Next Generation Space Surveillance System-of-Systems

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1. ABSTRACT

International economic and military dependence on space assets is pervasive and ever-growing in an environment that is now congested, contested, and competitive. There are a number of natural and man-made risks that need to be monitored and characterized to protect and preserve the space environment and the assets within it. Unfortunately, today's space surveillance network (SSN) has gaps in coverage, is not resilient, and has experienced a growing number of lost objects. Risks can be efficiently and effectively mitigated, gaps closed, resiliency improved, and performance increased within a next generation space surveillance network implemented as a system-of-systems with modern information architectures and analytic techniques. This also includes consideration for the newest SSN sensors (e.g. Space Fence) which are Net-Centric out-of-the-box and able to interface seamlessly with the Joint Space Operations center (JSpOC), global information networks, and future unanticipated users. Significant opportunity exists to integrate legacy, traditional, and non-traditional sensors into a larger space system-of-systems (including command and control centers for tasking) for multiple clients through low cost sustainment, modification, and modernization efforts. Clients include operations centers (e.g. JSpOC, USSTRATCOM, CANSPOC), Intelligence centers (e.g. NASIC), space surveillance sensor sites (e.g. AMOS, GEODSS), international governments (e.g. Germany, UK), space agencies (e.g. NASA), and academic institutions. Each has differing priorities, networks, data needs, and timeliness, security and accuracy requirements and formats. Enabling processes and technologies include: Standardized and type accredited methods for secure connections to multiple networks; Machine-to-machine interfaces for near real-time data sharing and tip-and-queue activities; Common data models enabling analytical processing across multiple radar and optical sensor types; An efficient way to automatically translate between differing client and sensor formats; Data warehousing of time based space events; Secure collaboration tools for international coalition space operations; and Shared concept-of-operations, tactics, techniques, and procedures. Some of the technologies are being implemented now throughout the enterprise and activities are getting started to define a joint concept of operations with coalition partners.

2. INTRODUCTION

Efficient and effective space surveillance requires complex interactions between space systems, launch systems, ground based sensors, space based sensors, communications networks, satellite operations, sensors operations, and command and control (C2) centers. It is useful to analyze these interactions from a systems-of-systems (SoS) engineering perspective to define the next generation of space surveillance network that provides maximum mission utility. From a practical perspective, and given limited budgets, one cannot assume a "clean sheet of paper". Once the "As-is" architecture is analyzed and the desired "To-be" architecture is documented processes and technologies can be implemented to transition over time. Key to supporting the architecture definition and transition is implementation of a network model for simulation, demonstration, and real world experimentation. This model measures and validates the impacts of changes over time and helps make decisions for an implementation roadmap.

There are many risks to space assets including collision avoidance, interference, cyber, and co-orbital threats. Space situation awareness (SSA) is needed to monitor, predict, detect, analyze, attribute, and act on these risks. An operational vision for an integrated and net-centric architecture is depicted in Fig 1.

