Can Crisis Management Be Helped From Space? A Contribution to the Decision Process

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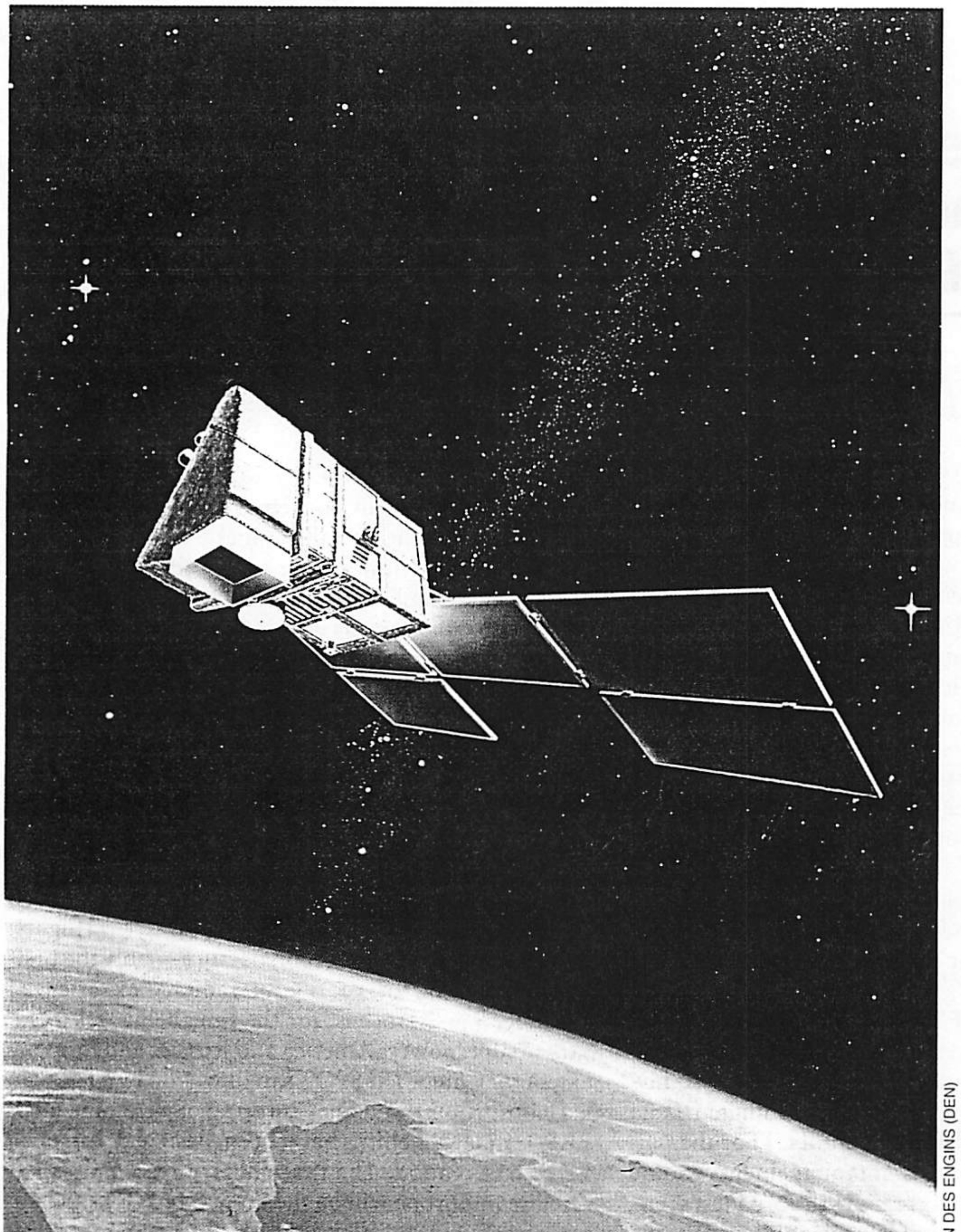
Europe will be taken more seriously by other powers if it responsibly manages its own crises. This will then give it a firm basis on which to help other countries prevent and manage their conflicts; a prominent role already played by the United Nations. Individual or grouped European countries can become involved in crisis management activities by striving for their own independent space systems, in parallel and in complement to other nations' systems earmarked for crisis management. Greater insights into current and future European systems of space observation will help indicate which methods are appropriate for crisis management, and which can be used in a complementary fashion. Nowadays, space technologies are considered essential for the systematic, synoptic and long-term collection of information necessary for effective crisis management.

