2011

EXECUTIVE SUMMARY

Full report at www.spacesecurity.org

SPACE SECURITY 2011

WWW.SPACESECURITY.ORG

Library and Archives Canada Cataloguing in Publications Data

Space Security 2011: Executive Summary

ISBN: 978-1-895722-84-5

Edited by Cesar Jaramillo

Design and layout by Creative Services,
University of Waterloo, Waterloo, Ontario, Canada

Cover image: The International Space Station is featured in this photograph taken by an STS-130 crew member on space shuttle Endeavour after the station and shuttle began their post-undocking relative separation on 19 February 2010. Image credit: NASA.

Printed in Canada

Printer: Pandora Press, Kitchener, Ontario

First published May 2011

Please direct inquires to:
Cesar Jaramillo
Project Ploughshares
57 Erb Street West
Waterloo, Ontario N2L 6C2
Canada
Telephone: 519-888-6541, ext. 708
Fax: 519-888-0018
Email: cjaramillo@ploughshares.ca

INTRODUCTION

Space Security 2011 is the eighth annual report on trends and developments related to security in outer space, covering the period January to December 2010. It is part of the broader Space Security Index (SSI) project, which aims to improve transparency with respect to space activities and provide a common, comprehensive knowledge base to support the development of national and international policies that contribute to space security.

The definition of space security guiding this report reflects the express intent of the 1967 Outer Space Treaty (OST) that space should be preserved as a global commons to be used by all for peaceful purposes:

> The secure and sustainable access to, and use of, space and freedom from space-based threats.

The primary consideration in the SSI definition of space security is not the interests of individual national or commercial entities using space, but the security of space as an environment that can be used safely and responsibly by all. This broad definition encompasses the security of the unique space environment, which includes the physical and operational integrity of manmade assets in space and their ground stations, as well as security on Earth from threats originating in space-based assets.

The actions and developments related to space security are assessed according to eight indicators that are organized under three themes:

- The condition of the space environment
  1) The space environment
  2) Space situational awareness
  3) Space laws, policies, and doctrines
- The type of actors in space and how space is used
  4) Civil space programs
  5) Commercial space
  6) Space support for terrestrial military operations
- The status of space-related technology as it pertains to protecting or interfering with space systems, or harming Earth from space
  7) Space systems resiliency
  8) Space systems negation.

Each of the eight indicators is examined in a separate chapter that provides a description of the indicator and its overall impact on space security. A discussion of the prevailing trends associated with that indicator is followed by an overview of key developments throughout the year and an assessment of their short-term

effects on the broader security of outer space. In previous editions an additional indicator on space-based strike capabilities was included. Even though speculation continues about the development of space-based strike-weapons (SBSW), the SSI noted an absence of reliably documented SBSW at the time of the report's publication. As a result, the decision was made not to include a chapter on space-based strike capabilities until clear evidence exists that such weapons are being developed or deployed. Readers can consult *Space Security 2010* (www.spacesecurity.org) for background information on space-based strike capabilities.

Last year's cover image, which depicted the first ever collision between two satellites, illustrated the challenges associated with space activities. Conversely, this volume's cover shows the International Space Station (ISS), which marked 10 years of continuous operations and uninterrupted inhabitancy in 2010. This exemplifies the benefits that can be derived from international cooperation in outer space. From search-and-rescue operations to weather forecasting, from arms control treaty verification to banking, the world has become increasingly reliant on the benefits derived from space-based technologies. The key challenge is to maintain an environment for the sustainable development of such peaceful applications while keeping outer space from becoming a battlefield congested with debris that restricts its use by all.

A recurring theme in the annual SSI publications has been the inadequacy of the normative regime to regulate space activities and ensure the security of outer space. While there is widespread international recognition that the existing regulatory framework is outdated and insufficient to address the current challenges facing the outer space domain, the development of an overarching normative regime has been painstakingly slow. International space actors have been unable to reach a consensus on the exact nature of a space security regime despite having specific alternatives on the table for consideration—either legally binding treaties, such as the Sino-Russian proposed ban on space weapons (known as the PPWT), or non-binding norms of behavior, such as the European Union's proposed Code of Conduct for Outer Space Activities. The proposals under consideration for a space security regime, which are highlighted in this volume, suggest that multilateral efforts to adopt a legally binding space security treaty are less likely to succeed than non-binding, technical approaches to govern outer space.

As seen in the growing number of public-private partnerships for space operations, the boundaries between civil, military, and commercial space assets are blurring, creating interdependence and mutual vulnerabilities. The fact that space is inevitably becoming more congested each year underscores the need for a comprehensive space security normative regime that not only reflects current threats to space security, but also tackles the emerging legal questions that will inevitably arise as access to orbital slots for satellites, for example, becomes more highly contested.

Although often used as interchangeable concepts, militarization and weaponization of space must be clearly distinguished. While the former is a reality, thus far there is no documented evidence of the latter. The use of space assets for military applications such as reconnaissance, intelligence, and surveillance has been ubiquitous for several years, yet space apparently has remained weapons-free. The development and use of SBSW by any state would likely trigger an uncontrollable arms race. With an ever growing number of spacefaring nations, the implications of such a scenario could be dire.

The need for greater collaboration and data sharing among space actors to prevent harmful interference with space assets is becoming increasingly apparent. Although greater international cooperation to enhance the predictability of space operations is strongly advocated, the sensitive nature of some information and the small number of leading space actors with advanced tools for surveillance have traditionally kept significant data on space activities shrouded in secrecy. But recent developments covered in this volume suggest that there is a greater willingness to share space situational awareness data via partnerships such as the one recently initiated between the United States and Australia. In addition, commercial entities have begun to establish independent surveillance and data-sharing mechanisms, such as the Space Data Association (SDA) formed by a group of major satellite operators.

Decreasing costs and wider availability of launch technologies could permit the number of spacefaring nations to increase in the coming years. But intensifying space use creates governance challenges in managing space traffic, limiting the indiscriminately destructive potential of increased orbital debris, and distributing scarce resources such as orbital slots and radio frequencies. Already, new actors seeking entrance to a congested space environment are questioning the inherent fairness of the first-come-first-served system, which has been the de facto norm for orbital slot allocations. On a positive note, 2010 broke away from the trend of the three preceding years, in all of which there was a major debris-generating event (anti-satellite test conducted by China in January 2007, destruction of satellite USA-193 by the United States in February 2008, collision of U.S. Cosmos and Russian Iridium satellites in February 2009).

