

SPACE SITUATIONAL AWARENESS: IT'S NOT JUST ABOUT THE ALGORITHMS

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SSA – THE VISION



USAF Space Command saves an orbiting satellite from a direct collision with some space junk.mp4

INTRODUCTION

- February 2009 → Iridium 33 collided with Cosmos 2251
- Early 2007 → China tested an anti-satellite weapon against one of its own satellites
- Both events highlighted importance of accurate knowledge of the orbit of every object in space
- Space asset owners/operators need to know
 - *if* objects might come close to each other
 - *and* the probability that they might collide
- Current catalog > 20,000 objects



IN THE UNITED STATES ...

- The U.S. Air Force (**USAF**) is tasked with maintaining the space object catalog
 - collecting data from a multitude of different sensors
 - fusing the tracking data along with other data
- Trackable ephemerides are maintained at U.S. Strategic Command (**USSTRATCOM**) Joint Space Operations Center (**JSpOC**) using a set of algorithms known as the “Air Force Space Command (**AFSPC**) standards”
- The JSpOC Mission System (**JMS**) is current USAF program to modernize the JSpOC infrastructure used for maintaining the space object catalog

WHY AM I HERE?

- Early 2011 → AFSPC asked National Research Council (**NRC**) to evaluate capabilities of its astrodynamics standards
- TODAY: we review conclusions reached by the committee regarding some broader aspects of the AFSPC standards
 - architecture, interoperability, automation, and personnel issues
 - strategic, environmental, and cultural issues
- Conclusions regarding more technical issues (e.g. sensor measurement errors, estimation algorithms, covariance realism, etc) can be found in the committee's full report

SYSTEMS ISSUES - ARCHITECTURE

- The AFSPC astrodynamics standards are a set of algorithms defined in specific computer codes for specific hardware
- These Space Defense Operations Center (**SPADOC**) computer systems were traditional Air Force acquisitions that took decades to develop and deploy
 - developed as closed systems on proprietary hardware with customized software and operating systems
 - deeply embedded in the operational software in these systems, which were tightly configuration-controlled
- **HOWEVER!** ... they must function in a system-of-systems environment

SYSTEM-OF-SYSTEMS

- AFSPC software users ...
 - have different needs
 - do not have standard hardware
 - bury software in their own systems
- The Bottom Line
 - USAF must maintain compatibility with existing systems in new system development to continue supporting legacy customers
- Realizing limitations of SPADOC systems, AFSPC is developing a new, more flexible system called the JSpOC Mission System (**JMS**)
 - open, service-oriented architecture on commodity hardware



SYSTEMS ISSUES – INTEROPERABILITY

- What does this mean?
 - JSpOC orbital data products should be compatible with user software so that users can achieve same orbit accuracy as JSpOC
- Currently, 2 types of orbital data are published by JSpOC:
 - two-line element (TLE) sets, and
 - vector covariance messages (VCMs)
- However, users need satellite ephemerides at future times
 - that is, to propagate orbit state contained in TLEs or VCMs to the desired time since JSpOC does not publish ephemeris data
- The Bottom Line
 - to maintain interoperability, AFSPC must provide users same propagating algorithms as used in JSpOC operation system

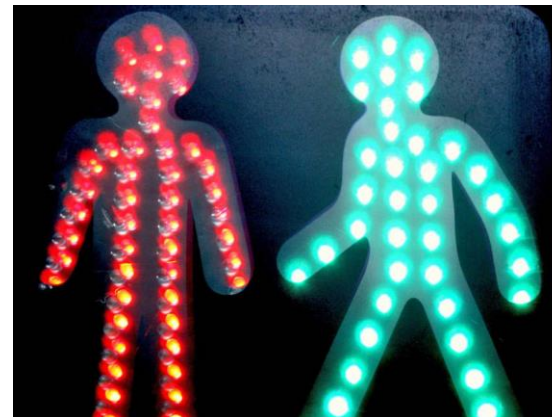
INTEROPERABILITY AND DATA SHARING

- Prior to the Iridium-33/Cosmos-2251 collision in 2009 → a culture of secrecy in the USAF regarding detailed and accurate information on space objects
 - low-fidelity TLEs made public for only a few national assets
 - TLE propagation insufficient for collision avoidance planning
- The reluctance of USAF to share higher-accuracy information likely stemmed from two concerns
 - such information could be used for anti-satellite targeting by US adversaries, and
 - knowledge about US tracking capabilities might be derived from such information



