New BESA Publications

Dual Use Aspects of Commercial High-Resolution Imaging Satellites

Gerald Steinberg
Mideast Security and Policy Studies,
No. 37, February 1998
Begin-Sadat Center for Strategic Studies
Bar-Ilan University

Table of Contents

Notes

Until recently, high-resolution space imagery was available only to a few nations, and distribution of images was tightly regulated and limited. However, as additional states seek to develop this capability, the policies of the major space powers, and of the United States, in particular, have changed. A combination of the changing military and strategic environments, including the end of the Cold War, and the perceived growth of the market for high-resolution images have amplified the role of commercial forces in policy making. As a result, the limitations and regulatory mechanisms, with respect to the distribution of high-resolution satellite images that had been in effect since the early 1960s, have been weakened. This process may contribute to transparency and confidence building in some regions, but it also has the potential for aggravating regional conflicts and international instabilities, changing the balance of power in regional conflict zones, sharpening existing asymmetries in military capabilities, and making regional and international conflicts harder to manage. As will be argued in this monograph, high-resolution satellite images constitute a new type of dual-use technology. Although not directly related to weapons, as in the case of other dual-use technologies, this data is directly applicable to intelligence gathering, targeting and other military applications.

In this study, we examine: 1) the nature of the commercial capabilities being developed; 2) the implications of the increased availability of high- resolution satellite imaging on international as well as regional stability and conflict; 3) the changes in the policies of the major actors, particularly the United States; 4) the specific problems faced by Israel, and the negotiations on this issue with the US; and 5) the feasibility of multilateral responses to this type of dual-use technology, including an international regime to regulate export and distribution of satellite imaging technology and data.

I. Background: Reconnaissance Satellites During The Cold War

From 1960 to the early 1990s, military satellites, including space-based communications, navigation, meteorology, early warning and, most important, strategic intelligence were developed and deployed by the two superpowers. Indeed, the dedicated military reconnaissance satellite systems, operated by the US and the Soviet Union from the early 1960s, constituted the most important technological development since thermonuclear weapons (with the possible exception of MIRVs). Early US satellite programs, code named Corona, Samos, and Discoverer, were developed in response to perceived Soviet threats, following the testing of an intercontinental ballistic missile and the launch of Sputnik in 1957. [1]

During the 1950s, the US used high-altitude reconnaissance aircraft such as the U-2 to obtain information on the Soviet Union, Eastern Europe and China, but these aircraft were limited and, as was demonstrated dramatically in 1960, vulnerable to ground-based anti-aircraft missiles. Satellites in orbit were, in practice, invulnerable to attack, and the first successful Corona launch took place in August 1960. A combination of technological limitations in the development of anti-satellite systems, as well as tacit agreements between Washington and Moscow established the legitimacy of overhead reconnaissance through the use of satellites. [2]

By 1972, when the Corona program ended and was replaced by new technology, 94 satellites had been launched successfully.[3] The satellites took thousands of photographs from orbit, after which retrorockets triggered the reentry of the film capsule, which was recovered either in mid-air, or on the surface of the ocean.[4] Since 1960, US reconnaissance satellites received hundreds of thousands of images, covering a wide variety of strategic and tactical targets, including Soviet and Chinese missile locations, the site of the detonation of the first Chinese atomic weapon,[5] submarine ports, aircraft carriers, combat air bases, etc. The Soviet Union developed similar systems shortly after the US, and, much later, the Chinese also produced reconnaissance satellites.

In the past two decades, these systems have been augmented by infra-red and broad spectrum imagery, space-based synthetic-aperture radar, and other technologies to allow for all-weather, all-hours imaging. Other systems collected electronic information and monitored (or eavesdropped on) military and civil telephone communications. In addition, navigation satellites allowed for increasing accuracy in a variety of platforms and kill-systems.

Satellites also became non-intrusive technical means of verification (NTM). During the Cold War, the first stages of confidence building and information exchange between the US and USSR began tacitly and unilaterally through the use of overhead satellites. Although this was not the primary purpose of the programs, both US and Soviet leadership acknowledged the important contribution of such systems to stability and confidence building.[6] In the 1972 SALT and ABM agreements, the two sides formally agreed not to interfere with each other's NTM.

Recently, satellite surveillance has been used increasingly in tactical warfare and regional conflicts. Reports have been published alleging that the US provided images to Britain during the Falklands war in 1982. Satellite data were used extensively by the US and allied forces in the 1991 Gulf War, and by NATO in the Balkans conflict (see discussion below). There are still significant technical limitations in tactical, real-time application of satellite imaging on the battlefield, and these were apparent in the Gulf War, but the potential for these tactical applications is increasing. Space-based imaging can provide targeting information in regional contexts, and the data is also useful for post-attack damage assessments. Just as satellite reconnaissance played a major role in the strategic balance during the Cold War, the same technology can be applied in the post-Cold War era of regional conflict.

As analysis of the implications of these technical developments, and the potentially unrestricted policy regarding high-resolution commercial imaging satellites began, questions emerged. The issues include the impacts of such systems on regional conflicts, access by terrorists and rogue states. Henry Sokolski has noted that, "With the increasing availability of civilian satellite imagery services, such as Landsat and SPOT and Russian marketing of archival imagery of 2 to 5 meters resolution, what were once supersecret capabilities limited to the superpowers are becoming publicly accessible at affordable subscription rates."[7] Similarly, Ann Florini warned that "the advent of imaging satellite systems owned and operated by a variety of third parties, including governments other than the superpowers...and private companies, is raising new concerns for U. S. peacetime foreign relations and military activities, and for crisis management and wartime operations."[8]

Until the early 1990s, access to the images and to high-resolution satellite surveillance technology has been restricted to the major powers (the US, Russia, and China). Since then, France, India and Israel have acquired some capabilities in this area, and other states have announced programs to develop this technology. In addition to the commercial sale of SPOT images, some photos provided by Russian military reconnaissance satellites were made available for purchase. In response to these developments, the US government began to declassify many of the hundreds of thousands of images returned by military reconnaissance satellites, while at the same time, also loosening the restrictions on commercial licensing of high-resolution satellites systems. In February 1995 President Clinton signed an executive order declassifying images from eight satellite reconnaissance programs, covering the years 1960 to 1972, including Corona. By early 1997, a number of commercial satellite firms were preparing to launch high-resolution satellites, and plans called for up to 12 launches in the following decade.[9]

In theory, the increased availability of high-resolution commercial space imaging services of the data that is transmitted can have positive as well as negative consequences. For the enthusiasts, this development will contribute not only economic benefits but political benefits, linked to transparency.

However, like many other technologies, these systems and the data are inherently dual-use, with both civil and military applications. Henry Sokolski includes satellites in a list of what he terms non-apocalyptic weapons and warns of the consequences had satellites been used by Saddam Hussein in the Gulf War.[10] For the first time, many countries and non-governmental actors, in areas such as the Middle East, North Asia, Central Europe, and South America will have access to very detailed and almost real time images of neighboring states. Iran and Iraq will be able to obtain information and photos of strategic sites in the Persian Gulf, United States, Europe and Israel. A former CIA official notes, "The issue is going to heat up the first time we get a real crunch between two friends, like Pakistan and India."[11]

The impacts, both stabilizing and destabilizing, will depend on a number of technical factors, including the resolution, the form in which the data is sold (original digital data, or derivatives), the nature of the distribution system (direct real-time ground links to receivers, or delayed transmission via filtering stations), available software, and similar factors. However, as Ray Wilson, of the George Washington University's Space Policy Institute notes, "Iraq would be interested in information about Saudi Arabia. Iran would like to see data about Israel. India and Pakistan would like to have information about each other. If you were concerned about troop buildup on your border, you could put in a standing order for the satellite to take a picture every time it passed over."[12]

Thus, it is clear that the implications of the proliferation of this technological capability, and the policy options for limiting the impact on security and stability should be carefully considered before these capabilities are widely available. High-resolution imaging satellites are dual-use technologies, and in making policies for the commercialization of this technology, the potential impacts must be examined and understood.

II. Satellite Imaging Policies of the US and USSR

For decades, high-resolution satellite imaging was the exclusive province of the United States, the USSR and later, China, and the technological complexity of high-resolution space imaging restricted the availability of this data to a very small group. Although commercial launch services provided by these states and the European Ariane allowed many other nations to develop civilian satellites, mainly for communications and scientific research, these satellites had little military utility.

During the Cold War, the US and USSR held their high-resolution space surveillance capabilities very closely. The level of secrecy was extremely high, and the technology was restricted to the military sector; no civil applications were allowed for imaging below 30 meters GSD. Most of the hundreds of thousands of images returned by these satellites were also tightly classified, and the exceptions, such as the unauthorized leak of a photograph of a Soviet aircraft carrier in construction, were so rare as to demonstrate the degree of security maintained in the vast majority of cases.[13] In the late 1970s, under the Carter Administration, proposals to allow the release of some classified images were restricted. (Both Washington and Moscow did allow the publication of relatively high-resolution images for manned space missions, such as the Mir Space Station and the Shuttle's Large Format Camera and Space Radar Laboratory, but these were not systematically programmed for imaging strategic or military targets, and did not provide the systematic coverage of dedicated military reconnaissance satellites.) In 1995, the US government declassified over 800,000 images taken between the years 1960 and 1972, including information that contradicted Soviet claims regarding mass production of ICBMs in 1959.[14]

The US and France also developed and operated lower-resolution civil-commercial satellite imaging systems, known as Landsat and SPOT (Systeme Pour l'Observation de la Terre). Their respective resolutions had only limited military applications. Landsat, with a monochromatic resolution of 30 meters, a multi-spectral imager, and an infra-red sensor for detecting ground temperature variations with a resolution of 120 meters, was first launched by the US in 1972, and the first 10-meter SPOT satellite was launched in 1986. Despite the official claim that it "is not suitable for tactical purposes," Spotimage's marketing efforts suggest awareness of some potential military applications.[15] (Zimmerman notes that the Golan Heights and other "sensitive" areas are among the more popular targets for clients of SPOT imaging.)[16] In addition, the combination of Landsat and SPOT, using computer enhancement techniques, can provide a greater degree of militarily useful information, such as the detection of large area targets like missile or space launching facilities, railroad yards, and coastal features.[17]

SPOT-2 and SPOT-3 were launched in 1990 and 1993 respectively. In March 1998, Spotimage will launch its next satellite, SPOT-4, to replace the loss in November 1996 of SPOT-3.[18] SPOT-4 will have 10 meter monochromatic resolution like its three predecessors, as well as an additional mid-infrared imaging capability. Plans for SPOT-5A and 5B, scheduled for launch in 2000 and 2003 respectively, include a 5 meter panchromatic resolution.[19] More recently, the European Space Agency has developed ERS-1 and 2, (launched in 1991 and 1994, respectively), with SAR resolutions of 30 meters**.** The Russian Almaz satellite (launched in 1991) uses synthetic-aperture radar with a resolution of 15 meters, and carries an infra-red radiometer with a resolution of 30 meters. Another commercial Russian system, Resurs, launched in 1994, includes imagers with a GSD of 45 meters. However, compared to dedicated intelligence satellites, these systems are generally of very limited military value, and can largely be considered to be civil systems, rather than dual-use or military technologies.

III. The Changing Rules Among The Major Space Powers

At the end of the Cold War and following the breakup of the Soviet Union, some of the space-imaging policies of Washington and Moscow began to change. In 1987 the USSR (Soyuzkarta) initiated the sale of photos from the Cosmos KFA-1000 and MK-4 and MFK-6 cameras, with resolutions of approximately 5 meters.[20] In 1992, two Russian firms began to sell selected images with resolutions as low as 2 meters, based on the KVR-1000 system.[21] Although the Russian share of the commercial imaging market is limited, the potential for competition contributed to changes in the US policy, restricting the resolution of commercial imaging satellites. In addition, a number of other states announced plans to develop and launch high-resolution commercial imaging systems, as will be discussed in detail below.

During the early 1990s, France emerged as a major player in this area. SPOT, although restricted to 10 meters resolution had, as noted, some limited military and reconnaissance applications. More significantly, in 1995, France (with small shares held by Italy and Spain)[22] launched Helios, which is a dedicated military reconnaissance satellite with a 1 meter GSD**.** Helios was the first European space-based intelligence system, and France plans to launch Helios-2, and the more advanced Horus (nee Osiris) all weather, IMINT space intelligence system in 2005.[23] France, Germany and other WEU member states are currently negotiating to gain financial contributions to this program. As of December 1996, Germany had agreed to jointly develop Helios-2 and Horus with France, but German participation is still uncertain, due to budgetary issues and the need for parliamentary approval.[24] Thus, until budget finalization in September or October of 1988, German participation is still uncertain. Eucosat (European Control by Satellite) is currently trying to establish a European structure using satellite images for security purposes. Jean-Pierre Fourre, (the president of Eucosat) has stated that by the end of 1997 or early 1998, the organization expects to obtain Germany's formal commitment to participate in the Helios-2 and Horus military observation programs and the establishment of a European coordinating structure using satellite images for security purposes. The coordinating structure will also allow the use of these systems in environmental monitoring, treaty verification and crisis management but, according to Fourre, will not engage in commercial activity.[25] The project also includes military photo interpretation. In cases where images from the military Helios satellite are not available, images from high-resolution commercial satellites may be used. [26]

In February 1997, Spain and Italy, the two other contributors, announced that their participation in the Helios-2 was dependent on German participation, in part due to Germany's responsibility for the development of a new infra-red radar channel that would give the satellite night observation capability.[27] The Helios images are also available to the WEU's satellite center located in Torrejon, Spain (outside Madrid), and the data returned to this and other ground stations has been used extensively for military planning by NATO in the Balkan conflict, as well as by individual governments. Since 1 May 1996, the center has been receiving imagery from the Helios-1 satellite under the terms of the memorandum signed between WEU and the Helios program countries (France, Italy, Spain). The imagery is then made available to WEU members associated states that participate in the financing of the project. According to WEU Secretary General Jose Cutiliero, "This center is the only European organization capable of dealing with operational military missions."[28] (For example, Belgium received data regarding the Great Lakes region of Africa, the site of large-scale ethnic conflict and international relief efforts in Rwanda, Burundi, and Zaire.)[29]

In addition, Aerospatiale is proposing a Mediterranean system, Cosme, which will include a small remote sensing satellite, Coalas, that would be used, among other things, for risk management for insurance purposes, and responses to natural disasters, (earthquakes, storms, floods, etc.). It could be launched in 2001 or 2002, and Aerospatiale claims that the investment would be recovered in 3 or 4 years. In addition, the Cosme/Skymed cluster for the Mediterranean basin will-consist of three optical and four radar satellites. Spin-offs of the Globalstar (450 kg) cost estimates are listed between $30 million and $40 million per unit. Alenia has also done a study for ESA (European Space Agency) on the next-generation version scheduled to go up in 2010. The cluster would then be composed of five optical satellites (0.5 meter resolution) and ten other radar satellites (1 meter resolution). [30]

While Helios and Horus are officially military systems, the relatively wide distribution system and other factors have been seen as indicators of an intention to use these as the basis for a commercial system. Officials have acknowledged that Helios is already operated in coordination with SPOT "to maximize returns and exploit commonality."[31] Thus, US industry and government analysts have declared that they expect that France and its European partners are preparing to enter the high-resolution commercial image market in the near future.

