

Joint Space Operations Center (JSpOC) Mission System (JMS)

Maj Michael Morton, USAF

Chief, JSpOC Branch

Situational Awareness and C2 Division

Directorate of Requirements

Headquarters Air Force Space Command

Mr Timothy Roberts, DAFC

JSpOC Branch

Situational Awareness and C2 Division

Directorate of Requirements

Headquarters Air Force Space Command

US space capabilities benefit the economy, national security, international relationships, scientific discovery, and our quality of life. Realizing these space responsibilities is challenging not only because the space domain is increasingly congested, contested, and competitive but is further complicated by the legacy space situational awareness (SSA) systems approaching end of life and inability to provide the breadth of SSA and command and control (C2) of space forces in this challenging domain. JMS will provide the capabilities to effectively employ space forces in this challenging domain. Requirements for JMS were developed based on regular, on-going engagement with the warfighter. The use of DoD Architecture Framework (DoDAF) products facilitated requirements scoping and understanding and transferred directly to defining and documenting the requirements in the approved Capability Development Document (CDD). As part of the risk reduction efforts, the Electronic System Center (ESC) JMS System Program Office (SPO) fielded JMS Capability Package (CP) 0 which includes an initial service oriented architecture (SOA) and user defined operational picture (UDOP) along with force status, sensor management, and analysis tools. Development efforts are planned to leverage and integrate prototypes and other research projects from Defense Advanced Research Projects Agency, Air Force Research Laboratories, Space Innovation and Development Center, and Massachusetts Institute of Technology/Lincoln Laboratories. JMS provides a number of benefits to the space community: a reduction in operational "transaction time" to accomplish key activities and processes; ability to process the increased volume of metric observations from new sensors (e.g., SBSS, SST, Space Fence), as well as owner/operator ephemerides thus enhancing the high accuracy near-real-time catalog, and greater automation of SSA data sharing supporting collaboration with government, civil, commercial, and foreign entities. Continued success in JMS depends on continued support from across the space community. Key activities where community participation is essential include the C2 SSA Community of Interest (COI) development and refinement, creative strategies for faster, better, cheaper development, and defining the next set of capabilities.

1. INTRODUCTION

US space capabilities benefit the economy, national security, international relationships, scientific discovery, and our quality of life. Recognizing the special importance of space capabilities to the US military, the Commander of United States Strategic Command (CDRUSSTRATCOM) designated Commander, Joint Functional Component Command for Space (CDR JFCC SPACE) as the single point of contact for assigned military space operational matters, to include planning, tasking, directing, and executing space operations [1]. CDR JFCC SPACE conducts C2 of assigned and attached forces via the JSpOC at Vandenberg AFB, CA.

Accomplishing these Space responsibilities is challenging not only because the space domain is increasingly congested, contested, and competitive, but is further complicated because the legacy systems supporting JFCC SPACE are either approaching end of life or do not provide the breadth of capabilities necessary to provide the space situational awareness (SSA) and C2 of space forces in this challenging domain. The JMS was established to provide JFCC SPACE with the capabilities to effectively employ forces in this challenging domain.

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Today, the JSpOC uses 48 separate systems and applications to perform its mission. JMS will reduce that to 39 systems and will reduce SSA-specific systems and applications by 46%.

2. REQUIREMENTS

The requirements legacy for JMS is extensive. The space surveillance part of JMS has a long history within AFSPC; space surveillance processing requirements have been continuously refined and honed over the past 40 years. Capabilities for space surveillance and space defense have been developed since the mid-1960s. Systems such as the Delta and 427M computers supported space surveillance analysis from the early 1970s. The linear descent of JMS requirements starts with the Space Defense Operations Center (SPADOC) System Operational Requirements Document (SORD) in 1989 and results in a highly refined, well-understood set of SSA requirements. The legacy of C2 requirements is scarcely less rich, being based on the Air and Space Operations Center (AOC) C2 construct.

