Service

Ikonos-2 Block-1

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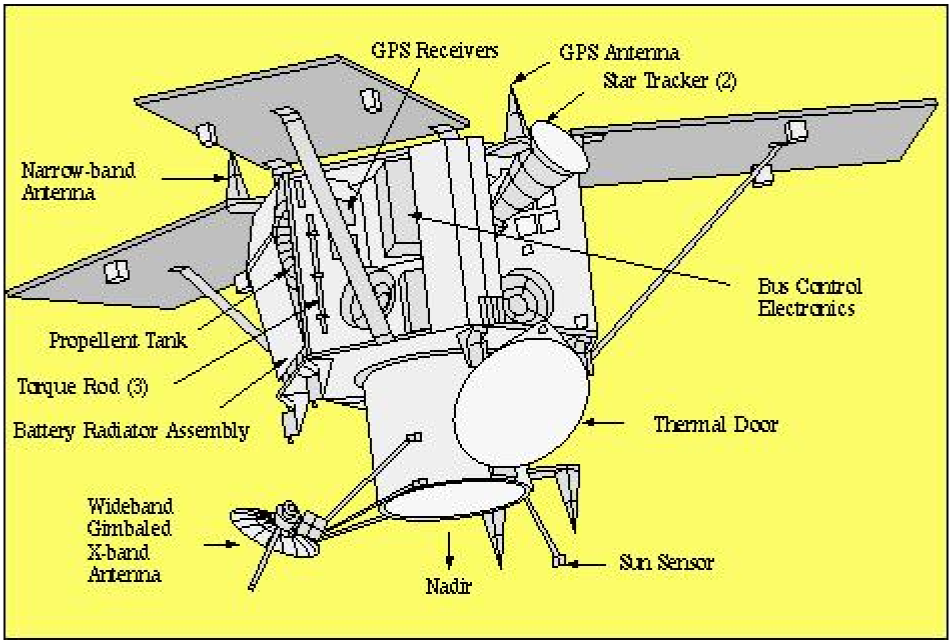
Ikonos-2 is an imaging satellite of Space Imaging Inc. of Thornton, CO, providing high-resolution imagery on a commercial basis. With Ikonos-2, a new era of 1 m spatial resolution imagery began for spaceborne instruments in the field of civil Earth observation. The Ikonos satellite system was built by LMMS (Lockheed Martin Missiles & Space) of Sunnyvale, CA.

Some background on the Ikonos program: CRSS (Commercial Remote Sensing System) was a remote sensing imaging satellite project of Lockheed Martin that started in 1991. In 1994 a new company was formed for this venture, namely Space Imaging Inc. with the following partners: Lockheed Martin (Sunnyvale, CA: space segment, satellite operations, and tasking of ground segment), Raytheon/E-Systems (Garland TX: communications, image processing and customer service center). Eastman Kodak Co. of Rochester, NY designed and built the digital camera/sensor. The overall objective was to offer commercial high-resolution (1 m GSD panchromatic and 4 m GSD multispectral) imagery with excellent location knowledge in near real-time and offline. In Aug. 1995, Space Imaging was awarded a license by the FCC (Federal Communications Commission) to construct, launch and operate a commercial remote sensing satellite system comprised of two satellites. In 1997 the CRSS satellite was renamed by Space Imaging to "Ikonos-1," supposedly a variant of the Greek word `eikon' (icon), meaning "image." 1) 2) 3)

A launch of Ikonos-1 took place on April 27, 1999 from VAFB aboard an Athena 2 launcher. Unfortunately, the rocket's nose cone failed to separate as planned at 4 minutes, 27 seconds into the flight - resulting in a complete loss of the satellite. With the protective shroud still attached, the rocket's upper stage and satellite did not have enough speed to reach a stable orbit around Earth. The vehicle then reentered the atmosphere over the South Pacific Ocean.



Resources of same Organisation

Space Imaging

Service (1)

- **Ikonos-2 Block-1**

Resources of same Type

Service>Satellite mission>Earth observation

Figure 1: The Ikonos spacecraft (image credit: Space Imaging Inc.)