Space Security 2011 does not provide absolute positive or negative assessments of 2010 outer space activities. Instead, it indicates the range of implications that developments could have on the security of space across the various indicators and highlights the difficult challenges faced by policymakers. The Space Security Index project partners hope that this publication will continue to serve as both a reference source and a policymaking tool, with the ultimate goal of enhancing the sustainability of outer space for all users.

Information contained in *Space Security 2011* is from open sources. Great effort is made to ensure a complete and factually accurate description of events that is based on a critical appraisal of the available information and consultation with international experts. Strategic and commercial secrecy with respect to space activities inevitably poses a challenge to the comprehensive nature of this report; but many space assets and activities are, by their very nature, in plain view to those with the technical ability to observe them. Increasingly that includes so-called amateurs who make their observations of such space assets as satellites widely available.

Expert participation in the Space Security Index is a key component of the project. The primary research is peer reviewed prior to publication through three processes:

1) Various technical and policy experts are asked to provide critical feedback on the draft research, which is sent to them electronically.

2) The Space Security Working Group consultation is held each spring for two days to review the draft text for factual errors, misinterpretations, gaps, and statements about the impact of various events. This meeting also provides an important forum for related policy dialogue on recent outer space developments.

3) Finally, the Governance Group for the Space Security Index provides its comments on the penultimate draft of the text before publication.

For further information about the Space Security Index, its methodology, project partners and sponsors, please visit the website **www.spacesecurity.org**, where the publication is also available in PDF format. Comments and suggestions to improve the project are welcome.

ACKNOWLEDGEMENTS

The research process for *Space Security 2011* was directed by Cesar Jaramillo at Project Ploughshares. The researchers based at the McGill University Institute of Air and Space Law and at George Washington University's Space Policy Institute were supervised on site by, respectively, Dr. Ram Jakhu and Dr. Peter Hays. The research team included:

Timiebi Aganaba, McGill University

Laura Delgado, George Washington University

Catherine Doldirina, McGill University

Diane Howard, McGill University

David McArthur, George Washington University

Brian Weeden, Technical Advisor, Secure World Foundation.

The Governance Group for the Space Security Index would like to thank the research team and the many advisors and experts who have supported this project. Cesar Jaramillo has been responsible for overseeing the research process and logistics for the 2010-2011 project cycle. He provides the day-to-day guidance and coordination of the project and ensures that the myriad details of the publication come together. Cesar also supports the Governance Group and we want to thank him for the contribution he has made in managing the publication of this volume. We also want to thank Brian Weeden at Secure World Foundation for providing his time and technical expertise to the project, in addition to being part of the research team.

Thanks to Wendy Stocker at Project Ploughshares for copyediting, to Creative Services at the University of Waterloo for design work, and to Pandora Press of Kitchener, Ontario for printing and binding. For comments on the draft research we are in debt to the international experts who provided feedback on each of the report's chapters during the online consultation process, and to the participants in the Space Security Working Group. For helping to organize the Space Security Working Group meeting held on 8-9 April 2011 in Montreal, we are grateful to Ms. Maria D'Amico at the McGill University Institute of Air and Space Law, and Ms. Nancy Regehr at Project Ploughshares.

This project would not be possible without the generous financial and in-kind support of the following organizations:

- Secure World Foundation
- The Simons Foundation
- Project Ploughshares
- International Security Research and Outreach Programme at Foreign Affairs and International Trade Canada
- Erin J.C. Arsenault Trust Fund at McGill University.

While we, as the Governance Group for the Space Security Index, have benefited immeasurably from the input of the many experts indicated, responsibility for any errors or omissions in this volume finally rests with us.

Gérard Brachet

Peter Hays

Ram Jakhu

William Marshall

Paul Meyer

John Siebert

Dana Smith

Ray Williamson

EXECUTIVE SUMMARY

The Space Environment

TREND 1.1: Amount of orbital debris continues to increase, particularly in Low Earth Orbit (LEO) — Space debris poses a significant, constant, and indiscriminate threat to all spacecraft, regardless of the nation or entity to which they belong. Most space missions create some amount of space debris, mainly as rocket booster stages are expended and released to drift in space along with bits of hardware. More serious fragmentations are usually caused by energetic events such as explosions. These can be both unintentional, as in the case of unused fuel exploding, or intentional, as in the testing of weapons in space that utilize kinetic energy interceptors. Traveling at speeds of up to 7.8 kilometers (km) per second, each piece of space debris may destroy or severely disable a satellite upon impact. The number of objects in Earth orbit has increased steadily; today, the U.S. Department of Defense (DOD) is using the Space Surveillance Network to catalog more than 15,000 objects approximately 10 centimeters (cm) in diameter or larger. It is estimated that there are over 300,000 objects with a diameter larger than one centimeter and several million that are smaller. The annual rate of new tracked debris began to decrease in the 1990s, largely due to national debris mitigation efforts, but has accelerated in recent years due to events such as the Chinese intentional destruction of one of its satellites in 2007.

2010 Developments:

- Software failure leaves Galaxy 15 adrift in the Geostationary Orbit (GEO) belt, but it is eventually recovered
- Cataloged debris field from the 2007 intentional destruction of a Chinese satellite passes 3,000 objects
- Trackable space object population increases by 5.1 per cent
- The U.S. military continues to track and predict atmospheric reentry of space debris

Space Security Impact

Although there were no major fragmentations in 2010, the number of cataloged objects increased by 800, mostly due to the continued discovery and cataloging of debris from major events in 2007 and 2009. Satellites in the critical 800-km Sun-synchronous region are making more maneuvers than ever to avoid collisions. Some debris in LEO will reenter the Earth's atmosphere and disintegrate in a relatively short period of time due to atmospheric drag, but debris in orbits above 600 km will remain a threat for decades and even centuries. Thus, despite growing awareness of the problem and some voluntary mitigation efforts, space debris continues to pose an increasing threat to operational satellites and the long-term sustainability of space activities.

TREND 1.2: Increasing awareness of space debris threats and continued efforts to develop and implement international measures to tackle the problem — Significant debris-generating events as well as improved tracking abilities have encouraged the recognition of space debris as a significant threat. The 2007 Anti-Satellite Weapon (ASAT) test conducted by China, the 2008 U.S. destruction of the failed USA-193 satellite, and the 2009 collision between a Russian and a U.S. satellite have served to underscore the need for effective measures to curb the creation of space debris. Spacefaring states, including China, Japan, Russia, and the U.S., as well as the European Union (EU) have developed debris mitigation standards, and the United Nations (UN) has adopted voluntary guidelines. Most states require residual propellants, batteries, flywheels, pressure vessels, and other instruments to be depleted or made passive at the end of their operational lifetimes. All major national debris mitigation guidelines address the disposal of GEO satellites, typically in graveyard orbits 235 km above the GEO orbit, and most seek the removal of dead spacecraft from LEO within 25 years. However, these guidelines are not universally or regularly followed.

