



Continuing Kepler's Quest

Assessing Air Force Space Command's
Astrodynamics Standards

*Summary points from the final report of the
Committee for the Assessment of the U. S. Air
Force's Astrodynamics Standards*

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Continuing Kepler's Quest—Summary

- 1. AFSPC's current system has done an adequate job, but demands are increasing**
 - *Where drag is not important, the key limitations are not connected to algorithm accuracy, but to sensor tracking data*
 - *Where drag is important, the key limitation is our understanding and modeling of the atmosphere*
- 2. AFSPC must be more open/transparent in the creation and dissemination of its algorithms and products**
 - *Some users need more advanced products and a deeper understanding of the products provided to use them*
 - *Other users need standard, legacy products and can't accommodate much change*
 - *AFSPC itself needs peer review of its products and more interaction with the broader S&T community*
 - *The AFSPC Astrodynamics Advisory Committee needs internal and external SMEs*
- 3. The Air Force needs to take advantage of recent research advances and invest in new initiatives**
 - *Modeling of drag and other forces*
 - *Better data association methods*
 - *Understanding and dissemination of errors*
 - *Application of modern dynamical systems theory*
 - *Development of classical analytical techniques*
 - *Investigation of new algorithms, new techniques*
- 4. The Air Force should continue the JMS program with a modern, modular, and extensible architecture**
 - *Needs to accommodate different user needs in less manually intensive manner*
 - *Needs to accept owner/operator provided tracking data and pro forma maneuvers*
 - *Needs to provide a platform to more easily accommodate system evolution and user defined products.*
- 5. The Air Force should review its personnel policies and staffing plans for SSA and increase automation**
- 6. AFSPC should conduct a strategic analysis of its SSA activities with respect to the National Space Policy**

AFSPC's current system has done an adequate job, but demands are increasing

Community needs and changes in national space policy are leading to increased demands. The number of objects in space and the number of operators are increasing and so too is the challenge of maintaining accurate ephemerides of these objects, as well as the difficulty of communicating information about the objects.

- For objects not experiencing significant drag, the primary limitation in the current system is not the accuracy of the algorithms, but rather the quantity and the quality of the sensor tracking data. The key system limitations are current sensor coverage, understanding of the quality of the observations, and the challenge of fusing disparate data from different systems and phenomenology. Understanding the quality or statistics of the observations is necessary for obtaining a realistic covariance, which is needed for computing an accurate probability of collision.
- For objects experiencing drag, such as near-Earth orbiting satellites, another limitation is understanding and modeling of the atmosphere.

AFSPC must be more open/transparent in the creation and dissemination of its algorithms and products

While recognizing security issues, Air Force Space Command should become more open and transparent in the creation and dissemination of its algorithms and products. Specifically:

- The newly created AFSPC Astrodynamics Advisory Committee should be modified to include a balance of internal (e.g., Air Force Research Laboratory, DARPA, Missile Defense Agency, etc.) and external subject matter experts to encourage the introduction of new approaches and new ideas. Examples of external members include representatives from other federal agencies (e.g., NASA, NOAA, NRO, etc.), research centers (such as federally funded research and development centers), commercial industry, and academia
- AFSPC should create a process and an infrastructure to identify and incorporate improvements into the JSpOC and a way to evaluate candidate improvements (for example, test beds, benchmarks)
- AFSPC should expand opportunities for astrodynamics and computation specialists to participate in improving the algorithms used in JMS. This expanded participation should be achieved by advocating for research initiatives and engaging members of the research community to serve in peer review capabilities, and by appropriate sharing of data
- The JSpOC should provide a database containing a reasonable amount of sensor tracking data that would be available to the research community for the development and validation of new algorithms that support space situational awareness

AFSPC must be more open/transparent in the creation and dissemination of its algorithms and products

The Air Force should review its information distribution policies and work with external customers toward the objectives of (1) more freely sharing data products, algorithms, and documentation and (2) ensuring that such information is timely, accurate, useful, and actionable. Items historically restricted because of ITAR, classification, or other national security or liability concerns should be reevaluated. While the committee recommends a system-wide review, it also recommends consideration of the following specific examples:

- Examination of whether there is a valid justification for restricting the distribution of SGP4
- Distribution of propagated ephemerides, which would provide users with greater insight into pending conjunctions and facilitate the further de-coupling of Air Force systems from those of its external customers
- Publication of collision probability, which would benefit some members of the owner/operator conjunction assessment community

AFSPC must be more open/transparent in the creation and dissemination of its algorithms and products

JSpOC algorithm and model developers should fully communicate the results of their work and their development activities, such as in appropriate peer-reviewed publications and conferences, so that users gain greater insight into and understanding of the underlying assumptions associated with catalog activities.

The Air Force needs to take advantage of recent research advances and invest in new initiatives

Air Force Space Command should work with Air Force Material Command, NASA, NOAA, and other community members to create and expand research programs in the astrodynamics R&D community through AFRL to:

- Measure, model, and forecast conditions in the upper atmosphere
- Develop and implement improved nongravitational models for solar radiation pressure and atmospheric drag
- Develop and implement continued improvements to gravitational modeling
- Investigate new data association methods, especially for breakups in low Earth orbit and geostationary Earth orbit clusters
- Develop a program to better characterize sensor level errors including biases to improve the input to orbit determination
- Improve nonlinear estimation and the representation of uncertainty to ensure realism in estimations of uncertainty (covariance)
- Investigate modern methods of dynamical systems to develop new ways to analyze and handle astrodynamics challenges
- Continue to develop and improve classical analytical techniques for the efficient description and prediction of satellite motion
- Explore new techniques to meet community needs

The Air Force should continue the JMS program with a modern, modular and extensible architecture

The Air Force should continue with the design and development of the service-oriented architecture-based JSpOC Mission System and employ modern, modular, and extensible hardware and software architecture design practices to ensure the following capabilities:

- Insertion of new technologies, capabilities, and algorithm modifications while preserving interoperability with the external community
- Hardware and software scalability including explicit adaptation to parallel computing
- Rigorous configuration management practices to ensure backward compatibility, change control, and full documentation
- Accommodation and exploitation of nontraditional data types, including object meta data, new sensor data types, and owner/operator ephemerides and operations information

The Air Force should create an open-architecture, application programming interface to facilitate the bidirectional exchange of a wider array of data, algorithms, and documentation with a growing number of external entities.

The Air Force should review its personnel policies and staffing plans for SSA and increase automation

The Air Force should automate routine processes to the extent possible to minimize manual intervention, decrease operational workload, and reduce possibilities for error.

The Air Force should review personnel recruiting, retention, promotion, and training policies and practices so that DOD military, civilian, and contractor staffing levels and expertise are budgeted for and maintained in space situational awareness mission-critical functions including the JSpOC.

AFSPC should conduct a strategic analysis of its SSA activities with respect to the National Space Policy

AFSPC should conduct a strategic analysis of its space situational awareness-related activities, particularly as they pertain to the directives of the new National Space Policy.

AFSPC should further develop the vision for the future of the JSpOC Mission System and the system of systems based on the new National Space Policy.

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