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Soviet Commercial Space Photography: Offering Resolution as the Solution

A Research Paper

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A Research Paper

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Soviet Commercial Space Photography: Offering Resolution as the Solution

Summary

Information available as of 1 April 1990 was used in this report.

The USSR has been aggressively marketing satellite imagery [1] of the Earth since 1987. The Soyuzkarta trade organization is responsible for marketing film-based products, and Glavkosmos markets other types of remote-sensing imagery, including synthetic aperture radar (SAR) imagery. The Soviets' estimated share of the world market remains small—only 5 to 13 percent. Although Soviet imagery has the highest spatial resolution available commercially (5 meters), its competitiveness in the world market is questionable, due to its technical limitations and Soviet marketing inexperience. The Soviets plan to make modest improvements in spatial resolution and major improvements in spectral resolution of their imagery, but, given present competition and that anticipated in the future, the USSR may have only a short time to establish itself in the marketplace if it is to be a major supplier of commercial satellite imagery

The Soviets, however, are likely to remain in the world market, regardless of the share they obtain. Budget constraints within their space program have forced the Soviets to emphasize space missions with the potential to generate hard currency or improve the national economy. Remote-sensing satellites accomplish both objectives. By marketing imagery, the Soviets generate much-needed hard currency. Imagery also holds the promise of improving Soviet agriculture

The most competitive feature of the Soviet commercial photography is its spatial resolution. None of the USSR's four commercial competitors—the United States, France, Japan, and India—match the Soviets' spatial resolution capability

The appeal of Soviet commercial imagery is reduced, however, by several disadvantages:

- Soyuzkarta's film-based products lack the broader spectral sensitivity obtainable with nonphotographic systems.

[1] The term "imagery" in this paper is used to refer to photography, as well as other recorded pictorial representations of electromagnetic signals emitted by objects. These other representations can be produced by optical, electro-optical, optical mechanical, or electronic means and do not use film as the original detection mechanism for the image

- Limited data handling and computer processing capabilities, software problems, and computer incompatibility problems have impaired the Soviets' ability to supply digital imagery that is required by Western customers. Although Glavkosmos [redacted] has archived digital remote-sensing data from 1984 for sale, the Soviets have not made this historical data available to the West.

- Neither the Mir space station nor Earth resources satellites, which [redacted] carry Soyuzkarta cameras, see the same sun angle on each orbit. This condition is necessary to provide continuity in ground coverage patterns—an important feature for mapping.

- Unlike the US Landsat's Thematic Mapper, Soyuzkarta cameras do not image in the thermal infrared band, and their coverage of the near-infrared band is more limited than that provided by Landsat's Multispectral Scanner. Thermal infrared data applications include change detections and patterns of activity.

- Soyuzkarta film is deorbited with the satellite; therefore, Soviet imagery is not as timely as that of its competitors', which is transmitted electronically.

- SAR data from Cosmos 1870 has been of average quality, with evidence of handsplicing that degrades the images. Despite Soviet claims to the contrary, digital imagery from the satellite has been unavailable, further restricting its utility to Western scientists.

In addition to these inherent disadvantages [redacted] cite other factors, such as dissemination policy, limited photography archives, a poor distribution system, the failure to offer related goods and services, and a rigid pricing structure, as weaknesses in the Soviet offering.

[redacted] the Soviets expect to increase their market share by offering imagery with 2-meter spatial resolution, imagery with greater spectral range and/or resolution, and digital data. The USSR currently has space sensors collecting such imagery. For example:

- Sensors flown on Soviet Earth resources photographic satellites, medium-resolution photographic reconnaissance satellites, photographic/geophysical satellites, and near-real-time imaging satellites can achieve better than 5-meter resolution.

- Sensors flown on Mir, Interkosmos-22, Meteor-Priroda satellites, and Cosmos-1870 can supply greater spectral range or resolution. For example, the spectral resolution of one of these sensors—a 256-channel spectrometer flown on the Mir space station—probably is far better than that currently marketed by Soyuzkarta. Glavkosmos already is marketing radar imagery from Cosmos-1870.

- Glavkosmos states that digital data—albeit of much poorer spatial resolution—is available from Meteor-Priroda and Resurs-O satellites, as well as Cosmos-1870

The USSR also intends to introduce three new Earth resources space systems—the Earth Resources Survey Satellite System, an Earth resources space station module, and the Almaz-series of Earth resources satellites. These systems, which should be launched in the early 1990s, could enhance the Soviets' product line by providing digital data, better spatial and/or spectral resolution, and an all-weather imaging capability

In spite of Soviet claims that they will adhere to their interpretation of the UN Principles on Remote Sensing—an interpretation that condones the sale of imagery only of the customer's own territory—Soviet policy on remote-imagery sales is evolving. Soyuzkarta claims it will sell photography of all countries except the USSR, most Warsaw Pact countries, and a few others. By deviating from its previous position, the USSR has broadened its potential customer base

We estimate that Soviet earnings from satellite imagery sales could increase through the end of the century if world demand—particularly from Third World countries—rises sharply. In addition, the hiatus of US Landsat coverage anticipated by many experts could allow the Soviets to siphon off some US clients. However, because of technical constraints, Moscow will be hard pressed to sign clients who need extremely time-sensitive imagery

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Scope Note

This paper discusses Soviet commercial remote sensing, including what the Soviets are marketing and how viable their product is. Excluded from the discussion are nonimaging Soviet remote-sensing instruments and ocean surveillance satellites used for ice mapping

Soviet Commercial Space Photography: Offering Resolution as the Solution

Introduction

In June 1987, the Soviets unexpectedly entered the world market for commercial satellite imagery and announced that they would sell imagery with a spatial resolution as good as 5 meters—the best spatial resolution available commercially. Australia, Kuwait, Angola, North Korea, Vietnam, East Germany, Syria, and Cape Verde quickly expressed interest in obtaining the photography, according to the Soviet press. Soviet entry into the Earth satellite remote-sensing [1] market required little investment because the cameras supplying the photography previously had been developed for and flown on satellites and space stations already in the Soviet inventory

To promote commercial sales of space photography, the Soviets established a trade organization—Soyuzkarta—under the Council of Ministers' Main Administration for Geodesy and Cartography. Soyuzkarta was formed by joining three existing organizations:

- Kosmokarta—responsible for selling space photographs and for Soviet map production.
- Aerogeodesia—responsible for topography, geodesy, and aerial photography.
- Geodespribor—responsible for selling technology, licenses, and equipment

Glavkosmos, the focal point for Soviet civil and commercial space products and services, entered the satellite remote-sensing imagery market in 1988. Soyuzkarta sells film-based products, whereas Glavkosmos sells digital data, including electro-optical and synthetic aperture radar (SAR) imagery (see inset).

