

# Attaining Situational Understanding in the Space Domain

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## Abstract

The information available today in the space domain consists primarily of basic positional, mission, and status data for ground and space based assets. This data provides a necessary, but not sufficient, basis for understanding the true situation of the overall space domain. Experts analyze this information, put it into context with other ongoing events, and then make assessments of the risks posed to allied assets. The potential for unknown, unexpected, and unprecedented situations to overwhelm this manual process is increasing as the number of space faring nations and orbiting objects increases.

This paper describes a product family called iSpace that Lockheed has created, and continues to invest in, to help tackle the problems of attaining space information more timely, deriving deeper space situational understanding from the data, and integrating components and tools generated throughout the world-wide industry to contribute towards a comprehensive space solution. We will also update the group on iSpace's usage in the USSTRATCOM Space Situational Awareness (SSA) Table Top Exercises (TTX), used to explore future SSA cooperation concepts and procedures among allied nations.

## 1. Background

Technological improvements have dramatically expanded space accessibility for commercial and civil use, reduced active payload size, and diversified space-based and ground-based space sensing capabilities. With new SSA sensing capabilities, such as Space Fence, the number of Resident Space Objects (RSOs) will dramatically increase in the near future. Moreover, the nature of the space domain, as viewed by many countries of the world, is also changing. On September 20, 2016, Gen. John Hyten, the head of Air Force Space Command at that time, told the Senate Armed Services Committee in written testimony that space control programs and a battle management command and control system should be among the Defense Department's top space priorities. Gen Hyten also said the Joint Interagency Combined Space Operations Center (JICSpOC<sup>1</sup>) will "change the warfighting culture of our space cadre as well as ensuring we have the ability to fully plan and employ our space control capabilities." [1] General Raymond, the current lead of Air Force Space Command continues to pursue and expand the vision elaborated by Gen Hyten. It is these changes that are forcing Space Situational Awareness (SSA) and Command and Control (C2) functions to rapidly evolve to attain a better situational understanding of the space domain.

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<sup>1</sup> The JICSpOC has been renamed to the National Space Defense Center (NSDC)

## 2. Lockheed's iSpace Product Family

Lockheed Martin (LM) has been intimately involved in Space C2 since its inception. We developed one of the first Space C2 capabilities back in the late 1950s and have remained prime developers and maintainers of crucial U.S. Space C2 and sensor systems for Air Force Space Command. LM-corporate extensive programmatic and research & development efforts in all aspects of the space domain helps ensure our latest Space C2 and Battle Management Command & Control (BMC2) products address today's, and are ready for tomorrow's, space challenges.

To address the evolving needs of the space domain, Lockheed has developed a product family called iSpace, shown in Figure 1, composed of three layers of products that can work together or independently. Starting at the bottom layer are a set of Sensor Mission Processor products that can be paired with sensors to provide local catalog management, net-centric communications to one or more C2/BMC2 centers as well as other sensors, policy-based-sensor-control and tasking and a number of other key features.

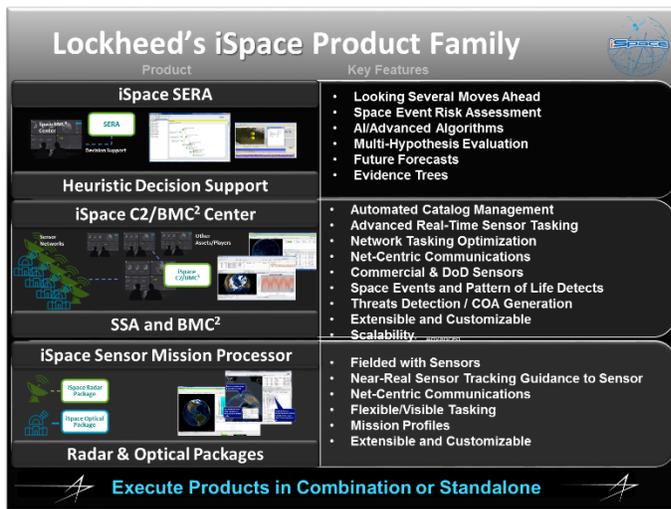


Figure 1 - LM's iSpace Product Family – Products can operate together or standalone

At the middle layer in is the iSpace C2/BMC2 product. It allows you to: add sensors to the system dynamically, receive and process measurements from sensors and other entities, perform automated catalog management, designate a set of sensors as taskable, detect and alert to space events of interest, and to identify threat conditions and auto-generate Courses-Of-Actions (COAs). iSpace C2/BMC2 supports Radar, Passive RF and Optical space/ground based sensors. An open architecture including net-centric communications and displays provide a platform that is rapidly deployed, configured, and customized. This product is in operational use today and is the C2 SSA capability being used for the USSTRATCOM Global Sentinel 2017 (GS 17) international SSA Table-Top-Exercise (TTX), held in September 2017.

