Journal of Space Operations & Communicator (ISSN 2410-0005)
Vol. 16, No. 3, Year 2019

SPECIAL ISSUE: SpaceOps Workshop 2019 (Montreal, CSA-hosted), Part I.

From the Editor-in-Chief:

Our magazine's co-founder and editor-in-chief, David Welch, has retired from a long, successful career with the Journal of Space Operations and Communicator, leaving big shoes to fill. I feel very fortunate for the opportunity to continue his legacy. Although totally inexperienced in this new role, I'm eager to learn and grow into the position and will benefit by Mr. Welch remaining with the Journal as Associate Editor.

My background consists of a career in academia and a 10-year volunteer career with American Institute of Aeronautics and Astronautics. At the American Institute, I spent three years as a member of the Space Operations and Support Technical Committee. My education earned me a Bachelor's of Science in Mathematics, a Master's of Science in Aerospace Science from Embry-Riddle Aeronautical University, and more recently a Ph.D. in Management from Northcentral University. With a research background, I have presented conference papers on the Apollo program and spacecraft safety. I welcome the opportunity to provide articles on various aerospace topics to the Communicator readership.

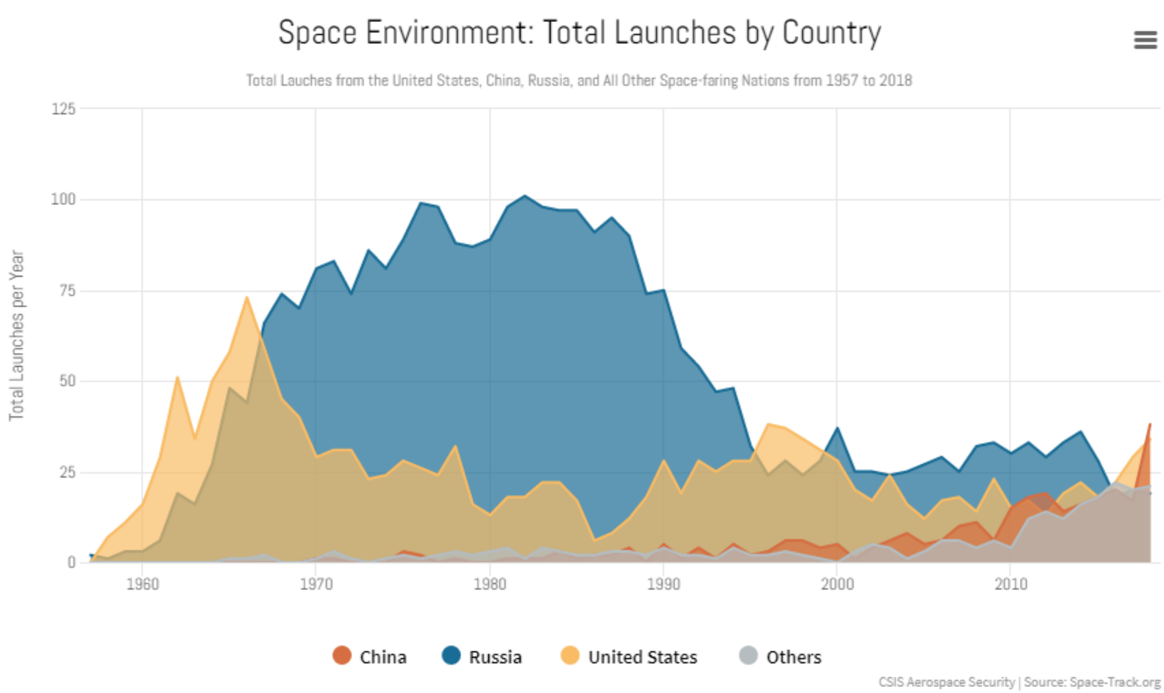
This quarterly issue is special, because it represents reflections of the SpaceOps Workshop 2019 (Montreal) hosted by the Canada Space Agency, which I attended. This issue is devoted to Space Situational Awareness and the sensor system which it manages. Developing technologies and cryptographies underlying the data transmissions between the sensors and ground or inter-space stations will be discussed in a future quarterly issue.

Again, thanks for the opportunity to serve you.