We believe that the Soviets entered the commercial remote-sensing data market primarily for one reason—economic opportunity. They probably expect to gain a foothold in the market, which many people believe has a strong growth potential because of an ever-increasing number of remote-sensing applications. In addition, we believe that the Soviets may view the sale of space photography as a way to earn hard currency and to gain access to other commercial markets within a country

The USSR also may have entered the remote-sensing market to gain influence among lesser developed countries that have no remote-sensing capability. The imagery could be used to respond to non-time-sensitive military intelligence tasks involving broad area searches to detect bridges, roads, large ships, and medium-to-large aircraft on the ground.[2] Submarine identification, assessments of airfield serviceability, and detection of force readiness changes, however, cannot be made on the basis of such low-resolution photography

Soviet Film-Based Imaging Systems Providing Soyuzkarta Photography

Soyuzkarta is marketing photography from four cameras—the MKF-6, Kate-140, Kate-200, and KFA-1000 (see table 1). The MKF-6 and Kate-140 cameras are carried on multifunctional manned space stations. Military-controlled, modified Earth resources-photographic satellites (ERPHO-Bs) carry the KFA-1000 and probably the Kate-200 cameras.

[1] Remote-sensing techniques are used for remote acquisition and subsequent processing of information about the properties of electromagnetic waves emitted, reflected, or scattered by an object. Remote-sensing data are used in the military and civilian sectors. Governments, private organizations, and individuals acquire unclassified remote-sensing data for commercial/scientific/environmental/land use applications. Governments also acquire imagery from space to identify and monitor military and other objects or areas of strategic or tactical national security concern. Such data are usually classified, although sometimes intelligence can be derived from unclassified remote-sensing data

[2] No well-defined boundary exists between imagery that is useful and imagery that is not useful for intelligence purposes. Generally, the greater the spatial and/or spectral resolution and the more timely the receipt of the imagery, the more its potential intelligence application. Virtually all imagery, no matter how old or poor in resolution, has some intelligence value. For example, the construction of large missile test ranges can be detected even on poor quality civil satellite imagery, and, because the construction cycle of such a facility is measured in terms of years, old imagery may be useful if newer imagery is unavailable

The Roles of Soyuzkarta and Glavkosmos

Soyuzkarta is a Soviet foreign trade organization established in 1987 to market Soviet space photography. The organization is subordinate to the Council of Main Administration for Geodesy and Cartography. Soyuzkarta primarily markets film-based product:

The Soviet Main Administration for the Development and Use of Space Technology for the National Economy and Scientific Research (Glavkosmos) was founded in 1985 to facilitate international cooperation in the Soviet space program and the commercialization of Soviet launch services. Glavkosmos entered the digital imagery market in 198E.

Soyuzkarta and Glavkosmos have competed for the same customers in the past, creating tensions within the organizations

Glavkosmos is prohibited from entering into independent trade agreements to market imagery abroad, and Soyuzkarta is the sole Soviet entity authorized to sell or distribute imagery

In spite of these changes, Soyuzkarta still has primary marketing responsibility for film-based products, and Glavkosmos is responsible for digital products.

Advantages of Film-Based Imaging Systems

The most competitive feature of Soyuzkarta photography is its spatial resolution. Photographic systems offer a high degree of spatial detail and geometric integrity and require relatively little sophistication and expens nalysis indicates that the resolution of KFA-1000 photography is a nominal 5 meters—as good as the Soviets claim. The other four commercial competitors in the market currently cannot match this resolution. The thematic mapper (TM) on the US Landsat provides 30-meter resolution imagery. The French *Systeme Probatoire d'Observation de la Terre* (SPOT) satellite provides 10-meter resolution panchromatic imagery. The Japanese Marine Observation Satellite (MOS) and the Indian Remote-Sensing Satellite (IRS) acquire imagery with nominal 50- and 36-meter resolutions, respectively.

Limitations of Film-Based Imaging Systems

Soyuzkarta film-based imagery, however, also has several important limitations when compared to its digital data competitors.[4] For example, its photographic system lacks the broader spectral sensitivity obtainable with nonphotographic systems. (Film generally is not sensitive to wavelengths longer than about 1 micrometer.) Because spectral band options with film are highly limited, it is often impossible to accurately record the energy reflected or emitted from the Earth. For applications where spectral patterns are highly informative, digital data, as opposed to photography, are preferred

For some applications film must be digitized, which degrades the resulting product. Although Soyuzkarta sells film, the resulting digital data is limited to the information content of the film

The requirement to resupply and retrieve film further limits photographic systems. Before photography can be exploited, film must be deorbited from space, transported to a processing center, developed, and disseminated. Therefore, receipt of imagery from cameras providing Soyuzkarta photography is not as convenient or timely as electronically down-linked data from Landsat, SPOT, MOS, or IRS. Even during crises, film from the KFA-1,000 and Kate-200 has never been retrieved before the third day of the mission. These cameras fly on unmanned ERPHO satellites that normally deorbit film buckets at the end

Table 1
Cameras Currently Providing Soyuzkarta Photography

	KFA-1000	MKF-6	KATE-200	KATE-140
[redacted]				
Advertised spatial resolution (*meters*)	5 to 10	20	15 to 30	60
Focal length (*millimeters*)	1,013	125	200	140
Format (*centimeters*)	30 by 30	56 by 81	18 by 18	18 by 18
Coverage (*kilometers*)	60 by 60	140 by 200	180 by 180	270 by 270
Scale	1:200,000	1:250,000	1:1,000,000	1:1,500,000
Stereo capability	Yes (60-percent overlap)	Yes (20-, 60-, or 80-percent overlap)	Yes (60-percent overlap)	Yes (20-, 60-, or 80-percent overlap)
Platform used	ERPHO-B	Soyuz-22; Salyut 6 and 7	Probably ERPHO-B	Salyut 4, 6, and 7; Mir
[redacted]				
Nominal orbit (*kilometers*)	250 near circular	250 to 280 for Soyuz-22; 320 to 350 near circular for space stations	250 near circular	320 to 350 near circular
Comments	Three-camera panchromatic array built in the USSR; uses either panchromatic film or two-emulsion film (one green band and one near-infrared band)	Array of six film cameras in a common mount; made by Zeiss of East Germany	Array of three film cameras built in USSR	Metric camera; built in USSR