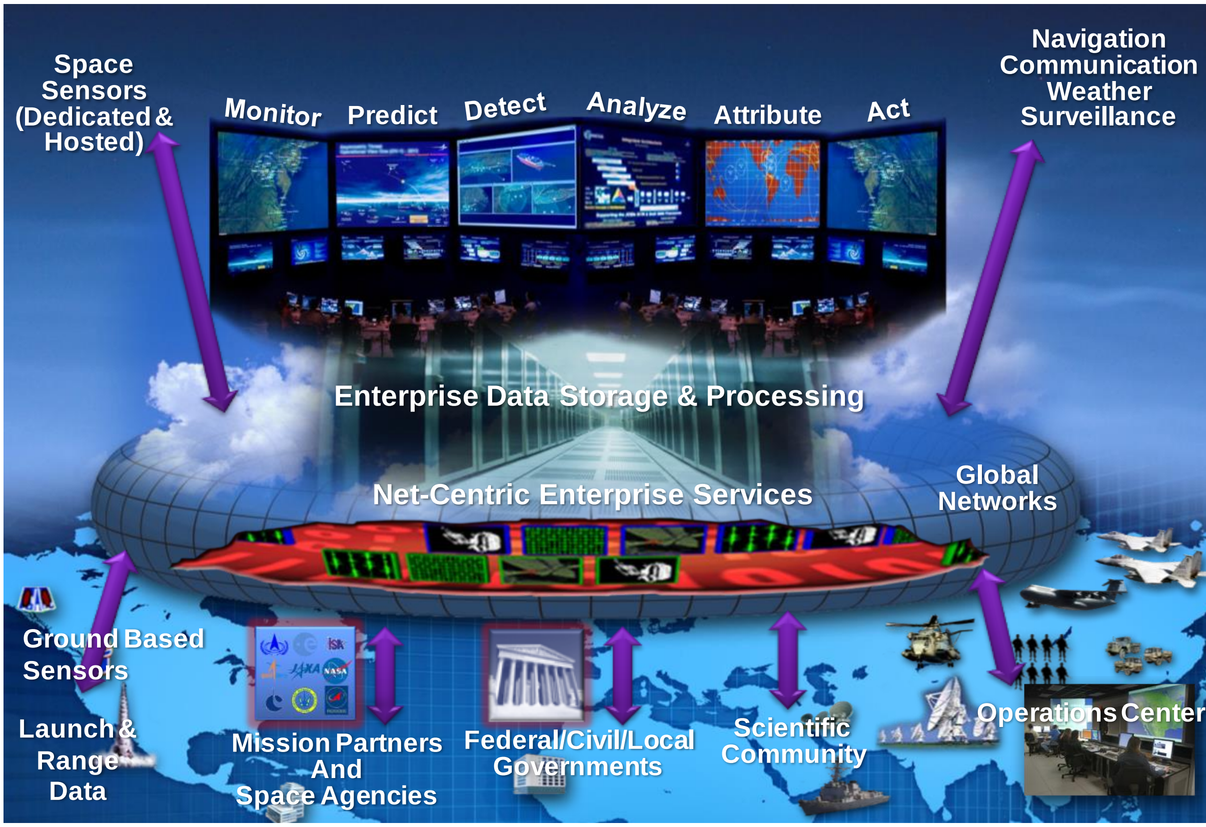

Fig. 1 – Integrated and net-centric system-of-systems space situation awareness vision.

In this vision all relevant assets communicate net-centrically via global networks. In addition, all mission partners, space agencies, federal/civil/local government, and scientific communities are sharing SSA data for the benefit of all. Seamless data sharing is integral to the vision. Within an integrated end-to-end SoS, data can be transformed to enable SSA. Net-centrically exposed data (such as sensor observations, telemetry, weather, launch, and interference) can be processed into space event information to be fused and placed in context providing knowledge to perform action. Data can be shared in machine-to-machine and human-to-machine formats depending on the need. Machine-to-machine information provides timeliness and a simple human format is needed when operator involvement is required. Given the vast amounts of data across global networks in a wide variety of formats and sources common standards and protocols are useful along with a method to warehouse the data for historical and near real time access.

3. AS-IS AND TO-BE ARCHITECTURE

The limitations of today's space surveillance architecture in providing SSA are well known. Many users are effectively locked out of participation due to network and security concerns. Catalog creation and tasking is performed in batch mode. There are limited unified inter-mission protocols between related missions (e. SSA, missile defense, missile warning). There are coverage gaps causing lost items. Legacy hardware and software, unique to each sensor, is becoming increasingly costly to support. Given limited communications bandwidth some useful sensor data does not get processed. Too many data transfers happen manually. The system is non-real time and reactive. All of these limitations result in a fragile, less responsive, and potentially unaffordable system.

In a future architecture opportunities exist for unanticipated and ad-hoc users to be serviced and C2 centers to be integrated with legacy sensors and new sensors across global networks (Fig 2).