Ronald H. Freeman, Ph.D.
Vice-Chair, SOSTC

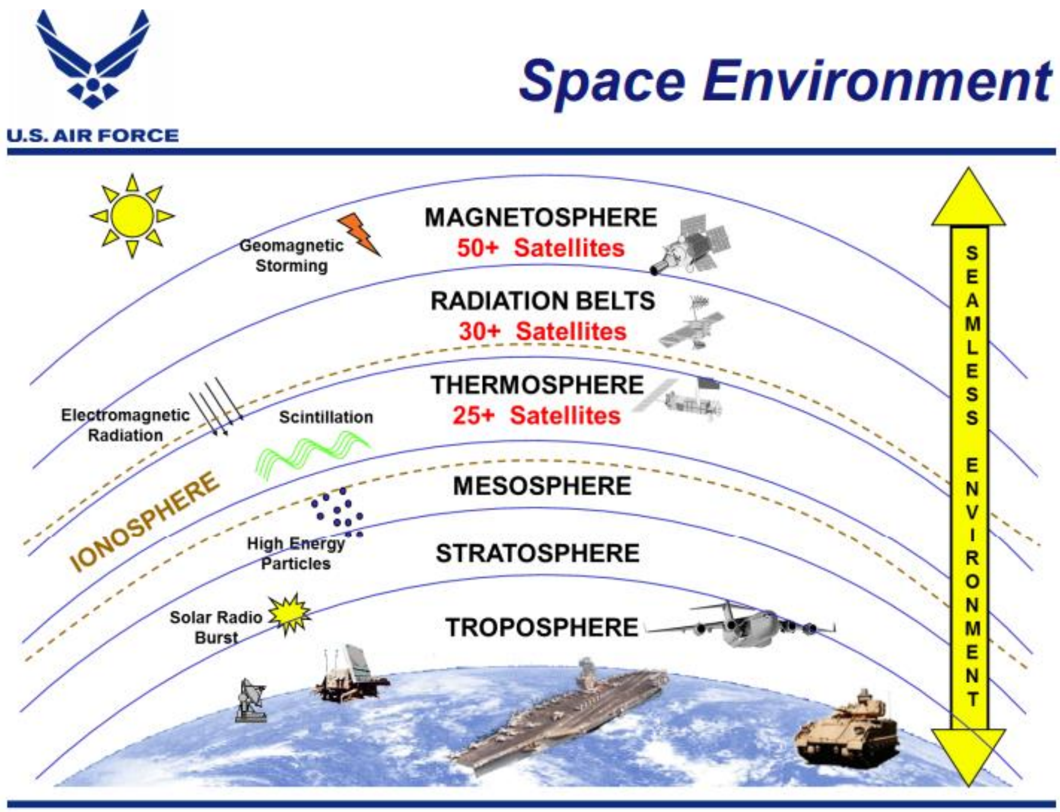
Space Ops Workshop 2019 (Montreal) consisted of three tracks: (1) Space Situational Awareness – space weather and ops management (SSA); (2) IT Security on Operational Ground Segment; and (3) Spacecraft Operations Concepts with Optical Links. As an application of ESA data management, G. di Girolamo (Ground Segment Engineering Department, ESOC) described the functional architecture for managing SSA for satellite/ space operators in terms of sensors layer, server processes layer, and the SSA user layer. Additionally, the Workshop addressed the need to protect the SSA server processes layer for the quality-assured SSA user layer. This issue will address the former, and a future issue will be devoted to the latter.

Studies of space weather, space debris and asteroids characterize space environment. The real space environment showed a higher concentration of single space weather upsets over South America than other global regions, expanding atmosphere drag due to high energy radiation. Modeling orbital and re-entry predictive data affected by such factors help simulate spacecraft/ satellite operations. Satellites launched to geostationary regions wherein micro-meteoroids and other space debris challenged collision avoidance.