Note [redacted] the Soviets are "declassifying" photography from the MK-4 camera so that it also can be marketed. The MK-4 senses the following spectrum regions: 400 to 700 nanometers, 460 to 505 nanometers, 515 to 565 nanometers, 580 to 800 nanometers, 635 to 690 nanometers, and 810 to 900 nanometers. It uses either panchromatic or two-emulsion film, has a 300-mm focal length, and has a 180-by-180-mm frame format. It provides 60-percent overlap stereo capability and 5- to 8-meter resolution photography at a scale of 1 – 650,000 to 1 – 1,500,000, depending on the orbital altitude flown. Swath width of the area covered varies from 120 to 270 km, also depending on orbital altitude [redacted].

of 14- to 30-day missions. In addition, film buckets have been deorbited a single time during the mission of a few ERPHOs

Film from the Kate-140 and MKF-6 cameras, which are carried on space stations, is retrieved on an even less timely basis. Soviet Progress and Soyuz TM (transport modified) vehicles resupply film for these cameras when they ferry cosmonauts to space stations. After weeks to months in orbit, film is retrieved from these stations by returning Soyuz TM.

Orbital Limitations. Soyuzkarta cameras operate in satellite orbits that are not as advantageous for remote sensing as are the sun-synchronous orbits of competitors' spacecraft (see inset). The effectiveness of cameras in optical bands is dependent on solar illumination. The orbits in which Soyuzkarta cameras operate result in changing sun angles and elevations for different passes

Unlike the French SPOT and US Landsat cameras, Soyuzkarta cameras do not provide complete coverage between the polar regions. This limitation is the result of the cameras' inability to view off nadir, the sensors' swath width, and orbital limitations. (SPOT, for example, can image 27 degrees off nadir.

Spectral Coverage. The Soviets presently are marketing photographs that are more limited in spectral coverage than photographs taken by the United States. Unlike the US Landsat system, current Soyuzkarta cameras do not operate in the thermal infrared (from 7 to 15 micrometers) (see figure 1). The Landsat thermal infrared band is used in vegetation monitoring, soil moisture discrimination, and thermal mapping application:

Soyuzkarta cameras also are more limited in their coverage of the near-infrared band (from 0.7 to 2 or 3 micrometers) than US Landsat sensors. Some remote-sensing specialists believe that imagery from 0.76 to 1.05 micrometers within the near-infrared band is essential for an Earth-sensing system. Soyuzkarta sensors only partially cover this range (0.7 to 0.9 micrometers). The near-infrared band gives a high response to growing vegetation and clearly delineates water boundaries. Cameras operating in this band also can record through atmospheric obscurations such as haze, smoke, and thin clouds

Sun-Synchronous Orbits

For remote sensing of the Earth in the visible range of the spectrum, a sun-synchronous circular orbit offers many attractive features. A satellite in sun-synchronous orbit always crosses the Equator and other points along its ground trace at approximately the same local sun time each day. (Orbital perturbations cause the crossing times to vary slightly.) This orbit ensures repeatable sun illumination conditions within a season—conditions desirable when mosaics of adjacent tracks of imagery are created to compare annual changes in land cover. Sun-synchronous orbits, however, do not compensate for changing solar azimuth, altitude, intensity, and variations in atmospheric condition:

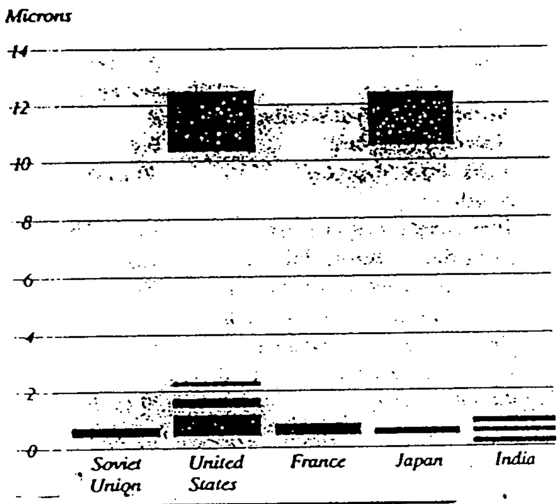
Data Handling and Digital Processing Shortcomings. Soviet remote sensors currently have limited data handling and computer processing capabilities. These limitations may explain why the Soviets entered the commercial market with only film-based products

Although the Soviets have less capable computers than the United States, their computers probably can be linked to provide a ground-based processing capability required for some remote-sensing imagery. We believe, however, that the number of computers available for such a link forces the Soviets to carefully prioritize their use. Therefore, the commercial processing of remote-sensing imagery probably suffers because military/intelligence requirements are assigned higher priority

Expansion of the Soviet Product Line

The Soviets reportedly are increasing their customer base by selling Resurs-O and Met-P imagery through Glavkosmos. Although imagery from Resurs-O and

Figure 1
Spectral Coverage of Operational Commercial Remote-Sensing Satellites



Met-P sensors has nowhere near the 5-meter spatial resolution now marketed by Soyuzkarta, it does have two important advantages. First, Resurs-Os and some Met-Ps have flown in sun-synchronous orbits, which are more conducive to remote sensing than either the Mir or ERPHO orbits. Second, Resurs-O and Met-P carry electro-optical sensors, so their imagery would have greater appeal to customers preferring to work with non-film-based data. Furthermore, data transmitted from Resurs-O could respond to the time-sensitive needs of customers. The Soviets also could establish ground sites and processing centers outside the USSR for even more timely distributior

The marketing of Resurs-O and/or Met-P imagery would expand the spectral range of Soviet remote-sensing products. Present Soyuzkarta cameras only sense wavelengths as long as 0.9 micrometers; Met-P and Resurs-O imaging sensors—with the exception of the MSU-2—image up to at least 1 micrometer. The Fragment device that flew on Meteor Priroda 1/30 sensed in three bands between 1.2 and 2.4 micrometers, and a modified MSU-SK (also flown on Meteor Priroda 1/30) sensed in the thermal infrared.

