

Workshop Report: The Potential Uses of Commercial Satellite Imagery in the Middle East

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JUN 30 1999
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ABSTRACT

With the end of the Cold War, information from remote sensing gathered by sensors mounted in satellites and aircraft has become more assessable and cheaper. Private companies are entering the international market and providing a variety of imagery and related services. These new tools can potentially help solve a number of international and regional problems: environmental protection, natural resource management, urban planning, development of infrastructure, and the achievement of peace and security by means of treaty verification, arms control, and transparency. The Middle East, perhaps more than any other region in the world, faces all these problems. The U.S. Arms Control and Disarmament Agency sponsored a workshop hosted by the United Nations Institute for Disarmament Research and Sandia National Laboratories Cooperative Monitoring Center to assess the utility of commercial remote sensing to solving regional problems in the Middle East and fostering cooperation. A variety of technical and security specialists from Israel, seven Arab parties, and several extra-regional organizations participated. The participants presented and discussed analyses and options for the use of commercial imagery in the topics of regional arms control, the environment, and infrastructure development. (The views expressed in this report do not necessarily represent those of the workshop sponsor and organizers.) The consensus was that the application of commercial imagery for arms control purposes is limited as this time, however a number of opportunities exist for regional cooperation using imagery in the topics of the environment and natural resource development, particularly water. By the end of the workshop, the participants had developed a list of ideas and proposals in the following categories: linkage of regional remote sensing organizations with international programs in space science, development of regional remote sensing organizations, information and data accessibility in the region, geophysical hazard mitigation, water resource management, sustainable land use, training of regional remote sensing specialists, natural heritage resource management, and confidence building measures.

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EXECUTIVE SUMMARY

Background and Goals of the Workshop

Remote sensing tools from satellites and aircraft can be applied to help solve a wide variety of international and regional problems: environmental protection, natural resource management, urban planning, development of infrastructure, and the achievement of peace and security by means of treaty verification, arms control, and transparency. Until recently, many of these tools were either restricted to military purposes or were too expensive for most governments and companies. With the end of the Cold War, several governments and a number of private companies are making affordable, up-to-date images of virtually every part of the Earth available commercially. The United Nations Institute for Disarmament Research (UNIDIR) has conducted several studies associated with the use of imagery from commercial satellites and aircraft for monitoring arms control applications. These projects have stimulated international discussion of the utility of commercial satellite imagery – particularly in regional contexts such as the Middle East. Consequently, the U.S. Arms Control and Disarmament Agency (ACDA) asked UNIDIR hold an unofficial meeting to bring together political and technical experts from the Middle East and other regions to discuss and assess the benefits and limitations of commercial imagery for regional security and other purposes.

UNIDIR and the Cooperative Monitoring Center of Sandia National Laboratories hosted the workshop at the United Nations (UN) Palais de Nations in Geneva, Switzerland from Aug. 31 – Sept. 3, 1998 with funding support from ACDA. The workshop was organized to include presentations and focused discussion in the categories of regional arms control, the environment, nature resource management and infrastructure development. Twenty-six scientists, remote sensing specialists, and arms control and regional security specialists from Israel, seven Arab parties, and several extra-regional organizations participated. Most of the regional participants were familiar with non-security applications of commercial satellite imagery since virtually all countries in the region have centers for remote sensing.

General Conclusions and Possible Applications of Remote Sensing in the Middle East

In spite of regional interest, most participants in the workshop agreed that commercial satellite imagery is currently under-utilized in the Middle East. Regional parties and organizations generally do not share data or imagery or engage in collaborative projects even when they have common problems and research interests. Participants agreed that the political context for regional cooperation is important. The cooperative use of commercial satellite and aerial imagery will require the development of the region's capability to make use of the information remote sensing can provide as well as the right political conditions.

The applications of commercial satellite imagery to arms control and regional security stimulated the most discussion during the workshop. It became clear that the applicability of commercial satellite imagery to the verification of future regional arms control agreements is limited at this time. However, its applicability will increase during

the next three years as new, more capable satellite systems are launched. There was general consensus that non-traditional security topics such as environmental protection, natural resource management, and the development of infrastructure offer the most promising applications for commercial satellite imagery in the short-term. Unlike traditional security applications, cooperative use of imagery in non-traditional security topics can occur independently of formal regional security negotiations. Aerial imagery can also make significant contributions to both traditional and non-traditional security applications but has the disadvantage of requiring access to national airspace and potentially higher cost.

Points of Consensus:

- Expectations from the use of imagery must be realistic and technology, by itself, cannot solve the problem of verification.
- Current and future commercial satellite imagery can provide only limited insight into the operations of nuclear or chemical facilities.
- Current commercial satellite imagery has limited applications to monitoring conventional forces but future systems will have more utility.
- Commercial imagery must be timely to be useful for arms control purposes.
- Cooperation is possible at the scientist-to-scientist level.
- Training to develop Middle Eastern image analysts is needed and this offers an opportunity for collaboration.
- In the absence of regional arms control agreements to verify, initial training in topics such as environmental monitoring of joint concerns may be the best way to develop new regional imagery analysts.
- Pilot projects that involve image analysis could be a viable alternative to general training and a confidence building measure as well.

Points of Concern:

- Too much publicly available information can at times be harmful to relations.
- Faulty interpretation of imagery for arms control purposes may result in frivolous allegations or false alarms.
- Imagery could be used for military targeting or planning of terrorist attacks.
- Countries could use commercial imagery to hide illicit activities.
- Commercial imagery and related tools may be too costly to be used in the region.
- The level of spatial resolution necessary for effective analysis may not be available.
- The ability of a country to restrict the distribution or type of imagery of its territory.

Potential Cooperative Projects

Most participants agreed that there is still not a large group of technically trained remote sensing specialists in the Middle East. This relative scarcity, however, provides an opportunity for collaboration in non-traditional security topics. Collaborations between scientists, businesses, and non-governmental organizations can work at the grass-roots level and yield contributions to confidence building as well as practical results. By the end of the workshop, the participants had developed a list of ideas and proposals in the following categories:

- Linkage of regional remote sensing organizations with international programs in space science,
- Development of regional remote sensing organizations such as a *Middle East Satellite Centre* based on the *Western European Union Satellite Centre*,
- Information and data accessibility in the region,
- Geophysical hazard mitigation,
- Water resource management,
- Sustainable land use,
- Training of regional remote sensing specialists,
- Natural heritage resource management, and
- Confidence building measures.

The Egyptian National Authority for Remote Sensing and Space Sciences (NARSSS) presented the most developed proposal during the workshop. The proposal suggested a regional study of the implications of global climate change on the Middle East. This project would use available imagery to study sea-level variation, temperature changes, and the effect of CO₂ emissions. To begin this project, the regional parties would have to cooperate in deciding on a uniform format for a digital database, and link this database to regional and international systems. The project should be associated with the UN, but the NARSSS would serve as the focal point for the research activity in the region.

Participants thought it was very important to identify and secure consistent funding from extra-regional as well as regional sources for cooperative projects. Extra-regional non-governmental organizations or UNESCO could play a further useful role by helping to organize regional remote sensing activities.

Remote Sensing: A New Tool to Foster Cooperation and Peace?

People have always climbed to high places when they wanted to survey their surroundings. Today, people also use remote sensing instruments mounted on aircraft or satellites to see a variety of characteristics about their environment. Remote sensing detects and measures reflected or emitted radiation from features on the Earth's surface. The origin of remote sensing began nearly a century ago when pilots carried cameras aloft in balloons and early aircraft. A greater variety of tools for remote sensing are available today than ever before. High altitude aircraft can reach the edge of the atmosphere. Satellites, available as never before, constitute the new "high ground."

Publicly available information about the Earth's surface is growing rapidly. Much of the new information is based on satellite imagery that until recently was either restricted to military purposes or was too expensive for all but the richest governments and corporations. With the end of the Cold War, many governments have privatized much of their satellite imagery activities. Private companies from a variety of countries are rapidly entering the market with affordable, up-to-date images of virtually every part of the Earth. Many satellites are equipped with sensors that can detect light in more than one spectrum – a capability that reveals an astonishing amount of information about the

Remote Sensing: A New Tool

- Remote sensing measures reflected energy from the Earth's surface.
- Satellite-based remote sensing, navigation, and communication technology originating from the Cold War is now available to the public.
- Private companies from many countries are launching satellites to sell images and services.
- The capability of computer software to analyze imagery has increase significantly.
- Commercial remote sensing can potentially be applied to solve regional problems such as arms control, environmental protection, natural resource management, and infrastructure development.

Earth's surface and subsurface that cannot be seen from the ground. Appendix A contains a summary of remote sensing concepts and capabilities of current and planned commercial satellite systems.

Another legacy of the Cold War is the Global Positioning System (GPS). GPS is a network of satellites developed and built by the United States to provide very accurate

geographic positions to enable navigation by missiles, aircraft, ships, and even troops on the ground. Since GPS was commercialized in the early 1990s, anyone with a relatively inexpensive receiver can determine his or her location to within 100 meters. GPS has lead to a revolution in low-cost precision mapping. Small municipal governments can convert old paper surveys into digital maps that contain the exact location of every item of public infrastructure.

In parallel the continuing revolution in personal computers and workstations have permitted the development of geographic information systems (GIS) software programs. GIS links information from many different sources to items on a digital map. A typical urban GIS might let users view an aerial photograph of every building in the city simply by clicking on a lot number in a digital map. The lot number can be linked to databases of census data, traffic volume, or any other measurable topic the user wants. In a rural

setting, GIS can provide information about geology, vegetation, type of agriculture, or water sources for a particular section of land on a digital map.

Governments in the developed world and large companies have used imagery, GPS, and GIS for years. In the public sector, GIS technologies are only now beginning to have an impact. The growth in competition led to a significant drop in the prices of computer hardware, GPS receivers, and GIS software. Competition is rapidly increasing in the commercial satellite industry not just in terms of price, but also in image quality, frequency of imaging, and time to delivery. Within five years a new generation of commercial satellites will be operating offering a variety of services that have not been available without restriction to the international community before.

Remote sensing tools can be applied to help solve a wide variety of international and regional problems: environmental protection, natural resource management, urban planning, development of infrastructure, and the achievement of peace and security by means of treaty verification, arms control, and transparency. The Middle East, perhaps more than any other region in the world, faces all these problems. The question is whether the region can use these new tools to obtain the information it needs.

Origin and Goals of the Workshop

The current Middle East Peace Process began at the Madrid Conference in October 1991. The Peace Process was organized into a group of bilateral forums (Israel with, respectively, Jordan, the Palestinian Authority, Syria, and Lebanon) and a multilateral forum consisting of interested countries both within and from outside the Middle East. Five working groups were organized within the multilateral process: arms control and regional security (ACRS), refugees, economic development, water and the environment. The technological developments profiled in the preceding section as well as political developments led the Middle Eastern states in the ACRS working group to begin discussing the potential cooperative use of commercial satellite imagery for arms control

and confidence building purposes. In 1996, independent of the peace process, the United Nations Institute for Disarmament Research (UNIDIR) (in cooperation with the European Institute of Global Mapping and Research and the Austrian GEOSPACE Institute) proposed to produce an atlas of the Middle East based on

Goals of the Workshop

- Assess the practical applications for commercial satellite imagery in the Middle East.
- Bring remote sensing and security specialists (who do not normally interact) from the Middle East together.
- Act as an unofficial forum whose conclusions and recommendations can be incorporated into the official process when conditions permit.
- Identify common problems and options for regional cooperation.

imagery from commercial satellites. The atlas was intended to be an educational and reference tool about the Arab-Israeli peace process and was to include topics such as border disputes, weapon deployment, and water resources. Review of a prototype atlas

by several individuals in the U.S. and Middle East raised fundamental questions about the utility of commercial satellite imagery.

The U.S. Arms Control and Disarmament Agency (ACDA) recommended that UNIDIR and interested parties hold a unofficial or Track II workshop to bring together political and technical experts from the Middle East to discuss and assess the benefits and limitations of imagery for regional security and other purposes. Given the technical nature of imagery analysis and its proposed cooperative use, ACDA requested that the Sandia National Laboratories Cooperative Monitoring Center (CMC) co-host the workshop.

The workshop held at the United Nations (UN) Palais de Nations in Geneva, Switzerland from Aug. 31 – Sept. 3, 1998. Twenty-six scientists, remote sensing specialists, and arms control and regional security specialists from Israel, seven Arab parties, and several extra-regional organizations participated.

Unofficial forums such as this workshop provide research and ideas that can be incorporated into the official process (“Track I”) in the future when conditions permit. The workshop organizers identified environmental protection, natural resource management, development of regional infrastructure, arms control, and non-proliferation as topics where cooperation would contribute to an environment of peace in the Middle East. The working sessions of the workshop provided descriptions of technical options in these topics and assessments of how they might be applied cooperatively in the Middle East.