Requirements Document	Effective Date	Key Components
Space Defense Operations Center (SPADOC) System Operational Requirements Document (SORD)	1982	First attempt to establish dedicated stand-alone SSA processing from the Combined CMC 427M (Air, Space, and Missile processor)
SPADOC System Operational Requirements Document	1989	Initial requirements for dedicated SSA and Soviet threat processing capability. The delivered SPADOC system currently at the JSpOC
Cheyenne Mountain Upgrade (CMU) SORD	1992	Initial requirements for upgrading the Cheyenne Mountain missile, air, and space warning capabilities - combined Integrated Threat Warning/Attack Assessment (ITW/AA) requirements combining air, missile, and space threat assessment and warning.
CMU Operational Requirements Document (ORD)	1995	Transitioning documentation for the CMU to a newer format
NORAD/USSPACECOM Warfighter Support System (NUWSS) Mission Need Statement (MNS)	1998	High level requirements for CMU follow-on systems for missile, air, and space warning and space catalog ITW/AA capabilities for air, missile, and space capabilities refocused on a post-cold war environment
Space Control Capstone Requirements Document (CRD)	2000	Detailed document addressing unique space surveillance requirements for future follow-on systems to SPADOC
Space Surveillance Reference Document (SSRD)	2002	Written to develop and document space surveillance requirements for the Space Control CRD. Expected to be a source of detailed requirements for future requirements documents.
Combatant Commanders' Integrated Command and Control System (CCIC2S) ORD	2004	Covered complete upgrade to Cheyenne Mountain Operations Center (CMOC) ITW/AA capability – missile warning, air warning, space catalog, space attack warning and command and control
Joint C2 Joint Capabilities Document (JCD)	2006	High-level Joint Service document outlining the need for Joint C2
Space Control JCD	2006	High-level documentation of evolving space control requirements – SSA is addressed as a foundational requirements set.
Space C2 CDD	2008	Requirements for C2 of space forces, including mission-type orders and a user-defined operational picture. Met Air Force Requirements Oversight Council (AFROC) but didn't proceed to Joint Requirements Oversight Council (JROC)
Integrated Space Situational Awareness (ISSA) Capability	2008	Described system that would deliver a highly accurate space object catalog, space event analysis tools, space intelligence and

Requirements Document	Effective Date	Key Components
Description Document (CDD)		environment effects assessment tools, and threat warning capabilities. Did not go to AFROC.
Rapid Attack, Identification, Detection, and Reporting System. (RAIDRS) Block 20 CDD	2008	First attempt to derive possible space threats from non-SSA sources. This CDD only completed the initial review by a Pre-High Performance Team, (HPT) when funding was withdrawn from the project and the threat processing for threat identification and notification requirements were consolidated in the JMS CDD
JMS CDD	2010	Incorporated all major elements of the Space C2, ISSA and the RB20 CDDs requirements
<i>JMS Functional Requirements Document (FRD)</i>	<i>2011</i>	<i>A focused set of operational requirements extracted from the JMS CDD. Expedites replacing current legacy space surveillance processing capabilities and delivering initial C2 functions. Not a JCIDS document.</i>

Table 1. History of Space Surveillance, C2, and SSA Requirements Documents

There has been significant user involvement in generating the requirements documents shown in Table 1 above. For example, requirements for the NUWSS MNS and the CCIC2S ORD were based on a business process reengineering activity which included an entire CMOC operations crew for a year defining current operations processes and identifying needed system improvements to keep pace with changing operational environments. Development of the Space C2, ISSA, and JMS CDDs involved a wide variety of SSA stakeholders across the Services, both producers and consumers. The SSA requirements in particular required wide review and discussion due to the broad and diverse nature of both producers and consumers – from traditional AFSPC customers to other Services, NASA, and other US Government agencies.

Another key facet of SSA and Space C2 requirements development is the long-standing and extensive use of architectural models. Starting with the CCIC2S program and continuing through Space C2, ISSA, and ending up with JMS, DoD Architecture Framework (DoDAF) products facilitated requirements scoping and understanding and transferred directly to defining and documenting the requirements in the CDD.

The current JMS Enterprise Architecture (EA) provides elaboration of the capabilities defined in the JMS CDD. These include C2 of space forces, generation of actionable information about the space situation, and warning of threats against space systems. The JMS EA presents the vision for net-centric system services and provides JMS stakeholders the means to trace from “CONOPS-to-code” in managing the development of the integrated solution. It is the primary vehicle for communicating requirements to the development team and will aid in the design, development, testing, and training activities associated with fielding and operating JMS as capabilities are incrementally deployed. It will be continually refined and updated as system implementation unfolds.