Similarly, the Canadian Radarsat, which uses synthetic-aperture radar technology rather than optical imaging, is also a candidate for the high-resolution commercial market. SAR has the advantage of being able to provide images at night and through cloud cover. Radarsat was developed by the Canadian Space Agency in cooperation with NASA and NOAA (National Oceanic and Atmospheric Administration), and was launched in 1995 with a five year design-life.[32] The satellite has a resolution range of 10-100 meters, and near-real time data calibration used for change detection.[33] (Radarsat-2 is scheduled for launch in 2000.)[34] In 1996, Canada provided night images of Burundi, in connection with the ethnic conflict, and international peace keeping efforts.[35] Radarsat images have also been used in the effort to investigate reports that India was preparing another nuclear test.[36] In January 1997 SPAR Aerospace, a Canadian corporation, signed a contract with the National Research Council of Thailand to construct a remote sensing satellite system that will be used to survey natural resources. (Information on technical characteristics and resolution was not published.)[37]

Beginning in the mid 1980s, these developments led to reevaluation of US restrictions on the commercial or civil applications of satellite imaging technology. (Escalating Landsat costs led to its commercialization in 1983, and in 1984 the Land Remote Sensing Policy Act turned over Landsat operation to the Eosat corporation.[38]) The Land Remote Sensing Policy Act of 1992 (P.L.102-555) streamlined the procedure for considering license applications for commercial imaging satellites, and eliminated many of the legal obstacles that had been imposed in 1972 to prevent approval of most such applications.[39]

During this period, American aerospace firms produced assessments of a very large market for commercial satellite imaging, and sought to decrease government obstacles to unlimited activity in this area. In 1995, commercial space activities generated $7.5 billion, and imaging accounted for an increasing portion.[40] Industry leaders claimed that the Soviet military threat had been replaced by a commercial threat from French and Russian companies that were preparing to enter the high-resolution market in which sales had already reached $700 million in 1994.[41] (In 1997, the cost of a SPOT image in 1997 was roughly $8000, Radarsat scenes estimated at $4000 each, and Russian images reportedly available for $3,600 in film form, and for $10/square km as digital data.[42] In contrast, single frames of the commercial high-resolution systems were expected to be priced at approximately $1000.[43]) Moreover, the growth rate is estimated at 15-20 percent per year once high-resolution systems come on line.[44] According to the French publication, *Air and Cosmos Aviation International*: "By the early years of the next millennium, the number of countries owning earth observation satellites will have doubled... Earth observation is going to enter a new phase this year, with more and more satellites going up, entry into service of the first high-resolution and hyper-spectral instruments, as well as deployment of the first private commercial systems and new systems co-financed by government and private industry. This should lead to broad changes of the landscape in this sector of activity over the next 10 years. The world market, which has seen no growth in the last decade, should finally see that long hoped-for expansion." [45]

Proponents of a change in US restrictive policy argued that since other countries were entering the market, by allowing US firms to compete in and to capture a major portion of this market, the US would also maintain some control over distribution of high-resolution images, particularly in crises, and allow the US government to maintain the option to prevent states such as Iraq from getting access to imaging.[46] (For example, they claimed that the French government sought to sell Helios images to Saudi Arabia after the US government had reportedly rejected a Saudi bid to acquire access to an American system.[47]) Scott Pace, a former Commerce Department official responsible for commercial space activities, and now at the RAND Corporation, has opposed all US government limitations on these activities.[48]

At the same time, as the US defense budget was reduced, the development of commercial high-resolution imaging systems was seen as a means of allowing the major firms that had mastered this technology to maintain capabilities in this crucial strategic area, without the massive budgets provided in the past by the CIA, National Reconnaissance Office, and other agencies. In other words, commercial imaging, which was based on technology developed for the

US government, would in turn, now subsidize the government and the security community's reconnaissance requirements**.** In a *New York Times* article published in February 1997, William Broad acknowledged that, "Today most of the American activity involves gear and contractors that once were, or still are, part of the sprawling government complex for military espionage, as well as former federal officials."[49] Space Imaging Corp. is owned, in part, by Lockheed Martin, which had a primary role in the US reconnaissance satellite program, and by Itek, which has supplied optics for military surveillance satellites for many years. E-Systems Inc., now a unit of Raytheon, and another partner in Space Imaging, has also played a major role in developing military space technologies. Many of the personnel in these commercial projects are also from the national security sector. For example, Jeffrey Harris, who served as Director of the National Reconnaissance Office (NRO), as Assistant Secretary of the Air Force for Space, and as Assistant to the Director of the Central Intelligence Agency, currently heads Space Imaging).[50]

Some industry advocates and journalists also began to press for a change in policy, arguing that restrictions on technology in this area violated "First Amendment rights to gather and disseminate information."[51] In Congressional testimony, Mark Brender, head of the Radio-Television News Directors Association, asserted that the Land Remote Sensing Act of 1992, and PD-23 both violate the First Amendment. He claimed that the national security threats, cited to justify prior restraint of information, do not present a "clear and present danger." Commercial news organizations and journalists envisioned increased profits through the use of high-resolution images from space. Thus, they provided an additional source of economic pressure for change of US policy.

In 1994, this combination of factors led President Clinton to issue Presidential Decision 23 (PD-23), which allowed private firms to develop, launch and sell high-resolution satellite imaging services. Shortly afterwards, the US government began to license commercial high-resolution satellite imagery systems. As of January 1997, the Commerce Department had issued licenses to nine US companies, some with foreign partners, for 11 different classes of satellites with a range of technical capabilities.[52] Orbview (initially known as Eyeglass), is planned for launch in 1999, and will have a 1 meter resolution and potential coverage of up to 14,400 km. Orbimage's Orbview Lite satellite will have corresponding resolution of 1 meter.[53] Earthwatch (200 employees) is developing two 3-meter satellites, with 15 meters resolution in multi-spectrum mode, the first of which (Earlybird) was launched by a Russian rocket in December 1997, but malfunctioned shortly after launch. The company has corporate partners that include Ball Aerospace and Technologies Group and Hitachi Ltd. of Japan.[54] Worldview Imaging Corporation is also developing two 3-meter resolution imaging satellites. The leader of the smaller imaging companies, Space Imaging, (which has renamed its satellites "Carterra/CRSS,") is owned by a consortium headed by Lockheed Martin (which produces many of the military's spy satellites) and is planning two space imaging satellites with a GSD of 1 meter,[55] the first of which is scheduled for launch in early 1998. A third is planned for 2002, with a 1 meter resolution and field of 700 km (26 degree angle), 1.5 meters with a field of 1,450 km (45 degree angle), or 2 meters with a field of 1,860 km (51 degree angle).[56] Orbital Sciences Corp. hopes to launch a 1-meter satellite (Orbview-3) by 1999[57], and other companies developing imaging satellites include Boeing, and Motorola. Such efforts are not exclusive to the private sector.

The implications of these policy changes and developing capabilities spread immediately beyond the boundaries of the United States. In 1992, the United Arab Emirates sought to purchase an imaging satellite from an American manufacturer on a commercial basis. Although the rules had not yet been changed, this offer was seriously considered and favored by the Commerce Department, before being rejected on political and military grounds (see detailed discussion below). A few years later, a Saudi firm, known as Eirad, purchased an equity share in the Eyeglass satellite, later renamed Orbview. While the objectives of the UAE and Saudi proposals were not articulated publicly, it was assumed that any information provided would be disseminated and available throughout the Middle East and beyond. These developments created a great deal of concern in Israel (as will be discussed in detail below), and also raised the specter of easy access by rogue regimes, terrorists, and other destabilizing groups to the real or almost real-time high-resolution images.[58]

IV. The Emerging Space Imaging Providers

As noted, the change in American policy regarding the licensing of commercial imaging satellites was in response to the emergence of similar programs in France, Russia and a number of other states. In the past five years, the number of states with indigenous launch capabilities has grown. In addition to the major space powers, Canada, France, Japan, India and Israel have placed satellites into orbit. Italy, Britain, Norway and other advanced industrial states have designed, produced and operated advanced satellite systems that were launched commercially. Brazil, South Korea, Taiwan and Pakistan are also developing some independent capability to produce satellites, including imaging and communications systems, which are claimed to provide even more competition for US imaging companies. However, as will be seen in this section, upon close examination many of these claims are exaggerated and the US is likely to dominate this market for many years.

Japan

Japan has an active and advanced space program, including the development of advanced launchers. Satellites and commercial imaging are viewed as a future growth industry, and government programs describe plans to use remote sensing data commercial applications.[59] The first Japanese space imaging system, JERS-1, a satellite with 18 m resolution, was launched in 1992.[60] In August 1996 Japan launched ADEOS (Advanced Earth Observing Satellite), developed by the STA (Science and Technology Agency) and NASDA (National Space Development Agency of Japan), which reportedly provides a panchromatic resolution of 7.5 m and multi-spectral resolution of 20 m.[61] Current R&D efforts focus on the development of Alos (originally named Hiros), an advanced remote sensing satellite with 2.5 m resolution and radar, planned for 2002.[62]

In 1996, a joint commission of the LDP (Liberal Democrat Party) Research Committee on Foreign Affairs and Security met with members of the NEC Corporation, which manufactured 41 of the 63 Japanese satellites, to discuss the feasibility and costs of a reconnaissance satellite system. (Japan is currently dependent on the US for space-based intelligence data.) Press reports note that the newly formed Japanese intelligence agency is currently lobbying for spy satellites, as is the Foreign Ministry, in order to lessen dependence on the US. The MFA is employing a US consultancy to determine how other countries use reconnaissance satellites, and on the basis of this study, will recommend a system for Japan. Estimates of the cost exceed $1.7 billion, with an eight year period from initial development to operation.[63] One program under consideration provides for the first launch in 2004, with an initial system of three satellites.[64] However, because the Japanese constitution contains a clause forbidding offensive military actions and acquisitions, the Diet (Japanese parliament) has restricted the Self-Defense Agency to undertake "outer-space development to peaceful purposes." Reconnaissance satellites may be considered a violation of existing law, as indicated by a resolution adopted in 1969 by the lower house of the Diet, which states, "The development and utilization of objects that will be launched into outer space and rockets that will be used to launch them shall be limited to peaceful purposes."[65] Thus, before this capability is developed and tested, there may be intense debate in Japan.

India

India has the most active and advanced space program among the emerging space powers. The Indian Space Research Office (ISRO), based in Bangalore, has a current budget of $300-350 million,[66] and declares that all of its programs are "intended for peaceful purposes," with specific emphasis on satellite communications and survey of earth resources. The Indian space efforts can be traced to a research and development program that began in the early 1950s. In 1975, India built the Aryabhata research satellite that was launched by a Soviet launcher.[67] On July 18 1980, an Indian launcher (the SLV-3) placed a 35 kilogram satellite (RohinI-1) in low earth orbit, making India the first developing country to launch its own satellite on its own launch vehicle.[68]

The Indian government placed a high priority on developing its indigenous capability, and between 1980 and 1990, allocated $1 billion for space research, including the development of satellites for telecommunications, meteorology and imaging.[69]

India has given high priority to the development of imaging satellites,[70] and five earth imaging satellites are already in operation,[71] beginning with the 1987 launch of IRS-1A (using a Soviet launch vehicle).[72] The IRS-1B was launched in 1991, and in October 1994, the IRS-P2 earth observation spacecraft was placed in polar orbit.[73] According to the Indian Space Agency, "Several advanced Indian remote sensing spacecraft are planned as a part of continuing PSLV launch series. These will include multi-spectral linear arrays with resolutions of 10 meters, making them somewhat comparable with current SPOT class spacecraft."[74] The IRS-1 launched in December 1995 has a panchromatic camera with 5.8-meter GSD.[75]

On 29 April 1996, the Indian Space Research Organization (ISRO) announced plans to launch ten additional remote sensing satellites over the next ten years.[76] This would rival the schedules of the US, Russia, France, and China. The first satellites, Carto-Sat and Varto-Sat-2, both have a planned resolution of 1 meter. Demand for products involving remote sensing is the highest in Asia.[77] The Indian Space Agency has signed an agreement with Eosat, a private US firm, to market space images around the world. Additionally, in February 1997, ISRO announced that it plans to negotiate a deal with Space Imaging Group (US) to supply space images to international SIG clients over a 15-year period.[78] India plans to launch eight more remote sensing satellites between now and the year 2003, including the IRS-P6, alias Cartosat-1, which will have 2.5-meter resolution.[79]

Israel

The ISA (Israeli Space Agency) was founded in 1983, and much of the activity focused on basic scientific research and development, in conjunction with the American and European civil space programs. The ISA's formal budget is very small ($6 million in 1993), but this does not include development and operational costs for the Ofeq and Amos satellites. Israel reportedly spent $1 billion through 1993 on the Ofeq satellite program. Other unverified reports claim that the Defense Ministry allocates $20 million a year for Ofeq, although this seems to be an underestimate.[80] (Gross estimates place the cost of development and launch of a first generation imaging satellite at $400 million.[81])

As in the case of other strategic technologies, space launchers and weapons, the Israeli government provides little official information regarding space launchers and satellites. However, using available information and drawing logical inferences, the outlines of the Israeli program can be discerned. The Shavit (Comet) launchers are apparently based on what is commonly referred to as the Jericho ballistic missile. According to unconfirmed press reports, the Jericho is part of Israel's strategic deterrent. The Jericho-1 reportedly carries a payload of 500 kg, to a 500 km range, and the more advanced Jericho-2 (in some sources Jericho 2b or Jericho-3) is estimated to have a range of 1450 to 2800 km, and a payload of 1000 kg.[82] The first two solid rocket engines of the Shavit are manufactured by TAAS (formerly Israel Military Industries) and the third-stage motor was designed and produced by Rafael (Arms Development Research Authority). Israeli Aircraft Industries is the prime contractor.

In 1988, Israel launched the Ofeq-1 (Horizon) test satellite, using the three-stage Shavit launcher. The launch site is near Palmachim on the Mediterranean Coast. To avoid flying over other countries, a highly unusual flight path was used (northwest over the Mediterranean) placing the satellite into a retrograde orbit at an inclination of 143 degrees.[83] The 156 kg satellite was reported to be a test vehicle designed to lead to the development of an orbital reconnaissance capability, and it reentered the earth's atmosphere in January 1989. Ofeq's orbit limited the satellite's view to areas 37 degrees north and south of the equator. Ofeq-2 was similar in weight and technical characteristics to Ofeq-1. It was launched in April 1990 and had an orbital lifetime of 3 months.[84] Both were spin stabilized.