Most of the regional participants were experienced with commercial satellite imagery applications but primarily from a non-security perspective. Virtually all countries in the region have centers for remote sensing with analytical capability but only Saudi Arabia and Israel have major receiving stations. Egypt has a receiving station for U.S. weather satellites. Israel is the only country with its own imaging satellite (the *Ofeq* series, a non-commercial system) although several operate communications satellites. Appendix B contains a list of institutions in the Middle East affiliated with the United Nations Program on Space Applications (not all regional institutions participate in this survey).

In spite of regional interest, most participants in the workshop agreed that commercial satellite imagery is under-utilized in the Middle East and a potential area for cooperation. Regional parties and organizations generally do not share data or imagery or engage in collaborative projects even when they have common problems such as desertification. A contributing factor is that there is still not a large group of technically trained remote sensing specialists in the Arab countries and, to a lesser extent, Israel. Archival imagery of the Middle East is also limited (e.g., only 12% of SPOT Image’s archives are of the region). As such, the cooperative use of commercial satellite and aerial remote sensing will require the development of regional resources and expertise and the right political conditions.

Political Context for Cooperation

Future cooperative use of commercial satellite imagery in the Middle East will be influenced by regional political conditions - particularly the peace process initiated at the Madrid conference. The workshop participants discussed their perspectives of peace process and opportunities for progress. The consensus was that to a large extent the peace process is irreversible. A participant described the peace process as having roots that are dynamic and self-correcting. For example, Egypt and Israel made a strategic choice to achieve a peace that has existed for over 20 years. In spite of regional and international crises, bilateral political disagreements, and internal shocks such as the assassination of national leaders, substantial economic, political, and military ties between Egypt and Israel continue.

For cooperation to move forward, some believe the Middle East peace process must address the threat perceptions of the regional parties. Asymmetry in military, intelligence, economic, and technologic resources and capabilities of Middle Eastern countries play a role in developing national perceptions. Nations may be deterred from entering into commitments if they think they are at a significant disadvantage or cannot independently verify the commitments of others. In such a situation, commercial satellite imagery may provide a neutral tool to help reduce perception gaps and ambiguity by creating a more transparent regional environment. Increased understanding of the actions of others contributes to the confidence needed to enter security agreements. Also, commercial satellite and remote sensing technology could contribute to the social and economic transformation of the Middle East if an environment of peace could be created.

Possible Applications of Remote Sensing in the Middle East

The workshop was organized to include presentations and focused discussion in the categories of regional arms control, the environment, natural resource management and infrastructure development.

The Role of Remote Sensing in Conventional and Non-Conventional Arms Control

Many participants stated that monitoring technology in general, and satellite and aerial platforms, in particular, are useful tools, but only means to ends. Effective arms control agreements and treaties depend on many variables, including threat perceptions, the security environment, political relations and national interests. Verification systems only come into play after an agreement has already been reached by the parties, and cannot substitute for the absence of these conditions. In the presence of these conditions, this technology can serve to increase confidence in such agreements.

Presentations and discussion of potential arms control options applications were divided into non-conventional (nuclear, chemical, and biological) and conventional applications.

Non-Conventional Arms Control

The participants discussed the use of imagery by the International Atomic Energy Agency (IAEA). The IAEA does not regularly use commercial satellite imagery at this time although the agency has had experience in the use of imagery acquired by Member States through the use of national technical means (NTM). Such imagery has been used in conjunction with the IAEA's Security Council-mandated activities in Iraq and safeguards activities in North Korea under the Nuclear Nonproliferation Treaty (NPT). The IAEA Action Team and United Nations Special Commission on Iraq (UNSCOM) have made extensive use of high resolution aerial imagery from UNSCOM helicopters and high altitude aircraft.¹ Occasionally, the IAEA and UNSCOM have been given images from the French SPOT commercial satellite. In the case of North Korea, a Member State provided the UN Secrétariat with satellite images of the nuclear research facility at Yongbyon. Based on the Secretariat's analysis and consideration of the imagery, the IAEA Board of Governors decided a special inspection was warranted.

Non-Conventional Arms Control

- The IAEA has used imagery from NTM in Iraq and North Korea.
- The IAEA is studying the potential use of commercial satellite imagery in enhanced safeguards.
- Commercial imagery might offer the IAEA the opportunity to be less reliant on NTM provided by Member States.
- Imagery can provide only limited insight into the operations of nuclear facilities but a number of specialized applications appear to be of value.
- Some of these applications might be used within the context of regional agreements.
- The CTBTO and the OPCW have no plans to use commercial satellite imagery at this time.

Although some Member States raised questions about the integrity of such imagery, the use of satellite imagery was not challenged in principle. North Korea, however, rejected the IAEA statement and claimed the agency had been manipulated.

A presentation was made about the current study by the IAEA to assess if commercial imagery could assist the implementation of safeguards.

The IAEA has not decided if and how commercial satellite will be used in the future. The Agency began to consider the routine use of commercial satellite imagery as part of its process to strengthen the effectiveness and efficiency of safeguards. Commercial satellite imagery is thought to potentially complement rather than substitute on-site inspections. In addition, based on the experience with North Korea, an IAEA representative said that commercial satellites might offer the agency the ability to be independent of the few states with the capability to acquire assess high resolution imagery. A number of potential applications were first identified:

- Reference material for facilities and inspections,
- Confirmation of IAEA acquired or generated information,
- Detection of changes at declared sites,
- Assessment of open source information, and
- Detection of undeclared nuclear activities and facilities when there are suspicions based on other information available to the IAEA.

¹ The aircraft was provided and controlled by the U.S. and flew missions at UNSCOM request.

After analysis, the following specialized applications appear to be of value:

- Reference data for inspection planning and orientation material for inspectors.
- Assistance in design review to check information submitted by a Member State for accuracy and completeness. Facility construction could be regularly monitored in a non-intrusive way.
- Determination of operational status. Imagery could complement inspections carried out prior to the start of operations at a new facility or determine when an operational facility has shut down (such as for refueling).
- Confirmation of special reports to the IAEA. Member States are obligated to report events (such as natural disasters or major accidents) involving potential damage to the facility or safeguarded nuclear material.
- Verification of sealed storage. Using design information provided by the Member State, the IAEA could complement the routine annual inspection of the site with more frequent monitoring using imagery.
- Monitoring of uranium mining. The IAEA could complement the routine annual inspection of the site with more frequent monitoring using imagery.
- The evaluation and corroboration of information about declared and undeclared sites acquired from other sources.

The figure below illustrates the appearance of a nuclear facility at Tokai, Japan using the French SPOT panchromatic and U.S. LANDSAT thermal spectrum sensors. The location and shape of facility buildings is visible in the SPOT image (10 m resolution). The LANDSAT thermal image has only 120 m resolution but shows an area of warm water (otherwise invisible) indicating that the facility is operational.

Figure 1. The Tokai, Japan Nuclear Facility Viewed with Panchromatic and Thermal Sensors

The Comprehensive Test Ban Treaty Organization (CTBTO) has no plans, at this time, to use commercial satellite imagery as part of its process of monitoring and verification. The CTBT treaty, however, provides for the use by States Parties of satellite imagery acquired by NTM. A presentation was made about how commercial satellites might conceivably be used to supplement verification of the treaty. Commercial imagery might be used to determine whether an ambiguous seismic event was a potential nuclear detonation by looking for physical changes in the area where the event occurred. If an event was determined by the CTBTO to warrant an on-site inspection, imagery might be used to help define the inspection area. Some participants pointed out that the CTBT does not prevent preparations for a nuclear test, only the test itself. Consequently, they argued, the use of commercial satellite imagery had low marginal benefit to the verification process.

The Organization for the Prohibition of Chemical Weapons (OPCW) has no plans, at this time, to use commercial satellite imagery in the process of verifying the Chemical Weapons Convention (CWC). The OPCW has given some consideration to using commercial satellite imagery for planning challenge on-site inspections. Negotiations at

the Conference on Disarmament for the verification of a revised Biological Weapons Convention have so far not included commercial satellite imagery.

Conventional Arms Control

Two presentations demonstrated that medium-resolution (10 m) imagery can detect military preparations for possible offensive operations in a desert environment. Unlike nuclear facilities, many of the visible characteristics (referred to as "signatures") associated with military activities tend to be small and temporary. The figure below is a SPOT panchromatic image and shows Gulf War military preparations by allied forces in Saudi Arabia in January 1991 prior to military operations the following month. Estimation of troop numbers or qualitative assessment of military units and facilities (e.g., weapon type and number, readiness, etc) with this particular sensor, however, is not feasible. Fixed positions and new military construction, however, can be readily detected

Conventional Arms Control
- Existing commercial satellites can detect large-scale military preparations for movement and construction. - Timeliness in receiving images affects the utility of commercial satellite imagery. - Aerial monitoring has certain advantages. - Planned satellites will have greater application to monitoring conventional forces.

with current commercial systems. Future commercial systems will be able to detect and characterize a wider variety of military activities.

Timeliness is a factor affecting the utility of imagery for arms control purposes. Imagery must be acquired and analyzed in

sufficient time for the parties to react to changing situations. The current delay between when an image is taken and delivery to a user is typically several days, which prevents its practical use as an early warning system. Based on the analyses presented, large-scale offensive preparations developing over a period of time can be detected. Future systems, in addition to shorter revisit times, are designed to deliver an image to users within hours.

Figure 2. A SPOT Image of Allied Military Activities in Saudi Arabia during the 1991 Gulf War

One analyst cited precedents, such as the military disengagement between Egypt and Israel in the Sinai Peninsula, where aerial monitoring of conventional forces was used when other forms of monitoring were rejected. Aerial monitoring has certain advantages over commercial satellite imagery in his opinion: 1) aerial monitoring forces the normalization of relations because political and military consent must exist, 2) it can be subject to carefully defined procedures, and 3) it can be linked with on-site inspection. In addition, existing aerial systems can achieve higher resolution than current or planned satellites. A third party operator might increase acceptability.

Points of Discussion

The discussion of the cooperative use of commercial satellite imagery for arms control and nonproliferation purposes focused mainly on the complexities and limitations of employing such data. An Israeli thought that commercial satellite imagery could contribute to confidence building in the absence of extensive on-site inspections. Several

participants cautioned that regional agreements must be realistic about the role of technology. The context and goals of verification must be clearly defined and incorporated in a political agreement. Technology, by itself, cannot solve the problem of verification.

Several participants thought a significant benefit of commercial satellite imagery is that, unlike imagery from NTM, it can be freely shared. The selective public use of NTM to determine if a treaty violation has occurred raises concerns about revealing national capability. Furthermore, imagery from NTM is subject to the charge that it has been altered for political purposes whereas a commercial satellite company is more insulated politically because its economic viability depends on being trustworthy.

Some participants made the point that too much transparency can potentially be harmful. For example, Israel's security is based on a strategy of deterrence that is supported by uncertainty about its military capabilities and status. Other participants made the point that the use of commercial imagery could partly offset the historic Israeli advantage in photographic reconnaissance. The resulting question was whether this new, more equal environment would help improve cooperation in the Middle East. The weakening of the Israeli advantage in imagery collection might make Israeli policy makers less inclined to take risks because their sense of security has been reduced. Widely available high

Concerns About the Dual Use of Commercial Imagery

- Too much publicly available information can be harmful.
- Imagery could enable frivolous allegations or cause false alarms resulting from faulty interpretation.
- Imagery could be used for military targeting or planning terrorist attacks.
- Imagery could be used to hide illicit activities by states.

resolution commercial imagery might thus make future agreements more difficult to negotiate.

Many participants raised the point that commercial satellite imagery has dual

uses. In spite of its potential benefits to confidence building, arms control, and nonproliferation, it can also be used for non-peaceful purposes. Some Israelis argued that, in the absence of "appropriate" political and security-related controls, the wide distribution of commercially available images could be destabilizing and even contribute to conflict. Several points of concern about misuse of imagery were raised:

- False alarms resulting from faulty interpretation,
- Targeting by nation states,
- Planning for attacks by terrorist groups, and
- Helping to hide illicit activities by states.

The problem of false alarms is closely related to the requirement for technically competent imagery analysts. The misinterpretation of imagery in arms control applications could actually be destabilizing and contribute to regional tensions. Imagery analysis is somewhat subjective and differences of opinion can be expected from well-intentioned people. A participant said the U.S. Government found that 90% of the judgements made by its analysts in their first year of work were wrong. Some were concerned that governments might deliberately misinterpret imagery as a form of political harassment. Non-governmental organizations can be expected to make

increasing use of commercial imagery in the future and this may result in poorly substantiated claims. The region can thus expect more “noise” to be present in the diplomatic and verification process. A suggested way to reduce false alarms and reject spurious claims is to build a regional community of experienced remote sensing specialists who can perform independent assessments. The need for training Middle Eastern imagery analysts and building their experience was widely discussed and the subject of a number of collaborative proposals described in a subsequent section.

Commercial satellite imagery could be used to support military targeting or planning terrorist attacks. Controls could be placed on buyers of imagery by vendors although this could be evaded to some extent by using third-party agents. The significance of this issue depends on whether commercial imagery provides information that is not otherwise available from NTM, other intelligence, public information, or ground observations.