A crucial piece of the JMS requirements process has been the use of the Information Technology (IT) Box requirements approach, illustrated in Fig 1. The IT Box was added to the Joint Capabilities Integration and Development System (JCIDS) to give IT programs the flexibility and planning to incorporate evolving technologies throughout a programs life cycle [3]. Importantly, this gives programs the authority to evolve requirements beyond initial minimum values. Using the IT Box approach will allow us to include as much capability in the initial increment as possible given the programmed resources. JMS will continue to evolve through future increments expanding the number of service and applications to address future requirements.

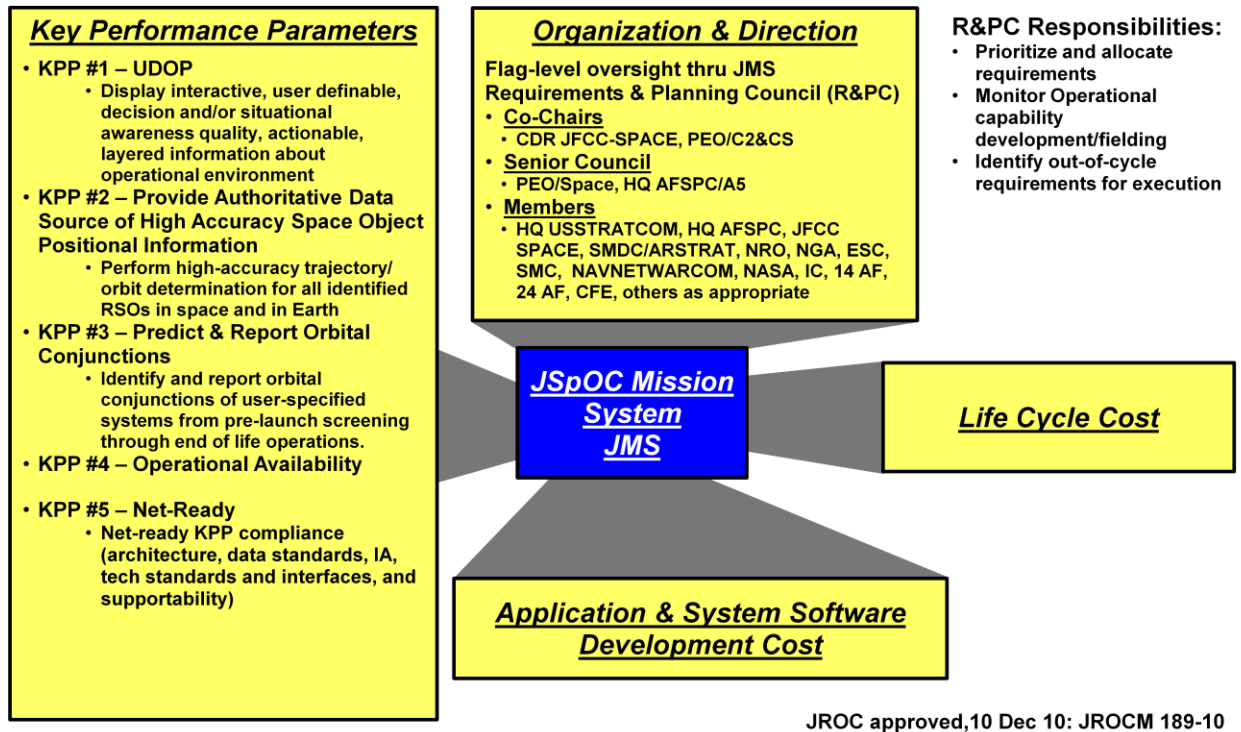


Fig. 1. The JMS IT Box

The purpose of the “IT Box” is to describe and visualize the overall bounds of an IT program in order to facilitate program initiation, as well as to reduce subsequent return trips to the JROC for approval of improved capabilities as the program is executed. The information in the chart was provided to the Joint Capabilities Board (JCB) and the JROC as part of the approval process for the JMS CDD.