Ofeq-3, launched in April 5 1995, weighed 255 kg at launch, including a 36 kg payload. Its higher perigee (369 km) and orbital maneuvering capability allows for a longer lifetime (one to three years). (According to reports in the Israeli press, this version of the Shavit launcher included a small new IAI rocket engine with 674 lbs of thrust. [85]) Its orbit takes it over sites in the Middle East, including Iraq. This version of Ofeq has small thrusters for three-axis stabilization. Officially, the head of the ISA described Ofeq-3 as "a very sophisticated platform on which many things can be placed."[86] In particular, Ofeq-3 is reported to be a high-resolution imaging satellite, including ultraviolet and imaging sensors.

A number of Israeli firms have been developing technology for orbital surveillance, including BEND (camera to photograph 100 km strips to a resolution of 16 meters), Elisra and Tadiran (communications systems), Rafael (thrusters), Elta (antennas), the Dimona nuclear center (vacuum chambers), IAI/Melam (solar cells) and IAI/ Tamam (gyros and manometers).[87] It is not clear which of this technology is incorporated in Ofeq-3.

Several other projects are under development in Israel. The Techsat-2 micro-satellite, is to carry a high-resolution camera. The German-Israeli David project, involving OHB, El-Op, GAF and Ben-Gurion University, is a small satellite that carries a 12-channel, multi-spectrum MSRS (0.435 to 1 micron). Images will have 5 meters resolution with a 30-km field, which is superior to Landsat-5's Thematic Mapper, and will be used for agriculture, hydrology, etc. The recording instrument is a spin-off of the ultraviolet (UV) telescope developed for the Tauvex experiment carried on Russia's Spectre-RG satellite. It has a new focal plane with four 3-channel sensors. Most of the equipment is "off-the-shelf," which makes for low program costs. Financing is being provided by the Israeli and German space agencies.[88]

In addition to the military reconnaissance, IAI and the ISA are also investing in commercial space ventures, (although there are reports that Israel has rejected requests from other states to purchase Ofeq-type platforms). Aby Har Even, the General Manager of the ISA, has stated that future commercial versions of Ofeq could include sensors, cameras, and communications equipment.[89] A series of news articles and press releases provided information on a joint venture involving IAI and Core Software Technology, (based in Pasadena, California), to launch a $70 million Eros satellite capable of gathering detailed, digitized pictures of much of the world by 1997.[90] (This prompted complaint by US firms who claimed the project was essentially being funded with US aid to Israel, and would not be subject to the regulatory controls over partnership and information distribution as are the US market entrants.[91]) However, the Israeli Ministry of Defense has not granted operation licenses (see discussion below). Core Technologies (the US company) was prepared to invest $150 million in a commercial Ofeq for real-time imaging to ground stations around the world; but the imaging technology would have been in orbit 18 months before the first US commercial system. Thus, because Ofeq satellite was, in effect, subsidized by the US military, the US claimed that such a launch would be "unfair" Israeli competition.[92] (Although the US government also effectively subsidized the development of US commercial imaging systems.[93]) In December 1996, the Israeli press published unconfirmed reports of an agreement between IAI, Lockheed Martin and Mitsubishi in which IAI agreed to supply Ofeq images to the civilian market through a satellite to be launched by the end of 1997.[94] On January 22 1998, the attempted launch of Ofeq-4 ended in failure when the booster malfunctioned. (At the time, it was not clear if this was designed as a replacement for Ofeq-3, or the first element in a commercial system.)

Brazil

The Organizing Group of the National Commission for Space Activities (GOCNAE) was created in 1961, in order "to provide Brazil with the infrastructure necessary for the exploration of outer space."[95] In 1981 the Brazilian Complete Space Mission (MECB) was created by the federal government with the goal of achieving self-sufficiency in space programs.[96]

The Instituto Nacional de Pesquisas Espaciales is responsible for the design and manufacture of indigenous satellites.[97] The Brazilian space agency has also discussed cooperation with other states, including China and Russia.[98] In July 1988, Brazil and China signed an agreement (CBERS- China Brazil Earth Imaging Satellites) for the development of two earth imaging satellites. According to Gasparini Alves, "The CBERS is aimed at the development of a complete remote sensing system by developing countries which would be both compatible to and competitive with other systems produced and operational during the present decade." The first satellite was originally planned for launch in 1993, with a replacement going up in 1995, but the future of this project is uncertain.

In March 1995, a Russian delegation visited Brazil and discussed specific cooperation programs and objectives.[99] Brazil intensified contacts with French space companies as part of the program to develop satellite technology. The French company Aerospatiale is to develop a $400,000 (US) project for high-resolution observation cameras to be used in the China-Brazil satellites program.[100]

Table 1

Non Military Imaging Satellites [101]

Satellite	Country	Operational or Planned	GSD	Maximum aerial coverage over a single pass	Orbital altitude	Effective Revisit Period at equatorial latitudes
JERS-1	Japan	operational	18m			
Alos	Japan	planned	2.5m			
ADEOS	Japan	operational	7.5m			
SPOT	France	operational	10m	5 days		
Landsat	US	operational	30m			
Radarsat	Canada	operational	20m			
KVR-1000	Russia	operational	<2m	200 km	14 days	
IRS-1	India	operational	5.8m			
Cartosat	India	planned	1m			
CBERS	Brazil-China	planned	20m			
Ofeq/Eros	Israel	planned 1998?	15m?	370 km?		
Earlybird (Earthwatch)	US	launched Dec.1997				

		malfunctioned	3m			
WorldView	US	planned	3m	1,800 km2	470 km	4.75 days
Orbview-3	US	planned	1m	14,400 km2	700 km	2 days
Space Imaging panchromatic sensor	US	planned	1m	20,000 km2	680 km	2 days
Space Imaging multi-spectral sensor	US	planned	4m	20,000 km2	680 km	2 days

Table 2

Range And Resolution Of Sensors [102]

Sensor	Spectral Range	Spatial Resolution
Metric camera	O.3-1.0 um	0.3-1 m
Panoramic camera	0.35-1.5 um	< 4m
Multi-spectral tracking telescope	0.35-1.5 um	<2m
Multi-band synoptic camera	0.35-1.5 um	<10m
radar imager	0.8 Ghz	10 meters x 10 meters
Radar altimeter/ scatterometer	0.4 & 0.8 Ghz	10 meters (vertical)
Wide range spectral scanner	0.32-14.0 um	~100 meters
IR radiometer/ spectrometer	8-16 um	~1000 meters
Microwave imager	9 Ghz	~1 km
Microwave radiometer	0.4-21 cm	3-7 kms
Laser altimeter/ scatterometer	visible	2.5 m (vertical)

Ultraviolet spectrometer/ imager	350-390 nm	<20 m (spatial)
		>1 nm (spectral)
Radio frequency reflectivity	75-450 Mhz	6-60 m
Absorption spectroscopy	UV, Visible, & IR	~50 m
Magnometer		~500 m
Advanced TV system	0.3-1.0 um	~20 m

New Providers or Marginal Actors?

Ostensibly, there is a great deal of activity and many states have advanced programs for the development of high-resolution satellite imaging systems.[103] From an American perspective, in addition to the Russian, Chinese and French capabilities, Japan, India, Israel, and even Brazil all have plans to orbit imaging satellites, and these programs can be expected to be commercial. Thus, argue executives in the American aerospace industry, the market will soon be flooded with systems from many sources, and there is no purpose to be served by continuing to limit the licensing of US-based commercial satellite imaging systems. However, upon closer examination, the commercial high-resolution space imaging systems offered by most of these states are likely to be very limited.

The current Indian and Japanese capabilities are limited to low and mid-resolution systems. Japan's only operating system has a resolution of 18 meters, and it is not clear when, if ever, higher resolution systems with a commercial potential will be developed and launched. India's IRS-1, with a reported 5.8 meter resolution, was launched in December 1995, but its operational characteristics do not allow for a major role in the commercial satellite imaging market. The higher resolution systems planned by India will require a major new level of investment that is unlikely to be available in the next five to ten years.

Israel has the technical capability to offer high-resolution imaging, perhaps on the order of 1 meter GSD or less, but the Israeli program was developed primarily for security purposes (see below), and the Israeli Defense Ministry has refused to provide operating licenses in order to preserve military secrecy (similar to the US policy throughout the Cold War). In addition, as will be discussed in greater detail below, the Israeli government, at the highest levels, has decided that it has a vital security interest in working with the United States in preventing the proliferation of this technology to the Middle East. As a result, Israel is seeking to cooperate with the US, and as long as this is the case, will avoid escalatory competition in offering high-resolution commercial satellite images or technology.

In the case of the Russian systems, although the technology is very advanced, the distribution system is extremely inefficient. The high-resolution systems such as the KFA-1000, MK-4, MFK-6 and KVR-1000 cameras are also in use by the Russian intelligence community; many of the operating characteristics are still unclassified, and orders for images take several weeks or months before they are filled. Indeed, Russia's space operating and imaging capabilities are deteriorating. In December 1996 Russia had no military reconnaissance satellites in orbit after the failure of one satellite and the launch failure of the backup. Although Sovinformsputnik signed a contract with US Aerial Images Company to provide 2 meter pictures on a commercial basis, the 14 May 1996 launch attempt for this dedicated commercial satellite failed.[104] At the time, Russia was not considered a reliable supplier of high-resolution commercial imaging.

With respect to France, Helios is a military system, and there is no clear program to commercialize its products. French security objectives are formidable, and military officials, like their American, Russian, and Chinese counterparts, are likely to be reluctant to transfer technology and details regarding this system to the private sector, where it will be widely accessible. In addition, the capability remains limited, with only one satellite currently in orbit, and the financing of additional or follow-on vehicles, such as Helios-2 or Horus, is uncertain.

This leaves the United States as the major provider of commercial high-resolution satellite imagery, at least in the short term (the next five to ten years). Systems such as Orbview-3, Earthwatch and the other entries, were ostensibly developed and licensed in response to the growing availability of French, Russian, Chinese, Israeli, and Indian systems, (In addition, the US government reduced direct allocations for intelligence satellites and licensing of commercial sources was seen as an inexpensive means to maintain the capabilities in this expensive sector). However, these systems will in fact determine the "rules of the game" regarding the availability of high-resolution imaging technology and the images themselves. These US-licensed systems will also have the greatest impact as intelligence sources in regional and other conflicts.

V. Security Related Implications of Satellite Imaging

During much of the Cold War, both superpowers used networks of dedicated reconnaissance satellites for strategic planning and intelligence. The United States developed these systems initially in order to monitor Soviet missile development, production, and deployment. Over the next three decades, this capability was applied to a wide range of military applications, and hundreds of thousands of images were returned. The US and the Soviet Union used these images to prepare targeting options for nuclear and conventional conflicts, and kept a close watch on each other's military capabilities, exercises and activities. Recently released US National Intelligence Estimates revealed that Corona sent back images including all Soviet medium range missiles, intermediate range, ICBM complexes, Soviet submarine classes, (from deployment to operational bases) and inventories of Soviet bombers and fighters. Corona also revealed the presence of Soviet missiles in Egypt protecting the Suez Canal in 1970, Soviet nuclear assistance to the PRC, and identified the site of early Chinese nuclear tests.[105] In addition, this system created the baseline data for SALT I, uncovered the Soviet ABM program and sites (Galosh, Hen House), located PRC nuclear testing and missile launching sites, provided mapping for Strategic Air Command targeting and bomber routes, and located the Plesetsk Missile Test Range, north of Moscow.

These capabilities clearly had an important impact on stability and the military balance during the Cold War. By revealing the movements and deployments of the opposing forces, such intelligence information reduced both the capabilities for launching surprise attacks, and the fear of such surprises. During most of this period, although a very high level of threat perception and suspicion existed in both Washington and Moscow, the tendency towards escalatory processes, resulting from fears and threats based on limited and incomplete or even misleading information, was reduced as a result of the information provided by the reconnaissance systems. The mutual deterrence system that existed from the early 1960s through the end of the Cold War was strengthened by the availability of direct reliable information provided by these and related reconnaissance systems. Although such technology could not provide information on the intentions of decision makers regarding the use of strategic missiles, it can be argued that confrontations in Eastern Europe and other regions were avoided as a result of the fact that decision makers on both sides were confident about their ability to prevent a major surprise attack. Corona images allowed Western intelligence to analyze Soviet troop buildup around the Berlin Wall, and as mentioned earlier, ended the "myth" of the missile gap.[106]

Extrapolating from this model, it can be argued that the proliferation of high-resolution imaging technology will also be a stabilizing factor in regional conflict situations. (In a somewhat similar argument, Waltz argues that the proliferation of nuclear weapons will also stabilize regional conflicts). However, the attempts to draw conclusions based on analogies with the Cold War are problematic. The US-Soviet confrontation, particularly by the 1960s, involved two status-quo powers, while current conflicts and threats to international stability involve a multi-polar system and many revisionist powers. In the Middle East and Persian Gulf, there are a number of rogue or pariah states, including Iraq, Iran, Libya and Syria. In Asia, North Korea is a prime example of a rogue state whose military capabilities are a source of instability and a threat to the region and beyond.

All of these states have some form of weapons of mass destruction (chemical and biological weapons), many are actively seeking nuclear weapons, and they also have ballistic missile capabilities. In terms of conventional weapons, many of these rogue states also have large armies and, as demonstrated in Iraq's invasion of Kuwait in August 1990, are capable of using these forces aggressively. It is in this environment that the proliferation of high-resolution satellite imagery must be evaluated. To date, the availability of high-resolution satellite technology and images to regional powers has been limited. As noted, the US Landsat program provides little in the way of militarily useful information. Images at these resolutions are useful for detecting large area targets, such as space launching facilities, railroad yards and coastal features. In 1985, Japanese defense analysts used Landsat images to identify improvements to a Soviet air base and to conclude that these improvements would allow the TU-22M Backfire bomber to be flown from this site.[107] In addition, Norwegian academics sought to use Landsat images to detect evidence of the Soviet naval build-up on the Kola Peninsula, with some apparent success.[108] (Landsat images were also used to identify the oil wells that were ignited by Iraqi forces during their retreat from Kuwait in February 1991.[109]) Florini notes that "even thus restricted, Landsat has demonstrated the ability to reveal militarily significant information."[110] However the utility of this information was very limited.[111] Similarly, other low and mid-resolution systems, such as the European ERS (30 meters), the Japanese JERS-1 (SAR, 18 meters) and the Russian Almaz (SAR, 15 meters), also have very limited military applications.[112]

Since 1986, 10 meter SPOT images have been available and in some cases, the data they provided had a military or security-related application. SPOT images were used to pressure the German government to end German industrial involvement in the construction of a chemical warfare plant in Rabta, Libya,[113] and provided images of the CSS2 missiles Saudi Arabia purchased from China.[114] There are indications that Iraq and Iran used SPOT images during their eight-year war.[115] SPOT has also been used to obtain information regarding the Dimona nuclear reactor complex in Israel, sites in Iran and Iraq, and in the areas of Serbia and Bosnia.[116] In the Bosnian conflict, SPOT data allowed pilots to conduct real-time practice "flyovers" -- allowing them to use the actual areas over which they would be flying. In a study involving the use of SPOT for observing military deployments in the Golan Heights, Jasani claimed to be able to identify anti-aircraft positions, barracks, perimeter fence locations, aircraft shelters and other objects.[117] (However, this claim is not entirely convincing.) SPOT also played an important role in revealing details of the situation at the Chernobyl nuclear reactor complex, and the distribution of these images demonstrated the inaccuracy of the official Soviet statements.[118]

Despite their limited resolutions, SPOT and Landsat were also used for some military activities during Desert Storm. A RAND report notes that during the Gulf War, the US Air Force was the largest consumer in the world of commercial satellite imagery.[119] Commercial sales of SPOT and Landsat images were embargoed during the 1990-1991 Gulf War, indicating that these images contained militarily useful information.[120] According to Sokolski, "Anyone who had access to SPOT images during the Persian Gulf War, for example, could have discerned the basic movement of coalition forces throughout January and February 1991."[121] The Coalition forces used Landsat data to determine spectral changes or ground disturbances, and SPOT was used to prepare for upcoming missions. SPOT and Landsat were also used to determine the extent of environmental damage caused by Kuwaiti oil fires and to create updated maps of the war zone.[122]

All of these systems, however, had resolutions (GSD) that were far below the capabilities of military reconnaissance satellites, which reportedly possess GSDs of a few centimeters. Johnson writes that although Landsat was useful during the Gulf War, "its utility was readily diminished by its relatively low spatial resolution, its lack of stereoscopic coverage to produce three-dimensional mapping products, its precise metric positioning data, and its long revisit times."1183 In contrast, the generation of commercial satellite systems currently under development will possess resolutions between 1 and 3 meters, enabling them to provide information close to that provided by dedicated military systems.

