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

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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
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
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
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
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
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.