Using an IT Box approach to requirements statement and approval has become a useful part of the JMS requirements process as the development and acquisition process continues to evolve. Due to the operational urgency in deploying JMS, the acquisition approach has had to become more responsive. The movement towards more use of existing prototypes and projects has forced AFSPC to reconsider the immediate emphasis in development and delivery; that is, the Command has had to examine its requirements and determine what can be delivered sooner based on existing prototype work.

3. WHERE WE ARE NOW

The JMS CDD was approved by the JROC in December 2010 [2], capping a multi-year, multi-document effort. The requirements in the CDD were vetted in two stages – once during development of the predecessor Space C2, ISSA, and RB 20 CDDs and again for the JMS CDD review and approval process. The Space C2 CDD was moved through the Joint Capabilities Integration and Development System (JCIDS) process to the AFROC and was approved in 2008. The ISSA CDD was ready for the AFROC but was stopped due to programmatic decisions that combined Space C2, ISSA, and RB 20 into the JMS program. The RB 20 CDD was on a later schedule and didn’t leave AFSPC for the same reason. However, the requirements were reviewed extensively both through an initial process that involved producers and consumers and (for Space C2 and ISSA) the formal JCIDS coordination process prior to reaching the AFROC. The JMS CDD completed the entire JCIDS process as it progressed to the JROC and approval.

The JMS acquisition approach has been modified to focus near-term efforts on replacing the current space surveillance processing system (SPADOC) and its supporting Astrodynamics Support Workstation (ASW). To meet this priority, the immediate focus of development efforts is to leverage and integrate prototypes and other research projects from the Defense Advanced Research Projects Agency, Air Force Research Laboratories, Space Innovation

and Development Center, and Massachusetts Institute of Technology/Lincoln Laboratories. To support this effort, HQ AFSPC produced a Functional Requirements Document (FRD), a subset of CDD requirements focused on the initial space surveillance processing need. The remaining JMS CDD requirements will be satisfied in later development releases. No new requirements documents will be needed.

In the meantime, JMS Capability Package (CP) 0 is now operational. CP 0's purpose is to develop a net-centric SOA infrastructure deployed to the GIG and provide initial infrastructure for future JMS capabilities. Some initial capabilities have been deployed within CP 0:

Architecture and Infrastructure	Data Consumed by JMS with Sources	Data Exposed by JMS CP 0
<ul style="list-style-type: none"> • Common modular infrastructure and core services • Security, messaging, data management, enriched collaboration, etc • Commercial off-the-shelf (COTS)-based middleware & Net-Centric Enterprise Services • Integrated, tailorable user workspaces • Space User Defined Operating Picture (UDOP) • Mission service development & integration focused on AFSPC mission threads • Force status and Sensor management 	<ul style="list-style-type: none"> • Source: COLT <ul style="list-style-type: none"> • Sensor Maintenance schedules • Source: Single Integrated Space Picture (SISP) <ul style="list-style-type: none"> • Element Set Data • Satellite system data • Space Order of Battle • Source: Defense Intelligence Space Order of Battle (DISOB) <ul style="list-style-type: none"> • Uncooperative launch schedules • Red/Grey on-orbit asset status • Source: Modernized Intelligence Database (MIDB) <ul style="list-style-type: none"> • Red/Grey ground target data • Source: Space Intelligence Preparation of the Battlespace (SIPB) <ul style="list-style-type: none"> • Country owner operator information • Source: SKIWEB <ul style="list-style-type: none"> • Events • Blog entries • Source: SPADOC <ul style="list-style-type: none"> • Cooperative launch data • T3 message • Source: nJET <ul style="list-style-type: none"> • Breakups • Confirmed maneuvers • Conjunctions • Reentries • SSN sensor data 	<ul style="list-style-type: none"> • Sensor maintenance schedule (COLT) <ul style="list-style-type: none"> • JMS developed web service • Event and sensor availability correlation (JMS) <ul style="list-style-type: none"> • Observation Schedule • Pass Schedule • High interest event data (nJET) <ul style="list-style-type: none"> • JMS developed web service • Cooperative launch information (SPADOC) <ul style="list-style-type: none"> • UDOP document (JMS) • JSpOC Crew Log (JMS) • Sensor characteristics (SPADOC, SISP) • Object owner/operator information (SIPB) • Analytical Services (Web ISSA) <ul style="list-style-type: none"> • Conjunction Assessment, Direct Ascent ASAT, Direct Energy, Overfly • Space Environmental Effects (SEEFs) • NTM mission data (BVI)

Table 2. CP 0 Content

4. BENEFITS TO THE SPACE COMMUNITY

JMS provides a number of benefits to the space community. Many of them are due to the use of modern software techniques, to include use of a service oriented architecture. Others stem from the use of modern hardware that enable high speed, high volume processing.