Table 3

Ground Resolution Requirements For Militarily Significant Targets [124]

Target	Detection	General ID	Precise ID	Description	Technical Analysis
Vehicles	1.5	0.6	0.3	0.06	0.045
Communications-					
Radio	3	1	0.3	0.15	0.015
Radar	3	1.5	0.3	0.15	0.015
Command and Control HQ	3	1.5	1	0.15	0.09
Missile Sites (SSM/SAM)	3	1.5	0.6	0.3	0.045
Aircraft	4.5	1.5	1	0.15	0.09
Airfield Facilities	6	4.5	3	0.3	0.15
Bridges	6	4.5	1.5	1	0.3
Troop Units	6	2	1.2	0.3	0.15
Roads	6-9	6	1.8	0.6	0.4
Surface Ships	7.5-1.5	4.5	0.6	0.3	0.045
Coasts, landing beaches	15-30	4.5	3	1.5	0.15
Railroad Yards and shops	15-30	15	6	1.5	0.4
Ports, Harbors	30	15	6	3	0.3
Urban Areas	60	30	3	3	0.75
Terrain Features		90	4.5	1.5	0.75

The availability and proliferation of higher-resolution satellite imaging systems with significant military impact is likely to contribute to instability in a number of regions that are characterized by conflict and warfare. Data from dedicated reconnaissance and other high-resolution imaging satellites can be applied in regional contexts, just as in the case of strategic confrontations. In Operation Desert Storm, US military reconnaissance satellites detected individual tank and artillery pieces and, according to official assessments, provided "extraordinary detail useful for battle assessment and the delivery of precision-guided weapons."[125] The USAF imposed high-resolution satellite images of downtown Baghdad (obtained before the war) over digital terrain maps in order to rehearse missions and increase attack accuracy.[126] NATO forces also used HELIOS images, for example, to detect and target guns and armored vehicles in the Mostar region. With the increased availability of high-resolution commercial imaging systems, similar capabilities will become accessible to other states and combatants.

Indeed, the emergence of capabilities for receiving detailed images from the battlefield, and distributing them (or the analysis) directly and immediately to the commanders in the theater, is increasingly recognized as one of the major innovations in conventional warfare. In 1995, US Secretary of Defense William Perry noted the central role that space forces play, stemming from their "exceptional capabilities" for collecting, processing and distributing data. Similarly, Russian military analysts note that "The collection processing, storage, transmission and display of information in them ... has been made the basis of operation. It permitted formalizing the process of assessing events that are occurring and coming up with preferable decisions...."[127]

If regional powers, rogue states, and even terrorist groups have access to this data and capability, they will be able to exploit it for the same purposes. Assessing the implications, Gupta argues that "The widespread availability of high-resolution imaging is a particularly problematic trend for the United States. As the preeminent global power, the United States faces the future prospect of having to intervene militarily against opponents that may be able to obtain a high-resolution satellite."[128] The risk, Gupta acknowledges is that the impact "depends on how the new remote sensing services will be distributed through the political landscape, how belligerent states will use the high-resolution images, and how observed states will respond to routine overhead imaging by their neighbors."[129] Unlimited sales could disrupt "delicate balances of power" and existing alliances, and the proliferation of high-resolution imaging could make international crises harder to contain, and the imaging could fuel developments in offensive weapons capability.[130] Theoretically, argues Charles Lane, "Islamic Jihad could get its hands on a one-meter resolution picture of .. a US Air Force General's headquarters in Turkey, convert the shot to a precise three-dimensional image, combine it with data from a GPS device.. and transmit it to Baghdad, where a primitive cruise missile, purchased secretly from China could await its targeting coordinates."[131] Former CIA director James Woolsey concludes, "This very comfortable world people have been living in where fixed target installations on land are safe,"[132] will vanish with the proliferation of high-resolution commercial imaging.

VI. Changes in the Regulation of High-Resolution Imaging

From the development of high-resolution military reconnaissance satellites in the 1960s, until the early 1990s, the technology available for high-resolution commercial imaging for other states (with exception of the four major space powers) was strictly controlled. In both the United States and Soviet Union, the technical capabilities and the images themselves were among the most classified of national security issues. Launches of such satellites were not publicized (although the agreements regarding United Nations registration of all space launches led both states to make declarations that launches had taken place, without providing any information on the payloads).

As civilian earth resource satellites developed, their capabilities were also restricted in order to prevent any encroachment on the national security-related reconnaissance activities. In June 1978, President Carter issued PD/NSC-37, which restricted commercial imaging systems, such as Landsat, to 10 meters.[133] The Soviet Union also adopted a policy that restricted this technology and the images that it produced to the military sector. (At the time, China and France were not yet active in this area.) US policy was reaffirmed in 1984, under the Landsat Commercialization Act, which gave the Secretaries of State and Defense the power to decide whether any satellite system should be approved for launch and operation.

These restrictions began to erode in the mid 1980s, with the commercialization of Landsat and the response to the development of SPOT. As noted above, this process accelerated in 1992 and in 1994, when PD-23 was formulated. This Presidential Directive allowed unlimited resolution for commercial systems.

However, as the analysis of the implications of this potentially unrestricted policy for high-resolution commercial imaging satellites began, questions emerged. The impacts of such systems on regional conflicts, access by terrorists, and other scenarios began to be considered. Analysts asked whether "the flood of newly available information [would] restrict the government's flexibility during negotiations or times of crisis?"[134] In addition, this development could provide unlimited access to critical intelligence information, which could then be used to destabilize regions or in planning attacks on American facilities.

Indeed, according to the Land Remote Sensing Policy Act of 1992 and PD-23 (1994), the limitations that the US government places on the export of military and dual-use technologies, as covered by the US Munitions List (USML) and the Commerce Control List (CCL) have been extended to include commercial imaging technology, and the data that is provided by these systems.[135] In addition, PD-23 includes 8 specific requirements for the licensing of commercial imaging systems, including the requirements for the use of a data downlink format and encryption devises that allow the US Government to impose limitations on the use of the data "during periods when national security, international obligations and/or foreign policies may be compromised," as defined by the Secretary of Defense or the Secretary of State. However, the White House Fact Sheet on PD-23 reflects the potential confusion in this procedure and the possibility that internal disagreement on the definition of such periods and policies would lead to continued access to high-resolution images while the bureaucracy debates the issue. According to the Fact Sheet, "Decisions to impose such limits only will be made by the Secretary of Commerce in consultation with the Secretary of Defense or the Secretary of State, as appropriate. Disagreements between Cabinet Secretaries may be appealed to the President. The Secretaries of State, Defense and Commerce shall develop their own internal mechanisms to enable them to carry out their statutory responsibilities."[136] There is, however, no indication of what such "internal mechanisms" may be, or how they would operate.

Additionally, no firm can knowingly sell vital information to a hostile buyer, at any time or under any conditions (not only in crises).[137] PD-23 mandates that all licensees keep records of "satellite tasking" and allow the USG access to the records. Firms are prohibited from changing the operational characteristics of the satellite system, as approved. The licensees must also provide the US government with the ability to receive all of the data, and are required to provide notification when they enter into "significant or substantial agreements" with new foreign customers. (According to the Fact Sheet, "The definition of a significant or substantial agreement, as well as the time frames and other details of this process, will be defined in later Commerce regulations in consultation with appropriate agencies.")[138]. Moreover, the licenses are valid for a "finite period" and are neither transferable, nor subject to foreign ownership. When deciding whether or not to issue an export license, the government will take into consideration the foreign customer's "willingness and ability to accept commitments to the US government concerning sharing, protections, and denial of products and data."[139]

US industry officials and their proponents in the government argued that US firms be allowed to use access to superior technology in order to dominate the market, and in the event of a conflict in areas such as the Persian Gulf, these firms would be able to "turn off" access to the high-resolution systems, as specified in PD-23. As added above, some members of the security community, (the CIA and State Department), disagreed with this approach, fearing that regular access to such images from any source would increase regional instability and interfere with conflict prevention and management or containment. Dr. Brian Dailey, Vice President of Business Development, Space and Strategic Missiles Sector of the Lockheed Martin Corporation, testified that PD-23 was, "the result of a protracted but ultimately successful effort to strike a balance between industry's.. need for clear, predictable regulation and the government's..need for an effective mechanism to address major national security or foreign policy contingencies."[140]

Dual-Use Technology

High-resolution imaging systems can be considered to be a form of dual-use technology. Technically, as is frequently noted, there is no clear difference between civil and military satellite systems. Orbital imagers and communications satellites are prime examples of dual-use technologies. A recent US Congressional Research Service report notes that "The distinction between military and civilian launches is arbitrary to a certain extent, since any satellite can be used for either sector."[141] Similarly, Florini noted that "Questions prompted by civilian systems parallel those of nuclear non-proliferation policy -- civil facilities could be used as cover for military programs, and perfectly legitimate civil programs might provide a government with a latent military capability."[142]

Thus, the debate on commercial imaging parallels the policy debates on restrictions and limitations regarding other dual-use technologies. In the 1950s, President Eisenhower promoted "Atoms for Peace," in which the US provided small nuclear reactors, training, and material, under the safeguards operated by the Atomic Energy Agency. But by the end of the decade, it had become clear that the IAEA safeguards could not prevent states from applying the facilities and knowledge to the development of nuclear weapons. Since then, many other dual-use technologies applicable to nuclear weapons, chemical and biological weapons, and missiles have been subject to unilateral restrictions and to limitations established under international supplier regimes. Such regimes include the London Nuclear Suppliers' Group, the Missile Technology Control Regime, and the Australia Group that formed the nucleus of the restrictions under the Chemical Weapons Convention.[143] In a broader sense, the COCOM system during the Cold War, and the Wassenaar Arrangement, created by 28 states in 1995, were designed to coordinate the policies of individual states to prevent potential dual-use technologies from being transferred to aggressive and pariah states.[144]

Some American opponents of restrictions also argue in terms of free market ideology, asserting that the high-resolution market is too immature, and government intervention could be distorting and ultimately counterproductive. They call for an "open skies" policy for commercial ventures, consistent with "US national interest and tradition." Mark Brender argues that the claim by the government for the right to screen all imagery before public release, as included in PD-23, "is blatant commandeering and expropriation of property of a private entrepreneur operating not in the role of government contractor."[145] Opponents of any limitations add that potential military and diplomatic disruptions caused by the deregulation of the imaging market will be offset by economic gains, and that "A vibrant economy is one of the most important elements of national security."[146] Charles Lane writes, "America's economic and national security interests lie in having the maximum number of satellite customers dependent on US companies before foreigners catch up with US technology. At least this way the market will be subject to US law and regulations."[147] In his testimony before the House Subcommittee on Space and Aeronautics, Scott Pace notes that restraining US sensing firms only creates a market for other countries, and lessens the US ability to act in a time of crisis.[148] In contrast, some industry officials, such as Dailey (Lockheed-Martin) argue that the adoption of clear governmental rules regarding the national security issues actually allays the fears of potential investors in this sensitive area. "Without the procedure set forth in PD-23 for addressing certain emergency situations, which is based firmly in current statutory authority, we could and would not have made the substantial corporate financial commitment required to implement a global commercial remote sensing system."[149]

VII. US-Israeli Negotiations on Limitations

The recent changes in technological capabilities of planned commercial imaging systems, and the changes in US policies, have also led to Israeli concern regarding the implications on the national security of affected states. Israeli officials realized that Arab states, and Iran, as well as terrorist groups, would be able to exploit these high-resolution images to obtain very detailed intelligence of Israeli capabilities and deployments, and would also be able to target Israeli sites with a high degree of precision, particularly if these images were combined with highly accurate cruise or ballistic missiles.[150] (In December 1989, a few months before the invasion of Kuwait, Iraq launched a three-stage missile (the Al-Abid), and the Iraqi government declared that this was a test of an independent space launching capability.[151])

It is not surprising that Israel would be particularly sensitive to the changes in American policy, and would be quick to raise the issue with the United States government. Israel's small territorial extent, which allows for detailed and repeated coverage with a relatively limited number of images, and the degree to which its deterrence posture and strategy is based on maintaining a high degree of uncertainty in the eyes of potential enemies, particularly with respect to the nuclear and ballistic missile potential, make this nation particularly vulnerable to the intelligence that can be made widely accessible through commercial high-resolution imaging satellites. In addition, the close strategic relationship between Jerusalem and Washington, and the degree to which the peace process and Israeli concessions have been dependent on US security guarantees and pledges to prevent the degradation of Israel's qualitative edge were also important factors in the Israeli decision to seek a change in the nascent US policy.

The Israeli government first raised this issue in 1992, shortly after the US adopted the Land Remote Sensing Policy Act (P.L. 102-555), when the United Arab Emirates (UAE) submitted an application to purchase an imaging satellite from Litton/Itek. On 19 November 1992 the *Jerusalem Post* reported that Israeli officials were outraged over the possible sale of an American super-secret spy satellite to the United Arab Emirates. A Defense Ministry official was quoted saying "For years we have been begging the Americans for more detailed pictures from their satellites and often got refusals -- even when Iraqi Scud missiles were falling on Tel Aviv.... The Americans have also done their best to deny us all help in building our own reconnaissance satellite. Now they are going to supply the Arab countries with binoculars that will enable them to see every military movement here."[152] Although the application was ultimately blocked by the US State Department (in part, in response to Israeli objections), the proposal was endorsed by the space industry and its supporters in the US government.[153]

In late 1994, a Saudi company known as Eirad, owned by Prince Fahd Bin Salman Bin Abdulaziz, sought to acquire a major interest in Eyeglass (now Orbview), in return for an agreement to build a ground station in Riyadh and exclusive rights of coverage in the Middle East. The main customer was said to have been the Saudi Defense Ministry.[154] In response, the Israeli government expressed concern that this would give the Arab States, including Iraq, access to highly accurate intelligence information and threaten Israeli security and vital interests. On 2 August

1994 the Clinton Administration asked Israel not to object to the Orbview agreement with Saudi Arabia. However, Israel cited the Saudi's negative role in regional instability, potential contribution to conflict, and support of radical Islamic groups.[155] This assessment was also supported by over 60 members of the US Senate, and number of Congressmen, who expressed concern about transfer of a system "that would be capable of receiving and distributing spy-satellite quality imagery of Israel throughout the Middle East."[156] This group urged the Clinton Administration to reject this proposal.