2010 Developments:

- Orbital debris continues to have a growing impact on operational spacecraft
- Compliance with international space debris mitigation guidelines is still inconsistent
- International awareness of orbital debris problem increases and progress on solutions continues

Space Security Impact

The increasing awareness of the need for active debris removal, particularly among spacefaring countries, demonstrates that a growing number of actors are taking the problem of space debris seriously. However, continued emphasis on solving the problem at some unknown future point does not build the political will needed to take immediate measures. Slow implementation and enforcement of the Inter-Agency Space Debris Coordination Committee (IADC) and UN debris mitigation guidelines at the national level and continuing reluctance to pursue more stringent measures do not bode well for space security.

TREND 1.3: Growing demand for radio frequency (RF) spectrum and communications bandwidth — The growing number of spacefaring nations and satellite applications is driving the demand for limited radio frequencies and orbital slots. More satellites are operating in the frequency bands that are commonly used by GEO satellites, increasing the likelihood of greater frequency interference. But new technologies are being developed to manage greater frequency usage, allowing more satellites to operate in closer proximity without interference. As well, frequency hopping, lower power output, digital signal processing, frequency-agile transceivers, and software-managed spectrum have the potential to significantly improve bandwidth use and alleviate conflicts over bandwidth allocation. Current

receivers have a higher tolerance for interference than those created decades ago. The increased competition for orbital slot assignments, particularly in GEO where most communications satellites operate, has caused occasional disputes between satellite operators. The International Telecommunication Union (ITU) has been pursuing reforms to address slot allocation backlogs and other related challenges.

2010 Developments:

- Drifting Galaxy 15 prompts complicated radio frequency interference (RFI) mitigation plans and causes interference
- Satellite operators continue to report significant harmful RFI or infringements of RF regulations

Space Security Impact

The relative ease with which intentional or unintentional RFI and signal jamming can occur indicates that the number of RFI or signal jamming events will continue to increase in the future and negatively impact space security. The difficulty in verifying the intentions of a specific RFI or signal-jamming incident and the lack of enforcement measures suggest that the international community will continue to struggle to improve the situation.

TREND 1.4: Increased recognition of the threat from Near-Earth Object (NEO) collisions and progress toward possible solutions — Near-Earth Objects are asteroids and comets in orbits that bring them into close proximity to the Earth. Over the past decade a growing amount of research has started to identify objects that pose threats to Earth and potential mitigation and deflection strategies. Deflection, a difficult process due to the extreme mass, velocity, and distance of any impacting NEO, depends on the amount of warning time. Kinetic deflection methods include ramming the NEO with a series of kinetic projectiles; some experts have advocated the use of nearby explosions of nuclear weapons, which could create additional threats to the environment and stability of outer space and would have complex legal and policy implications.

2010 Development:

- International awareness of the NEO problem and discussions on solutions continue to increase

Space Security Impact

An understanding of the potential threat posed by NEOs has begun to move from the astronomy community to the broader policy community. Discussions and progress on international detection, warning, collaboration, and decision-making are a positive step for space security, although follow-through is still lacking. The establishment of international governance mechanisms to respond to the NEO threat will likely prove beneficial in other areas of space security.

Space Situational Awareness

TREND 2.1: U.S. space situational awareness (SSA) capabilities slowly improving — The U.S. continues to lead the world in space situational awareness capabilities with the Space Surveillance Network (SSN). Sharing SSA data from the SSN could benefit all space actors by allowing them to supplement the data collected by national assets at little if any additional cost. Still, there is currently no operational global system for space surveillance, in part because of the sensitive nature of surveillance data. Since the 2009 Cosmos-Iridium satellite collision there has been an increased push in the U.S. to boost conjunction analysis—the ability to accurately predict high-speed collisions between two orbiting objects. A new Space Fence, currently under development, is expected to cost more than US$1-billion to design and procure. The system, with a target completion date of 2015, will likely include a series of S-band radars in at least three separate locations.

2010 Developments:

- U.S. launches orbital space surveillance sensor as part of 20-year plan to improve SSA
- S-Band Space Fence acquisition program moves to the next phase
- U.S. Air Force improves ability to integrate data from different sources for SSA
- Australia funds space debris tracking research and initiates SSA partnership with U.S.

Space Security Impact

The increase in U.S. SSA capabilities, especially tracking and cataloging of objects smaller than 10 cm, significantly improves space security The conjunction warnings issued by the U.S. military have had a significant positive impact on spacecraft operations worldwide, allowing all operators to protect their spacecraft from collisions with space debris. However, the slow progress on SSA data sharing with other countries and satellite operators impedes further improvement for both U.S. SSA and space security.

TREND 2.2: Global SSA capabilities slowly improving — As the importance of space situational awareness is acknowledged, more states are pursuing national space surveillance systems and are engaging in discussions over international SSA data-sharing. Given the sensitive nature of much of the information obtained through surveillance networks and the resulting secrecy that often surrounds it, states are striving to develop their own SSA systems to reduce their reliance on the information released by other space actors such as the U.S. For example, Russia maintains a Space Surveillance System using its early-warning radars and monitors objects (mostly in Low Earth Orbit), although it does not widely disseminate data. Similarly, the EU, Canada, France, Germany, China, India, and Japan are all developing space surveillance capabilities for various purposes. Amateur observations by individuals have also proven to be useful ways to gather and disseminate data on satellites.

2010 Developments:

- Europe continues push to develop its own SSA capabilities
- Commercial satellite operators continue efforts to share data with each other to improve safety
- Hobbyist satellite observers continue to demonstrate their capabilities

Space Security Impact

The European SSA preparatory program and increased data sharing among commercial operators are important contributions to space security. The increase in global SSA capabilities allows for multiple sources of data, improving quality, coverage, and validity. The increase in global capabilities also allows the use of SSA data to monitor activities in space, to increase transparency and confidence among space actors, and, eventually, to serve as a potential verification mechanism for future agreements.

TREND 2.3: International SSA data sharing and cooperation efforts between space actors continue to increase — While the U.S. moderates access to information from its SSN, it has expanded its SSA Sharing Program. In response to the 2009 Cosmos-Iridium satellite collision, the U.S. military announced that in December it would add personnel and resources to enable it to screen up to 800 maneuverable, active satellites for potential collisions, with the eventual goal of screening active payloads on orbit. As part of this development, it would expand the number of outside partners and share data about potential collisions. In addition, commercial entities (such as the Space Data Association formed by a group of major satellite operators) have begun to establish independent surveillance and data-sharing mechanisms. The SDA will mainly share data on the positions of members' satellites and information to help prevent electromagnetic interference.