The top iSpace product layer represents the Space Event Risk Assessment (SERA) tool. iSpace SERA accepts inputs from C2/BMC2 systems identifying the current space situation in terms of orbits and events of interest. SERA is also fed with various INTEL assessments. Using this information SERA employs Artificial Intelligence (AI) by means of a rule-based expert system engine, probabilistic reasoning, and machine learning to look-ahead for potential risks that may be indicated based on the current and predicted information. iSpace SERA was used by USSTRATCOM for GS-16 and is currently being used in the GS-17 exercise.

## 3. USSTRATCOM Global Sentinel SSA Experiment

The SSA TTX III experimented with different C2 constructs to determine which construct enhanced SSA to the greatest degree. The United States, Australia, Canada, France, Germany, Japan, the United Kingdom, and a commercial consortium participated. The baseline construct was distributed space operations with each C2 center collaborating much as they do today. A variant was introduced to determine if having a central coordination center with representatives from each country and a commercial representative would enhance SSA. The center was called the FedSpOCC and iSpace SERA was employed. Scenario events included conjunctions, maneuvers, breakups, launches, and an "unusual" event where a rocket body cataloged as being inactive moved into a co-planar condition with a Federation asset.

The ability of the Federation players to respond to these events with different C2 structures was measured. SERA predicted risks induced to defended assets by red and grey geo-synchronous satellites that were moving along the geo-synchronous belt. The risk of close proximity was predicted weeks and months in advance using SERA's rules. No other Federation tools detected these events.

As shown in Figure 2, iSpace will have a larger role in GS-17. The iSpace C2 Center product will be used by approximately 40 SpOC operators from Australia, Canada, France, Germany, Italy, Japan, The United Kingdom, and the United States. iSpace-SERA will be employed by each SpOC as well.

**Objective 1.0:** Determine which **elements\*** are necessary to optimize **unity of effort** for multinational **SSA operations**

**Study Question:** To what extent does altering these elements for multinational SSA operations improve individual and collective SSA and responses to contingencies?

**Goals:**

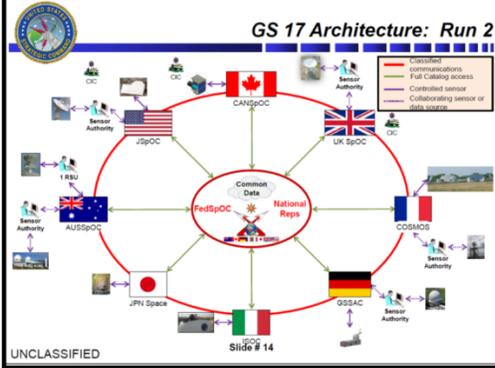
- Improve upon and test the SSA Federation Handbook developed in SSA TTXs I, II, and III
- Inform multinational ops cell CONOPS/TTPs mandated by FRAGO 48, CSPO Ops Working Group

**Outcomes:**

- Validate and update the SSA Federation Handbook developed for this event
- Provide support for further exploration of a multinational SpOC concept

**\* Elements:** Capabilities, roles, responsibilities, authorities, data, organization, and architecture





- Event held at Lockheed Martin's Lighthouse Center For Innovation Facility in Suffolk VI Sept 2017
- Server-Suite in Colorado Springs driving workstations in Suffolk
- ~40 Simultaneous Users running iSpace for 5 Days
- 10 Countries
  - 8 Active Participants
  - 2 Passive Observers
- SSN Sensors + other Allied Sensors
- Simulated & Form-1 data
- Fully Interactive tasking using multi-sensor network model
- Single Server Suite with Role-Based-Access Controlled Tasking
- Net-Centric I/Fs to STRATCOM tools

Figure 2 - GS-17 Event Help September 2017 at Lighthouse Center for Innovation Facility

Table 1 - Statistics

Scenario Characterization	
Real Objects	2597
Sim Objects	2533
Sensor Sites	52
# of Sensors	67
GEO Sensors	34
LEO Sensors	33
Space Events	51

Table 1 provides some key statistics about the scenario. It includes real world unclassified satellites and observations as well as simulated events. The events are comprised of breakups, conjunctions, maneuvers, launches, reentries, Rendezvous and Proximity Operations (RPO), ASATs, Lasing, and anomalous behavior. The iSpace modeling and simulation engine drives the events and also controls the sensor tasking using its Sensor Network Simulator. Another experiment is under planning for 2018 adding more events and more scenarios.