CRISIS MANAGEMENT

The term crisis is generally used to define the twilight area between peace and war. Little discrimination is made between a crisis in a limited sense (increasing tension) and armed conflict. For the purpose of this article, crisis management should encompass the control of a crisis in the broadest sense, including not only increasing tension and armed conflict, but also verification of arms reduction treaties and monitoring of confidence building measures. The latter two should be seen as the lowest form of crisis management, primarily aimed at the prevention of conflicts. When a conflict arises all the same, it has to be limited and a peaceful settlement has to be reached or imposed. In this article, no differentiation is made between conflicts among states and intra-state conflicts (civil unrest/war).

The purpose of the Conventional Forces Europe (CFE) talks started in 1989 was to strengthen the stability and security of Europe by creating a stable and secure balance in conventionally armed forces while decreasing the overall numbers. The verification process coupled with this treaty is used to determine both type and number of treaty-limited equipment and objects of verification, as well as the war organization of the forces involved. In November 1990, the CFE treaty was signed. The signing, and as a consequence, the compliance to this treaty, demands independent, selfsame and flawless verification measures of the first degree. The area covered by CFE (and for the purpose of this article) is "Europe from the Atlantic to the Urals." However, verification of certain control measures may require a more global approach.

Of a triad of formal methods that could be taken into consideration— on-sight inspections, overflights with aircraft and space reconnaissance— only the first two fall within the routine of military experience. Space reconnaissance is, for the time being, reserved for the superpowers America and Russia, and to some extent for China. The SPOT satellites (run by a France-led consortium) and the European Space Agency's ERS-1 radar satellite, have been designed for civil Earth observation. The first military reconnaissance satellite in Europe will be the French HELIOS, slated for launch in 1994. Crisis management by means of space reconnaissance is, therefore, a challenge in European military thought and strategy development. In the frame of overall crisis management, a space based observation system is, because of its characteristics, able to operate in a cooperative and in a non-cooperative environment. For this reason, the use of a space-based observation system is considered an essential tool in crisis management processes. Observations from space should be complementary to the normal intelligence acquisition, especially during the period of conflict prevention, or the escalation from tension to conflict.



France's HELIOS will be one of the first military reconnaissance satellites.

SYSTEMS DEVELOPMENT

Consequently, a European space reconnaissance system for crisis management has to be developed. The development of such a system should be considered a long term project and an interim system should be taken into consideration immediately. The successful execution of such space programmes requires an unprecedented level of international cooperation on three levels:

- Long term planning and financing of operational observation systems to guarantee the quality of the flow of information;
- Adequate (ground) infrastructure to collect, administer and distribute the information, including regulations for its functioning and prioritizing; and
- Scientific cooperation to conserve the programme.

Building an interim system based on current scientific and technological knowhow would make its relatively rapid development possible. Like in the Western European Union (WEU), it is possible to start the verification process by buying images from existing operational systems (LANDSAT, SPOT and ERS-1) or from systems soon to be launched (HELIOS). In order to gain experience in practical image interpretation, start with independent support for crisis management monitoring tasks and build an independent European database. A fully operational, independent system can be developed either from existing systems, or by modifying and improving systems as they are released onto the market. Another alternative is to lease an already-developed system, or develop one in parallel from a baseline configuration.