2010 Developments:

- Satellite operators work together to mitigate physical and RFI from Galaxy 15
- U.S. government continues to expand its SSA Sharing Program

Space Security Impact

As no single space actor can achieve true SSA on its own, increases in data sharing among governments and satellite operators greatly enhance space security. Although more public and universal data sharing would be welcome, the limited sharing done by the U.S. government after the 2009 Iridium-Cosmos satellite collision is a step in the right direction. A positive example of the collective benefits of sharing SSA data is the widely publicized recovery of the Galaxy 15 satellite following a malfunction in 2010.

Laws, Policies, and Doctrines

TREND 3.1: Gradual development of normative framework for outer space activities — The international legal framework for outer space establishes the principle that space should be used for "peaceful purposes." Since the signing of the Outer Space Treaty in 1967, this framework has grown to include the Astronaut Rescue Agreement (1968), the Liability Convention (1972), the Registration Convention (1979), and the Moon Agreement (1979), as well as a range of other international and bilateral agreements and relevant rules of customary international law. However, the existing regulatory framework is widely considered outdated and insufficient to address the current challenges to space security, which have escalated with more actors and space applications. Furthermore, what began as a focus on multilateral space treaties has transitioned to a focus on what some describe as 'soft law'—non-binding governance tools that include principles, resolutions, confidence-building measures, and policy and technical guidelines—as well as unilateral national regulations.

2010 Developments:

- Shift in U.S. National Space Policy toward increased international cooperation and responsible use of space, but domestic objectives face implementation problems
- Despite initial delay, the U.S. Space Posture Review concludes with the release of the National Space Security Strategy
- Russia proposes Group of Governmental Experts (GGE) to study Transparency and Confidence Building Measures (TCBMs), pending agreement on multilateral measures to prevent the weaponization of space
- EU's proposed international Code of Conduct for Outer Space Activities revised and ready for further international consultation

Space Security Impact

The new U.S. National Space Policy (NSP) signals that the U.S. is more open to dialogue and is committed to the responsible use of space. Because the actions and policies of the dominant space actor have a profound impact on the whole space environment, this development is welcome. However, some of the NSP declarations are vague and open to interpretation. The new policy could lead to real changes in the normative framework for outer space activities. However, the international dimension of the policy may have been overemphasized, if the lack of progress at the Conference on Disarmament (CD) and the First Committee is any evidence. Unlike Russia, China, and the EU, which have put forth specific proposals as the basis for further consultation on a multilateral regulatory regime for space activities, the U.S. has not assumed an active role by submitting a proposal of its own for the consideration of the international community.

TREND 3.2: UN Committee on the Peaceful Uses of Outer Space (COPUOS) remains active as a forum for space governance, while CD deadlock persists — A range of international institutions, including the UN General Assembly, the UN First Committee, COPUOS, the ITU, and the CD, constitute the key multilateral forums to address issues related to space security. The adoption of a Program of Work at the CD in 2009, after more than a decade of deliberations with no tangible results, could have allowed the CD to move forward on the Prevention of an Arms Race in Outer Space (PAROS) and to further discussions on a legal instrument to regulate space activities. But stalemate quickly resumed its grip. COPUOS remains active, with a principal focus on non-binding, technical approaches to security in space.

2010 Developments:

- The CD could not agree on a Program of Work, reverting to its pre-2009 deadlock
- Progress in COPUOS as a working group emerges to take on the long-term sustainability of outer space activities

Space Security Impact

Renewed deadlock at the CD heightens recognition that the premier disarmament body in the UN system is not the appropriate forum to determine the issue of PAROS. But it also illustrates the larger problem of a near-universal lack of political will to resolve such an impasse. Despite the difficulties, the acknowledgment by COPUOS of the need to liaise more closely with the CD and ITU on issues related to space safety is welcome.

TREND 3.3: Formalized African cooperation in space increases — Recent cooperation agreements on space activities have allowed emerging spacefaring nations from Africa to reap social and economic benefits from space applications. In 2009, after years of discussion, Nigeria, Algeria, South Africa, and Kenya signed a regional cooperation agreement for an African Resources Management Satellite (ARMS) Constellation. Following the launch of the South African National Space Agency in 2010, an interagency agreement with the Algerian Space Agency to cooperate in space science and technology was signed. In the same year, African nations requested that the African Union commission a feasibility study for the establishment of an African Space Agency and the development of an African Space Policy, in cooperation with the Regional Economic Communities, the UN Economic Commission for Africa, and the ITU.

2010 Developments:

- African regional cooperation in space on the rise
- A group of African states seeks to protect the "common heritage" of orbital assets through the International Telecommunications Satellite Organization (ITSO) and the ITU
- Africa considers the establishment of an African Space Agency

Space Security Impact

The implementation of the South African space strategy can serve to spearhead the continent's space initiatives as it will entail the development of private sector space science and technology companies, the development of an export market for South African satellites and space services, and the development of products and services that can respond to the needs of users. On the one hand, this objective will encourage more collaboration with regional international partners. On the other, there may be a risk of unhealthy regional competition in the space domain. This threat may be reduced with the establishment of the African Space Agency, though it may be several years before it is created.

TREND 3.4: National space policies continue to focus on the security uses of outer space, with increased concentration on developing national space industries — Fueled by a technological revolution, the military doctrines of a growing number of states emphasize the use of space systems to support national security. This tendency can be seen, for example, in the increasing development of multiuse space systems, which has led some states—the U.S., certainly, but also Russia, India, and China—to view space assets as critical national security infrastructure. In addition, countries increasingly view their national space industries as a fundamental driver and component of their space policies. A number of nations, including the UK, Germany, Australia, and the U.S., have made the innovation and development of their industrial space sectors a key priority within their national space strategies.

2010 Developments:

- Mixed signals regarding India's plans to develop an ASAT capability
- National space strategies focus on developing the space industrial sector alongside security objectives
- U.S. export reforms welcomed, but Senate must still consider removal of commercial satellites from Munitions List

Space Security Impact

While states continue to focus on space as a source of national security, they are also increasingly interested in developing a healthy commercial and industrial sector based on space. Linking national space strategies to the industrial sector may bode well for space security. Such interactions could lead to a framework that supports and encourages commerce through clear rules, allows for greater transparency, and promotes cooperation. It is inevitable that major spacefaring states will continue to

use space for national security. But, given the inherent vulnerabilities of operating in this domain, an overreliance on space for security may lead to a climate of mutual suspicion and mistrust that will ultimately be detrimental to space security.