First, JMS capabilities will reduce the operational “transaction time” to accomplish key activities and processes. For example, JMS will have the capacity to perform 40,000 uncorrelated target (UCT) observations associations per day. This performance is necessary due to the greatly increased numbers of UCTs expected from new sensors such as the Space-Based Surveillance System (SBSS) and Space Fence. JMS will need to correlate these UCTs with cataloged RSOs quickly so as to be able to process further UCTs. Performance enhancements like these cascade through other capabilities, such as conjunction assessment screening. Currently, CA updates for each RSO as run as part of a shift update in an all-active-on-all screening. The run takes between six and eight hours, which limits the amount of time the crew on shift has to perform any analysis they are tasked for. In contrast, JMS is required to perform a “one-on-many CA” every time an RSO’s state vector is updated. Launch processing during flyout is similarly improved.

Second, JMS will process the increased volume of metric observations from new sensors (e.g., SBSS, SST, Space Fence) as well as owner/operator ephemerides. Table 3 shows the expected production of observations from the new sensors.

Sensor	Number of Observations per Day
Space Fence	750,000 per site X 2 sites planned = 1,500,000
Space Surveillance Telescope (SST)	21,600
Space-Based Surveillance system (SBSS)	14,000

Table 3. Observation Throughput From New Space Surveillance Sensors

The current SPADOC system has demonstrated the ability to process up to 710,000 observations per day with a 20,500 RSO catalog [5]; beyond this level, performance dropped significantly due to SPADOC’s throughput limitations. The expected Space Fence loading from one site will exceed this current maximum. Note that, during the test period, the average throughput was 410,500 observations per day during routine operations [5]. Today’s catalog is now almost 18,000 RSOs larger with a consequent increase in the number of observations in the SPADOC system. Comparing just the Space Fence obs production number to the high-load test capacity in Ref 5, it’s clear that the SPADOC system won’t be able to ingest all those observations. JMS addresses this deficiency.

Finally, it provides greater automation of SSA data sharing with government, civil, commercial, and foreign entities. The emergence of SSA data sharing and, more recently, the Combined Space Operations Center (CSpOC) concept, has increased the importance of providing SSA data to a much wider user community crucial. The CSpOC is intended to leverage existing alliances to provide for common defense and safety of space assets and shared command and control. SSA data sharing is an integral part of combines space operations and automating this and other shared capabilities is fundamental to enabling shared SSA and C2 with our Allies and partners.

5. WHAT WE NEED

To build on the success of CP 0, we need continued support from across the space community. Key activities where community participation is essential includes C2 SSA Community of Interest development and refinement; creative strategies for faster, better, and cheaper development; and defining the next set of capabilities.

Gen James Cartwright, the Vice-Chairman of the Joint Chiefs of Staff (VCJCS) recently set four challenges for the JMS program. These challenges go beyond simply replacing the current legacy JSpOC systems, such as SPADOC and CAVENet; they challenge the traditional view of consuming, processing and distributing a limited set of space data for a limited audience. They are:

- Develop the Combined Space Operations Center (CSpOC) using JMS as the core processing capability.