SYSTEMS ISSUES – PERSONNEL

- Although JSpOC duties have increased, many operations within the JSpOC appear to be insufficiently staffed
 - many are “one active military person deep”
 - military personnel are moved in and out every few years
- Shallowness of personnel coverage could seriously jeopardize ongoing mission-critical operations should a program or activity lead retire, resign, or be reassigned
- The Bottom Line
 - if routine processes were automated, they would be less vulnerable to personnel turnover



SYSTEMS ISSUES – AUTOMATION

- AFSPC astrodynamics algorithms developed to enable a SSA capability using military surveillance systems
 - Initial customer base consisted mostly of DoD and NASA
 - JSpOC services now sought by a wide variety of users
 - The ever-increasing space object catalog + the increasing number of space-faring entities = more frequent and more accurate conjunction assessments and launch screenings
- greatly increased the workload at the JSpOC

BROADER ISSUES

- The 2010 Nat'l Space Policy gives a context for the JSpOC
 - “[to use] SSA information ... to support national and homeland security, civil space agencies, particularly human space flight activities, and commercial and foreign space operations.”
- Problem: the JSpOC's duties are continuous and long term, but funding is available only annually and is unpredictable
- Implementation of the 2010 NSP will increase the demands placed on the JSpOC's programs
- The Bottom Line
 - funding levels will have to increase as well to support these increasing demands



Strategic Analysis and Vision

- The AFSPC and the JSpOC could benefit from a strategic analysis of space situational awareness-related activities
- With such an analysis
 - budget decisions and model development priorities made through a coherent, well-thought-out, and prioritized strategy
 - as personnel or funding changes occurred, guidance as to how efforts could be (re)structured or resources (re)allocated



Strategic Analysis and Vision

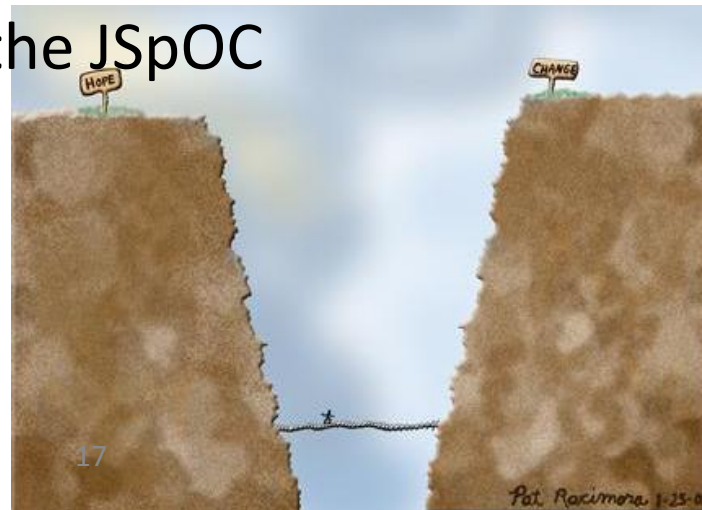
- Outcome of a strategic analysis = a vision that includes
 - short- and long-term objectives,
 - a schedule of benchmark achievements to be accomplished, and
 - priorities among them
 - noting budget realities will help focus its priorities
- Regular meetings involving JSpOC stake-holders and users
 - part of the vision's development, execution, and review,
 - provide opportunities for the JSpOC's activities and work to be communicated to the space community, and
 - allow algorithm / model developments to be peer reviewed

AFSPC Culture and Community Interaction

- Cultural changes within AFSPC will be necessary for the continued and future success of the JSpOC enterprise
- Current state of affairs: a significant disconnect between
 - advanced SSA research and actual practice per the current AFSPC standardized astrodynamics algorithms.
 - activities and needs of the user community and the activities of AFSPC / JSpOC
- Why the disconnect? A lack of ...
 - proper documentation of the AFSPC algorithms
 - interaction between the larger user communities and AFSPC
 - external technical peer review of AFSPC activities

The Great Divide

- Because of this disconnect, AFSPC
 - cannot take advantage of new ideas and processes that could improve the system and potentially increase efficiency
 - is unable to describe its current practices in terms of commonly used terminology within the larger space community
- This divide cuts both ways – also prevents the users from properly understanding and interpreting the information provided by AFSPC and the JSpOC
- How can we close this gap?