Civil Space Programs

TREND 4.1: Growth in the number of actors accessing space — The rate at which new states gain access to space increased dramatically in the past decade; this rate is expected to continue as launch costs decrease and some states develop indigenous space technologies. In 2009 Iran became the ninth state to join the ranks of spacefaring nations with independent orbital launch capacities. In addition, more than 60 nations and consortia currently have assets in space that have been launched either independently or in collaboration with others. In 2003 China joined Russia and the U.S. as the only space powers with demonstrated manned spaceflight capabilities, but eventually they could be joined by other states that have expressed an interest in human spaceflight programs. A 2010 report by Euroconsult forecast that more than 1,200 new satellites will be launched in the next 10 years, several of which will be the first for their respective nations.

2010 Developments:

- Various countries prepare or declare launching of their first satellites, mainly with partners
- New launch capabilities are advanced, with mixed results
- National and international space bodies continue to expand and grow in numbers

Space Security Impact

The increasing globalization of space technology has led not only to the diversification of suppliers and customers for space applications, but also to a sharp reduction in entry barriers to the space domain for many nations. As the number of space actors able to access space increases, more parties have a direct stake in the need to ensure the sustainability of space activities and preserve this domain for peaceful purposes. However, more space actors means greater overcrowding of space orbits and greater strain on such scarce space resources as orbital slots and radio frequencies. In a more crowded environment, the risk of accidental interference with space assets goes up. Even though the development of civilian space applications is driven mostly by economic development aspirations and public safety considerations, the spread of launch capabilities could exacerbate regional tensions.

TREND 4.2: Civil space programs continue to prioritize scientific missions and exploration — In recent years, as the social and economic benefits derived from space activities have become more apparent, civil expenditures on space have continued to increase. Virtually all new spacefaring states explicitly place a priority on space-based applications to support social and economic development.

Such space applications as satellite navigation and Earth imaging are a growing focus of almost every existing civil space program. Likewise, Moon exploration continues to be a priority for established spacefaring states, such as China, Russia, India, and Japan. New launch vehicles also continue to be developed. Following the cancellation of the Constellation program, the U.S. is focusing on the development of new launchers by private industry rather than NASA. The China Academy of Launch Vehicle Technology (CALT) is continuing development of the Long March-5, the next generation of launch vehicles. Russia continues to develop the new Angara family of space launchers, which are to replace some of the ageing Molniya-M launch vehicles currently in service.

2010 Developments:

- Spacefaring states continue to pursue Moon exploration
- Mix of successes and failures in the development of new launch vehicles
- Scientific space missions continue to be developed worldwide
- National space budgets increase slightly

Space Security Impact

Recent events highlight issues that will have longer-term impact. Global space industries face increasing economic and competitive pressures from limited government discretionary spending, existing overcapacity, and new entrants. These pressures on addressable markets, combined with uncertain future plans for space exploration, are leading to increasing costs for major spacefaring countries, which in turn may limit future flight opportunities. At the same time, continued scientific missions and international cooperation increase the level of transparency and contribute to security among spacefaring nations.

TREND 4.3: Steady growth in international cooperation in civil space programs — International cooperation remains a key feature of both civil and global utilities space programs. It enhances transparency into the nature and purpose of certain civil programs that could potentially have military purposes. The most prominent example of international cooperation continues to be the International Space Station, a multinational effort with a focus on scientific research and an estimated cost of over $100-billion to date. In 2010 the ISS completed 10 years of continuous operations and uninterrupted inhabitancy. By allowing states to pool resources and expertise, international civil space cooperation has played a key role in the proliferation of the technical capabilities needed by states to access space. Cooperation agreements on space activities have proven to be especially helpful for emerging spacefaring states that currently lack the technological means for independent space access. Likewise, cooperation agreements enable established spacefaring countries to tackle such high-cost, complex missions as the exploration of Mars by NASA and the European Space Agency.

2010 Developments:

- International Space Station marks 10 years of operations and uninterrupted inhabitancy
- More cooperation agreements on exploration and launchers

Space Security Impact

International civil space cooperation is a positive factor in improving space security, because it helps to build formal and informal ties across the global space community. It can also help groups of nations undertake vast projects in space, such as the International Space Station, which would be too complex and expensive for any one state. Working on challenging bi- and multinational space projects builds confidence for countries at all levels of space development. The relationships and interdependence created through cooperative space projects help foster transparency and allow for a more accurate assessment of the space capabilities of cooperating states.

TREND 4.4: Continued growth in global utilities as states seek to expand applications and accessibility — The use of space-based global utilities, including navigation, weather, and search-and-rescue systems, has grown substantially over the last decade. While key global utilities such as GPS and weather satellites were initially developed by military actors, these systems have grown into space applications that are almost indispensable to the civil and commercial sectors as well. Such systems have spawned space applications such as weather monitoring and remote sensing, which have become almost indispensable. Advanced and developing economies alike are heavily dependent on these space-based systems. Currently Russia, the U.S., the EU, Japan, China, and India have or are developing satellite-based navigation capabilities. Although theoretically interoperable and able to increase the accuracy and reliability of satellite-based navigation, in competition these systems face significant coordination challenges.

2010 Developments:

- Satellite navigation systems around the globe continue to evolve
- Development continues on disaster relief and remote sensing capabilities

Space Security Impact

The development of and reliance on space systems for global utilities support their reliability and give countries a strong incentive to ensure safe and responsible space operations. Progress made on the compatibility and interoperability of space-based communications, Earth Observation and navigation systems will likely have a positive impact on space security. However, increasing competition for radio frequencies represents a potential source of international friction and should be watched closely. Maintaining space for global utilities will likely require greater international cooperation to reduce the risks of orbital debris, protect the spectrum required by space systems, and promote safe and responsible space operations.

Commercial Space

TREND 5.1: The global commercial space industry continues to experience overall growth, but seeks creative solutions to offset probable future downturn — Commercial space revenues have steadily increased since the mid-1990s. From satellite manufacturing and launch services to advanced navigation products and the provision of satellite-based communications, the global commercial space industry is thriving, with estimated annual revenues in excess of $200-billion. Individual consumers are a growing source of demand for these services, particularly satellite television and personal GPS devices. In the face of decreased orders for satellite fleet replenishment, manufacturers and launch providers are looking to the robust demand for new services to facilitate new satellite orders.