Countries conducting illicit activities might buy satellite imagery as a means to identify their activities' signatures and detect vulnerabilities. This could permit the development of counter-measures to both cooperative monitoring and NTM. Since imagery purchases

Technical and Procedural Issues Influence the Cooperative Use of Commercial Imagery

- Imagery and related tools may not be affordable.
- There are relatively few remote sensing specialists in the Middle East and training of new analysts is critical.
- Specific spatial and spectral resolution may be necessary for effective analysis.
- Imagery analysis requires an understanding of conditions on the ground.
- Sellers may impose restrictions on the distribution of imagery.

are reportable to the system's national government, such purchases could also be an indicator of illicit activity. Purchasing controls could be instituted but they are subject to the limitations described in the preceding paragraph.

A number of technical and procedural aspects associated with the cooperative use of

remote sensing in arms control were discussed at length. A detailed description of these topics is contained in a subsequent section:

- Cost of imagery and related tools
- Spatial resolution necessary for effective analysis
- The role of “ground truth” imagery analysis
- Restrictions on the distribution of imagery

The general consensus was that the application of current satellite systems to arms control is limited at this time. Planned systems will have significantly more utility but still have limitations when monitoring physically small objects or rapidly changing conditions.

The Role of Remote Sensing in the Environment

Formal presentations were made on desertification of agricultural land, land use classification to enable sustainable land use, and assessment of pollution and

environmental conditions. Several participants were surprised to find that there were few regional interactions associated with the environment or sustainable land use.

Desertification and sustainable land use are closely related topics of great importance in the Middle East. Land degradation (loss of productivity) can occur as a result of both natural and man-made actions. Although wet and dry periods occur naturally with both short and long-term frequencies, the effect of these natural cycles can be exacerbated or moderated by human activity. In Egypt, where moving sand dunes are a problem, about 15% of the loss of agricultural land has been due to urbanization. Remote sensing by LANDSAT has been used to measure the size and direction of sand dunes. This analysis has shown that the movement of sand has caused little net loss of agricultural land. Information gained from remote sensing information has assisted actions to direct moving dunes into channels and to stabilize key locations. Region-wide assessments

Applications of Remote Sensing in the Environment

- Detection and assessment of changes in the condition of the land surface.
- Classifying land use and vegetation cover.
- Supporting the formation of regulations to achieve sustainable land use.
- Detection of the sources of pollution and assessment of the effects.

have also been performed using NOAA satellites that monitor very wide areas with low resolution (5 km).

Land use classification combines remote sensing and GIS and is useful in identifying trends and planning remedial

actions. GIS makes it possible to map, model, query, and analyze large quantities of data (e.g., spectral information, physical features, and political demarcations) in a database. Land use classification, however, can be impeded by definitional problems in political jurisdiction such as those that exist in the West Bank.

New research by the Space Applications Institute of the European Commission Joint Research Centre in imaging synthetic aperture radar (SAR) has indicted promise in assessing soil moisture and vegetation cover. SAR has the advantage being unaffected by light and weather conditions. A novel operational concept is for a geo-stationary satellite to use a low-power radar transmitter with the receiver(s) being either in space, aircraft, and/or on the ground. This is a relatively low cost approach that might permit continuous monitoring. Laboratory experiments have been able to distinguish between a fir tree and a ficus plant by the difference in leaf shape. Different vegetation types were distinguished in an experiment in the Hartz Mountains of Germany. The use of specific frequencies and polarizations may permit low-level vegetation beneath the tree level to be classified. The key to these applications is the use of interferometry from different radar transmitters and the use of sophisticated analysis software. Much of the recent work in this topic deals with the development of signatures based on controlled measurements. One participant thought that an experiment in the Middle East to measure lands with different levels of controlled grazing would be very useful.

Environmental pollution is an example of a topic that transcends national boundaries. A number of case examples from several regions were presented: industrial thermal emissions, aerosol chemical plumes, uranium mine tailings, oil slicks, smoked from

wildfires, water quality, and deforestation. The figure below is a false-color multispectral image from LANDSAT and is an example of the detection and assessment of damage from chemical plumes. (False color is an analytical technique that assigns specific colors to different spectral bands of reflected light to make detection and assessment easier.) The site is an iron ore processing plant in Ontario, Canada that expelled sulfur dioxide into the air without controls. Prevailing winds caused damage to vegetation to accumulate within a particular area. The surface false color near the plant is blue indicating that all the vegetation has been killed. As the plume traveled downwind, it became diluted and less toxic. The damage to the vegetation declines and the false color changes to pink and eventually to red indicating healthy vegetation. Total area damaged by the plant emissions was about 900 km².

Figure 3. Detection of Chemical Plumes Using the LANDSAT Multispectral Sensor

The Role of Remote Sensing in Natural Resource Management and Infrastructure Development

Ground water is a particularly valuable natural resource in the Middle East. Information from several forms of remote sensing (LANDSAT multispectral and thermal bands, RADARSAT, U.S. space shuttle imaging radar) can be combined to enable a geologic analysis. The shuttle radar penetrates the ground and reveals subsurface features such as former riverbeds and fractures. LANDSAT data has been able to distinguish between ancient and recent drainage. Thermal imaging may be used to identify locations where water near the surface in fracture zones causes cooling of the surface. Although remote sensing cannot identify locations where ground water exists with certainty, it can identify

Applications of Remote Sensing in Natural Resource Management and Infrastructure Development

- Imagery can identify geologic structures with a relatively high probability of containing groundwater.
- Collaborative multinational projects can be implemented to map geologic formations likely to contain groundwater or mineral resources.
- Imagery can identify and measure changes in human habitation over time.
- Imagery can be combined with GIS and GPS to enable long-term planning for growth.

likely areas for exploratory drilling. Groundwater collects in permeable zones associated with old river channels. Buried fractures can act as either a barrier or a channel for permeating water depending on the local conditions.

There has been limited cooperation in the Middle East associated with the development and management

of ground water basins. The Hamad Basin extends over southern Lebanon, Syria, Jordan, and northwest Saudi Arabia and is linked by a fracture zone. The neighboring states recognize the interconnectivity but have not developed bilateral or sub-regional plans to assess and manage the resource. The primary technical obstacle is incomplete geologic data of the area. It would be very useful to map the fault structure using a combination of remote sensing and ground observations. For example, the Nubian Basin has been mapped cooperatively by Egypt, Libya, and Sudan. A regional analyst observed that the

absence of information and development plans means that water may be pumped in a way that is unsustainable and/or inequitable. Another regional scientist said the management of surface and ground water needs to be integrated. Adequate ground water information is not available to governments and projections of capacity have been both over- and under-optimistic.

Developing countries throughout the world, especially in the Middle East and Pacific Rim, have experienced rapid economic growth. This economic growth results in the expansion of cities, industry, and agriculture and creates a demand for improved infrastructure. Managing growth is made more difficult by the expense and time involved in producing reliable maps. Remote monitoring provides a tool to view and map development over time and thus plan for needed improvements in infrastructure.

Three case studies for infrastructure development were presented: the provision of municipal services to urban populations, the development of communications networks, and the development of road networks. The figure below illustrates how the Dubai Municipality, UAE used commercial satellite imagery, GPS, and GIS software to implement long-term urban planning. Aerial imagery was judged to be too expensive as well as incomplete due to military restrictions on flights. The municipality merged LANDSAT multispectral imagery (the first image in the figure) with SPOT panchromatic imagery (for higher spatial detail) and used field surveys, correlated with GPS measurements, to verify land classifications made from the imagery. GIS was used to associate all the information into seven categories (geology, geomorphology, hydrology, soils, land use, erosion, and vegetation). The second image shows the land use categories within the Dubai Municipality derived from the project.

Figure 4. Urban Planning and Land Use Classification in Dubai, UAE

Issues Relevant to the Cooperative Use of Commercial Imagery

A number of topics related to the requirements for using commercial satellite and aerial imagery cooperatively were the subject of significant discussion during the workshop. The following sections describe the key issues, discussion, and conclusions.

Cost of Imagery and Related Tools

The cost of imagery and the resources to process and analyze data were a concern to most members. Some participants believed that commercial satellite technology was “an excellent tool for rich countries.” Current imagery prices are listed in the following table. Some satellite companies offer discounted prices to academic and non-profit institutions. Large users also negotiate discounts. Competition between the increasing number of imagery companies may drive down prices over time. The degree to which commercial satellite companies can distinguish their products from competitors will decline.

Table 1. Summary of Commercial Satellite Systems Imagery Resolution and Cost

Satellite	Resolution ² (m)	Image Area (km)	Approximate Image Cost
LANDSAT (USA)	MS: 30 Thermal-IR: 120	180 by 170	\$4400 or \$425 if over 10 years old
SPOT (France)	MS: 20 PAN: 10	60 by 60 60 by 60	\$1950 \$2900
IRS-1C,D (India)	PAN: 5.8 MS: 20	70 by 70 23 by 23 140 by 140 70 by 70	\$2500 \$900 \$2500 \$1900
Kometa (Russia)	PAN: 2 - pre 1993 - after 1993 PAN: 10 If less than 2500 km ² 2500 – 15000 km ² If over 15000 km ²	Variable Variable	\$30/km ² \$40/km ² \$1.00/km ² \$0.60/km ² \$0.50/km ²
JERS ³ (Japan)	SAR: 18 MS: 18/24	75 by 75 75 by 75	\$1000 \$1000
ADEOS (Japan) ⁴	PAN: 8 MS: 16	80 by 80	N/A
ERS (EU)	SAR: 30	100 by 100	\$1550
RADARSAT (Canada)	SAR: 10 – 100	Variable	\$2750 - \$4750
Quickbird (USA) (not launched)	PAN: 0.82 MS: 3.28	22 by 22	Not set
Ikonos (USA) (not launched)	PAN: 1.0 MS: 4.0	11 by 11	North America: \$10 - \$21/km ² International: \$20 - \$41/km ²
Orbview (USA) (not launched)	PAN: 1.0 MS: 4.0	8 by 8 8 by 8	Not set

The cost of imagery analysis hardware and software is not large relative to the total cost of operating a remote sensing center. Modern imagery analysis is typically performed on high-performance UNIX-based computer workstations costing between \$15,000 - \$25,000. However, increased performance by cheaper personal computers has enabled them to perform functions previously by workstations. There are a number of functionally similar analysis software (e.g., *ImageMate*, *ENVI*, *Imagine*, *ImageWorks*) that cost between \$3,000 and \$20,000 depending on the features ordered. Some software is also made in versions that operate on personal computers using WINDOWS-NT as the operating system. This software is cheaper than the UNIX-based software for workstations and has high functionality. Some inexpensive personal computer software such as *Adobe Illustrator* (\$300) can perform very useful tasks in analysis of images. Image archiving, storage, and retrieval will be necessary for managing large imagery databases.

Technical developments are reducing the size and changing the configuration of receiving stations. Some companies are developing mobile stations to be used during a

² NOTE: MS = multispectral, IR = infrared, PAN = panchromatic, SAR = synthetic aperture radar

³ The JERS satellite ceased operations on October 12, 1998.

⁴ The ADEOS-I satellite ceased operations on June 30, 1997. ADEOS-II is to be launched in 2000.

natural disaster or for short periods of time. These stations cost less than \$1 million. Larger permanent stations might cost \$7 million.

There was some concern as to whether the imagery market was really military masquerading as commercial. Satellite companies such as SPOT Image publish advertisements directed specifically toward this market (a SPOT representative estimated the surveillance market to be 37% of SPOT Image's sales). This leads to the concern that market competition may encourage imagery companies to sell to non-commercial users, such as terrorist groups or countries planning military operations, whose goals are not positive. The consensus was that the largest market for commercial imagery remains the traditional users: geologic and environmental science, natural resource development, urban planners, and mapmakers. Security applications, including arms control, are a secondary market whose ultimate size will not be clear for some time.

Several remote sensing scientists believed that some companies would ultimately fail financially due to competition. Participants distinguished between *commercial* (a privately owned business operating for profit) and *commercialized* (a government or government-affiliated organization that sells imagery) satellite companies. Satellite companies that are affiliated with national governments will probably survive because they support the national interest and may receive subsidies. National governments are likely to be one of the largest buyers of their companies' imagery.

Spatial Resolution Necessary for Effective Analysis

The level of spatial resolution needed for different analysis applications was a recurrent area of discussion. "High resolution" is commonly defined today as being less than 5 meters. Current commercial satellite systems produce images with spatial resolutions from 30 to 2 meters and have limited multispectral and stereo-imaging features. The only current systems that can be considered high-resolution are the Russian Kometa KVR-1000 system (2.0 m) and the Indian IRS-1 series (5.8 m) - both in panchromatic (black and white). Second generation systems to be launched over the next five years will have resolutions as low as 0.82 meters, better multispectral/stereo capability, and significantly shorter revisit and image delivery times. The resolution of aerial photographic systems is limited more by operational factors (weather, altitude) than technology. For example, the Open Skies Treaty limits photographic resolution to 30 cm by restricting the altitude at which the aircraft flies during its mission. Image resolution of 10 to 15 cm is possible using relatively simple systems at low altitude.