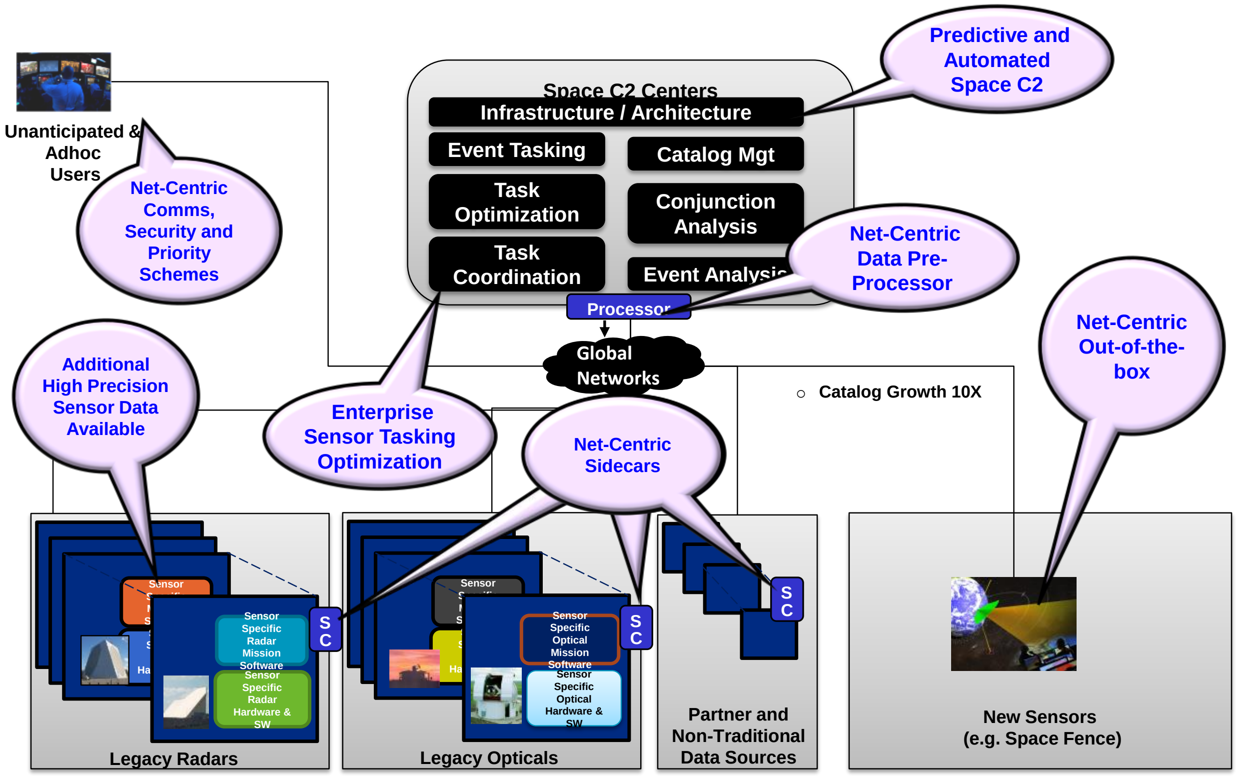

Fig 2. To-be space surveillance network architecture opportunities.

The future architecture is enabled by net-centric communications primarily via web services and defined security and priority schemes. Sidecars deployed at legacy sensor sites, partner, and non-traditional data sources unlock additional high precision data to be utilized. Data pre-processors translate seamlessly between differing formats to common data models. New sensors (e.g. Space Fence) can be designed net-centric "out-of-the-box" to interface with all other sensors. Sensor Sidecars can be deployed to legacy sensors to enable net-centric communications. As new sensors are added and upgraded, the network becomes more resilient and robust. This approach facilitates tasking to enable predictive and automated space C2 and SSA.

Enterprise mission benefits in this type of architecture are numerous. Tasking priorities for collections can be changes in near real time. Tasking accomplishment can be shared so limited resources can focus on other tasks. Un-cued and cued search patterns can be combined, with automated hand-offs, for better launch track custody. Unconventional sensors can be leveraged to provide higher precision data and fill gaps in legacy space surveillance networks. Multiple sensor data can be combined for multi-sensor characterization. Flight safety can be improved through improved precision and increased warning times. Closely space objects can be more rapidly detected. Maneuvers can be detected faster and lost objects recovered more quickly.

4. NET-CENTRIC EXPERIMENTAL TEST BED

The projected benefits of a net-centric to-be architecture may be intuitive. In addition, lab based SSN performance modeling can simulate similar improvements. However, real world implementation of such an approach is filled with challenges. To demonstrate the value of a future net-centric architecture an experimental test bed was built (Fig 3.)