Spacecraft:

Ikonos-2 is a 3-axis stabilized spacecraft, using the LM900 satellite bus system (also referred to as Block-1). The attitude is measured by two star trackers and a sun sensor and controlled by four reaction wheels; location knowledge is provided by a GPS receiver. The design life is 7 years; S/C body size=1.83 m x 1.57 m (hexagonal configuration); S/C mass = 817 kg; power = 1.5 kW provided by 3 solar panels.

Launch: Ikonos-2, (identical to Ikonos-1 and built in parallel to Ikonos-1), was launched successfully on Sept. 24, 1999 from VAFB, CA aboard an Athena 2 launcher of Lockheed Martin. On Oct. 12, 1999, Space Imaging released the world's first high-resolution commercial satellite image of the Earth - a 1 m resolution black-and-white image of Washington, D.C. (see Figure **3**).

RF communications: The downlink of all imaging data is in X-band at a rate of 320 Mbit/s to dedicated ground stations located around the world (on-board data recording capacity is 64 Gbit in solid-state memory). The TT&C function is provided in S-band (uplink of tasking and command data at 2 kbit/s, downlink of housekeeping data and metadata at 32 kbit/s). [4)]

The spacecraft operations of Ikonos Block-1 is unique among the current commercial imaging satellites in that it allows each international affiliate to operate its own ground station(s). These ground stations are assigned blocks of time on the satellite during which they can directly task Ikonos, and immediately receive the downlinked imagery for which they tasked. In addition to virtually instant data receipt, this allows each affiliate to make the best use of local weather data. However, this capability is only available when the ground station is in contact with Ikonos.

Figure 2: Artist's conception of the Ikonos-2 Block-1 spacecraft (image credit: Space Imaging Inc.)

Orbit: Sun-synchronous near-polar circular orbit, altitude = 681 - 709 km, inclination = 98.1º, period = 98 min, repeat cycle = 14 days (max), revisit cycle = 1-3 days (for observations at 40º latitude or higher). The local equator crossing time is at 10:30 AM on the descending node.

Mission status: Ikonos-2 is operational as of 2005 - and there are no signs of data deterioration or component failure. Current estimates of Space Imaging are that Ikonos-2 will last until 2008 (and possibly longer). - As of Sept. 2005, Lockheed Martin and Raytheon, the parent companies, have agreed to sell Space Imaging to OrbImage Inc. of Dulles, VA. Government approvals will take a while but they are most likely to happen.

Sensor complement:

OSA (Optical Sensor Assembly), designed and custom-built by Kodak Co. of Rochester, NY (Space Imaging owns the design of OSA). The instrument features a Cassegrain-type telescope with a 70 cm diameter primary mirror, a 10 m focal length (folded optics design). The OTA (Optical Telescope Assembly) captures imagery across a swath of 11-13 km, it uses five mirrors to reflect the imagery to the imaging sensor arrays at the back end of the telescope. Three of the mirrors are powered (curved), and are of TMA (Three Mirror Anastigmatic) design. Note: TMA refers to lenses that are able to form approximately point images of target (object) points. The other two mirrors are flat, and serve to `fold' or bounce the imagery across the width of the telescope.

Pushbroom detector technology (a large focal plane detector array, generation of 6500 lines/s of panchromatic image data) is employed. Simultaneous imaging in panchromatic and multispectral modes is provided. The pixel size on the detector array is 12 µm for the panchromatic (PAN), and 48 µm for the multispectral (MS) detectors. The MS bands correspond to those of TM on Landsat in the visible range of the spectrum. The instrument light level is governed by a 70 cm aperture and a choice of 10, 13, 18, 24, or 32 TDI (Time Delay Integration) stages for panchromatic (gray-scale) imaging. The detector array offers a cumulative exposure concept for panchromatic imaging.