2010 Developments:

- New applications in response to Federal Communications Commission (FCC) Ancillary Terrestrial Component regulations could help compensate for downturn
- Significant growth in commercial remote-sensing business
- Top satellite supplier Space Systems/Loral evaluates ways to offset imminent sales decrease

Space Security Impact

The diversification of space applications has an overall positive impact on space security. The development of new products and services lessens dependence upon one facet of commercial activity, thus helping to insulate against fluctuations in specific markets. A great positive impact can be found in the remote sensing sector, which has developed new markets. Increased access to space assets and applications has both positive and negative impact. On the one hand, the pool of stakeholders with a direct interest in preserving space as a peaceful domain is steadily growing. On the other, issues of congestion, competition, and spectrum management become more pressing as commercial space activity increases and could potentially result in friction among providers of commercial services.

TREND 5.2: Commercial sector supporting increased access to space products and services — Lower launch costs for commercial satellites have enabled greater accessibility to space, particularly by developing countries for which the costs related to space access were prohibitively high in the past. A few years ago, Earth-imaging data was only available to a select number of governments. Today any individual or organization with access to the Internet can use these services free of cost through various widely available online mapping applications, such as Google maps. An embryonic private spaceflight industry continues to emerge, seeking to capitalize on new advanced, reliable, reusable, and relatively affordable technologies for launch to suborbital trajectories and low Earth orbit. In 2010 Space

X became the first private company to successfully reenter the atmosphere with one of its spacecraft, the Dragon capsule.

2010 Developments:

- Two new services bring high-speed Internet to underserved markets
- Use of small satellites increases, providing a possible new market for dedicated launcher
- Intelsat satellite Galaxy-15 goes adrift following malfunction, reestablishes contact nearly nine months later

Space Security Impact

Developing underserved markets also creates more stakeholders with a vested interest in space security. The malfunction of the Galaxy-15 satellite showed how to responsibly manage an unexpected event that might otherwise have had a detrimental effect on space security. That the satellite corrected according to design has a positive impact upon security. The event also provides the industry with a working model of how to respond to similar problems transparently and collaboratively. The commercial sector's continued development has a positive impact upon access to space, but also comes at the price of congestion. Furthermore, developing regulations for private international corporations, including those venturing into the uncharted realm of space tourism, might be as challenging as regulating state activities in space.

TREND 5.3: Continued government dependency on the commercial space sector develops interactions between public and private sectors — The commercial space sector is significantly shaped by the particular security concerns of national governments. In 2010 the U.S. government released a new National Space Policy, which places great emphasis on maintaining a robust and competitive industrial base in the U.S. and specifically seeks partnerships with the private sector to enable commercial spaceflight capabilities for the transport of crew and cargo to and from the ISS. Government regulations of export controls may gradually be influenced by the way in which the controls affect the commercial sector's ability to engage in international cooperation. The joint development of strike systems with possible space applications by the U.S. Air Force and companies such as Boeing is an example of the rising number of military contracts with the commercial sector. The impending retirement of the space shuttle further opens the door for the commercial sector to provide what were formerly government-controlled services.

2010 Developments:

- Changes to U.S. Space Policy affect U.S. space companies and create uncertainty at NASA
- Export credit agency financing makes projects viable
- The European launch sector scrutinizes Arianespace, considers changes in governance and shareholding structure
- ISS partners agree to publish interface standards for interoperable spacecraft docking

Space Security Impact

Increased interaction between the public and private sectors in collaborative space projects has an overall positive impact upon space security. However, this impact is somewhat offset by the uncertainties caused by changes in U.S. Space Policy. Still, these interactions, often more intricate than simple partnerships, better spread the risks among actors and can supply a more cost-effective distribution of public services/public goods. Furthermore, the publication of ISS docking standards provides sustainable access to states and companies beyond the ISS partners, without sacrificing national security. And it potentially increases the number of stakeholders with a vested interest. A negative impact could result if hosted payloads make commercial assets a target, but no such developments in this area are noted for 2010.

TREND 5.4: Commercial space operators gradually embrace cyberspace capabilities — The link between cyberspace and outer space is becoming increasingly important for commercial operators. Exostar, a provider of software applications to the aerospace and defense industries, transitioned from traditional log-in formats to its cloud-based Managed Access Gateway in 2010. The company also announced a new version of its supply chain management application, SCP2, which is expected to improve aerospace and defense supply chain collaboration. Moreover, demand for Cisco's space router during its evaluation period exceeded company projections; the capability will be offered to commercial entities by mid-2011, sooner than originally anticipated. Space routers are intended to manage traffic and process signals aboard spacecraft, while traditional satellite networks rely upon ground-based equipment.

2010 Developments:

- Aerospace e-business platform Exostar providing cloud services to the space industry
- Cisco's Internet Router in Space is an immediate hit

Space Security Impact

The commercial space community is made more efficient by the increased availability of internet services in terrestrial contexts such as cloud services. As the American Institute of Aeronautics and Astronautics notes, the security, availability, and interoperability of such services are an ongoing concern for end-users. Internet routers in space, such as Cisco's IRIS space router, eliminate the need to downlink and uplink data to/from a ground station; thus threats can be minimalized and financial and time costs better managed.

Space Support for Terrestrial Military Operations

TREND 6.1: The U.S. and Russia continue to lead in deploying military space systems — During the Cold War, the U.S. and USSR developed military space systems at a relatively equal pace. At the time of the collapse of the USSR, however, Russian military space spending dropped sharply, while the U.S. expanded its military space capabilities. In recent years there has been a general decrease in the number of military launches by both states. While new systems are being orbited at a slower rate, they have greater capabilities and longevity. The U.S. is not only the biggest spender on military space programs, but is also the state most dependent on space systems. Although the operational status of many Russian space systems is uncertain, Russia is known to be replacing its Soviet-era military space assets. In 2010 it continued to move forward with its Global Navigation Satellite System (GLONASS). By the end of 2010 there were over 165 dedicated military satellites worldwide, with the U.S. operating approximately half and Russia approximately one-quarter.

2010 Developments:

- Despite persistent delays, the U.S. continues to update its systems
- Russia continues to lead in military satellite launches; GLONASS nears full operational capacity

Space Security Impact

Even as reliance on space systems increases, delays, cost-overruns, and other setbacks directly impacted efforts to update systems in 2010. As well, gaps in critical capabilities increase the vulnerability of these systems to attacks by adversaries. On the other hand, the situation creates incentives for both countries to advance policies to reduce the likelihood of conflict in outer space. Over time, growing interest in cooperating with international allies and commercial partners, such as in satellite navigation and military communications, may also reduce such vulnerability and increase interdependence, providing a positive impact on space security.