CHARACTERISTICS

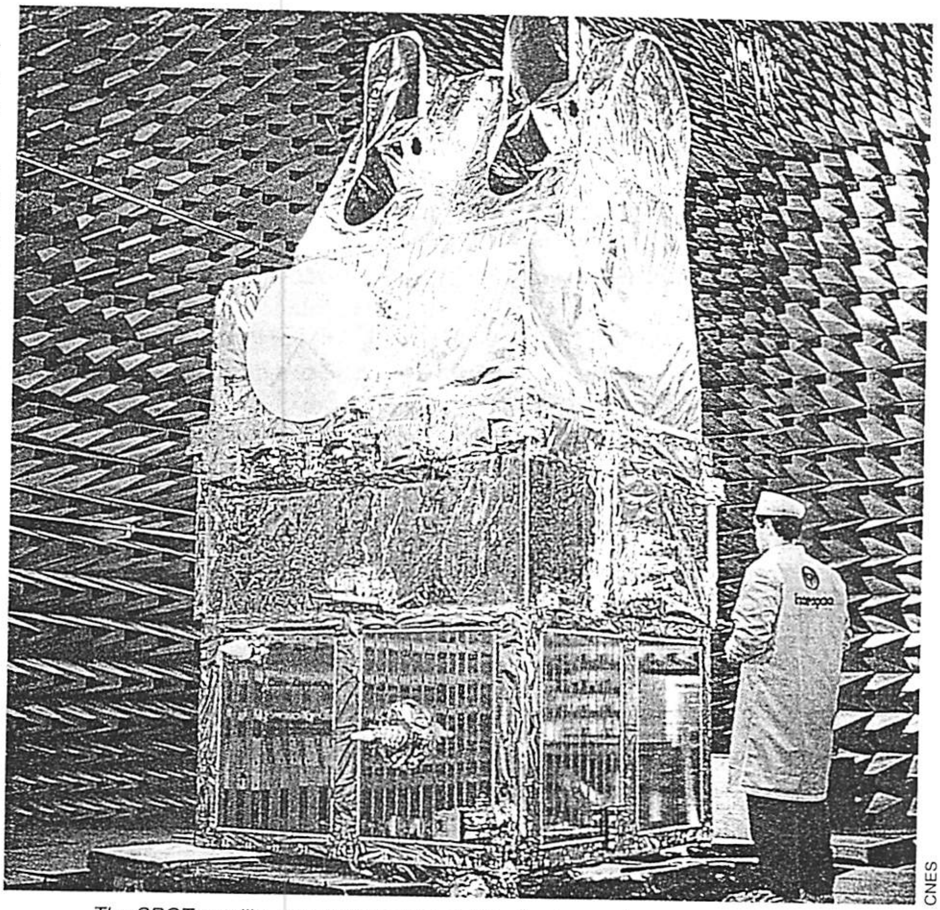
In general, spaceborne observation systems have the following advantageous characteristics:

Non-obtrusiveness. They are the only instruments of reconnaissance that can be used without the cooperation of, or even the knowledge of, the observed party.

Invulnerability. Practically seen, these instruments cannot be denied their assignment in a period of political tension. In such a period on-sight inspections and aircraft overflights can be denied.

Worldwide coverage. These observation systems can reconnoitre every part of the globe and are able to cover large areas in relatively short time.

Short reaction times. Because of the permanent stationing in space, these systems can be targeted at specific areas relatively quick. Observations can be distributed and acted upon, under conditions, in real-time.



CNES

The SPOT satellite was designed for civil Earth observation.

The following adverse characteristics in general apply to these observation systems in space:

Predictability of coverage. The foreseen satellite systems will have stable orbits (sunsynchronous) for to be described reasons and their operation, therefore, will be predictable.

Revisit frequency dependency. The revisit frequency for a certain area is dependent on the satellite orbit and latitude of the target area. Orbits likely to be used will necessitate multiple satellites.

Cost. Redundancy in the system to be devised is very costly.

Infrastructure complexity. The infrastructure of the ground segment to control the data streams and maintain up-to-date readily accessible databases will be very complicated. A profusion of data (so called data depots) should be expected.

REQUISITES

The following requisites are essential to operate a space reconnaissance system earmarked for crisis management:

- Low Earth orbiting satellites with electro-optical (visual and/or infrared) or Synthetic Aperture Radar (SAR) sensors, or a combination thereof. Data transmission to ground stations would either be direct or through Data Relay Satellites (DRS).
- Ground station(s) and antenna(s) for reception of data transmission.
- Antenna(s) to track the satellite, receive telemetry and transmit command and control signals.
- Facilities for satellite control (e.g. orbit corrections, tilt commands, on/off switching of the sensors, switching between ground stations).
- Mission Operations Centre.
- Facilities to scan and interpret images in (almost) real-time on the basis of which is decided to revisit the scene during the next orbit.
- Information-extraction/interpretation, photo production and reporting facilities.
- Good, fast and secure means of communication.

CAPABILITY AND EFFECTIVENESS

The dimensions of observed objects in the CFE treaty denote how necessary resolution, as a parameter, has become for space-based observation systems. However, the performance of imaging systems is determined not only by the abstract measure of the resolution parameter. Tanks and vehicles fix the "standard" resolution to about three meters. Practically though, a better resolution (<3 m) would be necessary to make a distinction between a tank and another vehicle about the same size (bulldozer), or to separate and count closely parked tanks. Even better resolution (<50 cm) would be necessary if those tanks had to be classified according to type. Tanks are, amongst others, most important verification targets. Moreover, aircraft, helicopters, tanks and fighting vehicles are usually parked in hangars or other such shelters and cannot be detected/counted by satellite. Furthermore, the capability of certain instruments to detect properly is influenced by factors including haze, solar altitude, spacecraft motion and last but not least, sensor variables. Verification should not be limited to counting tanks: monitoring of compliance with agreements, general surveillance and disaster monitoring are also necessary contributions and have a stabilizing effect in the early phase of a crisis.