In addition to the MKF-6 camera, the Soviets have placed a variety of remote-sensing instruments on manned platforms. Our knowledge of these instruments is limited, and, in many cases, we cannot judge whether they are imaging sensors. Instruments that most likely image include:

- The FARA instrument, which flew on Salyut 4, 6, and 7. This instrument is cryogenically cooled (which implies it is used to detect infrared radiation), senses in two bands, and can operate using either of two fields of view.
- The Bulgarian-designed Spektr-15 spectrometer—a hand-held spectrometer used on Salyut 6 and 7 to collect Earth resources data. The spectrometer is sensitive to radiation in 15 spectral bands between 0.4 and 0.9 micrometer. Scanning is performed electronically, and the detector output is recorded digitally on magnetic tape. Its swath width is not known

Second-generation Okean (Okean-O) satellites have carried or carry imaging sensors. These satellites, however, primarily are used to map sea ice and, therefore, are not discussed further in this paper

The SMP-32, a Bulgarian-built programmable spectrometer, was launched on Interkosmos 22 and on Meteor-Priroda 1/31 in 1981. According to Soviet claims, it operated in 32 bands, each spaced at almost equal intervals ranging from 0.45 to 0.9 micrometer. Scanning could be performed at the rate of 40 channels per second; and data could be transmitted in real time. We do not know the spectrometer's spatial or spectral resolution, and we have no indication if it has been carried on other satellites.

The Soviets already have begun marketing radar imagery (see figure 2) from Cosmos-1870, a Salyut-size spacecraft that was launched in July 1987 on a

Figure 2. Cosmos-1870 synthetic aperture radar image of Puget Sound area in the state of Washington

Earth remote-sensing mission. During its two years in orbit, Cosmos-1870 primarily conducted geophysical, cartographic, earth resources, and environmental research. Although Cosmos-1870 carried numerous sensors, including multispectral, infrared, and visible light detectors, the Soviets indicate that they are willing to sell imagery only from the onboard SAR (see inset). [redacted] the Soviets

Cosmos-1870 Synthetic Aperture Radar and Imagery Characteristics

Antennas	
Number	*2*
Dimensions (meters)	*15 by 1.5 (each)*
Type	*Slotted waveguide*
Beamwidth elevation (degrees)	*4*
Azimuth (degrees)	*0.4*
Look angle (degrees)	*30 to 60*
Transmitter	
Wavelength (centimeters)	*10 (3 GHz)*
Peak output power (kilowatts)	*250*
Average output power (watts)	*80*
Pulse duration (microseconds)	*0.1*
Pulse repetition frequency (pulses per second)	*3,000*
Resolution (meters)	*20 to 30 (range and azimuth)*
Imagery swath width (km)	*20 to 30*
Commercial data format	*Hardcopy and digital*

recently signed an agreement [redacted] to use Cosmos-1870 imagery for oil exploration in the USSR

Other Soviet Imaging Systems With Commercial Potential

[redacted] imagery from a 256-band visible and infrared wavelength spectrometer (of unknown spatial and spectral resolution) on the Mir space station will be for sale in the future. According to the Soviet press, the spectrometer, which was designed by the Bulgarian Academy of Sciences and installed on the Mir space station in 1988, will study optical characteristics of the Earth's atmosphere and its pollution. If the Soviets market this imagery, Soyuzkarta could attract additional customers whose applications require an assessment of the type, and/or condition, of features that are impossible to identify at lower spectral resolutions

[redacted] the Soviets intend to market 2-meter resolution imagery. [redacted] no details concerning which sensors will provide this imagery or the orbit or platform on which the sensors are or may be placed. ERPHO-Bs, MEDRESs, PHOTOGEOs, and IMSATs are candidate satellites for providing this imagery. All are operational platforms controlled by the military. Alternatively, a [redacted] the USSR is preparing a new satellite from which they will acquire 2-meter resolution imagery

If a currently operational satellite is used to supply commercial 2-meter resolution imagery, we believe the IMSAT is the least likely candidate. Although IMSAT currently is the only Soviet system capable of providing digital imagery at this spatial resolution, the fact that it is the Soviets' newest military imaging satellite probably will preclude its commercial use. The Soviets probably believe that the release of imagery from this system could provide insight into the limitations of their military reconnaissance capability.

The Soviets have flown a variety of electro-optical imagers on their Meteor-Priroda (Met-P) satellites and on a more recent series of satellites called Resurs-O (see tables 2 and 3). Although the Met-P satellites have served as test beds for experimental sensors, the Soviets have declared at least two of these scanners operational—the low-resolution MSU-M and the medium-resolution MSU-S

Future Sensors and Platforms

[redacted] Soviet press accounts, and [redacted] indicate that the Soviets intend to introduce three additional space systems, each with the primary purpose of acquiring Earth resources information. The marketing of imagery from any of these systems could significantly enhance the Soyuzkarta product line.