#### 4. Impact of Enterprise Architectural Alternatives

A successful space enterprise will consist of capabilities throughout industry, academia and government. Products must employ industry standards, have Software Development Kits (SDKs) supporting integration of third-party internal components, have key internal components swappable, provide the ability to dynamically integrate new sensors, and have integrated community XML standards and web services supporting flexible external interfacing. However, these steps by themselves do not ensure success at the enterprise-level. Industry off-the-shelf capabilities can be aided or hindered by the choices made for the enterprise architecture itself.

When building a space enterprise, fundamental architectural considerations have a major influence on which third-party capabilities can be efficiently employed, the resiliency of the solution, and the overall probability of success of the enterprise itself. Consider two enterprise architectural extremes shown in Figure 3.

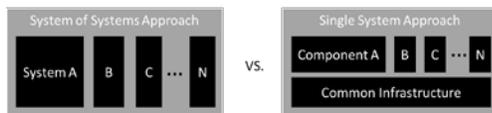


Figure 3 - Two Enterprise Architectural Extremes

At one extreme the enterprise consists of a system-of-systems where ideally the separate systems are loosely coupled from one another through the use of industry standard interface mechanisms and protocols. At the other extreme all capabilities are integrated into a single overall system that share one common infrastructure.

There are lots of variations in-between the two extremes. In the case of a common infrastructure that includes just Virtual Machines (VMs) and a security infrastructure, the single system approach is not that far away from the

system of systems approach. For analysis sake let's assume that the two approaches are far apart and examine some of advantages and disadvantages of the two extremes.

The System of Systems Approach has the huge advantage of enabling existing/off-the-shelf capabilities participation without modification. Since each of these capabilities could conceivably be running on its own infrastructure, this enables their usage in their own native environments. Some commercial entities may be unable or unwilling to move their products to other infrastructures. Forcing modification of an off-the-shelf component drives the vendor to support multiple baselines which is more inefficient and costly and may result in the custom version not being maintained as well as the mainstream baseline version. Multiple infrastructures in the system-of-system approach present some other advantages and disadvantages. Multiple infrastructures could drive up maintenance cost by increasing the number of piece parts, driving up the spare pool cost and other logistics cost associated with system maintenance. It will also increase security accreditation cost since each system will have a separate and unique security implementation that must be documented and approved. Some believe that multiple infrastructures also increases security vulnerabilities because "it's easier to lockdown one system – then multiple systems". Others think that cyber-security is improved by diversity and point to the computer and smart phone market experience of having different platforms experience distinct vulnerabilities. One major disadvantage of the Single System single infrastructure approach is that the entire enterprise's success is tied to the success of that single infrastructure. If it fails the complete enterprise fails. One major advantage of a single system approach is the system's state and health can be much more easily monitored and controlled.

Different approaches require different levels of effort and thus result in varying schedules and cost. For enterprises that have not committed to a given enterprise architecture we recommend a flexible case-by-case analysis that might allow hybrids between these two extremes. We also recommend that when a single system approach is being implemented the infrastructure stays as thin, flexible and uses industry standards allowing third-party products to run in native form whenever possible. For example, an infrastructure with just virtual machines, cross domain solutions, and security enabling agents and servers will allow most off-the-shelf/existing products to be deployed without modification. As an enterprise infrastructure becomes less flexible and burdensome to a variety of independently developed applications the cost and schedule to integrate the enterprise increases exponentially and end-to-end performance generally suffers.

## 5. Scalability, Automation and Timeliness

Figure 4, shows one estimate of space catalog growth when the new Space Fence sensor comes on-line in 2019. The volume of observation data and number of objects tracked will increase by an order of magnitude.