There is no doubt that satellites have proved their observation capabilities and their military usefulness.

Nowadays, crisis management satellite tasks would probably not encompass more than detection of troop concentrations, important non-moveable installations and infrastructural junctions, and similar indications that make changes known (cuing). In this case, crisis management would be restricted to control of the so-called confidence building measures, and, therefore, not unimportant. However, detection on this level requires a lower resolution than that used to detect individual targets. Relevant systems that can cope with such tasks are readily available. Future systems will need a better overall standard resolution, ample revisit frequency, all-weather capability, and will easily be switched from a high-resolution/narrow area coverage system to a low-resolution/broad area coverage system, and vice-versa.

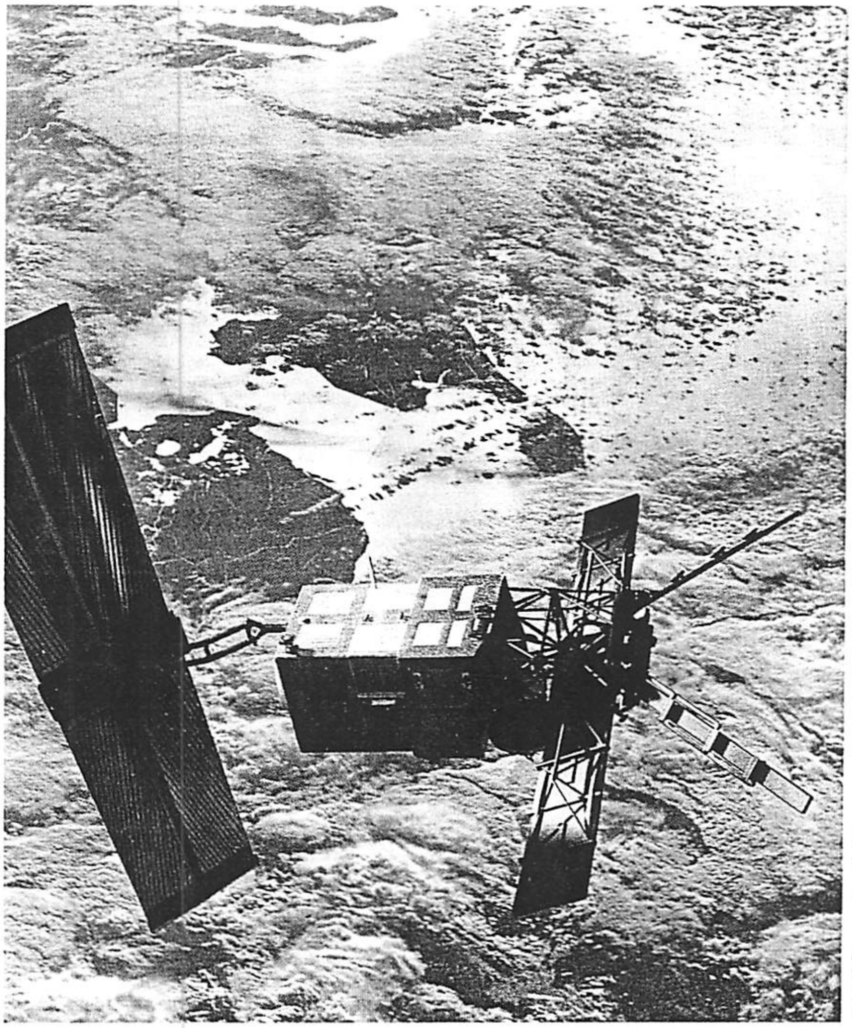
There is no doubt that satellites have proved their observation capabilities and their military usefulness. Both the United States and the former Soviet Union had, in the past three decades, satellites stationed in space that proved their operational effectiveness. Current resolution of these (electro-)optical systems is assessed to be about 10 cm under ideal conditions in the visual spectrum and about 1–3 m for infrared systems.