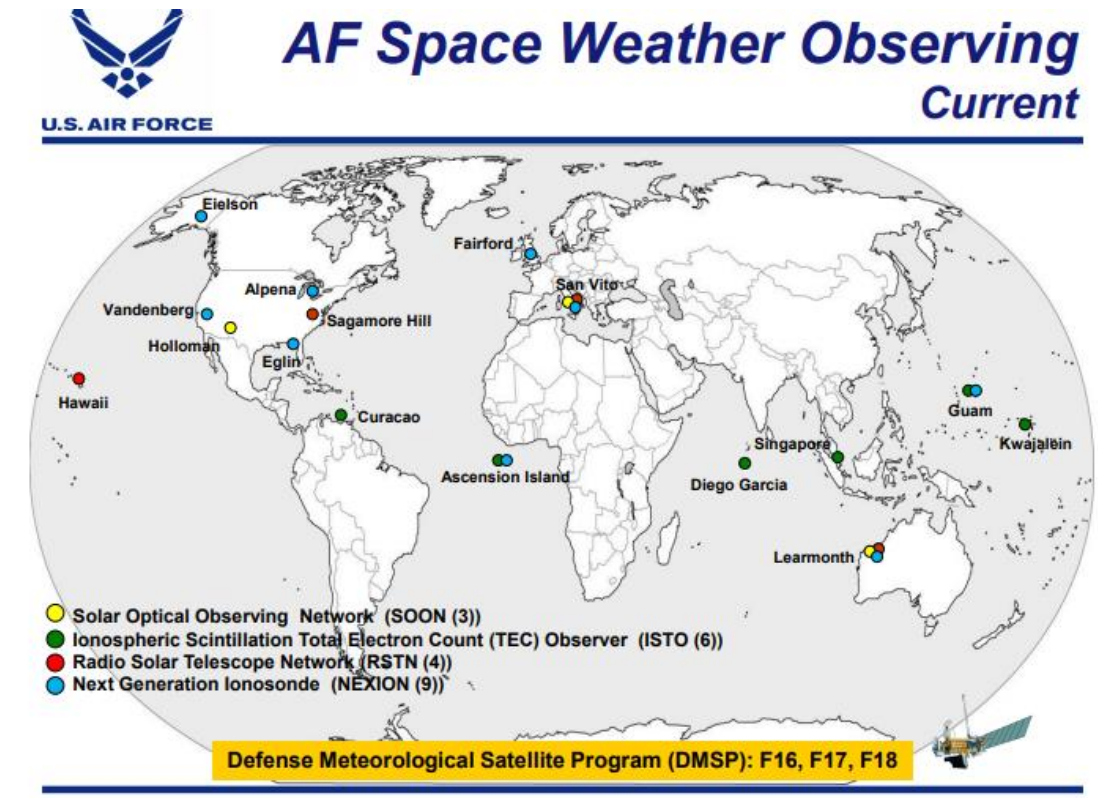
SSA Sensor Layer

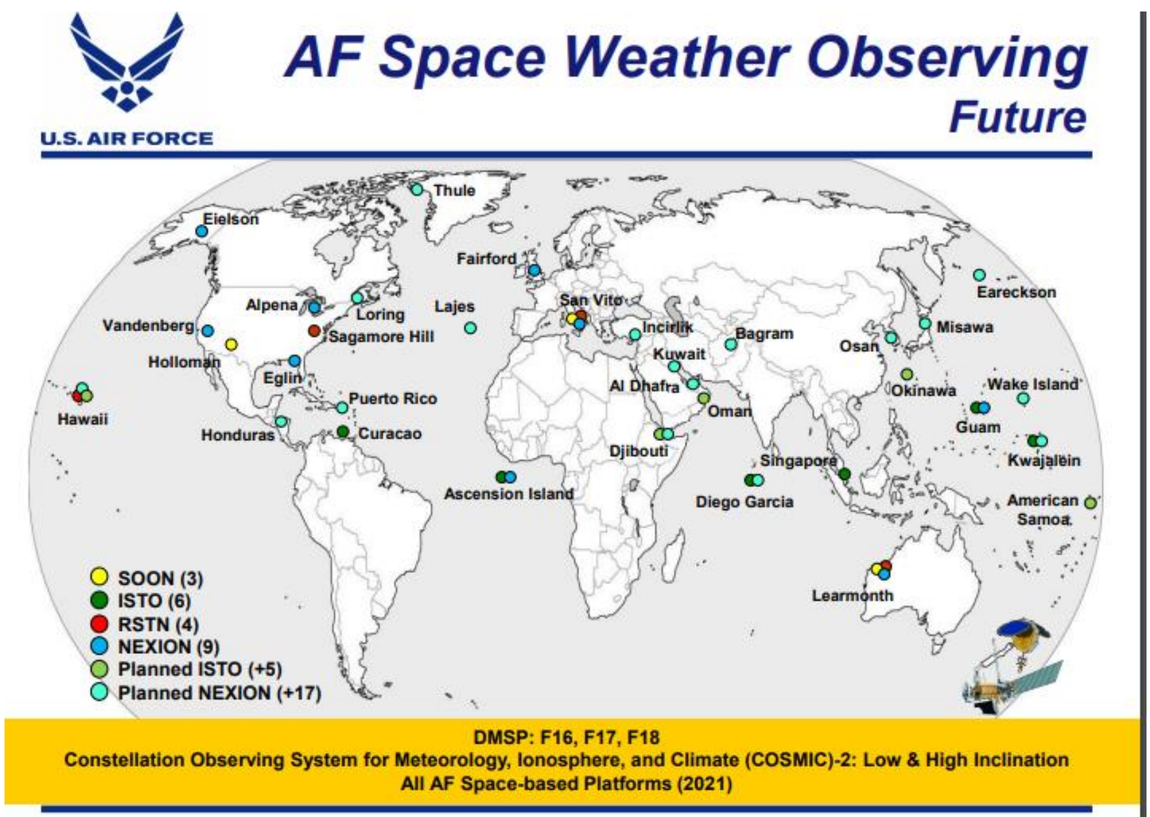
The community of telescope operators collects data of 30cm + objects, particularly in tracklets. Radar- and laser- tracking are used to monitor LEO traffic; telescopes for GEO. Space debris in geostationary orbits detected with optical telescopes is illuminated by the Sun. The advantage compared to Radar can be found in the illumination: radar illuminates the objects and thus the detection sensitivity depletes proportional to the fourth power of the distance. The German Space Operation Center, GSOC, together with the Astronomical Institute of the University of Bern, AIUB, are setting up a telescope system called SMARTnet to demonstrate the capability of performing geostationary surveillance.[1] Increasing space debris is a challenge for spacecraft operators. To ensure safe operations of their own satellites, the operators have knowledge about the orbits of the objects crossing or approaching in order to avoid collision. To gain this knowledge, the United States Strategic Command (USSTRATCOM) uses several sensors and sensor systems to surveillance Low Earth Orbits (LEO) as well as Geostationary Orbits (GEO). The sensor data is processed to catalogues by the Joint Space Operation Center (JSOC), and partially published. As an extra service, JSOC also informs spacecraft operators by sending warnings to the operators in form of Conjunction Data Messages (CDM) in case of a close approach of an object. [1]