One system—the Earth Resources Survey Satellite System (SSIPR)—will provide electronically transmitted data that probably will be of higher fidelity than the digitized film data now available through Soyuzkarta [redacted] SSIPR's main instruments will be "high-resolution multizonal optomechanical scanners." Other information [redacted] indicates the SSIPR system will consist of two satellites in sun-synchronous orbits. On the basis of the announced orbital parameters, each satellite will repeat its ground trace about every 13 days; therefore, a given spot on Earth could be covered about once a week. [redacted] SSIPR will down-link data to Eastern Europe, Cuba, Mongolia, and Vietnam. SSIPR probably will function in a store-dump mode, as no present Soviet data-relay satellite or future ones filed with the IFRB can handle the 8.025 to 8.4 gigahertz (GHz) frequency [redacted] We do not know when SSIPR, under development since at least the early 1980s, will be launched. Soviet statements in 1989 hinted strongly that a satellite matching the SSIPR description would be launched in 1992 under the Resurs-O program

A second system is the Earth resources space station module, which the Soviets plan to dock to their Mir space station in the next two to three years. If marketed, S-band radar imagery from this platform:

- Would be in a microwave range of the electromagnetic spectrum not presently marketed by Soyuzkarta.
- Could be obtained in all kinds of weather because clouds, fog, and precipitation have little effect on microwaves.
- Could be obtained at any time of the night or day because radar sensors provide their own illumination

Table 2
Other Soviet Space-Based, Remote-Sensing Imaging Systems With Commercial Potential [a]

	Fragment	MSU-1	MSU-2	MSU-E	MSU-S	MSU-SK	MSU-M
Resolution (*at nadir*)	80 meters; 240 meters, and 480 meters across track and in track, respectively, depending on the wavelength (the longer the wavelength, the worse the resolution)	30 meters across track and in track	34 meters in track; 46 meters across track	28 meters across track and in track or 68 meters in track (see comment)	140 meters in track and 240 meters across track [f]	243 meters in track and 175 meters across track; also reported as 140 meters in track and 175 meters across track	1,700 meters in track and 1,000 meters across track [f]
Coverage	88 km (in channels 1-5)	30 km	46 km	28 km to as much as 100 km [g]	2,000 or 1,380 km [g]	600 km	3,000 or 1,930 km [g]
Data transmission	Digital	Unknown	Unknown	Digital	Analog	Digital	Analog
Type of sensor	Optical-mechanical	Unknown	Unknown	Electro-optical	Optical-mechanical	Optical-mechanical	Optical-mechanical
Platform on which flown	Meteor-Priroda 1/30	Unknown	Unknown	Meteor-Priroda 1/30 and Resurs-O	Meteor-Priroda 1/18, 1/25, 1/30, 1/31, and Cosmos-1689	Meteor-Priroda 1/30 and Cosmos-1689	Meteor-Priroda 1/18, 1/25, 1/30, 1/31, and Cosmos-1500-type oceanographic satellites

Table 2 (continued)

	Fragment	MSU-1	MSU-2	MSU-E	MSU-S	MSU-SK	MSU-M
Orbital parameters	650-km nominal altitude	650-km nominal altitude	650-km nominal altitude	650-km nominal altitude	... [h, i]	Retrograde, near-circular orbit with nominal 650-km altitude [i]	... [h, i]
Comments	Built by Zeiss; data received in real time only; data collected in four to six of the spectral bands could be transmitted simultaneously at 3.84 megabits per second			Two MSU-E scanners operating simultaneously with an overlapping field of view extends the band of coverage to 80 km, and the resolution is degraded to 68 meters; data received in real time only; along with the MSU-SK, comprises the the BIK-E system	Along with the MSU-M, comprises the radio television complex (RTVK) that the USSR declared operational in 1977; used for hydrology, shipping, geodesy, and forestry; images from the MSU-S are photographically recorded; data can be transmitted in real time or stored and later dumped	A modification of this scanner flew with a fifth channel [ ] in the thermal infrared; data received in real time only; used to sense surface phenomena over water; part of the BIK-E system	Images from the MSU-M are photographically recorded; data are recorded and down-linked in real time when spacecraft is within sight of ground receiving station; part of the RTVK system; used for hydrology, shipping, geodesy, and forestry

[a] Excluding those with exclusively a meteorological application.
[b] Also reported as 0.8 micrometer.
[c] Also reported as 0.7 micrometer.
[d] Also reported as 0.58 micrometer.
[e] Also reported as 0.8 micrometer.
[f] The resolution at either of the two altitudes was approximately the same at nadir. However, the resolution near imagery edges markedly degraded.
[g] The greater coverage was from a higher orbit; the smaller coverage was from a lower orbit.
[h] The first two Meteor-Priroda satellites (Meteor-Priroda 1/18 and 1/25) were placed in near-circular, 890-km, 103-minute orbits inclined 81 degrees.
[i] Beginning with the third Meteor-Priroda (Meteor-Priroda 1/28), which was launched in 1977, the Meteor-Priroda satellites were placed in retrograde, near-circular, nominal 650-km, nearly sun-synchronous orbits inclined 98 degrees with periods of 97 to 98 minutes.

According to the Soviet media, the module being developed by the USSR and Czechoslovakia will carry television equipment, instruments for studying outer space, and an X-ray telescope. The module probably is part of, or could be, the Soviet's international space project "Priroda" (nature). According to 1987 information [ ] the joint project is to be conducted between 1990 and 1995 with Bulgaria, Czechoslovakia, Poland, and East Germany. [ ] the project will develop technologies in the visible to microwave regions of the spectrum for

Table 3
Meteor-Priroda Remote-Sensing Satellites

	Satellite Launch Date	Near-Circular Orbital Altitude (Nominal) (*kilometers*)	Orbital Inclination (*degrees*)	Approximate Number of Days Required for One Complete Ground Track Cycle
Meteor 1/18	9 Jul 74	890	81	25
Meteor 1/25	15 May 76	890	81	25
Meteor 1/28	29 Jun 77	650	98	26
Meteor 1/29	25 Jan 78	650	98	26
Meteor 1/30	18 Jun 80	650	98	26
Meteor 1/31	10 Jul 81	650	98	26

remote sensing of the Earth's biosphere. Part of project Priroda involves the placement of a variety of sensors on a Mir module, including a television system and an S-band side-looking SAR.

A third system that the Soviets hope to use is the Cosmos-1870 follow-on series—referred to by the Soviets as the Almaz series. The Soviets [redacted] will launch a preoperational satellite in July 1990 and already have approached the French with requests for onboard sensors. The second satellite in the series will be launched in 1993 or 1994. According to their recent statements, the Soviets want to market a wide variety of imagery from future Almaz flights.

Future Almaz satellites [redacted] will be in 500-km, 72-degree-inclination orbits. Each satellite will carry a SAR with a 15-meter resolution, a multichannel microwave radiometer operating at between 6 and 37.5 GHz, and optical sensors. The satellites will perform both digital data recording and processing.