Satellites have some unique observation capabilities. A reconnaissance plane, such as the non-operational SR-71, was capable of filming 250,000 km^2 per hour. During that same time, the SPOT satellite can cover some 1,500,000 km^2, and the ERS-1 covers about 2,000,000 km^2. Of course, there are differences in resolution. Nevertheless, the specific SR-71 capabilities (e.g. planning of time and place of battle damage assessment) were sorely missed during the Gulf War.

In general, military reconnaissance satellites operate from a couple of low Earth orbits. The height (±175 km) and inclination is determined predominantly by the desired or needed resolution and the area that has to be observed. Civil observation satellites are principally launched into low (750-850 km) polar orbits. These orbits are restricted for practical reasons between 500 and 1500 km; high enough to minimize atmospherical friction and low enough not to be troubled by the material destructive effects of the Van Allen radiation belts. The main advantage of the polar orbit is that the Earth can be observed in its entirety—a satellite launched with an inclination of 60° to the equator can only observe targets between 60° latitude north and south. A polar orbiting satellite at a height of about 700 km has an orbit period of about 100 minutes. Consequently, every twenty-four hours the satellite will orbit the Earth 14 times and will show 14 ground projections because the Earth rotates beneath the satellite. Time taken between observations of the same area, the "revisit interval," is determined by the height of the orbit, the latitude of the target area and the swath width of the reconnaissance instrument. With polar orbiting satellites, the areas at the poles are covered every orbit, while areas at the equator are covered proportionally less. The revisit time for SPOT for an equatorial area is five days. In an operational satellite reconnaissance system, the revisit interval could be reduced by adding more satellites or by tilting the satellite, or reconnaissance instrument or by using mirrors. However, the distance from monitoring path to ground path is technically restricted to about 1000 km (for optical as well as radar reconnaissance instruments) and the tilting will be kept to a minimum to prevent too great a deterioration of the resolution. An area can thus be monitored successively more than once, but always at the cost of others.

Adequate processing of data depends on the accessibility of the images. The practical line-of-sight limit of a ground station to a satellite at a height of 700 km is about 4000 km. Two strategically placed ground stations (e.g. in Norway and Greece) could maintain communications with the satellite during its overflight of the CFE area. With the assistance of two to three data relay satellites in geostationary orbit, global connection between satellite and ground station can be achieved. Future European DRS satellites will be able to connect every European location possessing ground control facilities with a reconnaissance satellite, at any point in its orbit, and deliver near real-time images from all over the world.

Resolution has become indirectly dependent on the design of the total system. Military reconnaissance satellites are able to manoeuvre in space and can fly at extremely low altitudes (175 km), with inclined orbits to enhance the resolution (fly closer to the target). Such satellites have, therefore, a relatively short lifetime due to their use of the limited amounts of fuel available for such manoeuvring. Such orbits are unsuitable for satellites geared to crisis management, systems which stay in orbit for much longer to defray costs. Observation satellites in a 750 km high orbit have a natural decay of some 300 years. The lifetime of such satellites is based on technical parameters (not breaking down, supply of propellants, etc.) and is judged nowadays at some three to four years. Extension of lifetimes to more than ten years can be achieved by more efficient use of propellants, better solar panels and duplication of critical parts.