SSA Server Processes Layer

Data collected from the sensor systems include measurements of object positions showing range, range rate, and angle. Tracklets showing sets of two+ detections on the same night, aligned along a line or great circle are shared among telescope system operators with ITAR-free servers. Data-sharing is free for those who subscribed to the service and is closed to non-subscribers.
Space weather observing entails both operational requirements as well as research for innovative sensor design, sustainability, and lifespan. Sensor- to -operator data transmission requires accuracy, timeliness, and relevant impacts and needs to be well-understood. The NASA Space Network or Tracking and Data Relay Satellite System are comprised of a constellation of Tracking and Data Relay Satellites (TDRS) in geosynchronous orbit and associated ground stations and operation centers.





NASA is developing technologies for the next generation of relay satellites.

Satellites can be polar orbiting, covering the entire Earth asynchronously, or geostationary, hovering over the same spot on the equator.

1. US- European Solar- and Heliospheric (SOHO) satellite records phenomena continuously, launched in 1997, to L1, or Earth-Sun L1 Lagrange point. SOHO monitors solar flares and coronal mass ejections, both threats to orbiting satellites, and is functional until 2025. It also monitors electrical charged particles and magnetic fields.
2. United States' National Oceanic and Atmospheric Administration (NOAA)'s Deep Space Climate Observatory satellite, launched in 2015 to L1. DSCO monitors magnetic fields. It tracks solar winds, does not monitor electrical charged particles.
3. NASA's Advanced Composition Explorer satellite was launched in 1997 to L1. ACE monitors electrical charged particles and solar winds; functional until 2024.
4. NASA's Solar TErrestrial RElations Observatory (STEREO), launched in 2006 to L5, will have a much diminished functionality in 2022 and need replacement. Consisting of two nearly identical spacecraft, it seeks to establish a one-to-one cause and effect relationship between coronal mass ejections as seen at the sun, the acceleration of particles in interplanetary space, and terrestrial consequences.
5. NOAA's Geostationary Operational Environmental Satellites (GOES), operated by its National Environmental Satellite, Data, and Information Service division, supports weather forecasting, severe storm tracking, and meteorology research. Spacecraft and ground-based elements of the system work together to provide a continuous stream of environmental data. The National Weather Service (NWS) and the Meteorological Service of Canada use the GOES system for their North American weather monitoring and forecasting operations, and scientific researchers use the data to better understand land, atmosphere, ocean, and climate interactions. Note GOES-2016, GOES-2017 and GOES-T for a 2020 launch.
6. NOAA's proposed Space Weather Follow-On Observatory to launch in 2023 (L1) will track ocean surface winds and tropical cyclone intensity.

Weather satellites in L1 require additional propellant to remain operational and 1meter-sized antenna to data 1.5 km to earth may have objectives more economically fulfilled by cubesats. The 2-kg- Firebird cubesats, launched to a high inclination orbit, measured energetic bursts of electrons in the earth's upper atmosphere and collected data for 7 months in the 2013 launch, 4+ years in the 2015 launch.

Insert Article 1: "Strategies to Maximize Science Data Availability for the GOES-R Series of Satellites." By

Dudley, R., Freesland, O**.,** Harvie, E., Kenny, T., Krimshansky, A., Napora, S., Wheeler, C., & Walsh, T. (2018)

SSA User Layer

Space operation service, a radiocommunication service concerned exclusively with the operation of spacecraft, in particular space tracking, space telemetry and space telecommand.

These functions will normally be provided within the service in which the space station is operating.

Space research service, a radio communication service, manages spacecraft or other objects in space used for scientific or technological research purposes. The allocation of radio frequencies is provided according to *Article 5* of the ITU Radio Regulations (edition 2012).

The locations and characteristics of SRS deep-space receivers are described in Recommendation ITU-R SA.1014. The United States of America's civil space agency, the National Aeronautics and Space Administration (NASA), and the European Space Agency (ESA) have provided characteristics of saturation and potential damage levels to their deep-space earth station receivers.