Some participants wondered if there is an all-around "best resolution." An approximation commonly used in remote sensing is that a resolution of 1/5 the major dimension of an object permits detection and a resolution of 1/20 of the major dimension permits identification. A U.S. Government interagency study was cited that suggested 3.0 m as the optimal resolution for a wide variety of commercial applications. 3.0 m resolution permits the detection of objects larger than 10 - 15 m and enables common projects such as the identification of houses for urban planning, faults in geological studies, and density of trees in forestry studies. Another scientist referred to a 1981 UN study that concluded 0.5 to 1.0 m resolution was needed for arms control monitoring purposes. In the opinion

of an experienced remote sensing scientist, the difference between 1 and 3 m resolution is not significant and only the best analysts can take advantage of the capability. The trend in the capabilities of new commercial satellites toward 1.0 m resolution is motivated by goal of capturing the mapping industry market from aerial survey companies – particularly in markets outside of North America. Stereoscopic imagery to generate topographical maps (typically 1 to 50,000 scale) requires 1.0 m resolution.

Many participants believed strongly that higher resolution is always better and should be sought. Others pointed out that high-resolution imagery has disadvantages such as being more expensive and requiring more processing per unit of land area prior to analysis. Several analysts pointed out that the utility of imagery, in practice, depends on a number of factors: the application, the spectral band or bands collected, the frequency with which a location is imaged, the cost, and the time to receive the images. Ancillary factors can be critical: the training and experience of the analyst, the hardware and software used for analysis, the contextual knowledge of the location, and the availability of "ground truth" (measurements of conditions on the ground) to define generic signatures for key features and activities. There can be disadvantages to having too much information for an application. Geological and environmental science applications have historically required wide coverage with multiple spectrums. High-resolution images have smaller scales. An analysis of large areas requires the integration of many images with the resultant requirement for more computer power, memory and analyst time. If high spatial detail is truly necessary, a two-stage analysis strategy might be used: 1) A survey of large land areas is conducted using low- or medium-resolution imagery, 2) An analysis of objects of interests detected during the survey is performed using high-resolution images of those points.

The Role of "Ground Truth" in Imagery Analysis

Participants in the workshop with technical backgrounds emphasized the importance of understanding conditions on the ground, commonly known as "ground truth," in imagery analysis. Ground truth results from field surveys or laboratory measurement of the physical conditions that remote sensing is attempting to measure. Imagery is then correlated with ground truth to develop "signatures" that are the identifiers of various types of activity or conditions being monitored by remote sensing. Analysts use these signatures to identify, describe, and classify conditions on the ground from the imagery. The acquisition of ground truth can be a cooperative activity and increase confidence between participants. For example, the Global Terrestrial Observing System is working with scientists around the world to obtain ground truth to develop signatures for environmental land quality indicators.

Restrictions on the Distribution of Information

There was significant discussion of countries operating satellites limiting either the availability or resolution of commercial imagery over particular countries (sometimes referred as "shutter control"). For example, the Indian Government has placed restrictions on the use of imagery from the IRS series of satellites. Customers in the U.S. may only purchase images archived from previous IRS missions and cannot request imagery of a specific location at a future time. Most Arabs present objected to any

restriction on the equal distribution of information. The Israelis, however, thought Middle Eastern countries should agree to some common restrictions or "rules of the road" to guide the use of high-resolution imagery. Israeli analysts make the argument that Israel is a very small country and that one of Israel's major military assets is the uncertainty in the assessment of its capabilities by potentially hostile forces.

There was some agreement that high-resolution imagery could affect both individual and national privacy. A major problem is the potential for misuse for purposes other than arms control, economic development or environmental monitoring. If high-resolution imagery can be obtained in near real-time, terrorist organizations might use this information to identify targets and plan attacks. Another concern was that countries with illicit intent might use imagery to develop deceptions to hide their activity from international inspectors or other countries' NTM.

Israel's concern about the impact of widely available high-resolution imagery resulted in a series of discussions with the U.S. government concerning the operation of planned high-resolution satellite systems owned by U.S. companies. There were misunderstandings among participants about formal or informal agreements between the U.S. and Israel regarding satellite technology and imagery distribution. United States policy regarding the distribution of imagery of Israel is as follows.

In March 1994, President Clinton issued Presidential Decision Directive (PDD) 23 that allowed private firms to develop and launch satellites to sell high-resolution imaging services.⁵ The U.S. and Israel conducted several meetings between 1994 and 1995 about the future distribution of high-resolution imagery of Israel. In 1996, Israel asked the U.S. to limit imagery sold by U.S. to 3.0 m resolution.⁶ In June 1996, the U.S. Congress passed the Kyl-Bingaman amendment to the National Defense Authorization Act for fiscal year 1997. The act enables the U.S. Government to prohibit the collection and release of detailed satellite imagery relating to Israel (including the occupied territories) or any other geographic area designated by the President unless licensed by the Department of Commerce.⁷ In effect, the act limits the resolution of imagery of Israel to the best available from non-U.S. satellites. The lowest resolution imagery commercially available today is 2.0 m from the KVR-1000 photographic system of the Russian Kometa satellite series. (Kometa satellites are limited to 45-day missions and do not provide either continual or worldwide coverage.) In July 1998, the United States agreed to prohibit the sale to foreign governments of satellites that would enable high-resolution

⁵PDD-23 allows the Department of Commerce to block the sale of images if it deems that distribution poses a threat to U.S. national security. The Department of Commerce issues export licenses based on the foreign customer's "willingness and ability to accept commitments to the U.S. Government concerning sharing, protections, and denial of products and data." The licenses are valid for a finite period, are not transferable, and are not subject to foreign ownership. The PDD also places a number of requirements on the licensees, including keeping records of satellite tasking, the use of approved encryption devices, as well as prohibitions regarding changes in the operational characteristics of the satellite system.

⁶ John Fialka, *The Wall Street Journal*, June 17, 1996.

⁷The text reads: "A department or agency of the United States may issue a license for the collection or dissemination by a non-Federal entity of satellite imagery with respect to Israel only if such imagery is no more detailed or precise than satellite imagery of Israel that is available from commercial sources."

photographs of Israel.⁸ The U.S., in turn, asked Israel to maintain similar restrictions regarding photographs taken by the Israeli Ofek-3 satellite, as well as any photographs that might be taken by a future Israeli commercial satellite venture - whether launched from Israeli soil or from abroad, or in cooperation with a foreign company.⁹ On July 22, 1998, the U.S. Departments of State and Commerce announced in a meeting with representatives of the three U.S. companies planning high-resolution systems (Space Imaging, EarthWatch, and Orbital Imaging) that they would be forbidden to distribute imagery of Israel with less than 2.0 m resolution.¹⁰ The Kyl-Bingaman Amendment was cited as providing the legal authority.

National policy may also restrict the use of otherwise freely available data. For example, some countries in both the Middle East and South Asia treat information about water resources as confidential making it difficult for scientists to conduct research in this topic. It is generally difficult to obtain maps more detailed than a scale of 1 to 50,000 in the Middle East. This level of detail is insufficient for many infrastructure development projects. Available maps are often old and commercial satellite imagery offers a potentially cost effective method to update them. A Palestinian scientist pointed out that Israel banned GPS receivers in the Palestinian Authority area as a security measure. This prevents imagery from being accurately geo-corrected so accurate maps can be made.

Potential Cooperative Projects

The participants identified international programs and new projects that would support the cooperative use of commercial satellite imagery in the Middle East.

Potential Areas for Cooperation in the Use of Commercial Satellite and Aerial Imagery in the Middle East Identified by the Workshop Participants

- Link regional remote sensing organizations with international programs in space science
 - *Global Terrestrial Observing System*
 - *United Nations Program on Space Applications*
- Development of regional remote sensing organizations
 - Establishment of a *Middle East Satellite Centre*
- Information and data accessibility
- Geophysical hazard mitigation
- Water resource management
- Sustainable land use
- Training of regional remote sensing specialists
- Natural heritage resource management
- Confidence building measures

⁸ "U.S. bans high-resolution satellite sales in bow to Israeli pressure"; Z. Schiff, *Ha'aretz*, August 17, 1998.

⁹ *Ha'aretz*, August 17, 1998.

¹⁰ "U.S. bans sales of 1-meter images of Israel," *Imaging Notes*, September/October, 1998, vol. 13, no. 2

Linking Middle East Organizations with International Space Science Programs

The need for affordable imagery, training, technical resources led a number of participants to suggest that links be established with ongoing international space science programs. Countries in the Middle East generally have not participated in these programs and it presents a significant opportunity for the region. Two programs were identified as being particularly promising: the *Global Terrestrial Observing System* and the United Nations *Program on Space Applications* of the Office of Outer Space Affairs (UN/OOSA).

Global Terrestrial Observing System

The Global Terrestrial Observing System (GTOS) was established in 1996 by five organizations: the UN Environmental Program (UNEP), the UN Food and Agriculture Organization (FAO), the UN Educational, Scientific and Cultural Organization (UNESCO), the World Meteorological Organization (WMO), and the International Council of Scientific Unions (ICSU). The goal of GTOS is to provide a deeper understanding of global change on Earth. GTOS is intended to provide data for detecting, quantifying, locating, and giving early warning of changes in the capacity of the Earth to sustain development and improvements in human welfare. GTOS seeks to foster an integrated, equitable partnership of a wide variety of data users in a way that meets both the short-term development needs of national governments and long-term needs of the research community. As such, GTOS is not a funding organization and is envisioned as a "partnership of partnerships" formed largely by linking existing monitoring sites and networks as well as present and planned satellite remote sensing systems. Progress is based on individual scientific and development projects with GTOS providing the framework within which outputs from commercial satellites and environmental databases can be integrated with on-site observations.

Primary GTOS focus areas are changes in land quality, freshwater resources availability, pollution and toxicity, loss of biodiversity, and climate change. Five space agencies participate in GTOS: the U.S. National Aeronautics and Space Agency and National Oceanic and Atmospheric Administration, the European Space Agency, The National Space Development Agency of Japan, and the Russian Space Agency. Eleven scientific networks participate including the Arab Center for the Studies of Arid Zones and Drylands. A participating scientific network, the U.S. Long Term Ecological Research network (LTER) of the National Science Foundation has established an affiliated international network (ILTER) that helps scientific organizations establish ground-based ecological monitoring systems.

In 1998, a new project began to assess global primary land productivity. Recognizing the importance of sustainable land use to developing countries, data and imagery from satellites will be provided free of charge to developing countries in exchange for ground observations. The information provided by the developing countries will be used to development signatures of primary productivity metrics. This project will also provide developing countries with an opportunity for training in data analysis and experiment design. This program provides an excellent opportunity for Middle Eastern countries to receive data and imagery relating to land use.

UN Program on Space Applications

Several participants cited the efforts of the Vienna-based UN Office of Outer Space Affairs to foster the increased use of space technology. The Program on Space Applications (OOSA/SAP) was established by the General Assembly in 1971 as a result of first UN Conference on the Exploration and Peaceful Uses of Outer Space. The goal of the program is to enhance the understanding and subsequent use of space technology for both peaceful purposes and for national development.¹¹ The program has six goals:

- Promote greater cooperation and exchange experience in space science and technology between industrialized and developing countries as well as among developing countries.
- Manage a fellowship program for in-depth training of scientists and technologists.
- Organize seminars on space technology and applications for both managers and technical specialists.
- Stimulate the growth of technological bases in space technology in developing countries in cooperation with other UN agencies and/or Member States.
- Disseminate information about new technologies and applications with emphasis on the needs of developing countries.
- Provide technical advisory services on space application projects upon request by Member States.

The Program on Space Applications has established several space technology centers around the world to develop regional expertise. Each center conducts training and research in remote sensing, meteorology, communications and atmospheric sciences. The first center opened in November 1995, in India with a focus on the Asia and Pacific regions. It has already held six nine-month courses serving a total of 128 post-graduate students from 25 countries. The second center opened in Casablanca, Morocco in October 1998. The Center will train students from French-speaking African nations in space and satellite technology in topics that ranging from assessing natural disasters and weather forecasting to education. In November 1998, a third center opened in Nigeria for English-speaking African nations. An agreement has been reached to establish a fourth center to be co-hosted by Brazil and Mexico for the Latin America and Caribbean regions. In addition, a seven-nation network linking space-related education and research institutions is in the planning stage for central, eastern and southeastern Europe. Data management units at the various centers are to be linked with global databases in the future.

Many participants thought that the establishment of a new center in the Middle East would be quite beneficial. Although citizens of Middle Eastern countries have participated in specialized UN space conferences, countries have not participated as a group nor has the Middle East been the subject of OOSA/SAP conferences. Since there are a number of remote sensing centers already in the region, several participants proposed the creation of a regional joint commission to survey Middle Eastern capabilities. This survey might be the subject of one of the periodic technical meetings

¹¹ Between 1992 and 1996, OOSA/SAP organized 42 conferences, workshops, and training courses. 1291 participants were fully or partly sponsored to attend these activities.

held by the OOSA/SAP. The conclusions of such a meeting could become the basis of a proposal to the OOSA/SAP to establish a Middle East space technology center.