DEUTSCHE AEROSPACE

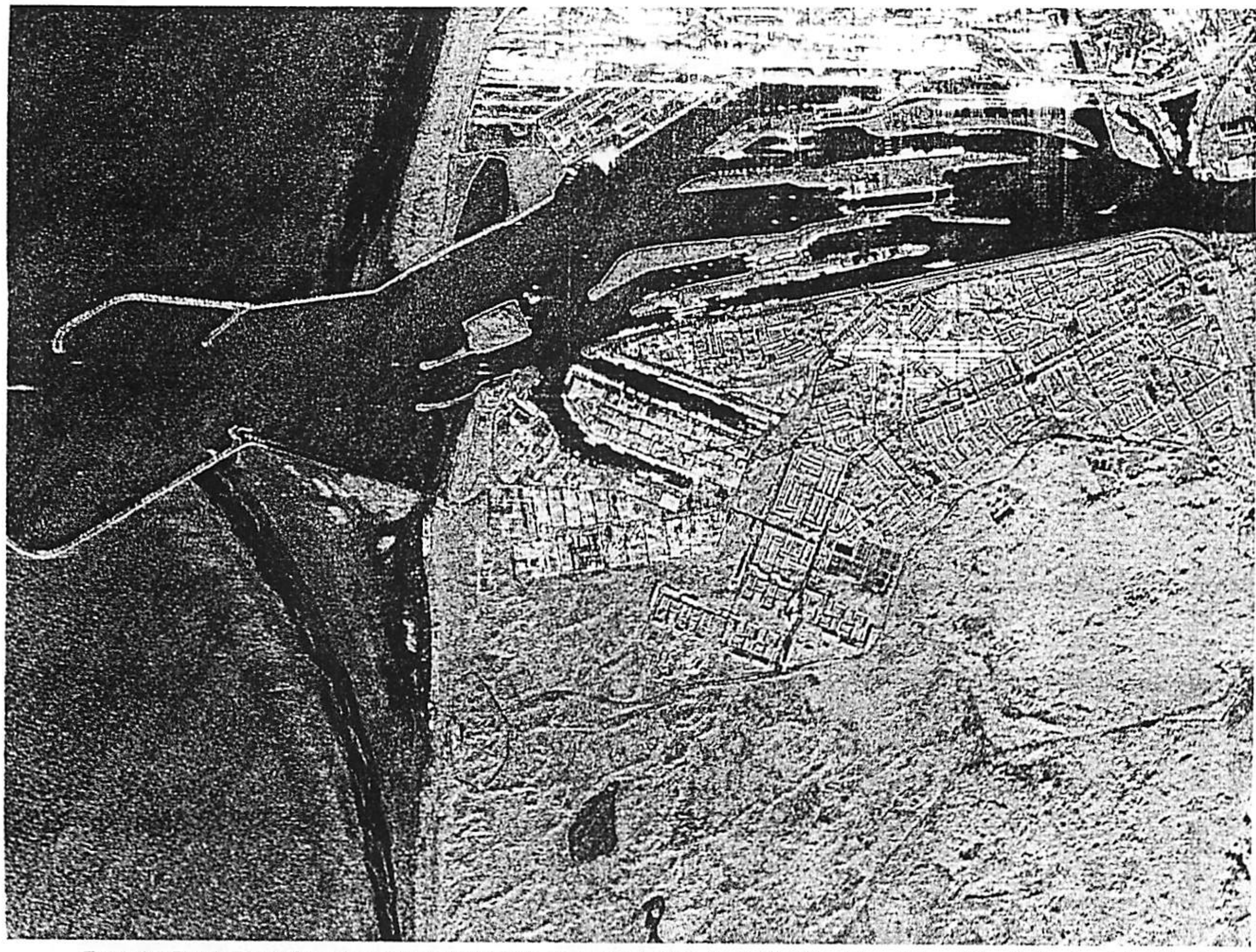
The European Remote Sensing Satellite, ERS-1, may be a precursor of a possible European space based system for crisis management.

Since 1986, images from the commercial SPOT observation satellite have been used by the American Department of Defense to reveal secrets such as the Russian laser facilities in Sary Shagan or ABM radars. This way, specific military developments in the former Soviet Union were made public. In editions of "Soviet Military Power," published by the Pentagon, the impression was given that intelligence could be acquired from SPOT images. The conclusion here must be that the initial discovery had been made by own (technical) means and that the SPOT images were only used not to compromise its own capability. SPOT images also provided the first, unclassified, information of the Chernobyl reactor accident. In this case as well, preknowledge from American means acted as the trigger.

As mentioned previously, satellites do not physically influence the observed party and do not require their cooperation. In times of increasing tension, the satellite overflight cannot be denied whereas on-sight inspections and aircraft overflights could. However, when there is some knowledge of the orbit, satellite presence is known and detection can be avoided by simply "taking cover," almost as effective as advanced counter measures. The satellite is, of course, more or less susceptible to counter measures, but most countries currently don't have such capabilities at their disposal.

EUROPEAN CAPABILITIES

During the last decade, the European space industry has developed technologies for Earth observation in the optical and microwave spectra. These technologies have been integrated in the SPOT and ERS-1 satellites. SPOT and ERS-1, therefore, are considered precursors



From the Dutch PHARS system, this radar picture shows part of the North Sea/Ijmuiden sluices (The Netherlands). This picture provides a 3 m resolution simulated Synthetic Aperture Radar satellite image.

of a possible European space based system for crisis management. Current operational (European) civil sensor technologies are:

- SPOT: 20 m resolution multispectral and 10 m resolution panchromatic optical images of 60 km * 60 km areas. Images can be made oblique to a maximum of 400 km at both sides of nadir.
- ERS-1: 30 m resolution radar images of a 100 km swath width at one side of the satellite ground projection.