Saturation and damage levels of SRS (deep space) earth station receivers

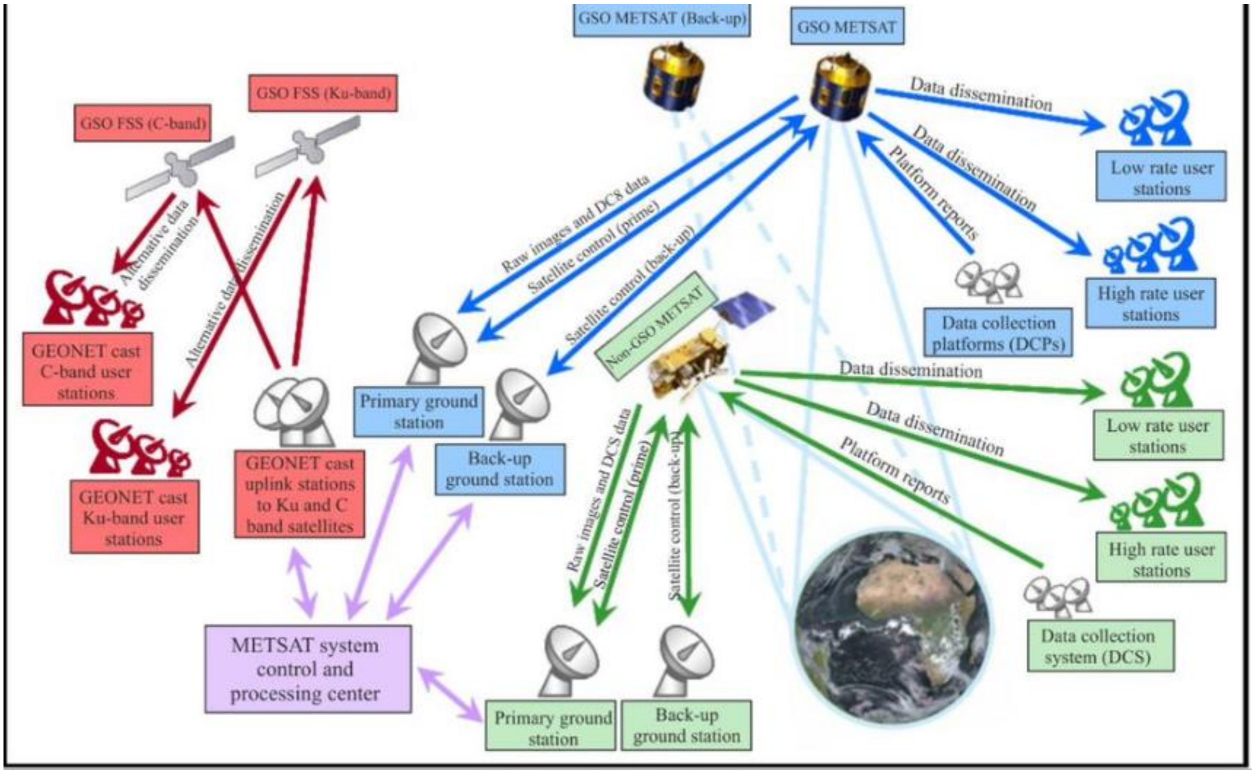
Parameter	Unit	NASA	ESA
Frequency band	MHz	8 200-8 700	8 400-8 500
Saturation level	dBW	–115	–117
Damage level	dBW	–105	–107

These saturation and damage levels are measured directly at the input terminal of the receiver front ends. NASA's SRS deep-space earth station receivers are designed to also support NASA's solar system radar operating in the 8 500-8 700 MHz band, which is allocated to the radiolocation service.

Meteorological Satellite Service (MetSat), an earth exploration-satellite service for meteorological purposes, manages radiocommunication operation between earth stations and one or more space stations, including links between space stations providing:

- Information relating to characteristics of the Earth and its natural phenomena obtained from sensors on satellites
- Information collected from airborne or Earth-based platforms
- Information distributed to earth stations
- Feeder links necessary for operating MetSat satellites and its applications

General Architecture of the MetSat System



MetSat system collects data with visible and infrared imagers as well as sensing instruments using microwave frequencies. Data gathered by geostationary satellites transmit to a primary ground station and is processed and distributed to the user community of national meteorological centers, official archives and other users. Processed data may be sent back to the satellite for re-transmission as part of a direct broadcast to user stations. Besides DSO and Non-GSO MetSat disseminated data systems, the Global Earth Observation System of Systems (GEOSS) initiative will develop a worldwide, operational, end-to-end Earth observation data collection and dissemination system using existing commercial telecommunications infrastructure based on Digital Video Broadcast technology and provide services to a common user community including partners – CMA (China Meterrological Administration), NOAA, WMO (World Meteereological Organization), and EUMETSAT.