On-board electronics provide low-loss data compression of the original 11-bit data using ADPCM (Adaptive Differential Pulse Code Modulation). - The OSA instrument design features lightweight materials and advanced manufacturing techniques. The mass of the primary mirror was reduced by cutting a honeycomb pattern into its core using abrasive waterjet technology, and fusing thin mirror plates to each face.

Optical telescope assembly	Assembly size: 1.524 m x 0.787 m (1 m^3 volume) Assembly mass without the focal plane unit: 109 kg Focal length = 10 m; focal ratio = f/14.3 Primary mirror aperture diameter: 0.70 m
Imaging detectors & electronics	Focal plane unit, unit size: 25 cm x 23 cm x 23 cm Detector array: 13,500 pixels cross-track (PAN) Detector array: 3375 pixels cross-track (MS), pixel size: 48 x 48 µm
Digital processing unit	Unit size: 46 cm x 19 cm x 31 cm ADPCM data compression, compression rate of 4:25 : 1
Power supply unit	Unit size: 18 cm x 20 cm x 41 cm
Total instrument mass, power	171 kg, 350 W

Table 1: OSA instrument layout

A body-pointing technique with antenna gimbals and reaction wheels is employed for instrument pointing (the entire S/C is pointed into the desired direction), permitting a field of regard of ±30º into any direction. The angular slew rate is sufficient to perform both wide-area monoscopic and same-pass stereo collections. The location knowledge accuracy of the imagery is 2 m horizontal (relative) i.e. with ground control points, and 12 m (absolute), i.e. without the use of ground control points. Smooth scanning is provided with accurate gyros, low disturbance torques (smooth antenna gimbals and reaction wheels), and a rigid high-frequency structure of the satellite.

The S/C may also be rotated about its imaging axis for proper (broadside) detector array orientation. This technique permits, for instance, the full-swath imaging of a particular feature of interest on the Earth's surface, such as a coastline, which traverses under some angle through the in-track direction.

Parameter	Value	Parameter	Value
Spectral range PAN	0.45 - 0.90 µm	Off-nadir pointing angle	±30º in any direction
Spectral range MS (µm)	0.45-0.52, 0.52-0.60, 0.63-0.69, 0.76-0.90	Stereo capability	along-track
Spatial resolution	1 m PAN (0.82 m at nadir), 4 m MS	Swath width (single image) Nominal strips	13 km x 13 km 11 km x 100 km (length)
Pixel quantization	11 bit	Field of regard (FOR)	±350 km at 1 m GSD

Table 2: Some performance parameters of the OSA instrument

Instrument calibration: The agile pointing capability of Ikonos is being utilized for instrument calibration. Solar, lunar and stellar scenes serve as radiometric instrument calibration sources. The ecliptic portion of the orbit is being used for stellar calibration. Absolute calibration of the Ikonos sensors is performed by comparing the total digital numbers found in the stellar image, to the absolute in-band spectral radiance of several radiometrically characterized stars. The radiometric calibration provides relative and absolute corrections for detector channel responsivity differences. 5)

Since launch, the Ikonos-2 satellite has undergone a series of geometric calibrations. The Ikonos geometric sensor model includes the interior orientation parameters, i.e. the Field Angle Map (FAM), and the elements of the exterior orientation parameter set, namely the interlock angles. The initial values of the interlock angles and the FAM parameters were determined by pre-launch measurements. They were subsequently refined by a series of on-orbit geometric calibrations. 6)

Ground image data processing provides geocoding along with image compensation algorithms [misregistration, image motion, radiometric correction, MTF (modulation transfer function) compensation, etc.]. Space Imaging Inc. introduced a global archive (of digital imagery and services) under the trade name CARTERRA, which in turn is made up of regional archives, operated by regional partners. A great variety of image products and services are provided. Standard products are:

· Radiometrically corrected images

· Geometrically corrected images

· Orthorectified images and mosaics

· Digital terrain model (DTM) data

· Multispectral images

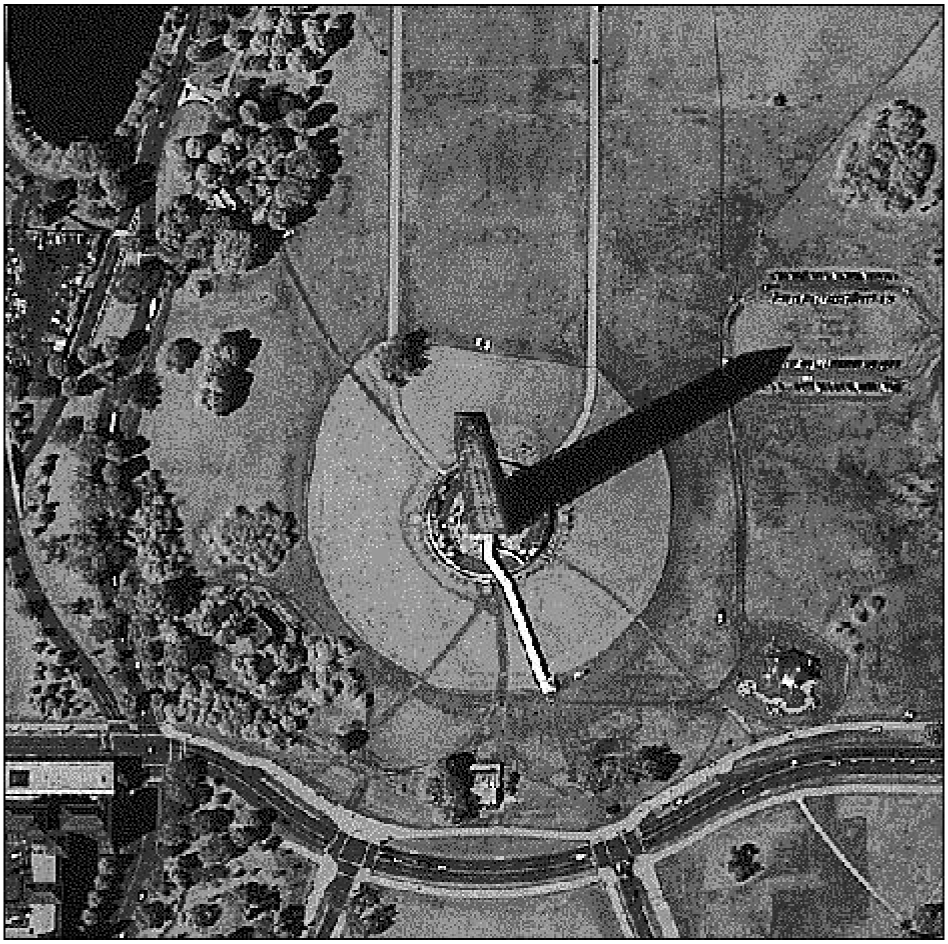


Figure 3: First Ikonos image of Washington D. C. with the Washington Monument (image credit: Space Imaging Inc.)

Kodak Model 1000 Camera System

As of July 1999, Kodak/C&GS (Commercial & Government Systems) is offering a "Model 1000TM camera system" of OSA camera heritage as an off-the-shelf product - at a 30% discount, deliverable within 24 months of order placement. This Model 1000 system design is owned by Kodak, containing some design changes with respect to OSA (reduced telescope aperture and instrument mass to fit onto minisatellites). 7) 8) 9)

The Model 1000 camera system consists of the following elements: OTU (Optical Telescope Unit), FPU (Focal Plane Unit), DPU (Digital Processing Unit), PSU (Power Supply Unit), and CU (Cabling Unit). The total mass of the system is <100 kg.

· The OTU is an all-reflective three mirror anastigmatic design with two flat fold mirrors to decrease package volume (Korsch TMA telescope design). The optical components are made from high quality, low thermal expansion glass substrates. The metering and mounting structures are made from low thermal expansion materials to match the expansion properties of the glass components. OTU has a mass of 45 kg, the power consumption is 15 W.

· The FPU includes the PAN and MS detectors and A/D converters. Timing and command signals are received from the DPU, power is received from the PSU. The mass of FPU is 16 kg, power = 85 W.