A participant noted a 1981 proposal to establish a UN International Satellite Monitoring Agency (ISMA) and a study sponsored by France on the structure and function of such an Agency.¹² Other participants were not supportive of the ISMA concept, arguing for a regional organization and noting the problem of political factors in an international organization causing the data to be "filtered."

Participants noted that the Third United Nations Global Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) is to be held in Vienna from July 19-30, 1999. This conference may provide another opportunity for the Middle East to participate in an international forum as a region. The objective of the Conference is to promote the use of space technology in solving regional and global problems, such as the protection and management of the environment, land and ocean resources, enhancement of education and medical services through tele-education, distant learning and tele-medicine. New applications being considered are detecting production of illicit drugs and landmines. The Conference is also intended to strengthen the capability to use space technology for economic and social development in developing countries. In addition, the Conference hopes to build a partnership between the United Nations, governments and the space industry. This will be the first United Nations conference to invite industry organizations as an equal partner with governments. Regional preparatory conferences have been held in Asia and Latin America and with others scheduled for Africa and Eastern Europe. Notably, none are planned for the Middle East.

Development of Regional Institutions for Remote Sensing in the Middle East

Participants discussed informal and formal approaches to build cooperation and a regional infrastructure in the Middle East for using remote sensing technology.

The informal approach identified professional organizations and scientist-to-scientist contacts as a way to build a network of regional contacts that may contribute to the subsequent development of regional institutions. Common interests and opportunities can be identified and discussed. For example, there has been ongoing interaction between individual seismologists and geologists in the Middle East to combine their local data to create a regional image of seismic activity. This type of interaction overcomes many of the political limitations present in the region. This approach may be applicable in other topics such as desertification or agriculture.

The Middle East Seismic Monitoring Cooperation Project is an example of how a productive effort can evolve with a small amount of outside support. The U.S. ACDA, the State Department, and the Department of Energy have funded the effort for the last seven years. The project is a joint effort between UNESCO and the U.S. Geological Survey and involves geological survey organizations in the Middle East, and several European organizations. The project is directed toward both seismic event monitoring

¹² United Nations Department of Disarmament Affairs, Study Series on Disarmament, No. 9, *The Implications of Establishing an International Satellite Monitoring Agency*, A/AC.206/14, 1983, New York.

and earthquake hazard mitigation and has been evolutionary and non-political. There is no "center" but the group has sponsored common activities. A fundamental principle of the project is that participants should have equal scientific knowledge so the group has conducted training courses. The group has performed joint observations of seismic activity. Seismic monitoring was initially conducted for periods of three months with data being sent to France for distribution throughout the Middle East. The monitoring periods were later expanded to one year and are now continuous. One advantage, in retrospect, was that collaborative activity consisted of select and definitive projects that required the participants to exchange data in order to be successful. Members of countries who do not normally have much contact set precedents by exchanging data.

A particularly interesting and useful project by the Seismic Cooperation Group dealt with the November 1995 earthquake in the Gulf of Aqaba. There were allegations in the region that the earthquake was really an Israeli nuclear test. Although international seismic monitoring stations stated that the characteristics of seismic signals did not conform to a nuclear detonation, there were still doubts in the region. Since the earthquake occurred during one of the joint monitoring periods, the group exchanged seismic data and subsequently conducted a workshop to interpret the seismic event. They established that the event was an earthquake. The analysis thus became a regional confidence-building measure and has been documented in a joint paper. Another goal of the Aqaba workshop was to define a common data format. One country is now developing software (to be distributed on CD-ROM), based on this workshop, to transform seismic data into a uniform data format. This will be helpful in further development of a geological hazard map of the entire Middle East.

A more formal approach to cooperation was the proposal by a participant to establish a Middle East Satellite Centre (MESC). The organization of the conceptual MESC is in the figure below. The Western European Union Satellite Centre (WEUSC) was cited by several as a potential model for a MESC.¹³ The participant thought a regional organization, rather than a center affiliated with the UN, was the best option because it could be adapted to suit the region.

Figure 5. Organization Chart of a Conceptual Middle East Satellite Centre

Imagery analysis by the WEUSC includes general security tasks including support for WEU operations, supporting humanitarian, peacekeeping and crisis management tasks, and maritime and environmental surveillance. The WEUSC uses supplemental

¹³ The WEUSC, a subsidiary of the Western European Union, is located in Torrejon, Spain and was formally established in 1993 following an experimental phase. The WEUSC has three missions: imagery interpretation and analysis, training imagery interpreters and developing new analytical techniques and procedures. It completed its first analysis project in 1996 and has a staff of 68. Analysis projects use imagery from SPOT, ERS, LANDSAT, RADARSAT, IRS-1, and various Russian systems. In addition, the Centre has access to the non-commercial French HELIOS satellite. Imagery is received, processed, and distributed within the Centre in electronic form using commercial workstations and software. Film and light tables are not used.

information such as publicly available reports, reference materials, and maps to aid interpretation and analysis of imagery. About 200 reports are produced and distributed to Member States and Associate Members per year. The WEUSC is investigating options for electronic distribution of reports to users.

Training of Middle Eastern Imagery Analysts

All the technical presentations illustrating regional applications noted the role of imagery analysis. The training of analysts was one of the most widely discussed topics during the workshop. There was wide consensus that the establishment of a community of trained regional analysts was the key factor in the effective and cooperative use of remote sensing data in the Middle East. Experience is also important. The distinction was also made between photo interpreters and imagery analysts. Training in photo interpretation (i.e., the ability to measure objects, recognize predefined signatures, etc) can be as short as 3 months. However, the ability to make full use of various kinds of imagery (panchromatic, multispectral and radar), develop signatures from ground measurements (ground truth), and understand the activity being monitored well enough to take advantage of collateral sources of information takes several years.

There was no clear consensus about the best way to implement training in the Middle East but many participants thought training could serve as a basis for regional cooperation. Training might be implemented under formal UN OOSA/SAP programs or by regional organizations such as the MESC proposed during the workshop. Satellite companies and a number of universities in world provide extensive training although commercial companies were thought to be too expensive. Some analysts in attendance thought that on-the-job training at existing institutes and companies in the region was best. International grants would be useful in funding remote sensing analysis projects at regional institutes. Professional associations and informal scientist-to-scientist contacts such as the Middle East Seismic Monitoring Cooperation Project offer additional options. Some thought the development of internet-based training should be explored because it could reach many people at relatively low cost. (NASA has publicly available remote sensing tutorial on the internet.¹⁴)

The design of remote sensing training curricula faces several obstacles. Technical developments in the field and obsolescence occur quite rapidly. Frequent updates will be necessary to keep training technically current. Several analysts pointed out that the implementation of training will be complicated by the fact that remote sensing data from commercial satellites comes in different formats. A similar situation exists in analysis software where similar functions in different software packages operate quite differently. The market will also affect where analysts work. Accompanying the growth of commercial remote sensing industry is an increase in demand for skilled analysts. The director of a research institute said that many of his staff have been hired by commercial companies after his institute invested in training.

¹⁴ The URL is <http://rst.gsfc.nasa.gov/TofC/Coverpage.html>. A CD-ROM is also available at low cost.

Specific Proposals Presented during the Workshop

Most regional participants expressed enthusiasm for working together on joint projects involving commercial satellite or aerial imagery. A senior scientist suggested that regional parties direct their energies to a defined problem rather than focus on the creation of a regional center right away. The workshop participants produced a number of ideas for cooperative projects using imagery that could be initiated in informal ("Track II") settings or during future proceedings of the official multilateral working groups.

Recommendations from the participants are grouped into eight categories:

- 1) Information and data accessibility
 - Establish a remote sensing image database for the Middle East, North Africa, and Southern Europe and integrate with ground measurement data.
 - Establish regional standards for GIS and a uniform, user-friendly GIS format.
 - Establish a World Wide Web site to list and link with regional remote sensing centers, commercial satellite services, and remote sensing references.
 - Establish an annotated bibliography of applications of remote sensing to arms control, environmental protection, and other topics.
 - Establish a database of NGOs and professional associations who work in the field of remote sensing.
- 2) Development of regional remote sensing organizations
 - Study the example of the Western European Union Space Centre as a model for a Middle Eastern organization.
 - Study the examples of African and South Asian Space Technology Centers established by the UN Program on Space Applications. Propose the establishment of a Middle East Space Technology Centre.
 - Create a network using the Internet and/or other communication system to link existing national remote sensing centers in the Middle East.
 - Conduct a conference to define the role of the Middle East in the Global Primary Productivity Project and use the results to establish links with the Global Terrestrial Observation System.
- 3) Geophysical hazard mitigation
 - Develop a geologic characterization map (including fault lines) of the Middle East using inexpensive archival LANDSAT imagery combined with seismic waveform data from the Middle East Seismic Cooperation Project.
- 4) Water resource management
 - Assess the potential for remote sensing data to identify the sources of water loss in distribution systems.
 - Use remote sensing data to assess and visualize water basin inventory as a tool for water resource management and resolution of cross-border disputes.
- 5) Sustainable Land Use
 - Use imagery and ground measurements to develop signatures to assess the effects of grazing on sustainable land use.
- 6) Training of Regional Remote Sensing Specialists
 - Develop CD-ROMs for use in tutorials on image processing and interpretation.

- Conduct training courses on image processing and interpretation by combining resources from industry, university, and government.
- Conduct a training course specifically on CTBT verification including potential use of imagery for post-test assessment.
- 7) Natural heritage resource management
 - Define the role of remote sensing in the conservation and management of natural heritage resources such as coral reefs and fisheries.
- 8) Confidence building measures
 - Demonstrate an Open Skies aircraft, monitoring technologies, and procedures in the Middle East.
 - Establish a regional commission on the use of remote sensing for peacekeeping purposes.

The most developed proposal was by the Egyptian National Authority for Remote Sensing and Space Sciences (NARSSS) for a regional study of the implications of global climate change on the Middle East. This project would use available imagery to study sea-level variation, temperature changes, and the effect of CO₂ emissions. To begin this project, the regional parties would have to cooperate in deciding on a uniform format for a digital database, and link this database to regional and international systems. The parties would meet twice a year with one meeting including a training course. The project should be associated with the UN, but the NARSSS would serve as the focal point for the research activity in the region and provide in-kind support including space, local specialists, and equipment.

Participants thought it was very important to identify and secure consistent funding sources. Several participants thought UNESCO would be receptive to proposals. In addition, they thought it would be useful to solicit help from extra-regional non-governmental organizations to organize regional remote sensing activities.

General Conclusions

It became clear during the workshop that the applicability of commercial satellite imagery to the verification of future regional arms control agreements is limited at this time. Non-traditional security topics such as environmental protection, natural resource management, and the development of infrastructure offer the more promising applications for commercial satellite imagery in the short-term. Many problems and opportunities in these topics are regional, or at least multilateral, in nature. A further advantage is that, unlike arms control and nonproliferation applications, cooperative use of imagery in these topics can be done independently of the formal Middle East Peace Process.

The value of commercial satellite imagery to regional arms control and nonproliferation, however, will increase during the next three years as new, more capable satellite systems are launched. Aerial imagery, such as that used in the Open Skies Treaty, can also make

significant contributions to both traditional and non-traditional security applications but has the disadvantage of requiring access to national airspace and potentially higher cost.

There was general consensus that commercial satellite imagery is under-utilized in the Middle East and resources for remote sensing, both human and institutional, are limited. This relative scarcity, however, provides a natural motivation for collaboration in non-traditional security topics. Collaborations between scientists, businesses, universities, and non-governmental organizations can work at the grass-roots level and yield contributions to confidence building as well as scientific and economic results. Joint analysis projects would benefit the region as well as establish precedents for cooperation.

There was also general consensus that training to analyze imagery is needed in the Middle East. Inadequate training and experience might cause the misinterpretation of imagery in arms control applications. This would have the undesired effect of increasing regional tensions. The collection of ground truth information to define signatures in imagery for various applications is also important. In the absence of regional arms control agreements to verify, initial training in topics such as environmental monitoring of joint concerns may be the best way to develop new regional imagery analysts. Pilot projects that involve image analysis could be a viable alternative to general training. Such projects would involve some formal training, but would focus on an issue of importance to the region. Many of the analytical skills used in non-traditional security projects are also applicable to the monitoring of future arms control and security agreements. In this way, a single project could contribute in two ways to confidence building.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

APPENDIX A: A SUMMARY OF REMOTE SENSING TECHNOLOGY

Spatial Resolution

Resolution is the smallest distance that a sensor can distinguish between two similar sized objects. When images are taken from space or from an aircraft, there will be both an azimuth (along the flight path) and a range (across the flight path) resolution. This is because the sensor is sensitive to radiation only within a solid angle defined by its operational characteristics. The sensor's view thus forms a spot on the ground called an *instantaneous field of view*. The instantaneous field of view is exactly square only when viewed directly below the satellite or aircraft. Resolution can be expressed two ways. For film systems, resolution refers to the highest spatial frequency that can be resolved in the focal plane or the equivalent *ground resolved distance* (GRD). Digital images are composed of picture elements commonly referred to as *pixels*. Resolution for digital systems refers to the *ground sampled distance* (GSD) between the centers of pixels. The more pixels, the more detail can be differentiated. The difference between GRD and GSD is approximately a factor of two.