TREND 6.2: China and India afford increasing roles to space-based military support — China's governmental space program does not clearly distinguish between civil and military applications. Although its space program is officially dedicated to science and exploration, it is believed to provide data to the military (other countries make similar use of their space programs). China operates the Beidou regional navigation system and has expressed its intention of upgrading Beidou to a global satellite navigation system—the Beidou-2 or Compass system—expanding on the initial system to include five satellites in GEO and 30 in Medium Earth Orbit (MEO). India has one of the oldest and largest space programs in the world, with a range of indigenous dual-use capabilities. Space launch has been the driving force behind the Indian Space Research Organisation (ISRO). To secure an

independent satellite navigation capability by 2012, India is developing the Indian Regional Navigation Satellite System (IRNSS), which is expected to be made up of seven navigation satellites.

2010 Developments:

- China continues an ambitious launch schedule to complete Beidou/Compass constellation
- China continues to upgrade its satellite systems and sets a new launch record
- India continues to launch dual-use systems and plans to launch dedicated military satellites
- India advances development of a regional satellite navigation system

Space Security Impact

China's and India's increasing dual-use and military space-support activities could have mixed results for space security. On the one hand, the strategic value of space assets increases as actors engaged in competition with each other begin to rely more on space-based support. The development of competing systems, such as individual satellite navigation systems, could result from this dynamic. On the other hand, their increased participation in space also raises the value of policies that reduce the likelihood of conflict in space. The growing roles of these countries as prominent space actors make space security discussions not only beneficial but necessary.

Trend 6.3: More states are developing military and multiuse space capabilities — States such as Canada, China, France, Germany, Japan, Israel, Italy, Australia, and Spain have recently been developing multiuse satellites with a wider range of functions. As security becomes a key driver of these space programs, expenditures on multiuse space applications go up. Hence, in the absence of dedicated military satellites, many actors use their civilian satellites for military purposes or purchase data and services from other satellite operators. Europe continues to pursue the development of the Galileo navigation system; EU member states exhibit a remarkable predisposition for collaboration in sharing several space capabilities with their partners.

2010 Developments:

- Japan launches "Michibiki" GPS augmentation satellite and considers an indigenous satellite navigation system
- Several countries pursue remote sensing capabilities
- Europe begins awarding Galileo contracts and continues exploring expanded cooperation in military space
- Canada prepares to launch first military satellite, continues expanding multiuse capabilities

Space Security Impact

Increased access to space by more actors reduces the asymmetric vulnerability of those countries that already rely on space assets. However, the proliferation of individual systems increases problems of congestion and may lead to the proliferation

of technology that threatens space assets and increases the possibility of conflict. This situation underscores the value of cooperating in enhanced space situational awareness as a way to protect space assets. Budgetary constraints have proven to be a positive motivator for increased cooperation and interdependence, moving some countries to look for ways to improve their access to and use of existing systems without necessarily launching their own. In the case of military systems, however, countries may choose to be less forthcoming about their capabilities or operations in space, thus increasing the risks of uncertainty or confusion.

Space Systems Resiliency

TREND 7.1: Efforts to protect satellite communications links increase, but ground stations remain vulnerable — Satellite ground stations and communications links constitute likely targets for space negation efforts, since they are vulnerable to a range of widely available conventional and electronic weapons. While military satellite ground stations and communications links are generally well protected, civil and commercial assets tend to have fewer protection features. Many commercial space systems have only one operations center and one ground station, making them particularly vulnerable to negation efforts. The vulnerability of civil and commercial space systems raises security concerns, since a number of military space actors are becoming increasingly dependent on commercial space assets for a variety of applications. While many actors employ passive electronic protection capabilities, such as shielding and directional antennas, more advanced measures, such as burst transmissions, are generally confined to military systems and the capabilities of more technically advanced states. Because the vast majority of space assets depend on cyber networks, the link between cyberspace and outer space constitutes a critical vulnerability.

2010 Developments:

- U.S. Cyber Command (USCYBERCOM) reaches Full Operational Capability
- Rapid Attack Identification, Detection, and Reporting System (RAIDRS) program reaches milestones

Space Security Impact

The establishment of the unified USCYBERCOM gives new focus and integration to U.S. cyber protection, affording a new level of security to its space missions. Enhanced mechanisms to protect cyber networks make space systems more secure against negation attempts, thereby providing a viable alternative to offensive means to defend space assets. Space actors may refrain from interfering with well protected space systems if such attacks seem both futile and costly. However, if USCYBERCOM sets a precedent for offensive cyber action, such capabilities could proliferate. The full operability for RAIDRS Block 10 means that the U.S. will soon

have a much improved ability to detect and defend from physical attacks on space assets, which would have a positive impact for space security.

TREND 7.2: Protection of satellites against direct attacks limited but improving — Direct interference with satellites by conventional, nuclear, or directed energy weapons is much more difficult to defend against than attacks against ground stations. The primary source of protection for satellites stems from the difficulties associated with launching an attack of conventional weapons into and through the space environment to specific locations. Passive satellite protection measures include system redundancy and interoperability, which have become characteristic of satellite navigation systems. While no hostile ASAT attacks have been carried out, recent incidents, such as the 2007 ASAT test in which China destroyed one of its own satellites and U.S. destruction of USA-193 in 2008 using a modified SM-3 missile, testify to the availability and effectiveness of missiles to destroy an adversary's satellite. Space-based surveillance systems, such as STSS and Space Fence, enhance the ability to detect potential negation efforts.

2010 Development:

- U.S. moves forward with STSS, Space Fence

Space Security Impact

In addition to increasing general space situational awareness, the launch of STSS will give the U.S. an increased ability to detect potentially hostile maneuvers against its space assets. The updated version of the Space Fence, with its ability to detect smaller space objects, could decrease the effectiveness of space mines and other attack measures that rely on smallness. Overall, the development of effective surveillance capabilities to detect potential attacks can have a positive impact on space security by increasing the ability of a space system to survive negation efforts, thus helping to ensure secure access to and use of space.

TREND 7.3: Efforts under way to develop capacity to rapidly rebuild space systems following direct attacks, but operational capabilities remain limited — The ability to rapidly rebuild space systems after an attack could reduce vulnerabilities in space. Although the U.S. and Russia are developing elements of responsive space systems, no state has perfected this capability. A key U.S. responsive launch initiative is the Falcon program developed by Space Exploration Technologies (Space X), which consists of launch vehicles capable of rapidly placing payloads into LEO and GEO. Organized under NASA's Commercial Orbital Transportation Services (COTS) program, the Falcon 9 uses less expensive components and systems than traditional rockets, including nine kerosene/liquid-oxygen-burning Merlin engines.