Present Marketing Policy

[redacted] indicate that the USSR will adhere to the UN principles (see inset) on remote sensing. Soviet interpretation of these principles, however, is not consistent with US interpretation or with the US practice of free and open data dissemination of unclassified space imagery for peaceful purposes. In January 1988, the Soviet newspaper *Trud* stated that, to avoid breaches of military security, the USSR would sell space photography taken only of a customer's own territory. A March 1988 Soviet broadcast stated that, ". . . the USSR supplies only pictures of the country from where the order comes."

[redacted] suggests that Soviet policy is evolving. [redacted] that they would sell imagery of all

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UN Principles on Remote Sensing

The UN principles on remote sensing state that such activity should not be conducted in a manner detrimental to the legitimate rights and interests of the sensed state. Although the principles do not directly address the sale of imagery to a country other than the sensed state, they basically reaffirm the policy that a state engaging in remote sensing need not obtain prior consent of states being remotely sensed either to conduct the sensing or to disseminate the result—even to a third countr

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countries except the USSR, Soviet Bloc countries, China, Cuba, Nicaragua, and Vietnam.[3] Marketplace realities, however, might force Soviet officials to reevaluate this policy if they believe it severely limits sales

Soyuzkarta literature indicates that its policy prohibits the sale or transfer of imagery to a third party without prior written consent of the country photographed. An unsigned Soyuzkarta contract obtained in 1987 states that photography of a customer's country should be sold only to that customer.

Soyuzkarta policy governing the duplication of its imagery is less clear. The 1987 contract indicates that the customer has the right to use Soyuzkarta imagery at his own discretion. However, a Soyuzkarta price list effective 1 January 1988 states that, "The customer has no right to copy documents bought from Soyuzkarta." More recently, the head of Soyuzkarta said that reproduction for "in-house" use was acceptable; reproduction for sale was not.

Table 4
Several Western Distributors of Soviet Remote-Sensing Data

	Location	Area of Responsibility
[redacted]	Australia	Southeast Asia, Pacific, and Middle East
	Finland	Western Europe
	Brazil	South America
	Japan	Japan
	United States	All countries in the Western Hemisphere, excluding Nicaragua, Cuba, Argentina, Peru, and Brazil

The USSR's Viability as a Contender in the Market

Although the Soviets have been marketing space imagery for three years, their future viability as a competitor remains questionable. Consumer response has been minimal, despite Soviet claims to the contrary. The Soviets must overcome numerous technical problems and improve their marketing skills if they want sales to improve. The Soviets also will face increasing competition in the 1990s as additional countries enter the space imagery market. In spite of these problems, we believe the Soviets will continue to market their imagery in hopes of generating much-needed hard currency

Consumer Response

[redacted] consumer response to Soviet imagery has been lackluster to date. [redacted] that the Soviets have been unable to penetrate the North and South American space photography markets. As of mid-December 1989, the Soviet [redacted] had sold only 100 scenes of KFA-1000 and MK-4 photography in North America, considerably below Soviet expectations. Customers have been turned off by the Soviets' failure to provide current imagery catalogues, poor responsiveness to customer inquiries, and unannounced price increases.

The Soviets, however, have made some inroads in the international space imagery market. We estimate that they have generated $5-8 million in business since mid-1987—an estimated 5 to 13 percent of the worldwide imagery trade [redacted]

[redacted] requests for imagery of the USSR should be made to the Soviet Academy of Sciences. We know of no sales of imagery of Soviet Bloc countries with the exception of Poland. Soyuzkarta [redacted] is willing to sell imagery of Poland because they have permission from that country to do so.

According to available information, Moscow has had three large-scale orders to date:

- [redacted] that the Brazilian National Institute of Coffee placed a $1 million order for photographic coverage of 100,000 square km of agricultural land in the Amazon highlands.
- [redacted]
- According to the Soviet press, China has purchased more than 600 photos of Chinese territory and has requested additional coverage

The Appeal of Soyuzkarta Photography

For cartographic applications, 5-meter resolution imagery is most valuable. As more potential customers become aware of the applications for 5-meter resolution imagery, however, we expect the demand for it—and even higher resolution—to increase

Another potential user of 5-meter resolution imagery is the news media, which requires imagery containing scenes or objects visually recognizable by the public. According to a Western industry expert, imagery with 3- to 5-meter resolution would be required for news media purposes. Moscow's dissemination and copyright policies severely limit media use. If the Soviets were to significantly shorten the turnaround time from when raw data is acquired by the orbiting sensor to the time imagery is available to the ultimate consumer, their product would be more attractive to the news network

Obstacles in Moscow's Path

Despite its marketing campaign, Moscow faces problems that probably will hamper its ability to expand sales of remote-sensing data, particularly to Western customers. Some factors inhibiting sales include:

- The Soviet policy of denying dissemination of all imagery to third parties could restrict the number of sales, particularly when "value-added" services, such as processing, analysis, interpretation, and integration with additional data, are performed almost exclusively in the West.
- [redacted] Soviet archives of imagery are limited and cannot be used to quickly satisfy large-scale requests. Indices of KFA-1000 and Kate-200 photography indicate that 1986 photography from those sensors is the oldest data archived.
- [redacted] Soviet space photography—despite high resolution—is of poor quality. Photos seen by potential clients have been marred by scratches and poor processing. In addition, recent SAR data from Cosmos-1870 apparently was spliced together by hand, which would greatly hinder high-volume production of commercial imagery.

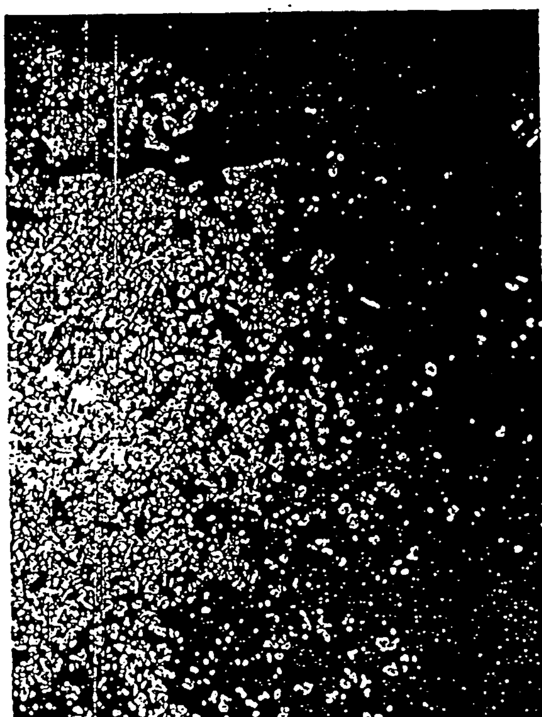

Figure 3. KFA-1000 photography of Kent County, England

- [redacted] the exposure intensity falls off from the center to the edge of the frames of Soyuzkarta photography (see figure 3). The imagery, therefore, has little use if radiometric data are needed.