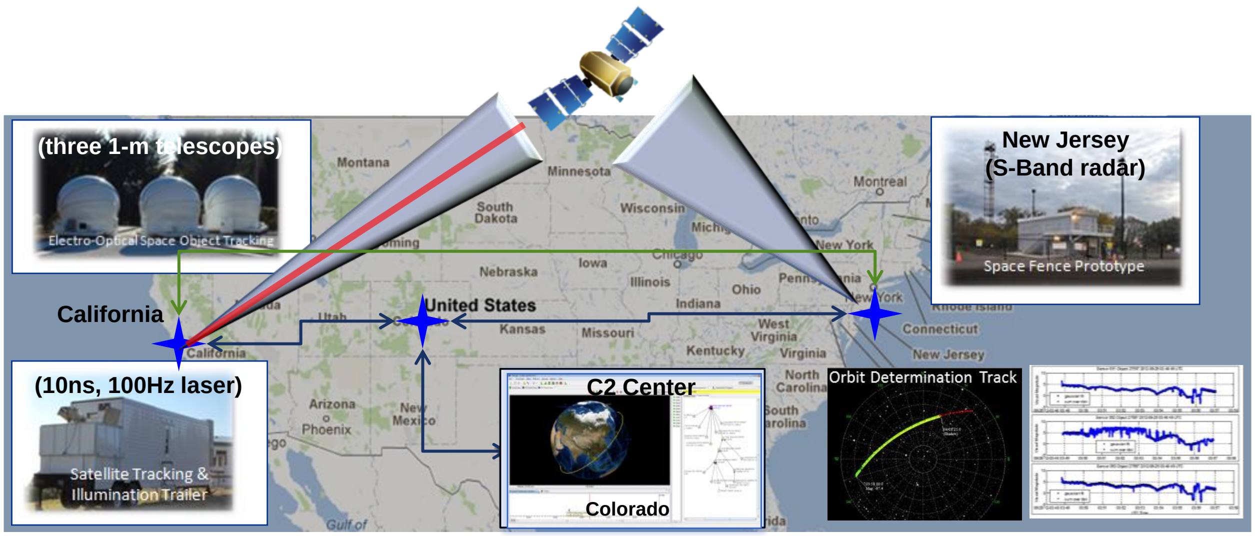

Fig 3. Net-Centric experimental test bed.

This test bed included three 1 meter class optical telescopes, a 10ns 100 Hz satellite tracking & illumination laser, and an S-band radar sensor. These five sensors, located throughout the United states, were net-centrically connected across a private network. An operations center, in a third location, provided integrated C2 and tasking. Connecting each node via web services was accomplished by defining a model of shared data and implementing open interfaces. Over several months' sensors were combined and experiments performed. Element sets were created from initial orbit determination. Space object and continuous custody tracking was performed via a hub-and-spoke tasking concept including some direct sensor-to-sensor tip-and-queue for higher resolution orbit determination. Multi-phenomenology radar and optical data fusion was performed for more accurate orbit updates, rapid target identification, and automated threat assessments.

5. CURRENT ENABLING EFFORTS

There are multiple efforts underway across the enterprise to make a similar to-be architecture a reality and start to reap the mission benefits. The current C2 center at the Joint Space Operations Center (JSpOC) is being modernized by the JSpOC mission system (JMS). The newest Space Fence radar will provide un-cued surveillance and tracking for tasked and high priority objects. The Space Fence system will be born configurable, net-centric, and open to seamlessly integrate with other SSA sensors and all authorized space users throughout global networks. Sidecars are being deployed and legacy sensors (e.g. GEODSS) to expose new and higher precision data to clients such as the JSpOC and NASIC. USSTRATCOM is developing and process and processor to transform to common formats non-traditional observations and element sets from international sensors into the JSpOC. They are also experimenting with coalition partners (e.g. Australia, Germany, United Kingdom, France, Canada) to develop tools, processes, and policies to increase SSA data sharing cooperation.

All of these efforts transition from a stove-piped to a space surveillance SoS architecture focused on net-centricity to improve SSA mission utility and performance. They maximize interoperability and resiliency. They also are designed to be affordable and reduce the cost of the network. Unlocked data is becoming available for use in new and innovative ways. This includes resident space object (RSO) characterization leveraging multiple phenomenology, improved catalog maintenance, and better collision avoidance. To be successful the technical as well as the non-technical challenges are being addressed along with coalition partners in the SSA mission area.