Earth Exploration-Satellite Service (EESS), a radiocommunication service between Earth stations and one or more space stations. Because all matter emits, absorbs, and scatters electromagnetic energy to varying degrees, the sensors detect variations in Earth's environment. Spaceborne sensors operating at radio frequencies detect variations under all weather conditions because of their longer wavelengths, and with penetration depths not possible at optical or infrared wavelengths. RF used for EESS are usually designated either as "windows" used for observing Earth's surface or as "opaque" used for observing the atmosphere. All window channels exhibit some atmospheric absorption and emission, and even atmospheric resonant frequencies or absorption bands are often not completely opaque.[2]

Satellite antenna used for tracking in Space Operations services Space Research Service Antennas at Goldstone (CA). Single satellite sensing the Earth is an Advance polar –orbiting meteorological weather satellite.
A typical EESS terrestrial receiver contains synchronized phase-lock loops designed to lock and track the received signal. The presence of a strong interfering signal may cause these receivers to lose lock with the desired signal resulting in a break in communications. Interference can be momentary, caused by the interfering signal sweeping across the loop bandwidth, or it may last for minutes. In such a case, a recovery procedure must be initiated to reacquire and regain lock with the desired signal. The duration of the reacquisition sequence may be longer than the duration of the interference itself. The result of such harmful interference is the reduction, interruption, or irretrievable loss of the data transmitted to the ground by the satellite during its pass over the earth station.[3]
To Improve the Situation for Satellites with Short Missions,

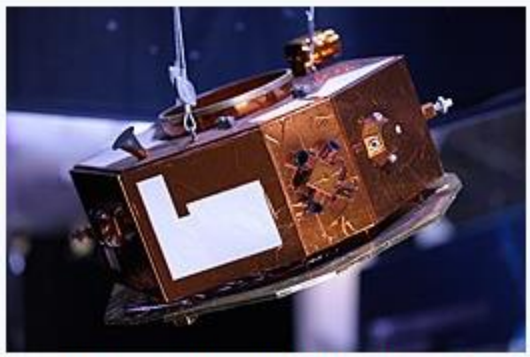
- Small satellites (typically having short duration missions) are increasing
- First time satellite operators tend to not fully understand their spectrum use requirements and responsibilities
- Radio Regulations do not differentiate between big vs. small satellites or short vs. long duration missions
- Small satellites have very short development, deployment and mission lifecycles in comparison to the timeline for submitting and processing satellite network filings

LISA Pathfinder Satellite, formerly Small Missions for Advanced Research in Technology-2 (SMART-2), was an ESA spacecraft that was launched on 3 December 2015 on board Vega flight VV06. The mission tested technologies needed for the Laser Interferometer Space Antenna (LISA), an ESA gravitational wave observatory planned to be launched in 2034. The scientific phase started on 8 March 2016 and lasted almost sixteen months. In April 2016 ESA announced that LISA Pathfinder demonstrated that the LISA mission is feasible.
LISA Pathfinder was a proof-of-concept mission to prove that the two masses can fly through space, untouched but shielded by the spacecraft, and maintain their relative positions to the precision needed to realize a full gravitational wave observatory planned for launch in 2034. The primary objective was to measure deviations from geodesic motion. Much of the experimentation in gravitational physics requires measuring the relative acceleration between free-falling, geodesic reference test particles.
In LISA Pathfinder, precise inter-test-mass tracking by optical interferometry allowed scientists to assess the relative acceleration of the two test masses, situated about 38 cm apart in a single spacecraft. For the follow-up mission, LISA, the test masses will be pairs of 2 kg gold/platinum cubes housed in each of three separate spacecraft 2.5 million kilometers apart.
The science of LISA Pathfinder consisted of measuring and creating an experimentally-anchored physical model for all the spurious effects – including stray forces and optical measurement limits – that limit the ability to create, and measure, the perfect constellation of free-falling test particles that would be ideal for the LISA follow-up mission. In particular, it verified:

- Drag-free attitude control of a spacecraft with two proof masses,
- The feasibility of laser interferometry in the desired frequency band (which is not possible on the surface of Earth), and

- The reliability and longevity of the various components—capacitive sensors, microthrusters, lasers and optics.

While ground-based telescopes are used to search for and follow up these objects, they have limitations. For example, any NEO coming from the direction of the Sun will be missed by ground-based telescopes. [*The Chelyabinsk asteroid in 2013 came from the direction of the Sun – Ed.*]. In fact, one of the best locations from which to spot asteroids is space – specifically, from an orbit that is closer to the Sun than the Earth. To demonstrate that ESA has the capabilities to use space-based telescopes for these observations, a test campaign was conducted using the LISA Pathfinder star trackers – optical cameras that are normally used to determine the craft's orientation.[4]