Also taken into consideration here are HELIOS and US's LANDSAT-6. The capabilities of the military reconnaissance satellite HELIOS are 2-5 m resolution multispectral and 1 m resolution panchromatic optical images. The American civil sensor technology in LANDSAT-6 is 15 m resolution panchromatic and 120 m thermal infrared.

Optical Instruments

The optical instrument that is used in SPOT and HELIOS satellites consists of a telescope that focuses the image on a row of Charge Coupled Devices during which an image is converted to a representative electronic signal that can be transmitted to Earth. With such instruments, the resolution is principally dependent on the aperture of the lens and its focal length. The size of the optical system, therefore, is a limiting factor. Under optimum conditions, a theoretical resolution in the order of 8-12 cm can be achieved (visual spectrum), and is only mainly restricted by atmospheric turbulences. A disadvantage of optical instruments in the visual spectrum is that they can only be used for daytime monitoring (hence the sunsynchronous orbits of SPOT and HELIOS), because of their inability to "see" through clouds.

Instruments able to detect in the infrared spectrum can be used for nighttime operations. Here cloud cover is also a limiting factor, but to a lesser extent than with the optical instruments. Theoretical resolution under optimum conditions will not equal the visual resolution and will become worse with a longer infrared wavelength. At best, current thermal infrared resolution is 30 m.

Synthetic Aperture Radar

Optical (passive) sensors are affected by natural phenomena such as clouds and light intensity. Clouds especially are a major problem in Europe. Microwave and radar sensors are not affected by these phenomena and can, therefore, operate independent of the time of day and the weather. Such active systems offer an image resolution independent of altitude, but the higher the altitude of the spacecraft the more power is needed. Theoretical resolution is about 1 m (frequency/radar wavelength dependent). As these sensors are able to detect movement, they are ideal for observing naval activity on the surface of large water bodies.

The use of conventional radars in space is impractical because of the very large antennae required. A SAR doesn't have those restraints. When kept to practical dimensions and normal transmitting power, SAR-derived images can be composed by coherently integrating a series of radar pulses received during a given time from a target area. This technology creates an artificial antenna with extreme large dimensions (5 km or more) which causes an improved resolution along track. Resolution improvement cross track is attained by conventional pulse compression techniques. The first European SAR flies on ESA's ERS-1 whose primary objective is to investigate applications and to develop uses of coastal, ocean and ice cover remote sensing. Improved SAR instruments with variable resolutions and swath width are being developed in Europe, and may become candidates for crisis management tasks. Future SAR systems will be equipped with electronically steerable antennas (phased array). Such a steerable beam makes it possible to quickly switch between "spotlight" (high resolution) and broad swath width (low resolution) modes. Also, switching between horizontal and vertical polarisation will be possible, thus increasing the discrimination capabilities of the SAR. The radar image (see picture) shows the possibilities of such systems. Other qualities attributed to phased array include: improved reliability, very gradual deterioration, better power transfer, longer operational time per orbit and a longer life time. Radar images have disadvantages; their interpretation is often complex, and they drain satellite resources by consuming an inordinate amount of power.

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FUTURE CAPABILITIES

Optical Sensors

Studies show that in the years 1995–97 capabilities will exist to provide commercial images with better than 5 m resolution in the visible and near infrared spectra. French sources have claimed that it will be possible around 1995, for civil purposes, to construct and launch a SPOT derivative with a resolution of 4–5 m. However, the higher the resolution, the narrower the field-of-view, i.e. a smaller swath width of only 32 km, and consequently a lower revisit frequency, i.e. 10 days. Some design and development activities are underway as in Germany's Modular Optoelectronic Multispectral Stereo Scanner. Systems like these are being developed for ground spatial resolutions of 2.5–5 m. The Landsat-7 Enhanced Thematic Mapper can be considered another example of the capability achievable in this timeframe. The highest capability includes 5 m resolution panchromatic stereo imagery.

For the term after the change of the century, instruments should show significant improvement in spatial resolution (both in the visible and infrared bands). However, technological breakthroughs in large lightweight mirrors, active optics, large stable structures and tilting capabilities (either with mirrors or flywheels) are a necessity. The goal is an optical capability with 1 m resolution, or better, and 10 m in the thermal infrared.