Peer Review

- Some groups and individuals within AFSPC might publish their work through a rigorous peer review process
 - A more common approach: networking at conferences and working within closed area communities
- There is little peer review by knowledgeable individuals outside the AFSPC community
- Lack of peer review means that:
 - the user community cannot obtain a detailed understanding of AFSPC algorithms that would allow it to better use its products
 - the AFSPC does not receive benefits that are typically associated with review of technical work by external subject experts

AFSPC Culture and Community Interaction

- It is important for AFSPC to foster relationships with a variety of external communities
 - to improve transitioning of technologies from research to operations
 - to stay informed about
 - the latest SSA research and development advances
 - the methods used by other organizations working on similar problems
 - other software tools that might be applicable to SSA activities
- IDEA: An advisory group that includes non-USAF members and meets regularly can be a mechanism to
 - review requirements
 - assess whether updates to requirements or models are needed
 - assess how well the JSpOC is meeting its strategic vision.

SUMMARY AND CONCLUSIONS

- Community needs and changes in national space policy are leading to increased demands on the AFSPC
- Architecture upgrades must handle current and unknown future needs → innovation will have to be encouraged
- Automation is key to addressing growing and diverse demands of user community and USAF staffing limitations
- Current Air Force staffing and personnel training shortfalls could threaten the viability of ongoing programs
- The AFSPC and the JSpOC could benefit from a strategic analysis of SSA-related activities

It's not science fiction.

It's what we do everyday.

Back-up Slides

3 FEATURES OF INTEROPERABILITY

- Data Products and Formats
 - current interfacing of catalog data requires a detailed understanding of algorithms and methods by all parties
 - time-consuming and expensive
 - A simpler form of interface other than the orbit state information, which must be propagated, would be helpful
 - a commonly used interface is *orbit ephemeris*
 - essentially the data on the position and velocity of an object as a function of time, usually written in a binary file

3 FEATURES OF INTEROPERABILITY

- Ingesting New Data
 - other countries and international commercial unions are beginning to develop their own space situational awareness tracking networks
 - substantial improvements to current U.S. SSA network might be obtained by accessing data from these networks

Peer Review

- Of course, peer review of work performed by AFSPC may not be appropriate in all situations
 - security concerns may prevent peer review by the un-cleared community → so workshops may sometimes be better suited for the presentation of new developments
- However, peer review can still exist in these cases and still represents an effective method for ensuring that best practices are pursued, developed, and maintained
- Adoption of peer review by AFSPC will help ensure the proper application of scientifically tested and accepted results, underlying intricacies, and other key developments.

SUMMARY AND CONCLUSIONS

- Community needs and changes in national space policy are leading to increased demands on the AFSPC
 - number of objects in space and number of operators are increasing, as is challenge of maintaining accurate ephemerides of these objects
- Architecture upgrades must handle current and unknown future needs → innovation will have to be encouraged
 - system must (1) emphasize interoperability, AND (2) decouple itself from users so upgrades can be implemented without affecting users
- Automation is key to addressing growing and diverse demands of user community and the limitations of USAF staffing
 - architecture of a new system must consider the evolving opportunities for automation, also because of likely increases in AFSPC staff workloads stemming from the continuing growth of the orbital population

SUMMARY AND CONCLUSIONS

- Current Air Force staffing and personnel training shortfalls could threaten the viability and scope of ongoing programs
- Culture change to emphasize openness should continue—
 - in the transparency of its algorithms,
 - in the interaction with the user and scientific communities, and
 - in its provision of sensor tracking data to scientific community for testing algorithms
 - Current restrictions are inhibiting algorithm development and innovation with little benefit to national security
- The AFSPC and the JSPOC could benefit from a strategic analysis of SSA-related activities, including
 - algorithm and model development and upgrades,
 - and operations and personnel management
 - without such analysis, the USAF could be making budget and model development decisions in an uncoordinated way