, which was acquired by Harris Corporation in 2015. SpaceView™ 110 data are commercially available.

Band	Lower	Center	Upper	GSD (m)
Pan	0.450	0.625	0.800	0.31
Blue	0.450	0.480	0.510	1.24
Green	0.510	0.545	0.580	1.24
Red	0.655	0.673	0.690	1.24
NIR	0.780	0.850	0.920	1.24



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