This challenge is intended to make sharing operational C2 of space forces with Allies a workable proposition. It includes accepting data from a wide variety of sources, processing it in an environment that allows maximum foreign participation, and providing a wide variety of SSA and C2 products to an international audience. Discussions with USSTRATCOM, JFCC SPACE, and 14 AF indicate that the key data handling, processing, and distribution considerations are addressed by JMS. For example, the JMS CDD contains all relevant requirements to enable Combined operations using JMS such as orbit determination, SSA event processing, and data handling security. The fundamental cross-domain security requirements have been extensively vetted by the SSA and JMS development community and are explicitly listed in the CDD

- Improve data integration, especially with ISR, missile warning, missile defense data

This is one of the key rationales for JMS – better, faster, broader data integration with a wider variety of data sources. In contrast to SPADOC, JMS is expected to not only be able to accept and integrate traditional SSN tracking data – including data from US missile warning radars – but also non-traditional formatted observations and ephemerides from a variety of sources, positional data derived from satellite telemetry, and tracking data from foreign sensors. In many cases, the data will be delivered net-centrally using the Net-Centric Sensors and Data Sources (N-CSDS) capability.

- Use of and interaction with foreign data providers

The CSpOC concept mentioned above also requires that the CSpOC's space surveillance processing system – JMS – be able to accept space surveillance data from foreign sensors and data sources. Designing JMS to meet the data integration challenge and instantiating effective cross domain solutions to protect data are key to meeting this challenge.

- Attain IT efficiencies

The current JSpOC capabilities are, in general, performed by IT systems that are several generations old. Current IT architectures will inherently provide significant IT efficiencies. Massively parallel and service-oriented architectures, modern programming languages, and modern hardware will all contribute to improving computational performance. DOD guidance requiring the use of the Defense Enterprise Computing Centers (DECC) cloud computing architecture will force use of state-of-practice systems and capabilities. The JMS CDD also forces use of modern IT due to performance criteria levied in the requirements. For example, look at the performance requirement for conjunction assessment:

The system shall screen a RSO following a state vector update, or at least every 24 hours, forecasting a five-day conjunction screening. The system shall screen a space catalog of 100,000 RSOs, or current catalog size (whichever is greater), in less than three hours.

Screening a 100,000RSO catalog within three hours means several hundred million orbit comparisons in that time. This requirement forces use of massively parallel processing and high-speed input/output. There are other areas where modern IT will be needed. A key area and one related to the CSpOC challenge above, is attribute-based access control (ABAC). This modern approach to personnel access to JMS will enable appropriate access by CSpOC operators based on their national policies and agreements.

6. CONCLUSION

JFCC SPACE needs a modern capability to command and control her assigned and attached space forces. Air Force Space Command has produced the JSpOC Mission System as the solution to the need. JMS has a long requirements pedigree – the need has been clear and consistent for over 30 years. As JFCC SPACE's responsibilities grow and transform the JSpOC into the CSpOC, the need for a modern, fully automated data processing solution becomes more and more obvious. JMS is starting to field a solution that already improves JSpOC crewmembers' operations today and lays the foundation for more improvements in the near term and for broader, further-reaching space C2 and SSA capabilities in the future. JMS will be a key contributor to mastering the increasingly congested, contested, and competitive space domain.

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ACRONYM LIST

AFROC	Air Force Requirements Oversight Council
AOC	Air and Space Operations Center
ASW	Astrodynamic Support Workstation
BVI	Battlespace Visualization Initiative
C2	Command and Control
CDD	Capability Development Document
COI	Community of Interest
COLT	Combat Capability Assessment Schedule (CCAS) On-Line Tool
COTS	Commercial Off-The-Shelf
DoDAF	DoD Architecture Framework
EA	Enterprise Architecture
GOTS	Government Off-The-Shelf
ISSA	Integrated Space Situational Awareness
JFCC SPACE	Joint Functional Component Commander for Space
JMS	JSpOC Mission System
JROC	Joint Requirements Oversight Council
JSpOC	Joint Space Operations Center
ORD	Operational Requirements Document
RAIDRS	Rapid Attack, Identification, Detection, and Reporting System.
SEEFS	SSA Environmental Effects Fusion System
SISP	Single Integrated Space Picture
SOA	Service Oriented Architecture
SORD	System Operational Requirements Document
SPADOC	Space Defense Operations Center
SPO	System Program Office
SSA	Space Situational Awareness
UDOP	User-Defined Operational Picture
CMOC	Cheyenne Mountain Operations Center
FRD	Functional Requirements Document
JCIDS	Joint Capabilities Integration and Development System
UCT	Uncorrelated Tracks
RSO	Resident Space Object
CSpOC	Combined Space Operations Center