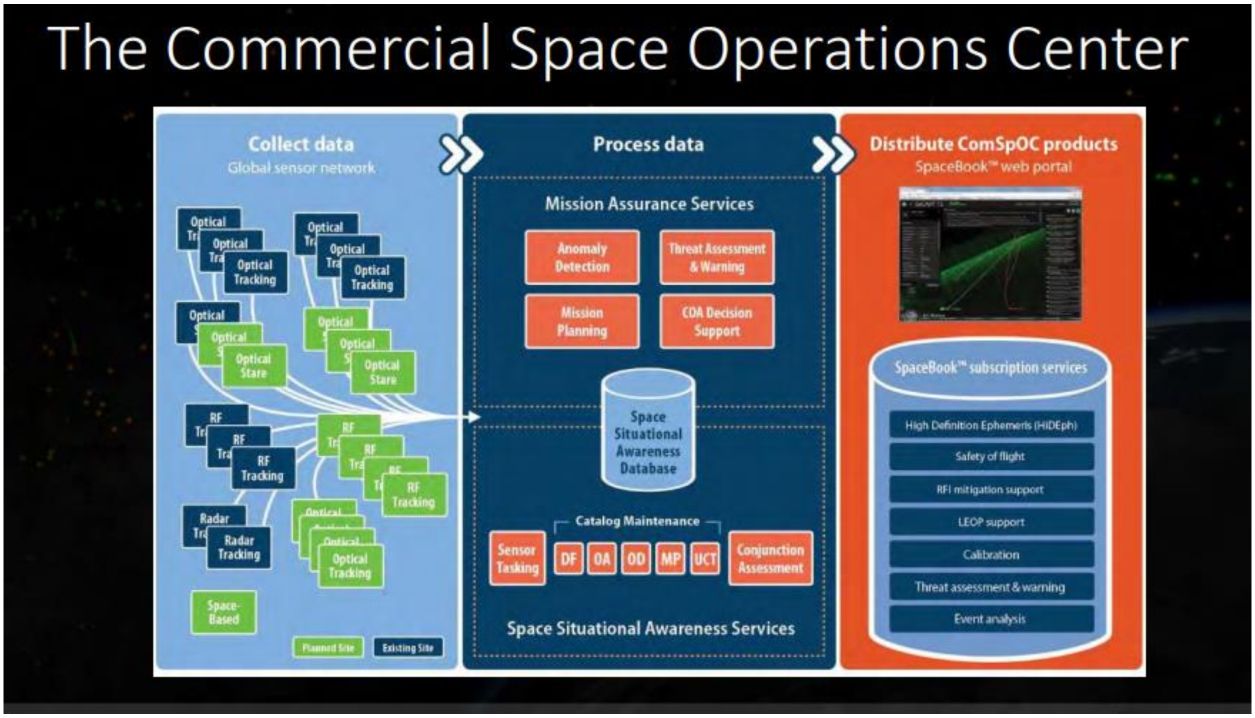
Model of the *LISA Pathfinder* spacecraft

Insert PowerPoint 1: "User Needs and Advances in Space Wireless Sensing & Communications."

By Kekege, O. (2017)

ADDENDUM: Managing the SSA Processes Layer

Data transmission from the SSA processes layer to the SSA user layer is susceptible to vulnerabilities that pose an end-use risk of the data integrity. Julien Airaud (CNES) described the evolution of cyber-infrastructure for space operations and of the cyber-environment showing a 15 year history of episodic lack of system mapping, configuration- and design-freezes, and a growing supply chain complexity, particularly in commercial -off- the shelf cyber products.



An increased cyber-attack surface resulted from developmental gaps in operational technologies, automation, cloud service utilization, and open-sourcing within the Internet. A few off-the-shelf solutions exist to fulfill the need of remote payload monitoring, and they mainly use proprietary devices. The recent advent of mobile technologies (laptops, smartphones and tablets) as well as the worldwide deployment of broadband networks (3G, Wi-Fi hotspots), has opened up a technical window that brings new options.

Airaud at the SpaceOps 2019 Workshop (Montreal) continued to identify the war zones of cyber-context:

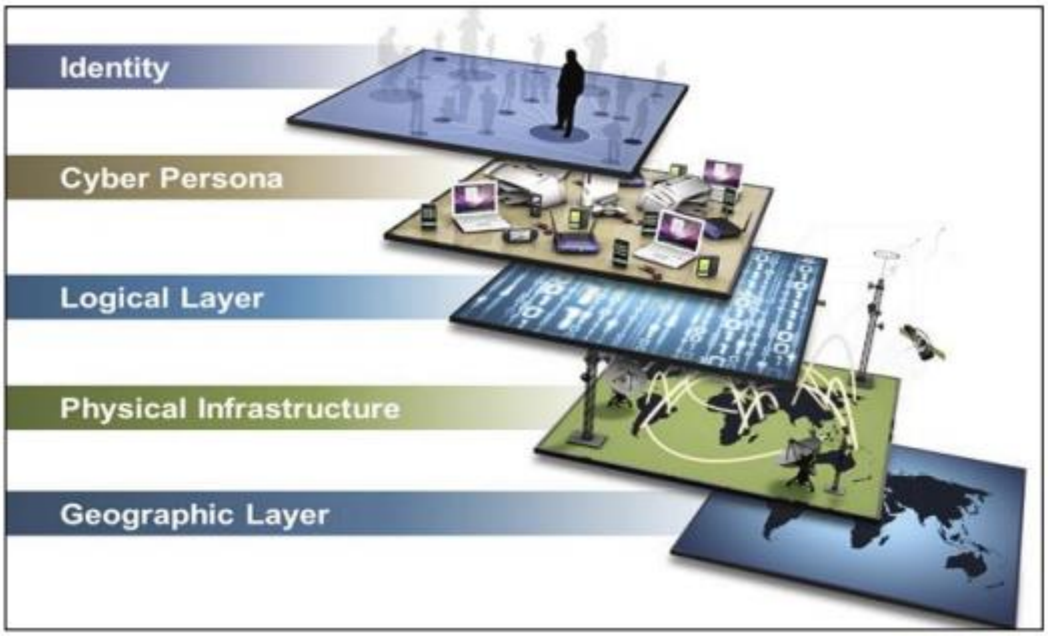
- Putter Panda, associated PLA 61486 (2014)