In response, officials of the Orbital Science Corporation noted that even if a foreign firm such as Eirad held an equity position in Orbview, it would still be subject to US law and license requirements.[157] In an exchange of letters between the Commerce Department and the partners in Orbview, "The firm agreed to exclude the territory of Israel from its viewing area and to put a technical fix on the satellite that would prevent such viewing."[158] However, Israeli officials reportedly considered the safeguards regarding the implementation of these assurances to be insufficient and too vague. In March 1995, the US government agreed to "study the matter in greater detail," and as of January 1997, the role of the Saudi firm in Orbview was unclear.

The US government's decision to declassify thousands of satellite images is also an issue in the US-Israel imaging negotiations. A declassified Corona photo of the nuclear reactor outside of Dimona was featured on the front page of Israel's largest daily, *Yediot Aharonot* (25 June 1996). In response, the US pledged to take Israeli security interests into account in the future.

At the same time, Israeli firms have also been developing a high-resolution commercial satellite imaging capability, as noted above. Indeed, some Israeli industry officials complained that the MOD's policy (Ministry of Defense) of negotiating limits with the US, and the delay in licensing IAI's program would result in the loss of IAI's advantage in marketplace. They argued that the US was using the negotiations to delay the IAI program until American US firms are able to launch their own civil imaging satellites. The MOD response emphasized the security implications for Israel of unrestricted civil imaging of the region, and the assistance the MOD provides to the IAI in other areas, including efforts to sell launch services with the IAI Shavit launcher.[159]

In 1996, after considerable negotiations, Prime Minister Rabin promised to coordinate with the US on this issue and the US agreed to restrict the Saudi role (by denying the Saudis control of the satellite track from the ground, and also blocking the sale of software for image enhancement). On 4 March 1996, following the publication of a number of inaccurate reports regarding Israel's remote sensing policy, the Israeli Ministry of Defense set forth Israel's official policy. In the first, and to date, the only official statement, the MOD declared that it would prohibit the use of Ofeq-3 images for commercial purposes. The MOD also emphasized its policy of maintaining a strict division between security related technologies and "any possible future commercial track," which would require licensing from the MOD . Licenses would be made available only "after a careful and thorough review of all aspects."[160]

Press reports indicate that in 1996, Israel asked the Clinton Administration to place restrictions on three US companies planning to launch commercial surveillance satellites.[161] The Israeli government requested that a limit of 3 meter resolution be placed on the companies' satellites. James Frelk, the vice president of Earthwatch, said that even if Earthwatch accepts the limits, Israel's neighbors will simply switch their business to Russia or France.[162]

The debate intensified when, on 26 June 1996, the US Senate passed an amendment to the 1997 Defense Authorization Act entitled, "Prohibition on Collection and Release of Detailed Satellite Imagery Relating to Israel and Other Countries and Areas." The amendment would have prohibited any agency or department of the US government from licensing (and declassifying) the collection or dissemination, declassification or release by any non-Federal entity of satellite imagery with respect to Israel, or any other designated area, unless the imagery is no more detailed or precise than imagery produced by that country's indigenous satellites. [163]

Critics of the amendment claimed that it sought to ban the release of information that was already available and published in newspapers and magazines.[164] Industry officials and other opponents also argued that the amendment was contrary to the 1992 Land Remote Sensing Act and the Presidential Directive of 1994, and the US commitment to open skies and freedom of information. Restricting US firms would only create more room in the market for foreign competitors and thus "undercut the effectiveness of wartime shutter controls on US firms."[165] Scott Pace argued that, "The window of opportunity for US industry will not last forever," and creating rules and exceptions for the operation of foreign firms "creates niches for others and reduces the ability of the United States to exercise influence during true emergencies."[166] Mark Brender declared that the Senate amendment, "amounts to the creation of a new multilateral regime to decide what images governments will allow private firms to release. That is an unconstitutional form of prior restraint."[167] If Israel were to have a blackout option, other countries would demand the same, and "Satellite companies could, thus, be faced with blackout areas around the world to accommodate the arbitrary requirements or political whims of individual countries, thus undermining investor confidence."[168] Other critics simply dismissed Israel's security concerns, stating that "Foreign countries that protest US entry in this market do so most often out of self-interest. Virtually all who do protest are building their own systems, many of which are being promoted commercially, if not today, then tomorrow. If US industry is not allowed to be first-to-market, then it is unlikely it can or will justify the investment in the future after foreign governments have subsidized and achieved dominance in the commercial market."[169]

Supporters of the amendment argued that Israel is a very small country, and one its main military assets is the "uncertainty in the calculations of intelligence capabilities of hostile forces."[170] The Israeli market is not large enough to threaten the health of US commercial imaging industry. In response to claims regarding imminent competition in this area, Senator Bingaman declared. "That frankly is hogwash. Our industry cannot and should not try to make profits by providing spy satellite images of Israel to Syria and Libya and Iraq and Iran. If they ever thought that market would be allowed to them, they were misreading the Congress."[171] Others noted that there is a vast middle ground between a total ban

of high-resolution systems and unfettered commercial remote sensing. The conference committee text, which became law, prohibits sale or release of satellite imagery of Israel of higher resolution than is available from other commercial sources. [172]

The precise definition and implementation of this statute are unclear, however. (For example, US industry officials can be expected to claim that sporadic sale of old Russian 2 meter images constitutes "commercial source," while opponents would clearly disagree.) Thus, the issue remains open and conflict between different perspectives is likely to continue.

VIII. Policy Options For The Future

A. Technical and Political Issues

From the late 1980s, the United States government has gradually developed a set of policies, as it began to declassify old reconnaissance images, and license high-resolution commercial systems. The approach to policy making in this area has been unilateral, with some corrections and negotiations in response to the Israeli concerns. As noted, the Israeli input has generally been post-facto, after unilateral decisions made by the US government on the release of images, and the promulgation of decision memoranda and policy guidelines.

However, as illustrated by the Israeli protests, the ad-hoc unilateral approach is inherently limited. The impact of the proliferation of high-resolution satellite imaging is important in many other states and regions, suggesting a bilateral approach in these cases, as adopted with respect to Israel, or a broader multilateral framework. The issues and technical changes that prompted the review in US policy are inherently multilateral. The growth of French, Russian, Indian, Israeli, and Canadian high-resolution imaging capabilities prompted the initial change in US policy. In this environment, in which there are many actors, with different security and economic perspectives and priorities, "the absence of regional or international guidelines could undercut national policies, such as PD-23, that attempt to allay such security concerns."[173] If the US were to unilaterally adopt a policy blocking commercial imaging below a certain resolution, or imposing a blackout on certain areas (such as Israel), other suppliers, such as France or Russia, could be expected to attempt to fill the void. Thus, a combination of systematic unilateral and multilateral measures might be necessary to maximize imaging opportunities while minimizing the security risks.[174]

Technically, as noted, there are a number of possibilities to limit the security risks and impact of high-resolution imaging for specific regions, states, or crisis situations. The prime methods are "*blackout*," *data quality reduction*, and *time delays*. The first option consists of a device (software driven) which prevents any image of a pre-determined area from being collected or downloaded. Thus, if an agreement was reached by which Israel would be blacked-out, Israel's coordinates would be loaded into the sensor targeting devices, which would be programmed to avoid receiving any images that included elements within these forbidden coordinates. Blackout capabilities could be built into the camera systems and space platforms, earth receiving stations, or distribution systems.

The second option, based on limiting the quality of data that is distributed, is a means of preventing certain type of data analysis that would promote identification and analysis for military-related objectives. Raw data can be processed using various computer techniques and software for edge enhancement, contrast stretching, and pattern recognition. These techniques increase the effective resolution and sensitivity of the imaging system, allowing analysts to extract more information from the data. As Jasani notes, this enables "more information to be extracted from images from electro-optical devices."[175]

By degrading the data that is provided commercially, the ability to extract certain information is also degraded. Thus, images and data that do not contain the full range of information provided by the sensors would be less amenable to abuse for military targeting and other related purposes. Some Russian high-resolution images that are made available commercially are degraded before they are released. (Similarly, efforts to prevent the export of computer software used for image enhancement might accomplish the same objective, but given the wide availability of this software, it is doubtful that such limitations could be effective.) A system based on time delays, in contrast, would allow for such imaging (no blackouts), but would require that downloading or distribution of some, or perhaps all images would be delayed for a significant period of time. For most military purposes, this might be a period of a few weeks (during which battlefields and deployments change significantly), and in many cases, a few days. (Gupta argues that in the 1991 Gulf War, satellite imagery that was a few days old was useless.[176]) However, in some cases, in which the main information may be gleaned from frequent observation, and in which a time delay does not reduce the importance of the information, this approach is less useful in reducing risk.

In the US, there is significant opposition to these approaches, from both industry officials and commercial imaging supporters in the government. Opponents argue that selected blackouts (limited, for example, to Israel) will set precedents for other and much larger countries, such as India, Pakistan, China, etc. to make similar demands, which will eventually create so many blacked-out areas as to undermine the economic viability of the commercial imaging. Similarly, mandated degradation of data and the introduction of time delays for some or all images are seen as economically undesirable.

B. Unilateral Approaches

As noted, the US has generally taken a unilateral approach to policies regarding space imaging systems. In the early 1960s, the Kennedy Administration unilaterally imposed a blackout policy on all information regarding reconnaissance satellites, and while the tacit and informal understandings reached with the Soviet Union regarding non-interference with these systems may be considered bilateral, the initiative as well as the formal and legal frameworks were unilateral. In the United Nations, successive US administrations resisted and rejected efforts to develop international "rules of the road" and limitations regarding space-based imaging in ways that would have significantly reduced US freedom of action in this area.[177] Similarly, the series of policy changes and Presidential decisions beginning in the mid-1980s and extending through PD-23 are unilateral.

While a series of parallel unilateral policy declarations by other countries, incorporating similar limitations and prohibitions is possible, the interests of these states and their previous behavior in other dual-use sectors suggest that it is highly unlikely. Such a result would require that France, Russia, Canada, and the other suppliers of high-resolution imagery in the next decade unilaterally adopt policies consistent with those of the US, without formal international coordination. The multilateral approach, discussed below, is more feasible. Thus, the unilateral option was and continues to be of relevance mainly in the case of the US.

One of the primary rationalizations for unilateral policy is that by acting unilaterally, the United States can determine the framework for the policies of other nations. The US is generally seen as the market leader in terms of technology and commercial capabilities, and as such, is viewed as having the resources to create rules and limitations that would also be accepted, albeit perhaps reluctantly, by the other players. This argument was made in the 1960s and 1970s with respect to nuclear power. US firms were encouraged to seek commercial contracts in this sector, thereby acquiring control of most of the market. Once in control, the US could then force recipient states to accept non-proliferation safeguards and limitations.

In applying this approach to commercial imaging satellites, the firms licensed by the US must 1) capture a major portion of the market, thereby becoming market leaders; 2) use this position to impose limitations and restrictions; and 3) prevent violations through technical or other means.

By providing 1 meter GSD real-time digital images of the world "to order", firms such as Earthwatch, Space Imaging and Orbital Sciences might be able to prevent Russian, French, Indian and other firms from establishing a significant foothold in the market. (Earthwatch has already announced that its database of geographic imagery and information products is now available on-line, allowing individuals to order images through the internet.[178]) Well-capitalized and operating with the support and encouragement of the United States government and intelligence institutions, these firms could afford to operate at a loss for a number of years.

However, the drawback of the first assumption is the fact that most of the other potential states would be unlikely to end operations in this area. For most, including the US, the commercial systems are spin-offs of military reconnaissance systems, which would be maintained, regardless of the absence of profits in the commercial ventures. As a result, it is unlikely that US firms would be able to use market leadership to impose global limitations and restrictions. In the case of nuclear technology, when the US refused to sell reactors to pariah states such as Iraq and Iran, France, Russia, and China have stepped in to meet the demand. Thus, the second requirement is also unlikely to be met.

The third issue in assessing the viability of any set of restrictions and limitations is implementation. Various restrictions and prohibitions that are listed formally in statutes and regulations are only valid to the degree that an enforcement mechanism exists and operates. While unilateral enforcement of technological limitations, in the case of nuclear technology transfer and other export controls, has proven to be the most reliable form of verification, this system has also failed on many occasions.

Similarly, unilateral restrictions on high-resolution space imaging requires enforcement and verification mechanisms. How will violations be detected, and how will they be addressed? Unless the verification system includes measures for timely detection, before illicit images are distributed and can be exploited, and a significant deterrence mechanism to insure that the violations will impose unacceptable costs on the firms and recipients of this material, formal restrictions are of little consequence.

The proposals for US unilateral limitation on commercial satellite imaging have failed to provide detailed analysis of the options and weaknesses of the selective blackout and time delay options. Although software limits have been proposed, the question is whether these can be defeated, and if so, what are the implications for security and what potential remedies could be suggested?

As noted, PD-23 allows the US Secretary of Commerce to intervene and shut off the distribution of images if there is a decision that continued distribution poses a threat to national security. The Commerce Department is also required to review requests for export licenses**,** taking into consideration the foreign customer's "willingness and ability to accept commitments to the US government concerning sharing, protections, and denial of products and data." This Presidential Decision 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.[179]

The questions regarding the effectiveness of PD-23 are not normative, but informative, asking how and whether they will be implemented. The language does not refer specifically to blackouts or time delays. To the degree that such approaches are adopted, if they are incorporated in the technology, it will require less monitoring and subjective decision making by particular individuals. However, software can be changed, and blackout coordinates can be altered, so monitoring is still necessary. Then, the focus shifts to the monitoring agents and practices. Will the firms be expected and entrusted with the monitoring task, with occasional spot checks by the US government, or will US government personnel be assigned on a permanent basis to insure compliance with limitations? If the latter, how many individuals will be needed, and who will provide the funding?

Thus, although unilateral approaches to limiting the negative and destabilizing impact of high-resolution commercial imaging is a natural first stage, the implementation will be complex and limited.