· The DPU generates the timing for the sensor electronics via a master clock. DPU accepts S/C commands over a standard 1553 bus and routes the information to the FPU and PSU. The DPU compresses the 11 bit digitized image data to about 2.5 bits/pixel using the Kodak proprietary algorithms of ADPCM (Advanced Differential Pulse Code Modulation). The DPU can format data for interface with an on-board storage unit and data downlink. DPU mass = 14 kg, power = 130 W.

· The PSU filters, regulates and generates the unregulated S/C power to the DPU and PSU. Mass = 8 kg, power 75 W. There is full redundancy.

· The CU provides the cabling between the various electronic boxes. Mass = 5kg, power = 10W.

Spectral range PAN (panchromatic)	0.45 - 0.90 µm
Spectral range MS (multispectral)	0.45-0.52 µm, 0.52-0.60 µm, 0.63-0.69 µm, 0.69-0.90 µm
Spatial resolution (GSD)	0.88 m PAN, 3.52 m MS, orbital altitude of 600 km
Swath width	12.2 km
Design life	5 years
Optical system parameters	
Clear aperture of primary mirror	44.8 cm diameter
Effective focal length; Focal ratio (f/number)	8.0 m / f/17.9
FOV along-track, FOV cross-track	0.75º, 1.19º
Panchromatic focal plane detector array Detector material, array type Pixel size Number of cross-track pixels Line rate TDI (Time Delay Integration)	 Silicon, CCD 12 µm x 12 µm 13,816 6500 lines/s 10, 13, 18, 24, 32
Multispectral focal plane detector array Detector material, array type Pixel size Number of cross-track pixels Line rate Spectral filters	 Silicon, photodiode 48 µm x 48 µm 3,454 1625 lines/s Multi-layer on glass
Imaging performance parameters	
MTF @ Nyquist PAN (41.6 lp/mm)	0.09 (camera geometric mean of in- and cross-track)
SNR (80% scene reflectance, 20% background reflectance, 2.66 mW/cm^2 sr µm, 30º sun angle), PAN (24 TDI stages)	>45
Data quantization	11 bits
Data compression technique	ADPCM, 2.5 bits/pixel

Table 3: Specification of the Model 1000 camera system

Figure 4: Illustration of Kodak's Model 1000 camera system

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1) Information provided by S. Kilston, formerly of Lockheed Martin, Palo Alto, CA

2) Note: Space Imaging acquired EOSAT (a joint venture of Lockheed Martin and Hughes Aircraft) in 1995. The new company was subsequently renamed into: Space Imaging EOSAT. Eventually, it became simply: Space Imaging Inc.

3) http://www.spaceimaging.com/

4) W. Martin, "Satellite image collection optimization," Optical Engineering, Vol. 41, No 9, Sept. 2001, pp.2083-2087

5) H. S. Bowen, "Absolute Radiometric Calibration of the Ikonos Sensor Using Radiometrically Characterized Stellar Sources," Pecora 15/Land Satellite Information IV Conference, ISPRS Commission I Mid-term Symposium/FIEOS (Future Intelligent Earth Observing Satellites), Nov. 10-14, 2002, Denver, CO

6) J. Grodecki, J. Lutes, "Ikonos Geometric Calibration," 2005, http://www.spaceimaging.com/whitepapers_pdfs/2005/IKONOS%20Geometric%20Calibrations%20-%20ASPRS%202005%20_final.pdf

7) Information provided by Michael J. Richardson of Eastman Kodak Company, Rochester, NY

8) "Kodak Introduces 1-Meter-Resolution Remote Sensing Camera In An Off-The-Shelf, Fixed Price Configuration," Kodak press release of July 19, 1999

9) T. Delaney, "Satellite Imagery in Land Development Applications," EOM, Oct. 1999, pp. 47-48

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*This description was provided by **Herbert J. Kramer** from his documentation of: "**Observation of the Earth and Its Environment: Survey of Missions and Sensors**" - comments and corrections to this article are welcomed by the author.*