A common approximation is that a resolution equal to 1/5 of an object's major dimension is needed for detection and 1/20 of the major dimension for identification. The following figure illustrates this approximation with an F-15 aircraft. The fact that an object is smaller than the resolution distance does not necessary mean it goes undetected. A long, thin object can be identified at a GSD resolution much greater than its width. The apparent width, however, will be distorted and appear to be the width of the pixel. Single objects well removed from other objects with a uniform background may be detected easily, but large objects closer than 1 pixel may be indistinguishable. If metal fence posts are resonant to the wavelength of synthetic aperture radar and the microwave illumination is at the correct angle, the posts will show up clearly.

Figure 6. F-15 Aircraft at 4.0 and 0.5 m GSD Resolution

Factors Affecting Spatial Resolution

Two images with the same GSD may not have the same quality and consequently the same effective resolution. Factors affecting the spatial resolution of both film and digital systems are ambient conditions when the image was made (level of illumination, sun angle, weather, the movement of masses of air with different refractive indices), sensor hardware (size of sensor collecting radiation, the spectral band measured, sensitivity of the radiation collector), and the sensor's platform (altitude, stability, ability to store or transmit large amounts of data). For film systems, additional factors include scale (focal length and distance), film type (sensitivity and grain size), exposure duration, optical characteristics of the lens.

Contrast

Contrast is the degree of difference between light and dark, or shades of color in an image. It is possible to have an image with high spatial resolution but low contrast where

objects are difficult to detect. Effective measurement of contrast is one benefit resulting from processing remotely sensed data digitally. Humans have only a limited ability to distinguish small differences in color and can typically distinguish only 8 to 10 shades of gray. Current satellite sensor systems collect information in 256 shades and new systems have the capability for 2048.

Spectral Range

The electromagnetic spectrum extends both above and below the range visible by humans (0.4 - 0.7 micrometer wavelength). Sensors are sensitive to a particular band of the spectrum. Satellite and aircraft sensors are referred to as *panchromatic* (1 band), *multispectral* (3 to 7 bands), or *hyperspectral* (8 to several hundred). Panchromatic (black and white) imagery gives maximum spatial resolution because more light is available over a wide spectral range. Multispectral (color) imagery uses moderately wide spectral bands, which adds additional information for discrimination, classification, and analysis. Hyperspectral imagery uses many narrow contiguous bands to further improve discrimination.

The relative transmission of electromagnetic energy through the atmosphere varies according to its wavelength. This characteristic combined with knowledge of how different surfaces reflect energy, enables analysts to identify features or conditions on the Earth's surface using multispectral and hyperspectral imagery. The following figure shows how the French SPOT-4 satellite's multispectral sensor measures four common surfaces.

Figure 7. Ground Reflectance in Different Spectral Bands

Different spectral bands can reveal information that is not evident in the visible band. For example, during the 1991 Gulf War, Iraqi troops ignited hundreds of fires at oil wells in Kuwait. The number of burning wells was difficult to assess at first because thick black smoke covered the area. The Government of Kuwait used LANDSAT images to plan remedial actions. The following figure shows how energy in the middle infrared band from burning wells penetrates smoke.

Figure 8. Oil Fires in Kuwait Observed in the Middle Infrared Band

The spectral sensitivities of operational satellites are illustrated in the figure below.

Figure 9. Comparative Satellite Spectral Resolutions

Synthetic Aperture Radar

Radar is an active sensor because it transmits electromagnetic radiation and then receives and measures the reflected energy. Consequently, daylight and weather conditions do not effect radar images. Radar measures range and the reflectance of objects but requires a large antenna to distinguish spatial detail in reflected signals. Synthetic aperture radar (SAR) uses the forward motion of the platform and computer processing to simulate a large antenna. Data from all ground spots are collected and stored for as long as the transmitted beam pulses illuminate them. The reflected signals are segregated by return time, frequency and phase, while measuring amplitude.

SAR data processing to construct an image is complicated. Variation in the reflected energy causes a grainy appearance in the image compared to passive sensors that measure reflected energy in other spectra (see figure). A limitation of SAR systems is that they produce so much data they can exceed the capabilities of the ground communication system or the onboard recording devices. Ongoing technological developments will improve both of these limitations. For this reason commercial aerial SAR systems have greater resolution (up to 1 m) than the Canadian RADARSAT satellite (10 m minimum) although their field of view is much smaller.¹⁵

Figure 10. 1.0 m GSD Resolution Aerial SAR Image of Helicopters and Building

Area Viewed by a Satellite

A satellite's orbital altitude and inclination (the angle of the orbit relative to the Earth's equator) determine the area it senses remotely. A sun-synchronous orbit is an inclination for a given altitude that permits the satellite to pass over a point on Earth at the same local time. This is a useful when comparing sequential images over time. The satellite's revisit time is the length of time between passes over the same point on Earth. Revisit times for commercial satellites vary between 16 and 44 days. The ability for sensors to make measurements to the side of the flight path (off-nadir) reduces the effective revisit time. A system of common satellites, such as SPOT, enables points to be imaged daily.

Stereo Imaging

Prior to the 1930s topographic maps were made exclusively from field surveys. Stereo pairs of aerial or satellite photographs permit contours to be drawn using special instrumental techniques. Stereo views use the parallax created by two images with about 50% overlap relative to the flight path. When the stereo pair is properly positioned left-right and viewed through a stereoscope, the eye-brain reaction is an impression of surface relief. A pair of synthetic aperture radars operating together (or a second image with a known dimensional offset) use interferometry to calculate height information and produce three-dimensional images.

¹⁵ RDL Space Corporation of California was issued a license in June 1998 to build and launch a satellite with SAR capable of up to 1.0 m resolution. The satellite, RADAR1, is scheduled to be launched in 2001 and will operate in a low-Earth orbit enabling daily coverage of most locations.

Common Types of Image Data Processing

- *Radiometric correction*: adjust sensor response to known value
- *Geometric correction*: adjust data to known map coordinates and projection
- *Atmospheric correction*: compensation for effects of atmosphere on radiation received by the sensor (e.g., sun angle, water vapor, carbon dioxide)
- *Ortho-rectification*: compensation for terrain distortion using elevation data

APPENDIX B: MIDDLE EAST CENTERS FOR SPACE SCIENCE AND TECHNOLOGY LISTED WITH THE UNITED NATIONS OFFICE OF OUTER SPACE AFFAIRS

In 1985 the United Nations began a regular survey of Member States, United Nations specialized agencies and international agencies regarding education, training, research and fellowship opportunities available in space science and technology. The survey contains information for each institution including its areas of specialization, educational and researches programs, facilities, and opportunities for cooperation. This appendix is based on the information submitted up to 1 June 1996.

EGYPT

NATIONAL AUTHORITY FOR REMOTE SENSING AND SPACE SCIENCES

Academy of Scientific Research and Technology, 101 Kasr El-Eini, Cairo, Egypt

Tel.: 3557110, 3540173, Fax: 3557110

Contact person: Prof. Dr. Hussein A. Younes

Principal function(s) of institution: Research and development, image production, training

Specific areas of interest: Software development and applications, joint research projects

Geographical preference: Arab and African countries

Academic and scientific program specialization(s): remote sensing

Summary of courses and research activities: Principles of remote sensing. Applications of remote sensing to geology, geomorphology, mineral resources, water, soil, natural vegetation, cultivation, land use, etc. image processing and production, and GIS.

IRAQ

SPACE AND ASTRONOMY RESEARCH CENTRE

P.O. Box 2441, Jadiriya, Iraq

Tel. 7765116, ext. 1100

Contact persons: Dr. Kadhim Mouala, Space Dept.; Dr. Quassim Abdullah, Remote Sensing Dept.

Principal function(s) of institution: Research and development

Specific areas of interest: Geomagnetism, cosmic rays, atmospheric and ionospheric research, digital image analysis, photo interpretation and processing, software development, remote sensing hardware design and maintenance, photogrammetry.

Geographical preference: Ground-based stations with same geographical co-ordinates as Iraq

Academic and scientific program specialization(s): basic space sciences, remote sensing

Summary of courses and research activities: Cosmic rays, geomagnetism, atmosphere and space research; basic and applied research in the field of remote sensing.

JORDAN

ROYAL JORDANIAN GEOGRAPHIC CENTRE

P.O. Box 20214, Amman - 11118, Jordan

Tel.: 962-6-845188, Fax: 962-6-847694

Contact person: Director General

Principal function(s) of institution: Training, education, and production

Specific areas of interest: Map production and remote sensing

Geographical preference: None

Academic and scientific program specialization(s): remote sensing

TELECOMMUNICATIONS COLLEGE

Jordan, Amman, P.O. Box 2703, Jordan

Tel.: 713320

Contact person: Dr. Abdel Fattah Abu Qayyas

Principal function(s) of institution: Education

Specific areas of interest: Exchange of information, instructors and course materials.

Geographical preference: Arab countries

Academic and scientific program specialization(s): satellite communications

Summary of courses and research activities: Satellite communications technology, which includes principles of satellite communications, RF & BB line calculations, principles of different Intelsat services. Theory of operation and maintenance of components and subsystems of satellite earth stations.

KUWAIT

KUWAIT INSTITUTE FOR SCIENTIFIC RESEACH

P.O. Box 24885, Safat, Kuwait

Tel.: 481-6988

Principal function(s) of institution: Training, research and development

Academic and scientific program specialization(s): remote sensing

LEBANON

NATIONAL CENTER FOR REMOTE SENSING

P.O. Box 11-8281, Beirut, Lebanon

Tel.: (961-1) 409 845-7, Fax: (961-1) 822 639, E-mail: consult@cnrs.edu.lb

Contact person: Dr. Mohamad Khawlie

Principal function(s) of institution: Research and development

Specific areas of interest: Training, resources, environmental conservation and protection

Geographical preference: none

Academic and scientific program specialization(s): remote sensing

Summary of courses and research activities: Workshops. Research in water resources, agriculture, geology, environmental conservation, sectoral databases

LIBYA

LIBYAN CENTER FOR REMOTE SENSING AND SPACE SCIENCE

P.O. Box 82819, Tripoli, Libya

Tel.: 218-21-607004 – 14, Fax: 218-21-607015

Contact person: General Director

Principal function(s) of institution: Training, research, development and services

Specific areas of interest: Remote sensing, aerospace engineering, and astronomy

Geographical preference: none

Academic and scientific program specialization(s): basic space sciences, remote sensing

MOROCCO

ROYAL CENTRE FOR REMOTE SENSING (CRTS)

16 bis, Avenue de France, Agdal, Rabat, Morocco

Tel.: (212-7) 77 63 07/06, Fax: (212-7) 77 63 00, E-mail: crts@mtds.com

Contact person: Mrs. Amal Layachi

Principal function(s) of institution: Coordination and promotion of remote sensing, development projects, satellite data distribution, training, research

Specific areas of interest: Remote sensing and GIS applications; space technology.

Geographical preference: None

Academic and scientific program specialization(s): basic space sciences, remote sensing

Summary of courses and research activities: Courses on remote sensing. GIS summer session, Program in space technology. Applied research in space technology (space oceanography, applications of remote sensing in agriculture, geology) conducted in collaboration with university, institution and research centre

QATAR

UNIVERSITY OF QATAR, SCIENTIFIC AND APPLIED RESEARCH CENTER

P.O. Box 2713, Doha, QatarTelex: 4630 UNVSTY-DH

Tel.: (0974) 874961

Contact persons: Dr. Homaid Almadfs, Dr. Jaber Al-Noaimi

Principal function(s) of institution: Research and education

Specific areas of interest: Remote Sensing

Geographical preference: Arab countries of the Gulf Cooperative Council (GCC)

Academic and scientific program specialization(s): remote sensing, satellite meteorology

Summary of courses and research activities: Application of remotely-sensed data from aircrafts and satellites to geological mapping, drainage basins, land-use pattern, coastal studies and other natural resource studies. Use of meteorological satellite data to monitor regional environmental phenomena, pollution and ground water studies

SAUDI ARABIA

SAUDI CENTER FOR REMOTE SENSING

King Abdulaziz City for Science and Technology (KACST), Kingdom of Saudi Arabia

Tel.: (966 1) 481-1141, Fax: (966 1) 488-3756

Principal function(s) of institution: Applied research, R & D

Specific areas of interest: Remote sensing

Geographical preference: based on availability of data in the Center.