C. Bilateral Options

While the approach of the American government has been primarily unilateral, the Israelis have taken a distinctly bilateral track. When the dual problems of high-resolution commercial imaging and release of old classified reconnaissance images arose, the Israeli policy makers initiated high-level talks with their counterparts in Washington. The first instance was in 1992, following the application by the UAE to purchase a satellite, and then in the case of Eyeglass, and the purchase by the Saudis of an equity interest in this system. These issues, and the impact on Israeli security, were discussed in meetings between President Clinton and the Israeli Prime Minister, as well as in talks involving the heads of intelligence agencies, defense officials, and military officers. Israeli interests were also explained to Congressional leaders, which resulted in the Amendment to the 1997 US National Defense Authorization Act (To Prohibit the Collection and Release of Detailed Satellite Imagery with Respect to Israel and other Countries in the Area) establishing explicit restrictions on the release or sale of high-resolution images of Israeli territory.

The bilateral approach, which can be considered, at least in a preliminary evaluation, to have been relatively successful in minimizing the impact on Israeli security, was based on a long history of close cooperation between Washington and Israel, and on commitments by successive US administrations to insure Israeli security. For two decades, the US had pledged to preserve Israel's qualitative edge in military technology, which is necessary to offset massive Arab quantitative advantages. The possibility that American technology, whether in the form of satellite hardware or imaging software, would be sold to Arab states, or made available, was seen as a violation of these pledges, and, as a result, Israeli views were taken into account.

Israel does not enjoy a similar strategic relationship with the other actors active in the area of high-resolution space imaging, but there is evidence that Israel is taking a similar bilateral approach with some of them. Published reports state that Israeli officials have also been negotiating with Russia for an agreement similar to those reached with the US to prevent release or sales of images of Israel.[180] Currently, the Russian images are considered to be the most detailed available, although, as noted above, marketing limitations raise serious questions regarding their "commercial availability." In any case, if Israel and Russia have reached a bilateral agreement similar in substance to that between Israel and the US, it will also help to insure that commercial high-resolution images of Israel from systems such as Space Imaging and Earthwatch, will continue to be restricted, as required under the US legislation restricting images of Israel to resolutions comparable to those commercially available from other sources. On this basis, it is possible that Israel could extend this bilateral approach to France, Canada, India, Japan, and other potential providers of high-resolution space imaging.

While this system of bilateral agreements might provide a cushion of a few years in which Israel would be protected from the security impact of commercial high-resolution imaging, this cannot be expected to provide a long term solution. Eventually, images of Israel will be made available, as the technology proliferates and access to images spreads. In addition, although this approach may buy some time for Israel, any other countries that wished to gain a similar degree of protection against the destabilizing impacts of high-resolution commercial space imagery would have to negotiate a series of similar agreements. For example, if Taiwan, Pakistan, or even Russia sought to prevent the large scale release of such detailed images, each state would have to begin negotiations with the US and other states which license or operate such systems. Such a patchwork system of bilateral agreements would be increasingly difficult to manage, and of questionable effectiveness.

D. Multilateral Regimes

Multilateral limitation and supplier regimes have become the norm in many areas of dual-use technology. The nuclear non-proliferation regime was the first and is the most developed of these regimes, based on the Nuclear Non-Proliferation Treaty (NPT), the inspection and verification system of the International Atomic Energy Agency, and reinforced with various limitation agreements among suppliers. In the past decade, a multilateral regime to limit proliferation of chemical weapons has evolved, based on the suppliers' limitations in the Australia Group and, more recently, the Chemical Weapons Convention. Traffic in missile technology is controlled by the Missile Technology Control Regime (MTCR), [181] while the Wassenaar Agreement provides the basis for agreed limits on the export of broader categories of dual-use technologies (computers, special metals and materials, etc.).

Based on this experience, the foundations or framework of a regime to set the parameters for commercial high-resolution satellite imaging can be considered.[182] If successful, this approach would potentially solve many of the logistical and negotiation problems and limitations in bilateral agreements, and would be more extensive than in the unilateral approach discussed above.

In examining the role of existing technology control efforts, the evidence indicates that the transfer of technology for nuclear weapons, cruise missiles, and even ballistic missiles, in some cases, has been slowed down by these international regimes. This is not the case in the Middle East, where MTCR-based limitations have not prevented Russian or Chinese transfers to Iran. However, the experience from the negotiation and operation of other supplier and non-proliferation regimes (nuclear, chemical, missiles, etc.) demonstrates the inherent difficulties of this approach. Negotiations take many years, and the agreements are generally based on the "lowest common denominator" among the participants.

Nevertheless, the number of states capable of launching and operating high-resolution satellites is limited. The major actors would be the US, France (or the consortium that operates the Helios satellites), Russia, Canada, Japan, Israel, China, and India. A few other states may be invited to join as they develop high-resolution imaging satellites, but for the foreseeable future, the number of actors will be 10 or less. Thus, it may be possible, both politically and economically, to reach agreed limits in this area.

Indeed, the first steps towards an international space imaging regime can be traced to policy initiatives in the late

1950s. In 1958, the US National Security Council took steps designed to "seek urgently a political framework that will place the uses of US reconnaissance satellites in a political and psychological context more favorable to the US intelligence effort."[183] In parallel, the possibility of an international regulatory regime for imaging satellites has been discussed in the United Nations. The 1967 Outer Space Treaty established the principle that outer space cannot be claimed as national territory, and this was seen to formally confirm the legitimacy of the overflight of satellites over the territory of individual states.[184] Although the Soviet Union and the Non-Aligned Movement argued for the right to prior consent regarding the dissemination of civilian remote sensing date, the 1986 UN resolution on remote sensing ("Principles relating to remote sensing of the Earth from Space") did not include any mention of prior consent.[185]

Negotiations of a multilateral high-resolution commercial imaging limitation regime will require agreement on a number of complex political and technological issues. As in the case of unilateral and bilateral negotiations, the various methods for restricting imaging (blackouts of certain regions, time delays, distribution of reduced resolution data, etc.) would have to be considered and agreement would be required among all the participants.

As the technological and market leader in this area, the US would be in a position to play a leading role in creating this international regime. In the next few years, as US firms develop and deploy the most advanced commercial imaging satellites, the unilateral restrictions and regulations imposed by the US government will become the de facto standard for the developing international regime.

The creation of institutions to implement and manage dual-use technology transfer limitation regimes has generally been an important component of the multilateral process. Although the number of images and transactions can be expected to grow rapidly, at this stage, and with the number of state actors limited to 10 or less, such institution building seems unnecessary. If multilateral agreements on "the rules of the game" are reached, it would seem that exchanges of data among the participants would be sufficient to monitor the degree to which the agreed limitations are being honored.

IX. The Alternatives To Regulation

In an unregulated free market for high-resolution commercial imaging, the negative impacts on stability and the security of some will be significant. Israel was the first to recognize the potential negative impacts of commercial imaging. A small country, easily imaged in its entirety, facing military threats from a number of sources and relying heavily on secrecy and uncertainty regarding its military assets and capabilities in response to military attack, Israeli security would be effected fundamentally by unrestricted high-resolution commercial imaging. It is also not coincidental that the first significant foreign attempts to invest in American commercial imaging satellite technology came from the Arab world.

However, the security impacts are not confined to small and vulnerable countries such as Israel. As Pike and others have noted, "Publicly available commercial images will have resolutions better than one meter, and will be available within a few hours after they are acquired. The US intelligence community did not obtain such high-resolution systems until the advent of the KH-7 satellites in 1966, and near-real time capabilities were not realized until the launch of the first KH-11 in 1976."[186] Pariah and rogue states with an interest in attacking American assets could use high-resolution commercial images to spot vulnerabilities in US military or civilian targets, and in planning and executing terror or even larger military attacks.

As noted in this paper, there are no technical differences between civil and military satellite imaging systems, and like other dual-use technologies, the risks and costs must be included with the economic benefits in assessing policy options. During the Cold War, orbital reconnaissance contributed to stable deterrence and the verification of arms control. However, if used by an aggressive rogue state for targeting and as a reliable and inexpensive source of intelligence in planning an attack, this technology can also prove to be very destabilizing in areas such as the Middle East, South Asia, and other regions.

These dangers and risks are being recognized, beginning in Jerusalem and Washington, but as this dual-use technology spreads, awareness of the destabilizing impacts of high-resolution commercial space imaging will also spread to other capitals. The elements of a satellite imaging limitation regime have already begun to be developed, beginning with unilateral policies in the US, and bilateral limitations involving Israel (with the US and Russia, to date). In the longer term, however, a multilateral approach to an international limitation regime, specifying limitations on resolution and image distribution, will provide the most efficient means for reducing the risks and maximizing the benefits of high-resolution commercial imaging technology. In the absence of such limits, states whose vital security interests are being threatened by the unrestricted availability of satellite images will act unilaterally to defend their security, and in some cases, this could even lead to technological measures, including the use of lasers and anti-satellite systems, to interfere with this imaging. When forced to choose between these options, the providers are likely to pursue a multilateral limitation regime.

Notes:

Prof. Gerald M. Steinberg is a senior research associate at the Begin-Sadat Center for Strategic Studies and Associate Professor of Political Studies at Bar-Ilan University, Israel.

This author is indebted to the many people who contributed to the research that led to this manuscript, including Scott Pace, John Pike, Dick Buenneke, Vipin Gupta, Gasparini Alves, and Dwayne Day. I am also grateful to the BESA Center for Strategic Studies, which provided a research grant, and research assistant Lea Rappaport, who spent many hours preparing this draft.

1 See Dino A. Brugioni, "The Art and Science of Photoreconnaissance," *Scientific American* (March 1996) and Albert D. Wheelon, "Corona: The First Reconnaissance Satellites," *Physics Today* (February 1997).

2 Gerald M. Steinberg, *Satellite Reconnaissance: The Role of Informal Bargaining* (New York: Praeger, 1983). See also John Lewis Gaddis, "The Evolution of a Reconnaissance Satellite Regime," in *US-Soviet Security Cooperation,* George Farley Dallin, ed. (New York: Oxford University Press: 1988), pp. 353-363

3 Brugioni, "The Art and Science of Photoreconnaissance," p. 78. The Corona orbiters lasted after the program had officially ended; some were known as keyhole (KH)-1,2,3 and 4 and were followed by seven KH-5 satellites of the Lanyard program and one of the Argon program. According to Albert Wheelon, 145 satellites were placed into orbit in the 12 years of Corona's operation. From those launches, 167 film capsules were recovered, producing over two million feet of film. See also Dwayne A. Day, "The KH-6 Reconnaissance Satellite," *Spaceflight Magazine* (May 1997), and Jeffrey Richelson, *America's Secret Eyes in Space* (New York: Harper, 1990).

4 Brugioni, "The Art and Science of Photoreconnaissance," p. 82. Beginning in 1962, dual cameras were used to make stereoscopic images.

5 Ibid. p. 78

6 See Steinberg, *Satellite Reconnaissance: The Role of Informal Bargaining,* op. cit., and Gaddis, "The Evolution of a Reconnaissance Satellite Regime," pp. 353-363

7 Henry Sokolski, "Nonapocalyptic Proliferation: A New Strategic Threat?," *The Washington Quarterly*, Vol. 17, No. 2 (Spring 1994), p. 122.

8 Ann M. Florini, "The Opening Skies: Third Party Imaging and US Security," *International Security*, Vol. 13 No. 2 (Fall 1988), p. 10.

9 William J. Broad, "Commercial Use of Spy Satellites to Begin; Private Ventures Hope for Profits," *New York Times*, 10 February 1997, p. 1.

10 Sokolski, "Nonapocalyptic Proliferation," p. 115.

11 Broad, "Commercial Use of Spy Satellites," p. 1.

12 Mary Graham, "High Resolution, Unresolved," *Atlantic Monthly* (July 1996), p. 26.

13 In 1984 Samuel Eliot Morrison Jr. leaked US photos of a Soviet aircraft carrier to *Janes Defence Weekly.* In 1997, another photo of a Russian aircraft carrier was published. (Bill Gertz, "Happy New Year, CIA!," *Washington Times*, 1 January 1997)

14 Brian Latell, director of the CIA Center for the Study of Intelligence said, "The missile gap evaporated as an issue once Corona started taking pictures." Caroline Smith, "CIA Satellite Photos Showed Soviet Cold War Ability," *Reuters*, 10 November 1996. The satellite photos also allowed Western intelligence experts to analyze Soviet troop movement around the Berlin Wall, and examine items on the ground wider than 2 meters. Wheelon adds that despite the fact that Corona was developed as a response to the possibility of a Soviet surprise attack, after the Corona missions began to return images of the USSR, CIA estimates were called into question. Six months before the first successful Corona mission, the National Intelligence Estimates predicted that by 1961 there would be 140 to 200

Soviet ICBMs deployed. This estimate would soon be reduced to between 10 and 25. Wheelon writes, "President Kennedy realized that the US was well ahead and had literally frightened itself through ignorance."

15 Michael Krepon, "The New Hierarchy in Space," in Michael Krepon, Peter Zimmerman, Leonard Spector, and Mary Umberger, eds., *Commercial Observation Satellites and International Security* (New York: St. Martin's Press, 1990), p. 22.

16 Peter Zimmerman, "From the SPOT Files: Evidence of Spying," *Bulletin of Atomic Scientists*, Vol. 45, No. 7 (July 1989), pp. 24-25.

17 Analysts claim that "The best kept secret in Washington DC and other world capitals is that 1:50,000 scale combat charts with contour lines can be created today using 10 meter commercial imagery and precise ground control points obtained from either classified satellites or eight points acquired from GPS receivers carried by legal travelers or space operations personnel." Press Release of SPOT Image Corp., Washington, DC, 18 March 1996.

18 Christian Lardier, "Proliferation of Remote Sensing Satellites as Market Expands," *Air & Cosmos/Aviation International*, 4 April 1997, pp. 34-35. See the charts in Lardier's articles.

19 Robert K. Ackerman, "Remote Sensing Advances Spur Geospatial Products," *Signal* (June 1996).

20 Vipin Gupta, "New Satellite Images for Sale: The Opportunities and Risks Ahead," *International Security*, Vol. 20 No. 1 (Summer 1995), p. 98; Broad, "Commercial Use of Spy Satellites," op. cit.

21 Ibid. The 2 meter imagery was old, but was detailed enough to detect planes, tanks, and troop movements.

22 The respective levels of investment are 78.9% for France, 14.1% for Italy, 7% for Spain. Germany is scheduled to participate in Helios-2 and Horus.

23 *Aviation Week and Space Technology,* 6 January 1997.

24 "Declaration a L'issue de la 15eme Session du Conseil Franco-Allemand de Defense at de Securite," 10

December 1996, Nuremberg (Paris: Ministry of Foreign Affairs, 1997). In February 1997, Bonn announced that it would defer its funding of Helios-2 and Horus by one year. (Bernard Bombeau, "Bonn Defers Participation in Helios," *Paris Air and Cosmos Aviation International,* 13 February 1997).

25 Christian Lardier, "Eucosat Works for Satellite Control," *Air & Cosmos/Aviation International*, 4 April 1997, p. 36.

26 Ibid.

27 "Declaration a L'issue de la 15eme Session du Conseil Franco-Allemand de Defense at de Securite," 10 December 1996, Nuremberg (Paris: Ministry of Foreign Affairs, 1997)

28 Christian Lardier, "First Visit to Torrejon Center," *Air & Cosmos/Aviation International,* 31 January 1997, p. 40. The center has four operations officials and 15 imagery analysts. As of January 1997, more than one hundred requests had been processed. The center's capabilities were also used to locate refugee camps during the East-central Africa crisis.