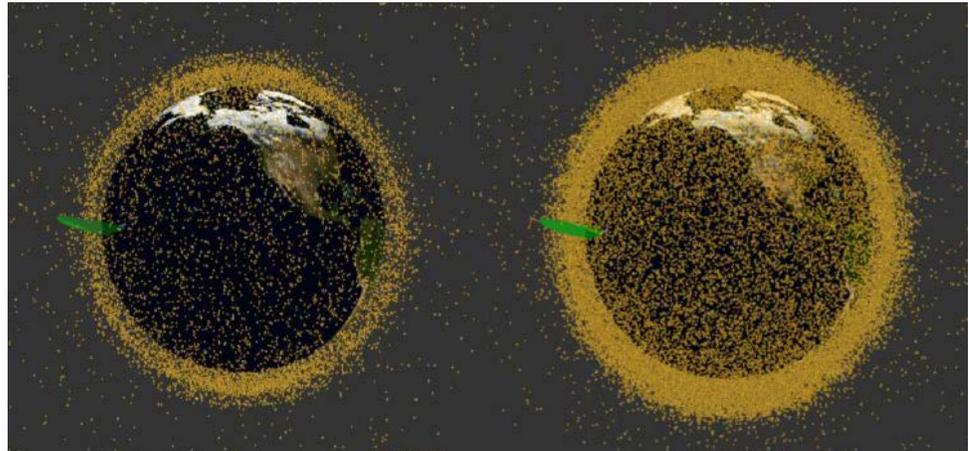


Figure 4 – Juxtaposition of the 13--July-2016 LEO Catalog versus an estimate of the Space Fence detected Objects [3]

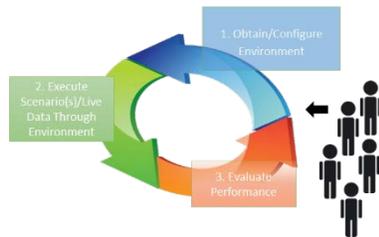
In addition, today's changes in the nature of the space domain requires near real-time information and assessments of situations that in the past have taken the space community often many months to ascertain. For example, the intentional destruction on Jan. 11 2007 of China's Fengyun-1C weather satellite via an anti-satellite (ASAT) device launched by the Chinese created thousands of fragments fluttering through space. This took the space community many months to catalog most of the debris from this test. [2]

To address these issues an SSA and Space C2 product must include:

- Scalability – new servers can be added, even dynamically, to increase the throughput and processing of the system supporting larger catalog sizes and the respective catalog maintenance and other C2 and BMC2 activities associated with them.
- Automation and Timeliness – all interfaces are machine-to-machine, all space events and pattern-of-life detections occur in near real time, catalog management is automated minimizing manual intervention, threat detection and initial COA generation is automated and occurs in near real-time, other space C2 and BMC2 processes like forecasting occur continuously.

## 6. Simulation & Exercise

Modelling and Simulation (M&S) along with Exercise capabilities are essential to a successful space enterprise. The ability to inject synthetic data, and/or replay captured real data is an obvious requirement for any space enterprise.



As shown in Figure 5, key M&S capabilities include a scenario generator, the ability to playback/inject scenario and catalog data, exercise vs. real-mode configurations allowing you to fight-as-you-train and train-as-you-fight, a sensor network simulator capable of simulating any number of sensors, and a full analysis suite for post scenario run evaluation. These capabilities provide a full interactive environment for exercises and training of a Space Mission Force, SSA operators, and space analysts.

Figure 5 –Exercise Mode Supports Iterative Evaluation and Improvement

## 7. Summary

An SSA and Space C2 product must offer real-time assessment, scalability, customizability, automation, real and exercise-modes, and community XML standards over web services for external interfaces. Enterprise architecture decisions can have a huge impact on what industry products can be employed and how cost effectively they can be integrated.

All aspects of a space enterprise need to be successfully executed to effectively and efficiently address the surging volumes of data, increased activity and changing nature of the space environment. Without these factors in place the ability to continue to monitor and assess the space environment will fall short. The old manual methods and processes simply won't scale nor will they provide the timeliness required. From a holistic standpoint, industry, governments, and academia will contribute to the enterprise-wide solution matured through experimentation such as the USSTRATCOM Global Sentinel events and deployed through new programs under agencies such as Air Force Space Command and the Federal Aviation Administration for Space Traffic Management.

## 8. References

1. Gruss, M, Hyten tells Senate DoD needs to focus on space control, battle management system, SPACENEWS, September 20,2016
2. David, Leonard, China's Anti-Satellite Test: Worrisome Debris Cloud Circles Earth, Space.Com, February 2, 2007
3. Koltiska, Michael G, AN/FSY-3 Space Fence System Support of Conjunction Assessment, Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS) 2016