- The time between data acquisition and customer delivery puts the Soviets at a disadvantage with other imagery providers, because many commercial customers demand timely delivery of data. [redacted] customers requiring timely data delivery will account for a growing share of the remote-sensing market in coming years.

- The Soyuzkarta distribution system is not as extensive or convenient as those for Landsat and SPOT. [redacted] some Soyuzkarta distributors are allowed to market Soyuzkarta products only of their respective geographical regions.

- For some remote-sensing applications, non-film-based imagery is preferable to film-based photography [redacted] an increasingly sophisticated user market has been drawn to the flexibility of digital media. These officials say 60 percent of their customers by count and 70 percent by revenue want their data on digital computer-compatible tapes.

- Soviet failure to offer a full complement of related goods and services has dampened interest in Soviet remote-sensing products [redacted] Limited, in part, by inadequate computer processing, the Soviets have not entered the market for value-added services, and they do not sell image-processing equipment. [redacted] also indicate that a customer requesting a computer-compatible tape (CCT) of data, rather than a contact print or piece of film, must supply the CCT.

- The Soyuzkarta pricing structure provides few options to customers [redacted] the customer cannot choose the level of image processing desired, buy data with unrestricted copy privileges, or request the option of along-track shifting. (Along-track shifting allows the customer's specific point of interest to be shifted to the center of the image, eliminating the need to buy two or three adjacent scenes.

The Health of Moscow's Competitors

At present, Moscow competes with a small number of remote-sensing suppliers (see table 5). The USSR's main rival is France, whose SPOT system made a splash in the industry in 1986 with its offering of 10-meter resolution imagery. In 1987, the firm SPOT Image sold about $23 million worth of satellite imagery, nearly 60 percent of the total commercial imagery trade. Industry experts attribute SPOT's success to its ability to provide timely data in a readily usable form to customers throughout the world [redacted] prospects for SPOT's success in the remote-sensing market remain good because of its responsiveness to clients' needs and its extensive network of ground stations

SPOT's share of the world market will fluctuate in response to changing customer demands. For example, in 1987, the media was exploiting SPOT capabilities to cover sensitive areas, such as Krasnoyarsk and Vladivostok. However, with the drought and subsequent crop losses in 1988, the Landsat infrared capability to monitor crop health (which SPOT lacks) boosted Landsat sales at the expense of SPOT sales.

How long Landsat data—now handled by the Earth Observation Satellite Company (EOSAT)—will be able to maintain its market share is unclear. A gap in coverage is anticipated because of the hiatus between the termination of Landsat-4 and Landsat-5 and the launch of Landsat-6, scheduled for the early 1990s. Neither EOSAT nor other US aerospace companies plan to launch a civilian remote-sensing instrument in the foreseeable future with a resolution that equals or exceeds Soyuzkarta's resolution

Moscow may have only a short time to establish itself in the market before competition heats up. By the end of this century, the list of nations with civilian imaging systems in space will at least double (see table 5). In March 1988, an Indian remote-sensing satellite was launched by the USSR. Although New Delhi officials indicate imagery is collected primarily for domestic purposes, some imagery is available for

Table 5
Competitors in the Remote-Sensing Market

	Type of Imaging System	Coverage	Timeliness	Resolution (*meters*)	Status
United States					
Landsat	Multispectral scanner	Worldwide	Near real time	80	In operation since 1972; Landsat-4 and -5 are working beyond their design lifetime
	Thermatic mapper	Worldwide	Near real time	30	
France					
SPOT	Multispectral scanner	Worldwide	Near real time	20	In operation since 1986; SPOT-2 launched 21 January 1990
	Panchromatic camera	Worldwide	Near real time	10	
Japan					
Marine Observation Satellite	Multispectral scanner	Worldwide	Near real time	50	In operation since 1987
Earth Resources Satellite	Multispectral scanner	Worldwide	Near real time	18	Scheduled for first launch in 1993
	Synthetic aperture radar	Worldwide	Near real time	18	
India					
Indian Remote-Sensing Satellite	Multispectral scanner	Worldwide	Near real time	36	In operation since 1988
USSR					
Modified Earth Resources Satellite	Photographic	Up to 82 degrees latitude	Film return up to 30 days	5-30	Commercial imagery since 1987
Resurs-O	Multispectral scanner	Worldwide	Near real time	30	In operation since 1985
Space Station	Photographic	Up to 52 degrees latitude	Film return	20-60	Commercial imagery since 1987
Canada					
Radarsat	Synthetic aperture radar	Worldwide	Near real time	40	Scheduled for launch in 1994
European Space Agency					
European Remote Sensing	Synthetic aperture radar	Worldwide	Near real time	25	Scheduled for launch in the early 1990s
Indonesia and the Netherlands					
Tropical Earth Resources Satellite	Multispectral scanner	Up to 10 degrees latitude	Near real time	20	Scheduled for launch in the late 1990s
China and Brazil					
	Multispectral scanner	Worldwide	Near real time	19	Scheduled for launch in mid-1990s

sale. Japan also sells remote-sensing data from i
Marine Observation Satellites. In the 1990s, Ja
plans to launch the Japanese Earth Resources S
lite with a SAR and visual scanners with 18-me
resolution. In addition, Canada and the Europe
Space Agency plan to launch SAR remote-sensi
satellites by the mid-1990s. Indonesia and the N
erlands, as well as China and Brazil, are planni
launch joint remote-sensing satellites. Italy, Sw
and the United Kingdom are considering orbiti
remote-sensing satellites

Implications for the United States

We estimate that Soviet earnings from remote-sensing services could increase through the end of the 1990s if world demand—possibly fueled by new applications—rises sharply. We estimate that:

- Third World nations will account for much of future Soviet sales.
- The longer the hiatus in Landsat coverage, the greater the opportunity for the USSR to siphon off some US clients. Because of technical constraints, however, Moscow will be hard pressed to sign clients who require extremely time-sensitive imagery.