Microwave Sensors

In the near future, only civil ERS-1 and -2 (30 m spatial resolution) and the Canadian Radarsat (10–100 m spatial resolution depending on swath width) microwave imagery will be available. Both are C-band SARs. The ESA funded Advanced SAR to be flown with the Polar Orbiting Earth Mission (POEM-1) is also a C-band radar, and when compared to ERS-1, this instrument will include significant improvements to provide imagery of alternative swaths at different look-angles, with wide swath coverage of up to 400 km, and the possibility to use different polarisations.

It is expected that after the year 2000, X-band and S-band (better resolution performances) radars will be available for space based platforms and will have pushed aside C-band. A technological breakthrough in data storage and processing is mandatory for successful application. The goal is a spatial resolution of 1 m in a high-resolution mode and 3-5 m in search modes.

Platforms

The SPOT platform has been developed specifically for a wide variety of Earth observation missions and has been used in the SPOT-1, -2 and -3, and for the ERS-1 and -2 (currently under development). An upgraded version for SPOT-4 and HELIOS has also been developed. This version uses a completely new avionics system and is equipped with a star-sensing device to cope with the high pointing accuracy required to achieve high ground resolution. The POEM concept is based on a SPOT-4 derived service module providing power, attitude and orbit control functions to the variety of payloads envisioned for this spacecraft. Also available will be the US LANDSAT-7 platform based on the advanced TIROS N series of polar orbiting satellites.

By making use of evolving technology capabilities, new spacecraft ranging from lightsats to large low Earth orbiting platforms can be made available after this decade. NASA's plans for Earth observing satellites should be taken into consideration. The availability of the above platforms means that no new platform technology needs to be developed.

CONSIDERATIONS

European space systems can complement other systems used for crisis management and can contribute significantly to the political decision making processes during crises affecting European states. It will not only enable them to monitor compliance to treaties and to collect information for crisis management in areas where other forms of verification have been denied, but it will also give those states prestige in international fora where decisions are made on aspects of European security. Their capability for independent analysis will strengthen their international standing. On the other hand, this autonomy will ensure that each member's government retains the ability to make decisions independently while benefiting from a shared source of information.

U.S. INTELLIGENCE GATHERING DURING THE GULF WAR

American satellite systems that were used during the Gulf War were the KH-11 (Key Hole), the improved KH-11 (sometimes referred to as the KH-12) and the radar imaging satellite LACROSSE. These systems were complemented by the French civil Earth observation satellite SPOT. KH-11's are assessed to be equipped with electro-optical sensors which on clear days are able to transmit images to Earth in real-time. These images have a reported resolution of 15 cm at best, but probably can be enhanced by computer technology. The LACROSSE imaging satellite provides images when the target is in darkness or under cloud cover with a resolution of about 60 cm. Images of such high resolution have the disadvantage that only small areas at a time can be observed. For target acquisition images with resolutions from 5-20 meter suffice. However, the mentioned images are secret and are distributed on a strict "need to know" basis only. It is even unlikely that KH-11 images have been shown on a routine basis to American pilots. SPOT images have resolutions of 10 m (panchromatic) or 20 m (multi spectral). These images have been used exuberantly for cartography (there were few maps of the walking dunes) and to give pilots, by means of simulation or three dimensional images, a "deja vu" feeling of targets they had never overflown. Also some battle damage assessment has been performed with SPOT imagery when the images were available.

It was expected that the powerful and versatile American system would be a determining factor in conquering the enemy. So it was. After the invasion of Iraq into Kuwait, a feverish activity commenced in which target allocators, catographysts and intelligence analysts started to make maximum use of these systems. With the information from satellites that can gather image and/or ELINT/SIGINT, the positions of the Republican Guard were established with such precision that bombing raids from B-52's effectively reduced this fighting force. Other target positions were recorded in the same way to be eliminated by precision bombardment or guided (cruise) missiles. Cartography, target allocation and battle damage assessment could be performed well by the available satellite means. However, in considering the use of the described satellites, it should be taken into account that they were only used under conditions comparable to those in a laboratory; the Iraqis had no way of interfering (ASAT, ECM).

Existing civilian space-based observation resources can be used to provide information on confidence building measures, even though they are not adequate crisis management tools. In some cases, data derived from these systems can serve as a trigger to counter threatening crisis.

Space resources available at the turn of this century can provide Europe with powerful verification tools, complementing other tools such as on-sight inspections and aircraft overflights, and will be considered vital to its international and diplomatic role in tomorrow's world.

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