29 Carlos Segovia, "Activities at WEU Spying center Near Madrid Viewed," *El Mudo*, Madrid (Spanish), 26 January 1997, p. 22 (translated and reprinted in FBIS Report, FBIS-WEU-97-018, US Government World News Connection, Washington DC, http://wnc.fedworld.gov/); Broad, "Commercial Use of Spy Satellites," p. 6

30 Lardier, "Proliferation of Remote Sensing Satellites," pp. 34-35.

31 Jean Paul-Phillipe, "Helios 1A: France's (and Europe's) First Spy Satellite," *Military Technology* (October 1995). Helios will not make its participants independent of the US, as it will only be able to take photographs in daylight and clear weather. In addition, while Helios 1A is thought to have 1 meter resolution, US spy satellites can send back images with 7-inch resolution, 24 hours a day, in all weather conditions, "France to Launch First European Spy Satellite," USAF Newswire, 5 July 1995.

32 In 1987, Canada introduced PAXSAT, or "Satellites for Peace" which was composed of two systems; one to inspect orbiting satellites involved in outer space disarmament agreements, and one to verify terrestrial

disarmament agreements. Pericles Gasparini Alves, *Building Confidence in Outer Space Activities* (Geneva: UNIDIR, 1996), p. 68.

33 All Radarsat information from http://www.rsi.ca/ 10 February 1997.

34 Ibid. Radarsat also has swath widths of 50-500 km, and incidence angles of 10-60 degrees.

35 Carlos Segovia, "Activities at WEU Spying center," p. 22.

36 Vipin Gupta and Frank Pabian, "Investigating the Allegations of Indian Nuclear Test Preparations in the Rajasthan Desert," *Science and Global Security*, Vol. 6 (1996) pp. 101-189. See also Bhupendra Jasani, *Verification of a Comprehensive Test Ban Treaty from Space: A Preliminary Study*, Research Paper No. 32 (Geneva & New York: UNIDIR, 1994).

37 "Team Canada Reaches High Watermark in Thailand," Press Release from the Office of the Prime Minister, Canada, 17 January 1997. The system will cost (Can) $115 million, and will be built to the specifications of the Thai government.

38 Dana J. Johnson, Max Nelson, Robert J. Lempert*, US Space-Based Remote Sensing: Challenges and Prospects* (Santa Monica: RAND, 1993). The Reagan Administration held that a commercial operation would be more efficient, lower system and operational costs, may encourage market growth, and limit the need for federal funding.

39 Scott Pace, "Promoting Commercial Space Activity," testimony before the House Subcommittee on Space and Aeronautics, US Congress, Washington DC, 31 July 1996, (http://www.fas.org/spp/civil/congress/1996_h/h960731p.htm)

40 Ibid.

41 Charles Lane, "The Satellite Revolution," *The New Republic*, 12 August 1996, p. 22.

42 B. Jasani, *Verification of a Comprehensive Test Ban Treaty from Space*, p. 22 (Citing *Flight International*, 19-25 January 1994)

43 Federation of American Scientist homepage (http://www.fas/org/eye/imint.htm.) 11 September 1996. According to Laurence Nardon, a SPOT image costs approximately $3000 [Laurence Nardon, *Test Ban Verification Matters: Satellite Detection*, No. 7 (Vertic: London, 1994), p. 30].

44 Lane, "The Satellite Revolution," p. 22.

45 Lardier, "Proliferation of Remote Sensing Satellites," pp. 34-35.

46 Lane, "The Satellite Revolution," p. 21. The first launch of an American satellite for this purpose is scheduled for December 1997 by Space Imaging. As a condition of their licenses, Lane adds that US satellite companies must agree to shut down their cameras should the government decide that the operation is a national security risk.

47 Bernard Ettinger, "France, Saudis Discussing Helios cooperation," 5 July 1996, AP (Associated Press Wire Service). The "rejected bid" may be a confused reference to Orbview, and the purchase of an equity interest by a Saudi firm known as Eirad in this project. This purchase led the US government to review the licensing terms of this project, as is discussed in detail below.

48 Scott Pace testimony, "Promoting Commercial Space Activity,".

49 Broad, "Commercial Use of Spy Satellites," p. 6

50 Ibid. p. 1

51 Testimony of Mark Brender, chairman, Radio-Television News Remote Sensing Task Force before the Subcommittee on Space and Aeronautics US House of Representatives Committee on Science, US Congress, Washington DC, 24 July 1996 (http://www.fas.org/

cgi-bin/AT-FASsearch.cgi?sum=d13360)

52 Broad, "Commercial Use of Spy Satellites," p. 1

53 Lardier, "Proliferation of Remote Sensing Satellites," op. cit.

54 William Broad adds, "Earthwatch draws on the innovations of the Pentagon's anti-missile program, which has spent more than $30 billion to find ways to spot and destroy rising rockets and warheads from space."

55 Ackerman, "Remote Sensing Advances Spur Geospatial Products," op. cit. The other companies include Raytheon, E-Systems, Mitsubishi, Vonder-Orst, Lokley, and Eastman Kodak.

56Ibid.

57 Orbview is in orbit and provides weather-related imaging, and Orbview-2, which is planned for launch in 1998, is designed primarily to provide ocean imaging.

58 See Broad, "Commercial Use of Spy Satellites to Begin," and Lane, "The Satellite Revolution,". See also Graham, "High Resolution, Unresolved,".

59 [unattributed article] "Japan Enters International Space Launch Market,"(Japanese) *Nikkan Kogyo Shimbun*, 12 September 1997 (translated and reprinted in FBIS Report, US Government World News Connection, Washington DC, http://wnc.fedworld.gov/).

60 [unattributed article] "Special Feature 1: Advanced Earth Observing Satellite, ADEOS," (originally published in *Science & Technology in Japan*, No. 59, 1 October 1996, pp. 3-19 (English), reprinted in FBIS Report, FBIS-JST-96-052, US Government World News Connection, Washington DC, http://wnc.fedworld.gov/)

61 Based on data provided by Spotimage 1996, and cited by Claude Jung, "Verification of Agreements on Arms Limitation and Disarmament" in Pericles Gasparini Alves, ed., *Evolving Trends in the Dual Use of Satellites* (Geneva: UNIDIR, 1996), pp. 110-1

62 Due to recent cuts in the Japanese budget, the launch of Hiros may be delayed. "Japanese Space Budget

Suffers Body Blow," *Spacenet*, 5 February 1997.

63 "Cloak, Dagger, and Muddle," *Economist,* 8 February 1997, p. 72.

64 Shunji Taoka, "A Plan to Have a Domestic Reconnaissance Satellite Has Emerged: Japan Seeks Intelligence Independence," FBIS-EAS-96-108, 3 June 1996, AERA Editorial Board. The three satellites will consist of one to orbit at 750 km with the ability to transmit images with a resolution of 40 cm (black and white) if the satellite is lowered to 300 km, a second satellite with high precision synthetic-aperture radar and a resolution of 2.5 m, and a third to relay digital signals sent between these two. The estimated cost is 204.5 billion yen.

65 Ibid.

66 Michael Mecham, "India Builds Crown Jewel," *Aviation Week and Space Technology*, 12 August 1996.

67 The launch of Aryabhata was followed by Bhaskara-1 in 1979, and Bhaskara-2 in 1981.

68 Chris Smith, *India's Ad Hoc Arsenal: Direction or Drift in Defense Policy?* (New York: Oxford University Press, 1994), p. 201. Rohini-1 was followed by the launch of the Rohini-2 on 31 May 1981 (which was in a very low orbit and decayed after 9 days), the Rohini-3 on 17 April 1983 (a 41.5kg. experimental research satellite), the RS-I (Rohini Satellite) and RS-D-I (Rohini Satellite for Development).

69 Raju G.C. Thomas, "India's Nuclear and Space Programs: Defense or Deployment?," *World Politics*, Vol. 38, No. 2 (January 1986), p. 339.

70 "Cost Conscious Indians Find Profits in Imaging Satellites," *Aviation Week and Space Technology*, 12 August 1996.

71 Ibid.

72 This payload includes a monochrome imager with a resolution of 36 meters, and a 73 meter multi-spectral system. The resolution of a given imaging system is a function of a number of factors and can vary according to

altitude, angle, weather conditions, sun-angle, contrast, etc. In general, the use of this term is based on a standard ground sample distance (GSD) covered by a single pixel. See Vipin Gupta, "New Satellite Images for Sale: The Opportunities and Risks Ahead," Center for Security and Technology Studies, Lawrence Livermore Laboratory, University of California, 28 September 1994, p. 2.

73 *Aviation Week and Space Technology*, 24 October 1994; TRW Space Log 1957-1991, Vol. 27, 1991, p. 21 (annual journal published by TRW, Redondo Beach, California). This satellite is equipped with a linear imaging scanner based on an advanced CCD array, providing a resolution of 40 m in four spectral bands.

74 "Space Activities of the United States, Soviet Union and Other Launching Countries/Organizations: 1957-1993," *Congressional Research Report to Committee on Science, Space Technology,* House of Representatives, 103rd Congress (Washington: US Government Printing Office, 1994), p. 158.

75 "Cost Conscious Indians Find Profits in Imaging Satellites," *Aviation Week and Space Technology,* 12 August 1996.

76 M. Achmed, "India: Space Organization's Scheduled Satellite Launches Detailed," *Delhi Business Standard*, 9 April 1996.

77 According to the Indian government, the imaging satellites are designed for civilian purposes, such as estimating agricultural yields, mapping water resources and for flood monitoring. Yet, imaging satellites are dual use, with military potential. The military focus of the Indian surveillance satellites is apparently Chinese and Pakistani military facilities, including the Kahuta nuclear weapons factory and the Kanachi naval base. Cartosat resolution from M. Ahmed, "ISRO in Space Imagery Deal with US Firm," *Delhi Business Standard*, 3 February 1997.

78 Ibid. Broad adds that in addition to the 5 meter imagery it is already selling, India hopes to have a satellite with 2.5 meter resolution by 2005.

79 Lardier, "Proliferation of Remote Sensing Satellites," pp. 34-35.

80 "Space Activities of the US, USSR and Other Launching Countries/Organizations: 1957-1993," p. 162; Aluf Ben,

"Another Attempt to Launch Ofeq Spy Satellite Planned for the End of the Year," (Hebrew) *Ha'aretz*, 5 February 1993, p. A6.

81 Michael Krepon, "The New Hierarchy in Space," in Michael Krepon et al, *Commercial Observation Satellites*, p. 27.

82 Alex Doron and Emi Ettinger, "Light Weight Satellite Orbits Earth Every 90 Minutes," (Hebrew) *Ma'ariv*, 6 April 1995; "Overview of Nuclear-Related Trade and Cooperation Developments," *The Non-Proliferation Review*, Vol. 2, No. 2 (June-September 1994), p. 160; John Simpson, Phillip Acton, and Simon Crowe, "The Israeli Satellite Launch," *Space Policy* (May 1989).

83 "Space Activities of the US, USSR and Other Launching Countries/Organizations: 1957-1993," p. 161; since additional thrust was needed to achieve the extra 1200 mph of velocity required to escape into orbit from a westward launch, this restricted the size of the payload to 156 kg (John Simpson et al., "The Israeli Satellite Launch," op. cit.).

84 "Space Activities of the US, USSR and Other Launching Countries/Organizations: 1957-1993," p. 161.

85 *Aviation Week and Space Technology*, 17 October 1994.

86 Sharone Parnes, "Israeli Officials Decline to Discuss Role of Latest Ofeq," *Space News*, 10-16 April 1995.

87 Aluf Ben, "The Cost of the F-15: $85-90 million: Israel and US Negotiating the Agreement," (in Hebrew) *Ha'aretz*, 10 November, 1993, p. A1.

88 Lardier, "Proliferation of Remote Sensing Satellites."

89 Sharone Parnes, "Israeli Officials Decline to Discuss Role of Latest Ofeq," op. cit.

90 Jeff Cole and Amy Docker Marcus, "Israeli-Led Venture in Satellite Imaging Poses Challenge to US Aerospace Firms," *Wall Street Journal*, 28 February 1996; Steve Rodan, "Space Wars," *Jerusalem Post Magazine*, 10 March

1995; Lardier, "Proliferation of Remote Sensing Satellites," op. cit. US officials reportedly agreed to link image distribution policies to the limitation adopted by the US government for US-licensed images. See also press release, "Israel Aircraft Industries and Core Software Technology Announce Formation of a Joint Venture Company to Enter High-Resolution Satellite Imagery Market," IAI Electronics Group and Core Software Technologies, Tel Aviv, 28 February 1996.

91 Cole and Marcus, "Israeli Led Venture," op. cit.

92 Testimony of Brian Dailey, Vice President of Space and Strategic Missiles Sector, Lockheed Martin Corporation, before the House Subcommittee on Space and Aeronautics, US Congress, Washington DC, 31 July 1996 (http://www.fas.org/spp/civil/congress/1996 _h/h960731_spac_com_wit.htm).

93 Broad, "Commercial Use of Spy Satellites," op. cit.

94 Arye Egozi, "IAI in Negotiations to Participate in Satellite Firm with Lockheed Martin and Mitsubishi," (Hebrew) *Yediot Aharonot*, 31 December 1996.

95 Gasparini Alves, *Access to Outer Space Technologies: Implications for International Security* (New York :UNIDIR, 1992), p. 13.

96 This program is coordinated by the Brazilian Commission for Space Activities (COBAE) and involves both civilian and military bodies (Ministry of Aeronautics, Secretary of Science and Technology). Goals included the production of launch vehicles and satellites. Before being transferred to civilian authority in 1969, Brazil's space program was part of the Navy, and in the 1980s, according to Aaron Karp, its higher echelon was still composed largely of military officers, "suggesting that military applications have not been overlooked". Aaron Karp, "Ballistic Missiles in the Third World," *International Security,* Vol. 9, No. 3 (Winter 1984/85), p. 183.

97 TRW Space Log, 1993, pp. 3-4. The SCD-1 (Satellite de Coleta de Dados) is a small 115 kg satellite designed to provide weather and climate data, and is used to monitor degradation of the Amazon rain forest. It was placed into orbit in 1993 by an American air-launched Pegasus booster. The Brazilian Space Agency is also reportedly in the process of developing three additional satellites in this series to collect environmental data and remote sensing

data.

98 Krepon in Krepon et al., *Commercial Observation Satellites*, p. 22.

99 Andre Kurguzov, 3/4 TASS 29, 3 April 1994 Itar-Tass (http://www.itar-tass.com/

news.htm)

100 "Brazil to Intensify Contracts with Space Companies from France," *Gazeta Mercantil*, 23 June 1996.

101 Vipin Gupta, *New Satellite Images for Sale: The Opportunities and Risks Ahead*, Lawrence Livermore National Laboratory, (University of California, 1994), p. 19, and sources cited in text.