Although the United States has consistently supported nondiscriminatory dissemination of remote-sensing data, the challenge of international competition could pit US commercial remote-sensing companies that want to acquire and sell higher resolution data against the US State Department or US Department of Defense. A 1984 remote-sensing law requires US companies that launch remote-sensing satellites to obtain a license from the US Commerce Department stipulating that the operator agrees to protect the national security of the United States. This law grants the Secretaries of State and Defense veto power over remote-sensing license applications when national security or foreign policy issues are involved. Some US companies argue that this veto power imposes excessive restrictions on them at a time when the remote-sensing business is about to boom.[4]

[4] Although the United States removed its restriction on licensing US civilian remote-sensing satellites that provide imagery with a resolution no better than 10 meters, it did not revoke the 1984 licensing law

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Appendix

A History of Soviet Remote-Sensing Policies

The USSR has been concerned about military and economic spying from outer space since the late 1950s. Early on, it denounced all reconnaissance programs as space espionage and, hence, illegal under international law. During the early 1960s, Moscow attempted to include a ban on observations from outer space in a UN General Assembly resolution. The Soviets eventually dropped this demand for a ban in order to reach agreements on the 1963 UN Declaration of Principles Governing the Use of Outer Space and the 1967 Outer Space Treaty

Soviet opposition to satellite photography increased with the United States' offer to share remote-sensing data with the world community in 1969. In 1970, the United States proposed to the UN General Assembly that UN members join in studying the data received by remote sensing. The USSR argued that the US proposal would legitimatize the photographing of foreign territory under the guise of developing methods to detect Earth resources, making it easier to carry out military reconnaissance. The Soviets demanded that no remote sensing be undertaken without prior notification to and approval by the country to be imaged and that access to remote-sensing data be controlled by international regulations. In 1971, a UN committee was established to debate the legal implications of remote sensing of the Earth, with the intention of concluding an international agreement.

The Soviet position changed in 1972, however, following the launch of the first US remote-sensing satellite, favorable world reaction to it, and the signing of the SALT I agreements. Moreover, the USSR began to develop its own remote-sensing systems. By the terms of SALT I, Moscow recognized the legality of some satellite reconnaissance activities when it agreed that "each party shall use national technical means of verification at its disposal in a manner consistent with the generally recognized principles of international law." At this time, the Soviets shifted their focus from demanding prior notification and consent of the country to be photographed to attempts to restrict the dissemination of remote-sensing data

Moscow's concept of national sovereignty had a direct bearing on its position on international dissemination of remote-sensing data and was reflected in the proposals it made in the UN to restrict such dissemination. The Soviets claimed that a state has full sovereignty over the natural resources located within its territory, that information about these resources has a value and belongs to the possessing state, and that this information cannot be transferred to another state without permission of the possessing state. Moscow's position was that any dissemination of information to third parties on Soviet natural resources could have military or economic significance, thereby violating their national sovereignty and interfering with internal affairs. The Soviets also claimed the right to counter satellites conducting reconnaissance over their territory, which was not required for verification of the SALT agreements

The Soviets made several proposals to control the dissemination of remote-sensing data. One proposal would have given Moscow veto power over release of unprocessed data on the USSR coming directly from a satellite to third parties. Another proposal would have classified remote-sensing data as global, regional, or local. Only global and regional data would be released without consent, protecting data of higher resolution on the USSR. A third proposal would have limited the dissemination of data of better than 50-meter resolution without prior consent of the country imaged

As Soviet systems developed to the point that Moscow could offer other nations remote-sensing information to develop their resources, the Soviets concluded several bilateral agreements. In May 1978, the USSR and its East European allies signed a remote-sensing cooperative agreement based on the 50-meter resolution limit for data dissemination and requiring prior consent for dissemination. The constraints on dissemination of Soviet imagery also applied to information derived from the Soviets' remote-sensing data. This information was broadly defined as the "end-product of the analytical process" of exploiting these data and potentially included any book or article that made even slight use of satellite imagery. The Soviets probably expected this agreement to serve as a model for international restrictions, and they put pressure on the West to accept a similar agreement.

The Soviets continued to lobby against unconstrained dissemination of remote-sensing data in 1982 at the Second UN Conference on Exploration and Use of Outer Space for Peaceful Purposes. To support their position against unlimited dissemination, they cited the US transmission to Great Britain of satellite data gathered over the Falkland Islands during the 1982 conflict as an example of a sensing state violating the sovereign rights of the target state. The final conference document, however, did not reflect their position.

After failing to gain UN support for limits on the dissemination of remote-sensing data, the Soviets began in 1983 to stress the moral obligation of states not to release data harmful to other countries. For the next three years, the issue of state responsibility for remote-sensing activities was a focus of UN debate. The Soviets maintained that the collection and dissemination of remote-sensing data from space had to conform with the Outer Space Treaty. This treaty requires nations to assume international responsibility for their activities in outer space, whether conducted by governmental or nongovernmental organizations. During this period, Moscow almost certainly realized that an irreversible step had been taken with the launch of the French SPOT satellite, making it impossible to develop legal restrictions on the dissemination of remote-sensing data

In 1986, the Soviets finally succeeded in getting the UN General Assembly to adopt a resolution on "Principles Relating to Remote Sensing of the Earth From Space." These principles state that remote-sensing activities should not be conducted in a manner detrimental to the legitimate rights and interests of the sensed state. Although the Soviet delegation was concerned that neither commercial remote-sensing activity nor dissemination of remote-sensing data to third parties was restricted by the principles, they did hail the resolution as a success. As recently as 21 May 1988, Soviet Deputy Foreign Minister Petrovskiy stated publicly that the USSR believes that UN General Assembly resolutions have "a special moral and political character" and that they play an important role in shaping international law. In spite of the controlled dissemination of Soviet 5-meter resolution photography, we believe that the USSR would point to the 1986 resolution to protest the future dissemination of remote-sensing data that it found harmful.