2010 Development:

- Progress in the research and development of low-cost launch capabilities

Space Security Impact

Moving to cheaper launch capabilities through innovative propulsion, privatization, and miniaturized satellites should allow space systems to become more adaptive in many ways. New technology can be integrated more quickly, and in theory losses due to offensive action could also be more quickly replaced. However, advancements have been slow, and present gains may prove temporary. Cheaper technologies will also be more widely available, making proliferation a concern. More privatization of space launches has the potential to dramatically improve innovation in space systems and save money, thereby facilitating increased access to space. It remains to be seen whether effective controls will be placed on private industry as it moves into space.

Space Systems Negation

TREND 8.1: Increasing capabilities to attack space communications links — Ground segments, including command and control systems and communications links, remain the most vulnerable components of space systems, susceptible to attack by conventional military means, computer hacking, and electronic jamming. Intentional jamming of communications satellites continued in 2010. For example, European satellite signals, including broadcasts of BBC Persian language, Deutsche Welle, and France's Eutelsat, have been intentionally jammed from Iran, though it has not been determined that the jamming is state-sponsored. The challenges associated with addressing cases of jamming that are not always easily attributable to one particular actor have been brought to the forefront of space security debates.

2010 Developments:

- European satellite broadcasts continue to be jammed from Iran
- Jamming incidents and capabilities continue to proliferate

Space Security Impact

The technologies used to hack into computer networks and jam satellite communications links are widely available; the relative ease with which such attacks are carried out has a negative impact on space security. Paradoxically, more incidents of jamming and the proliferation of jamming capabilities may also have a positive effect on space security, as they seem to be creating some impetus for more assertive action from the ITU. The proven ability of even minor powers to jam satellite transmissions, including ones used by the U.S. military, should generate increased interest in protecting communications from interference.

TREND 8.2: Ongoing proliferation of ground-based capabilities to attack satellites — Some spacefaring nations possess the means to inflict intentional damage on an adversary's space assets. Ground-based anti-satellite weapons employing conventional, nuclear, and directed energy capabilities date back to the Cold War, but no hostile use of them has been recorded. The U.S., China, and Russia lead in the development of more advanced ground-based kinetic-kill systems that are able to directly attack satellites. Recent incidents involving the use of ASATs against their own satellites (China in 2007 and the U.S. in 2008) underscore the detrimental effect that such systems have for space security.

2010 Developments:

- Directed energy weapons continue to be developed and tested
- Development of ASAT capabilities considered by some countries

Space Security Impact

The development of directed energy and ASAT weapons has a direct impact on space security. Such capabilities enable an actor to intentionally restrict the secure access to space by others by compromising the physical and operational integrity of space assets. While possession of these capabilities does not necessarily entail their imminent use, it could foster an arms race and hasten the weaponization of space. In any case, the development and testing of anti-satellite capabilities remain highly contentious. Moreover, increasing proliferation of ASAT technology is also likely to be destabilizing at the regional level. India's stated intentions regarding ASAT capabilities, for instance, have already spurred Pakistan to increase its nuclear arsenal.

TREND 8.3: Increased access to space-based negation-enabling capabilities — Space-based negation efforts require sophisticated capabilities, such as precision on-orbit maneuverability and space tracking. Deploying space-based ASATs—using kinetic-kill, directed energy, or conventional explosive techniques—would require enabling technologies somewhat more advanced than those used for orbital launch. While microsatellites, maneuverability, and other autonomous proximity operations are essential building blocks for a space-based negation system, they have dual-use potential and are also advantageous for a variety of civil, commercial, or non-negation military programs. For example, microsatellites provide an inexpensive option for many space applications, but could be modified to serve as kinetic-kill vehicles or offer targeting assistance for other kinetic-kill vehicles. While a number of nations have developed such technologies, there is no evidence to suggest that they have been integrated into a dedicated space-based negation system.

2010 Developments:

- Complex rendezvous capabilities continue to be advanced
- Secrecy surrounds X-37B launch, raising questions about a precise mission and potential capabilities

Space Security Impact

The development of more technologies that allow space-based ASAT capability will force spacefaring nations to incorporate greater protection measures into their spacecraft and invest more in responsive situational awareness. Costs could go up for almost all satellites with any military value, including those funded by private industry. More ominously, the existence of space-to-space ASAT abilities might encourage the weaponization of space for defensive purposes. Fear of such developments could lead to adoption of norms of behavior governing offensive technologies. In some cases, such capabilities have actually fostered transparency; to allay suspicion, nations that are testing rendezvous capabilities freely disclose the nature of their activities.

2011

Full report at **www.spacesecurity.org**

"The Space Security Index is a valuable treasure and useful tool for those who want to understand and grasp the tendency and information of space security in a single book. It stimulates thoughts on global security."

Prof. Dr. Li Juqian
Standing Council-Member of China Institute of Space Law, Associate Director of International Law Research Center at China University of Political Science

"By its very existence, the Space Security Index keeps present in our minds the vulnerability of space and space assets, and the need to promote space security. The Space Security Index provides a concrete means to measure how much progress is made from year to year."

Mr. Jean-Marc Chouinard
Chief, Policy and Regulatory Affairs, Canadian Space Agency

"Space security is a prerequisite for the sustainable use of space assets upon which we are increasingly dependent. As a comprehensive annual summary of significant space-related events the Space Security Index is a most useful policy tool for anyone involved in promoting space security."

Dr. Eva Bernhardsdotter
Researcher, Space, Defense and Security, Swedish Defense Research Agency

"I recommend the annual monograph by Space Security Index to my students, experienced aerospace professionals, policymakers, diplomats, and security officials. It is a really independent source of information and reflection on the evolution of space affairs. There you can find the most accurate data and the best policy analysis."

Dr. Bertrand de Montluc
Associate Professor, Institut d'Études Politiques de Paris; Senior member, Association Aéronautique et Astronautique de France

"The Space Security Index continues to represent the most thoughtful, informed and nonpartisan summary of annual space activities and policy developments relevant to the safe access to and use of space. In its broad view of space security, covering issues ranging from space weapons to orbital debris and space traffic management, the Index has contributed to defining the field."

Dr. Jonathan McDowell
Astrophysicist, Harvard-Smithsonian Center for Astrophysics