  CrowdStrike is a global provider of security technology and services focused on identifying advanced threats and targeted attacks. Using big-data technologies, CrowdStrike's next-generation threat protection platform leverages real-time Stateful Execution Inspection (SEI) at the endpoint and Machine Learning in the cloud instead of solely focusing on malware signatures, indicators of compromise, exploits, and vulnerabilities.

  CrowdStrike has been tracking the activity of a cyber espionage group operating out of Shanghai, China, with connections to the People's Liberation Army Third General Staff Department (GSD) 12th Bureau Military Unit Cover Designator (MUCD) 61486, since 2012. The attribution provided in this report points to Chen Ping, aka cpyy (born on May 29, 1979), as an individual responsible for the domain registration for the Command and Control (C2) of PUTTER PANDA malware. In addition to cpyy, the report identifies the primary location of Unit 61486. PUTTER PANDA is a determined adversary group, conducting intelligence-gathering operations targeting the Government, Defense, Research, and Technology sectors in the United States, with specific targeting of the US Defense and European satellite and aerospace industries.

- Turlu Group (2015)

The concept of cyber geography serves various targeted purposes, finds depth, in particular, through a connection based on "surveillance, carrying, production and sanction”. The delivery of local information to the global market via the internet constitutes a digital structure, and the written and visual dimension of this structure constitutes the practice of cyber space. In this context, an information-based structure including the activities, expectations and global-oriented reflections of individuals, societies and countries / political systems in relation to the use of geographical location technologies in the perspective of various perspectives, is brought to a global scale with the practices of cyber space.



- Luch-Olymp-K (2018)
  Unlike most objects in the geostationary belt, Russian satellite Olymp-K has made a series of orbital maneuvers, widely varying its position in GEO from July 2017 to November 2018. According to the data of Space Threat Assessment 2019 (CSIS Aerospace Security Project), the satellite approached Athena-Fidus (a French-Italian comsat) and attempted to intercept communications. Close approach to a satellite is consistent not only with espionage, but also with destruction, which seemed to be the point of the earlier US complaint.

A significant number of the functionalities offered by a payload control center remain the same from one mission to the next. In this context, CNES initiated the CMSG project which aims at listing and organizing these common functions to avoid the need to redefine them for each new mission. The objective is to optimize the technical specification and development phase by leaving engineers free to concentrate on the specific aspects of their mission. A functional architecture decomposed into three layers, was then proposed: a data management layer, an application layer and a ground monitoring layer. In the application layer, a function dedicated to the payload health monitoring is identified. This function, as the other ones, must be seen as the addition of a recurrent part and a mission specific part.[5]

Insert Article 2: "Science and Technology (S&T) Roadmap Collaboration between SMC, NASA, and Government Partners." By Betser, J., Ewart, R., & Chandler, F. (2016)

SpaceOps Workshop 2019 (Montreal) closed SSA track with an open discussion "Social Responsibility: On Removing Space Debris." Space satellite operations are shared by multiple agencies, all of which are challenged by collision avoidance threats. While LEO and GEO regions are increasingly becoming spacecraft-populated, self-regulation versus international cooperation that addresses non-functioning, defunct spacecraft introduced by their providers needs a definitive policy. The following article reports one initiative being undertaken.

Insert Article 3: "NASA's Marshall Space Flight Center Recent Studies and Technology Developments in the Area of SSA/Orbital Debris." By Wiegmann, B., Hovater, M., & Kos, C. (2012)

References

1 Fiedler, H., Weigel, M., Herzog, J., Schildknecht, T., Prohaska, M., Ploner, M., & Montenbruck, O. (2015). SMARTnet: First Experience of Setting Up Telescope System to Survey the Geostationary Ring.
2 Meteorological Satellite Service (2017). Use of Radio Spectrum for Meteorology Weather, Water, and Climate Monitoring and Prediction.
3 ITU-Handbook for Earth Exploration-Satellite Service (2011).
4 European Space Agency, Science and Technology. LISA Pathfinder.
5 Queyrut, O. (2012). IMIS: Solutions for Assessing Instruments Health from Anywhere. In *SpaceOps 2012* (p. 1263662).