Academic and scientific program specialization(s): remote sensing, satellite meteorology

Summary of courses and research activities: Remote sensing applications, supporting National Development Plans and academic research in education. Providing data from NOAA 9 and 10 for weather forecasting. Facilities: Image processing systems, receiving station

SYRIAN ARAB REPUBLIC

GENERAL ORGANIZATION OF REMOTE SENSING (GORS)

P.O. Box 12586, Damascus, Syrian Arab Republic

Tel.: 963-11-2218765, 2218764, Fax: 963-11-3910700

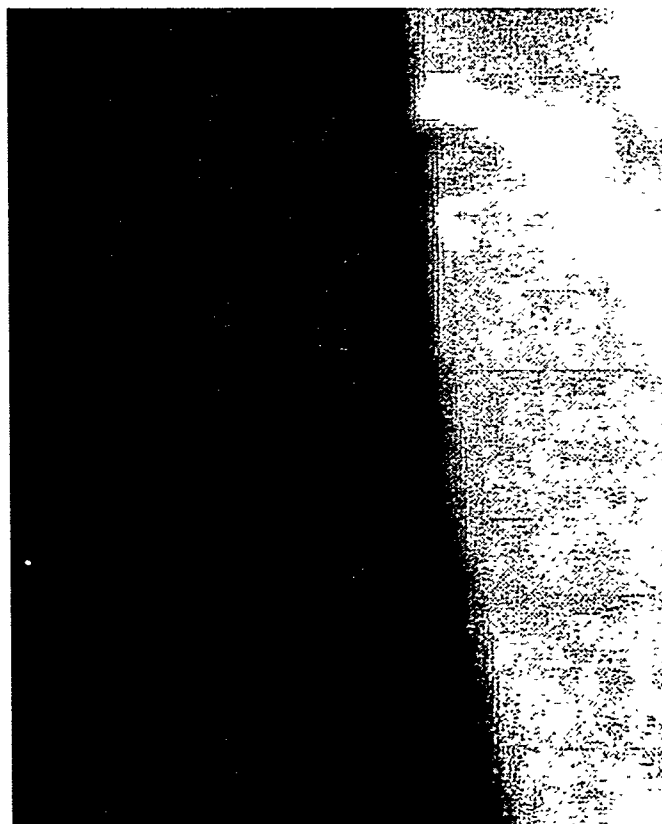
Contact person: Dr. Eng. Hussein Ibrahim, Director General

Principal function(s) of institution: Research, development, training and applications

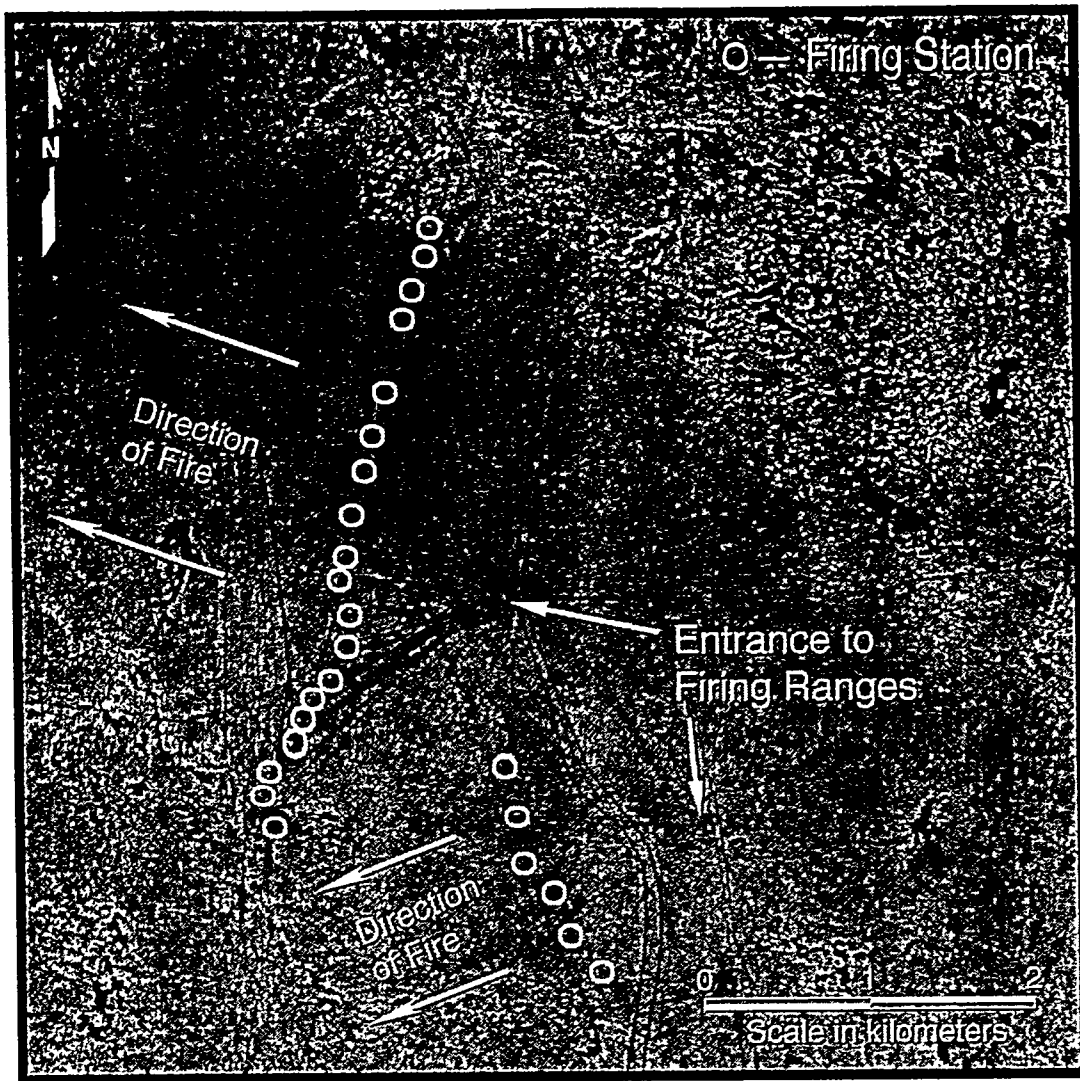
Specific areas of interest: Training specialists from Arab countries in implementing national projects

Geographical preference: Countries of the Arab League

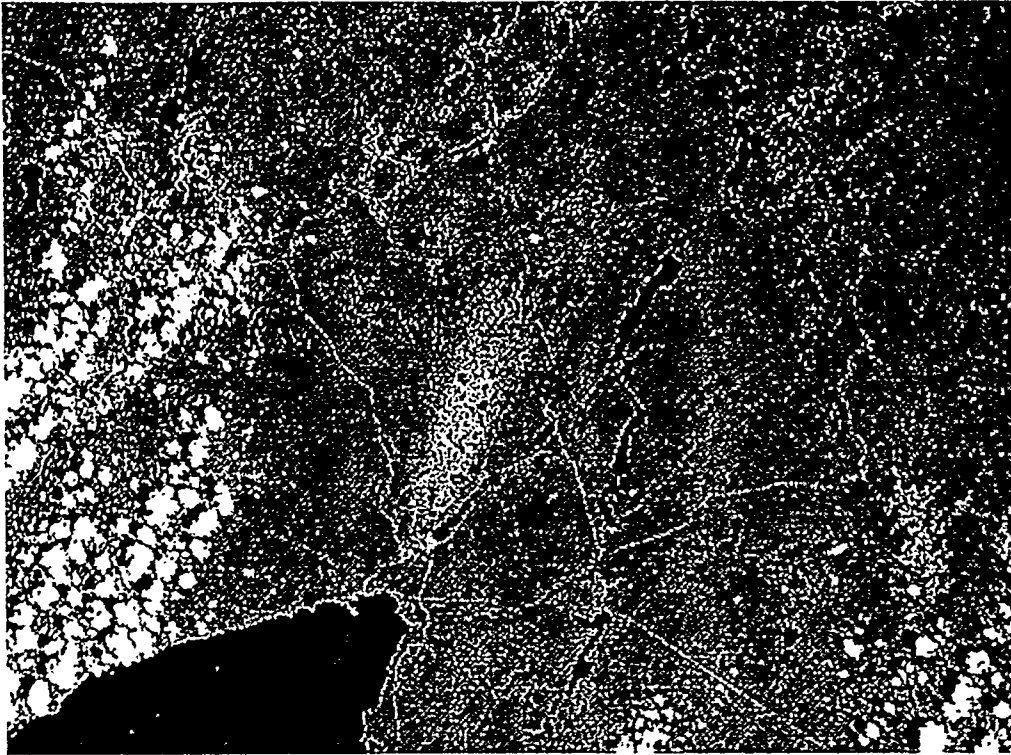
Academic and scientific program specialization(s): remote sensing, satellite meteorology



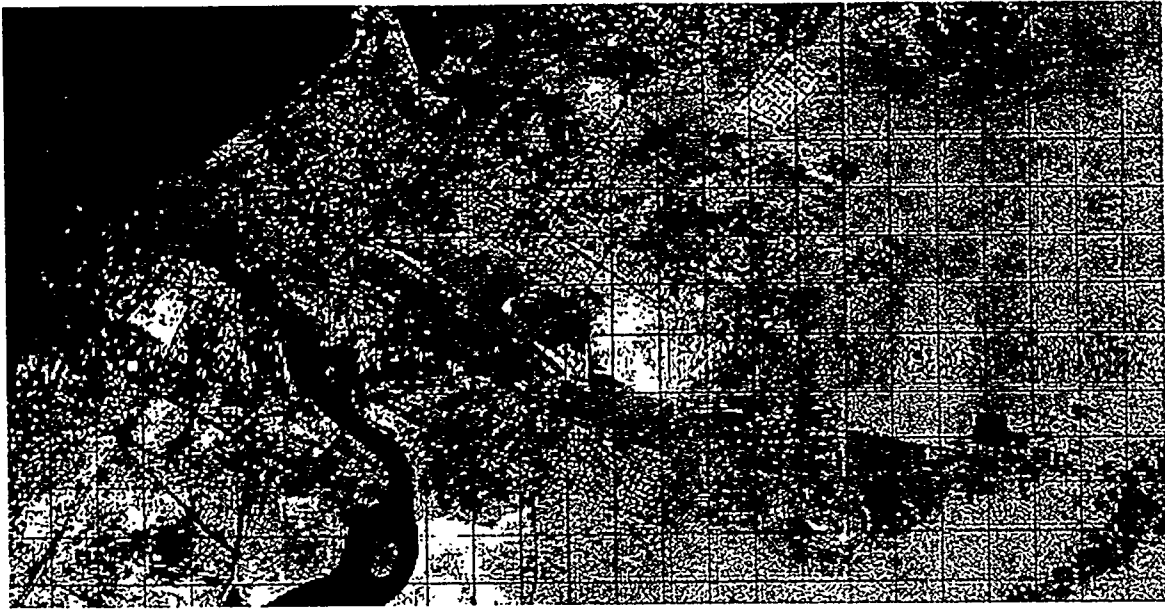
The Nuclear reprocessing Plant at Tokai, Japan Viewed With SPOT Panchromatic and LANDSAT Thermal bands