102 Stephen E. Doyle, *Civil Space Systems: Implications for International Security*, (Geneva: UNIDIR, 1994), p. 66.

103 Other Countries with indigenous programs are Taiwan, South Korea, and Pakistan. On 6 July 1995, Lockheed Martin won a contract to launch Taiwan's first satellite. The $18 million contract stipulated that Lockheed will launch Rocsat-1, a 400-kilogram scientific research satellite, from Cape Canaveral, Florida, in April 1998, National Space Program Office Director Hsu Chia-ming said. TRW Inc. is building Rocsat-1, while Allied Signals Technical Services Corp. is building the satellite's ground control system. The German Press Agency reports that under a $509 million space program, Taiwan plans to put three satellites into orbit by 2006. ("Lockheed Martin Wins Bid to Launch Taiwan Satellite," USAF Newswire, 6 July 1995).

South Korea currently operates a small space research program. Kitsat-A is a 50 kg platform that includes a small communications relay and two experimental charge coupled device imagers. It was built by the South Korean Advanced Institute of Science and Technology, in collaboration with the University of Surrey (which designed the platform), and launched by an ESA Ariane launcher in 1992. (TRW Space Log, 1992, p.17) Kitsat-B was placed into polar orbit in September 1993 aboard an Ariane launcher. It is based on the same platform as the Kitsat-A satellite, and its payload includes an earth imaging and communications experiments. (TRW Space Log, 1992, p. 19) On August 5 1995, the Mugunghua satellite, ROK's first multi-purpose telecommunications satellite was launched from Cape Canaveral; however, the satellite failed to reach desired orbit due to low performance of the Delta II launch rocket. (Yee Cheong-Moo, "Mugunghua Satellite Launch," *Korea Herald*, 6 August 1995; "Mugunghua Satellite Fails to Reach its Proper Orbit," *Korea Times,* 7 August 1995).

The Pakistan Space and Upper Atmosphere Research Commission (SUPARCO), along with the Space Research Council (SRC) are responsible for space activities and development plans. SUPARCO sponsors satellite development and the Badr-A experimental digital communications satellite was launched by a Chinese Long March 2E in July 1990. It weighed 52 kilogram and had an orbital lifetime of 6 months. The design for this micro-satellite was apparently based on the University of Surrey platform. Pakistan is also seeking to develop and operate remote sensing spacecraft. Officially, Pakistan claims to seek this capability in order to obtain data for precise mapping, flood control, pollution, and the location and development of mineral deposits and other natural resources. Despite a small budget ($7.5 million annually), Pakistan developed the Badr-B satellite, which employs a gravity gradient stabilization system, and carries a charge-coupled-device (CCD) camera to test image transmission. *(Aviation Week and Space Technology*, 10 August 1992)

104 Itar-Tass 14 May, 1996 (http://www.itar-tass.com/news.htm).

105 V. Gupta and D. Rich, "Locating the detonation point of China's First Nuclear Explosive Test on 16 October 1964," *International Journal of Remote Sensing*, Vol. 17, No. 10 (July 1996), pp. 1969-1974.

106 Caroline Smith, "CIA Satellite Photos Showed Soviet Cold War Ability," ; See also Albert Wheelon, "Corona: The First Reconnaissance Satellites,"

107 Jeffrey Richelson, "Implications for Nations Without Space-Based Intelligence Collection Capabilities," in Krepon et al., *Commercial Observation Satellites*, p. 55.

108 Peter Zimmerman, "Remote Sensing Satellites, Superpower Relations, and Public Diplomacy," in Krepon et al., op. cit., p. 35.

109 Peter Zimmerman, "The Use of Civilian Remote Sensing Satellites During and After the 1990-1991 Gulf War," in John Poole and Richard Guthrie, eds., *Verification Report 1992: Yearbook of Arms Control and Environmental Agreements*, (London: Vertic, 1992) pp. 230-240.

110 Ibid.

111 Gupta and Rich argue that the Large Format Camera flown in the US Space Shuttle can also provide militarily useful information, in conjunction with the higher resolution military reconnaissance satellites, such as Corona. They provided the example of the site of the Chinese nuclear test of 16 October 1964. The KH-4 satellite image, which was declassified in 1995, provided a detailed photo of the site, but its precise location could not be ascertained from this image. When combined with a LFC image from 1984, the location can be determined. See Gupta and Rich, "Locating the Detonation Point."

112 TRW Space Log , Vol. 27 (1991) p. 5.

113 Krepon in Krepon et al., *Commercial Observation Satellites*, p. 21

114 Richelson in Krepon et al., op. cit., p. 55.

115 Krepon in Krepon et al., op. cit., p. 23.

116 Peter D. Zimmerman, "From the SPOT Files: Evidence of Spying,", pp. 24-5.

117 Bhupendra Jasani, "The Value of Civilian Satellite Imagery," *Jane's Intelligence Review*, Vol. 5, No. 5 (May 1993), pp. 235-239.

118 Krepon in Krepon et al., *Commercial Observation Satellites*, p. 20.

119 Dana J. Johnson, et. al., *US Space-Based Remote Sensing,* op. cit.

120 Peter Zimmerman, "The Use of Civilian Remote Sensing Satellites," pp. 230-240.

121 Sokolski, "Nonapocalyptic Proliferation," p. 125.

122 Ibid.

123 Dana J. Johnson et al, *US Space-Based Remote Sensing*, p. 15. The authors cite the Department of Defense, *Conduct of the Persian Gulf War: Final Report to Congress* (Washington D.C: USDOD), April 1992. "Tactical Commanders considered intelligence support at the division, wing, and lower levels insufficient because of over-reliance on national and theater systems, lack of adequate tactical imagery systems, and limited imagery production."

124 Vipin Gupta, "New Satellite Images for Sale: The Opportunities and Risks Ahead," Center for Security and Technology Studies, Lawrence Livermore National Laboratory, (University of California, 1994), p. 2; Anne Florini, "The Opening Skies: Third Party Imaging and US Security," *International Security*, Vol. 13, No. 2 (Fall 1988), p. 100

125 Steven Lambakis, "Space Control in Desert Storm and Beyond," *Orbis*, Vol. 39, No. 3 (Summer 1995), p. 119. In addition, military satellites provided "reliable and near-total intra-theater communication (secure and non-secure voice, data, and facsimile transmissions) for military aircraft, maneuvering troops, and ship-to-shore operators". GPS (Global Positioning System), which allowed the coalition to coordinate troops movements, mark minefields, position artillery, and assist guidance of stand-off missiles.

126 Ibid.

127 Major General Valeriy Menshikov and Colonel Boris Rodionov, "Opinion on the Subject," Russian National Information Service, Moscow Armeyskiy Sbornik (in Russian), No. 10 (October 1996), pp. 88-90 (reprinted in FBIS Daily Report, 30 January 1997, UMA-97-018-S, US Government World News Connection, Washington DC (http://wnc.fedworld.gov/).

128 The examples of Bosnia and Korea are cited explicitly in the statement of Senator Bingaman, *Congressional Record*, Hearings on National Defense Authorization Act For Fiscal Year 1997, Amendment No. 4321, "Purpose: To Prohibit The Collection And Release Of Detailed Satellite Imagery With Respect To Israel And Other Countries And Areas," US Senate, Washington DC, 26 June 1996, p. S6924-5 (http://www.fas.org/eye/1 _01.htm).

129 Gupta, "New Satellite Images for Sale: The Opportunities and Risks Ahead," *International Security,* p. 115.

130 Ibid. p. 117.

131 Lane, "The Satellite Revolution," op. cit.

132 Ibid. p. 23.

133 Ann M. Florini, "The Opening Skies," p. 100.

134 Ibid. p. 92.

135 Fact Sheet, "Foreign Access To Remote Sensing Space Capabilities," The White House Office of the Press Secretary , 10 March 1994

136 Ibid.

137 Gupta, "New Satellite Images for Sale," p. 123.

138 Fact Sheet, op. cit.

139 Ibid.

140 Testimony of Brian Dailey.

141 "Space Activities of the US, USSR and Other Launching Countries/Organizations: 1957-1993," p. 93. See also in Alves, ed., *Evolving Trends in the Dual Use of Satellites*, op. cit.

142 Florini, "The Opening Skies," p. 92.

143 Chronology on Australia Group events 1985-1996, ACDA Fact Sheet, Washington, DC, 29 October 1996.

144 The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual Use Goods and Technologies, "aims at promoting transparency and greater responsibility in transfers of conventional arms and

sensitive dual-use goods and technologies," statement by press secretary December 1995. Thirty-three states met in Vienna in July 1996 to discuss avoiding national policies that undermine the goals of the agreement.

145 Testimony of Mark Brender.

146 Broad, "Commercial Use of Spy Satellites," op. cit.

147 Lane, "The Satellite Revolution," p. 24.

148 Scott Pace, "Promoting Commercial Space Activity," 31 July 1996, testimony before the House Subcommittee on Space and Aeronautics.

149 Testimony of Brian Dailey.

150 Gupta has noted that states with long-range weapons may be able to create highly accurate maps of enemy territory and will thus be encouraged to "develop or import new guidance systems capable of directing weapons to the designated point at a comparably high accuracy" (Gupta, "New Satellite Images for Sale," p. 117).

151 "Space Activities of the US, USSR and Other Launching Countries/Organizations: 1957-1993," p. 135.

152 Michael Rotem, "Spy Satellite for Arab Emirates 'Serious Threat'," *Jerusalem Post,* 19 November 1992**;** Sergey Koulik and Richard Kokoski, "Verification Lessons of the Persian Gulf War," *Conventional Arms Control* (New York: Oxford University Press, 1994), p. 199

153 Ibid.

154 Lane, "The Satellite Revolution," p. 24.

155 *Aviation Week and Space Technology*, 2 August 1994. On 8 August the *New York Times* reported that Muhammed Hilawi, the Saudi diplomat who defected in May of 1993, claimed that the Saudis were interested in nuclear weapons. Hilawi also claimed to have 14,000 documents, including evidence of corruption, terrorism, the

tracking of Jewish organizations, and evidence of a Saudi-Iraqi alliance for Saudi participation in military technology development programs. (Paul Lewis, "Defector says Saudis sought nuclear arms," *New York Times*, 7 August 1994).

156 Statement of Senator Bingaman, pp. S6924-S6925.

157 Lane, "The Satellite Revolution," p. 24.

158 Statement of Senator Bingaman, *Congressional Record*. See also Ferster, Warren. "Eyeglass to Refrain from Photographing Israel," *Space News,* No. 7, 13 November 1994.

159 Statement from the Israeli Ministry of Defense, Tel Aviv, 4 March 1996.

160 Lane argues that it is in America's interest to continue to lead the regulation in remote sensing, and claims that the loss of US international leadership in launches has contributed to lower disincentives for missile proliferation. (Lane, "The Satellite Revolution,").

161 John J Fialka, *Wall Street Journal*, 17 June 1996.

162 Ibid.

163 Statement of Senator Bingman, *Congressional Record*, p. S6924-S6925.

164 Scott Pace, "Senate Does Not Get It," *Space News*, 15-21 July 1996, pp. 25, 30. Pace referred to the pictures of Dimona in the Israeli daily, *Yediot Aharonot,* 25 June 1996, p. 1. Pace also asserted that reconnaissance aircraft could fly over Israel and photograph sites prohibited to satellites.

165 Scott Pace, "Promoting Commercial Space Activity," 31 July 1996, testimony before the House Subcommittee on Space and Aeronautics.

166 Ibid.

167 Mark Brender testimony.

168 Ibid.

169 Brian Dailey testimony; Scott Pace, "Senate Does Not Get It," pp. 25, 30.

170 Gerald M. Steinberg, "Rationality in Space Imaging," *Space News*, 12 August 1996, p. 13.

171 Statement of Senator Bingaman.

172 Conference Report on HR 3230, National Defense Authorization Act for Fiscal Year 1997; sec. 1064. Prohibition on Collection and Release of Detailed Satellite Imagery Relating to Israel.

173 Gupta, "New Satellite Images for Sale," p. 121.

174 Ibid.

175 B. Jasani, *Verification of a Comprehensive Test Ban Treaty from Space*, p. 10

176 Gupta, "New Satellite Images for Sale."

177 Such proposals were discussed in the meetings of United Nations Committee on the Peaceful Uses of Outer Space during the 1970s and 1980s.

178 Press Release, Earthwatch Incorporated, 19 November 1996.

179 "Foreign Access to Remote Sensing Capabilities," text of PD-23, 1994.

180 "Israel Petitions Russia To Stop Prying Satellite Eyes," *Space News*, 8 August 1996

181 The Missile Technology Controls Regime (MTCR) was formed in 1985 to control the spread of ballistic missiles after India's successful civilian satellite launches of 1980 and 1983. Such export controls have been criticized for

being leaky, counterproductive, and discriminatory. Brahma Chellany argues that the MTCR prompted India to design and build what it could not acquire from abroad. "An Indian critique of US Export Controls," *Orbis*, Vol. 38, No. 3 (Summer 1994).

182 In 1978, France proposed the establishment of an International Satellite Monitoring Center (IMSA) to "promote the use of high-resolution satellite imagery for 'benign' security applications such as verification and early warning, with safeguards to minimize access to the data for 'malign' security applications such as warfighting" (Gupta, op. cit., p. 124). According to the proposal, the Center was to first compile satellite data from states that used or had satellites, and then outline a universal system of satellite observation. (Alves, *Building Confidence in Outer Space*, p. 87) In 1988, the French proposed the creation of SIPA (Satellite Imaging Processing Center), which was to be a UN agency for processing and monitoring imaging. (Ibid. p. 68). The WEU center in Torrejon, which was established in 1991, originally supplemented the monitoring of disarmament and environmental agreements. Since the Gulf War, it collects and processes crisis management information. Alves writes that the WEU center "is a concrete example of the possibility of regional cooperation in a domain of decisive importance for security and confidence, cooperation that could gradually be extended to a multilateral framework". (Ibid. p. 69). Such institutions were seen as providing the ability to search for evidence of development of non-conventional weapons, prevent the outbreak of war, provide broad threat assessments, and support CBMs and peacekeeping. Similar objectives were cited for the Canadian PAXSAT program (1987).

183 Cited by Florini, "The Opening Skies ," p. 119. This effort was designed primarily to prevent United Nations resolutions or other international efforts that would have made space-based imaging illegal under international law.

184 Steinberg, *Satellite Reconnaissance*, pp. 65-67.

185 In the 1970's Brazil, Argentina, and France proposed the establishment of some "rules of the game" for commercial applications of space-based remote sensing. Shortly thereafter, France began the SPOT program, and advocacy of agreed limits on commercial space imaging ended. However, in the case of Brazil and Argentina, these policies were apparently motivated primarily by concerns that access of raw materials and other commercially important information obtained from space-based imaging would give those countries and firms an economic advantage. Since commercial imaging satellites would provide data on an unrestricted basis, except for militarily

sensitive sites, these issues are no longer central to the debate.

186 Federation of American Scientists, *Secrecy and Government Bulletin*, Issue No. 59 (June 1996).