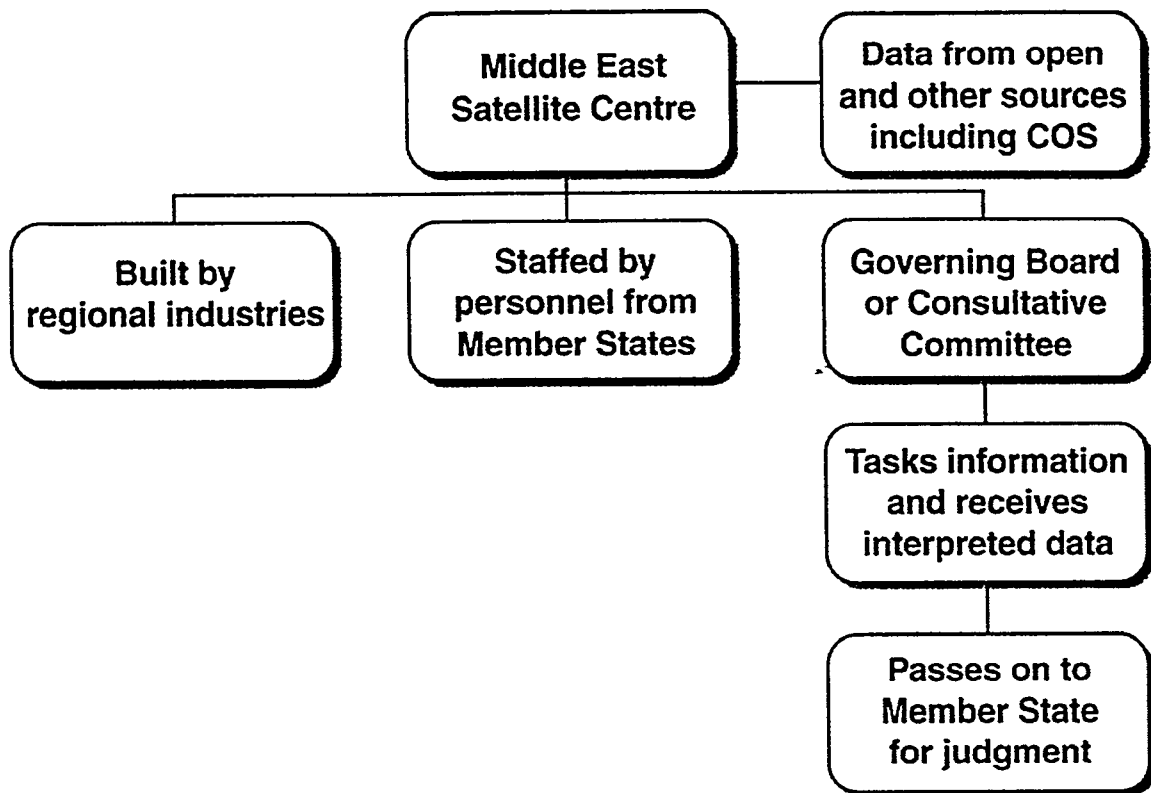
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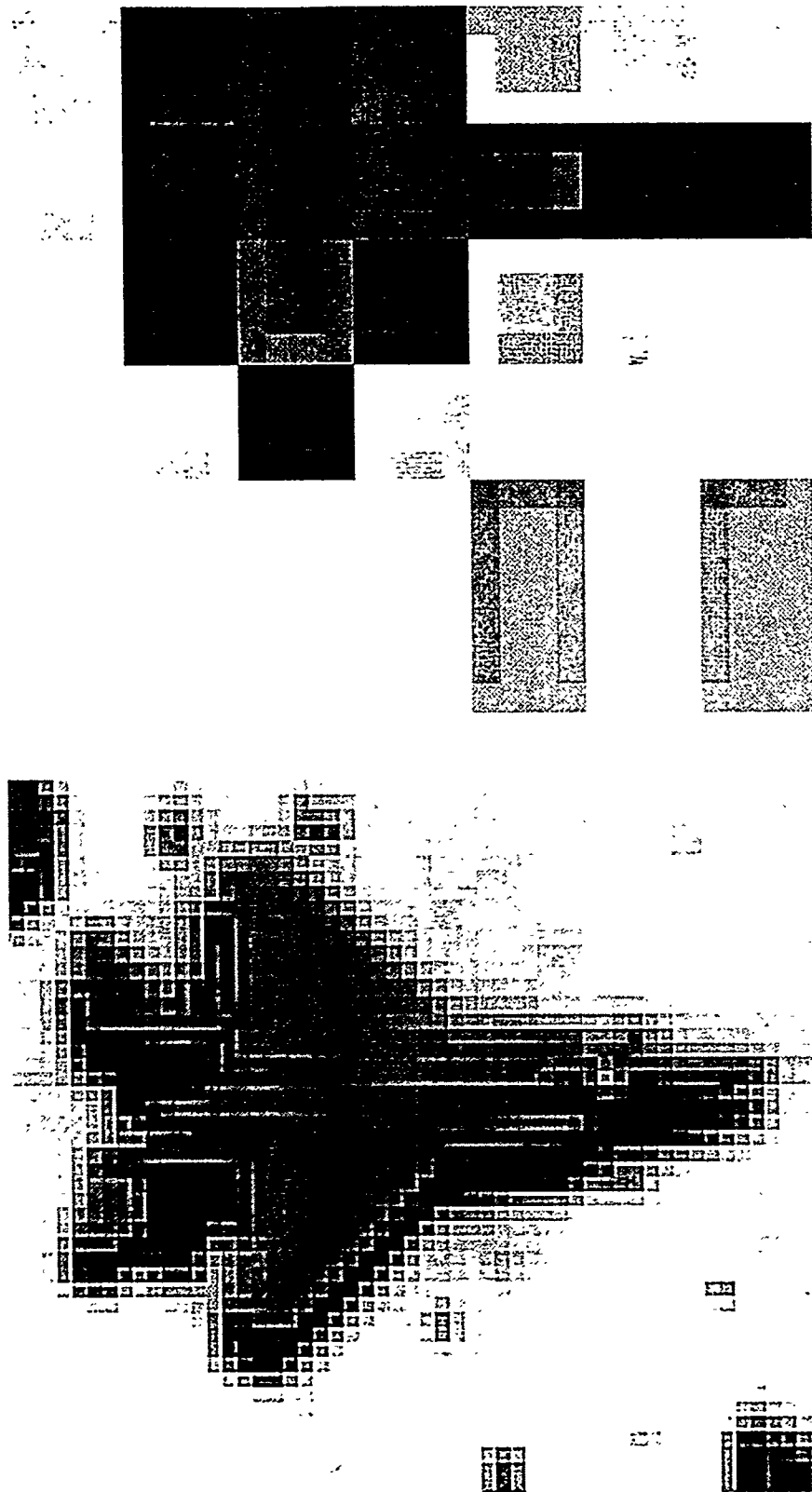
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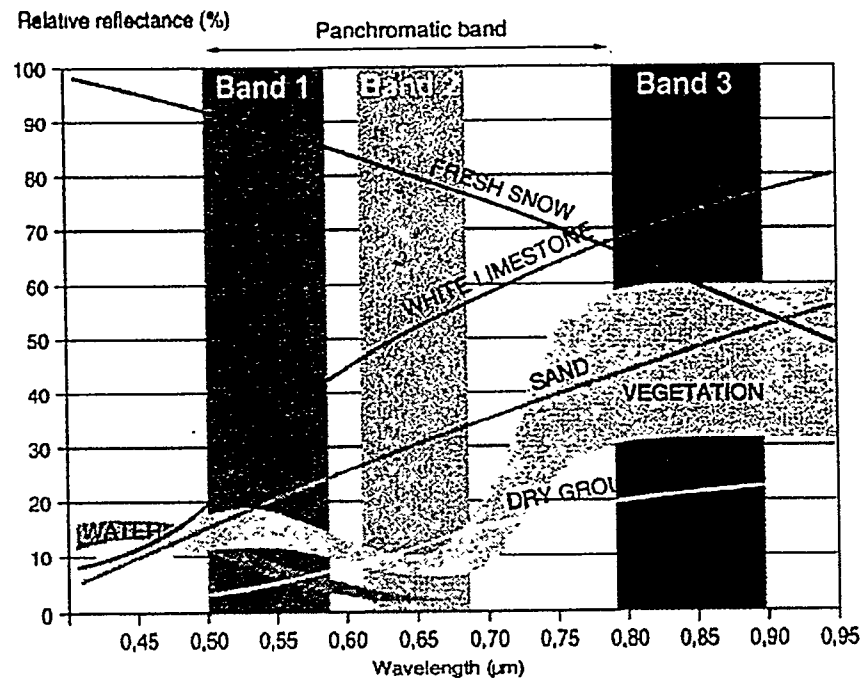
Urban Planning and Land Use Classification in Dubai, UAE



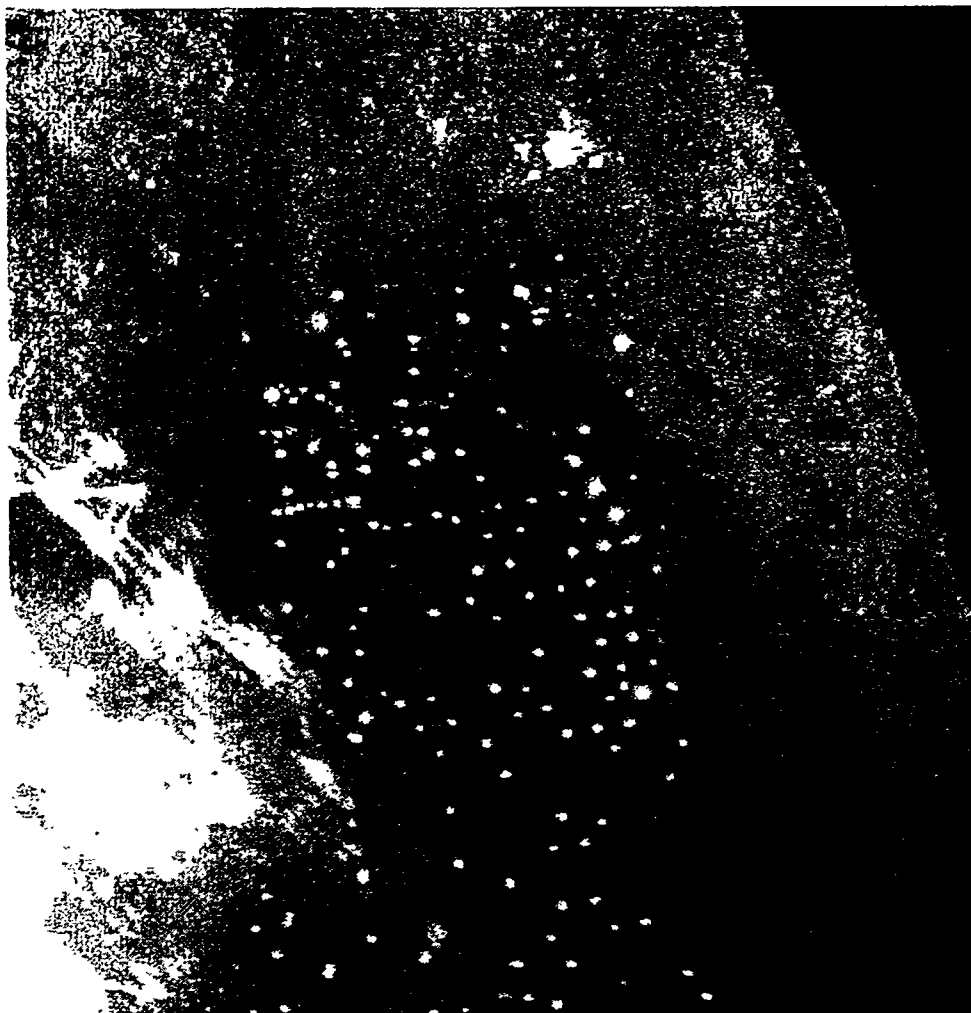
Organization Chart of Conceptual Middle East Satellite Center



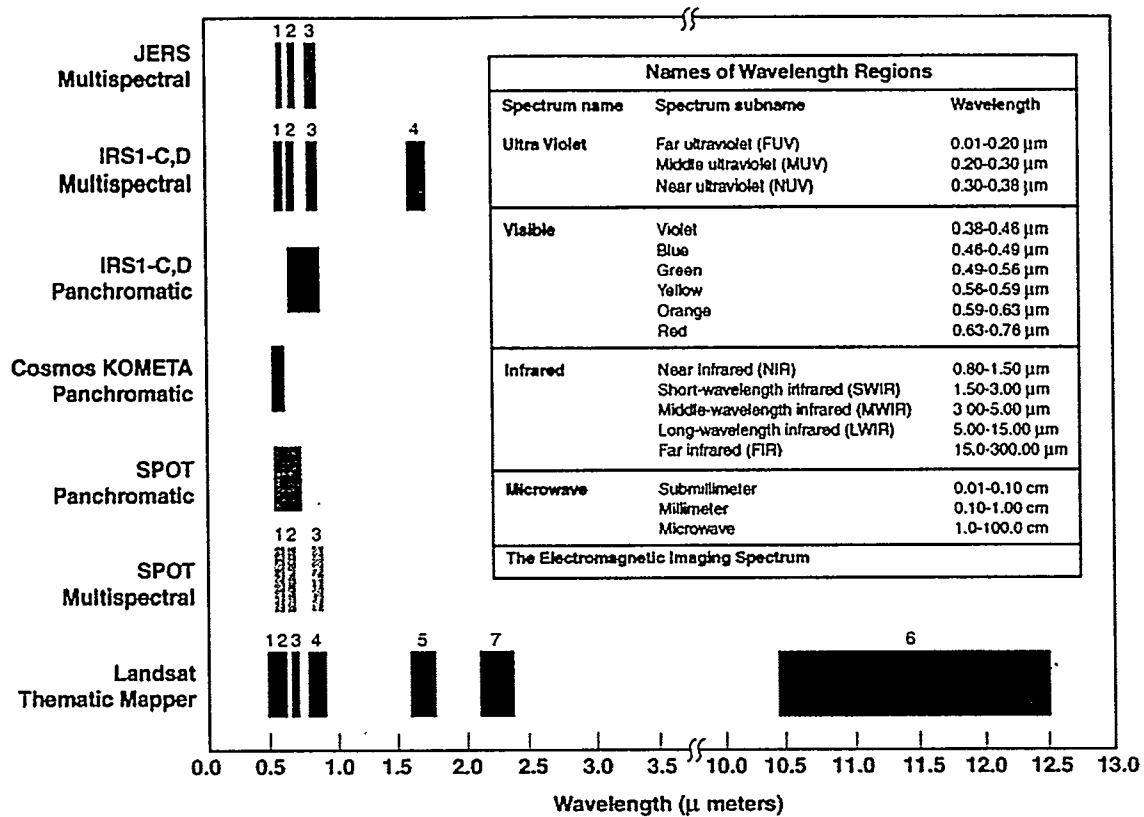
F-15 Aircraft at 4.0 m and 0.5 m GSD Resolution



Ground Reflectance in Different Spectral Bands



Oil Fires in Kuwait Observed in the Middle Infrared band



Comparative Satellite Spectral Resolutions



1 m Aerial SAR Images of Helicopters and Building