INFUSION OF CCSDS FLIGHT DYNAMICS STANDARDS IN THE NASA AMMOS GROUND SYSTEM SOFTWARE

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The CCSDS (Consultative Committee for Space Data Systems) is affiliated with the International Organization for Standardization (ISO). CCSDS has developed a large number of space data related international standards that have been used by hundreds of space missions since its creation in 1982 (reference [1]). A component of this body of international standards is several standards in the area of flight dynamics developed by the CCSDS Navigation Working Group. Some of these flight dynamics standards have been implemented into the NASA Advanced Multimission Operations System (AMMOS) ground system software (reference [2]).

Specifically, the CCSDS Navigation Working Group is chartered to provide "development of technical flight dynamics standards (orbit/trajectory, attitude, tracking, maneuver, pointing, orbital events, etc.)." Since 2004, several standards have been published in these areas: the Orbit Data Messages, Attitude Data Messages, Tracking Data Message, Conjunction Data Message, and Navigation Data Messages XML Specification. Several other standards are currently in various stages of development. The development, history, and features of these standards have been featured in three previous ISSFD papers (references [3], [4], [5]).

NASA's AMMOS provides most of the functions needed to support the design, implementation, and operation of a Mission Operations System (MOS), consisting of multimission tools and services for the activities of mission planning/sequencing; command/telemetry processing; spacecraft control/analysis; instrument data processing; data management; and the focus of this paper, mission design/navigation. AMMOS is based on a simple idea: build the core elements of an MOS that are common to multiple missions once rather than having individual missions duplicate the effort, then adapt the core elements to account for the specific needs of individual missions. The foundation of common multimission tools and services enables mission customers to operate at a lower total cost to NASA, with comparable or higher reliability and performance and lower risk, than would be the case if these customers developed their own unique tools and services. The AMMOS program provides substantial funding for the development and maintenance of NMD software that is utilized in preliminary mission design, launch analysis, navigation planning, tracking data planning, trajectory design/optimization, orbit determination, optical navigation, maneuver design/reconstruction, entry/descent/landing analysis and design, and real time event monitoring. The AMMOS has been discussed frequently in a wide variety of Space Ops papers, but never previously at ISSFD.

While the AMMOS is a mature "system of systems" that has existed since the late 1980's, it is continuously evolving and being improved. Since 2004, the use of CCSDS standards in the AMMOS/NMD software has been increasing. The evolution of AMMOS guided by a set of nine key architecture principles formulated by the AMMOS Program Office. Among these principles are several that directly apply to the infusion of international standards:

- Use of Common Services: By their very nature, international standards imply a degree of commonality that is central to the AMMOS concept.
- Customer Focus: Space operations organizations that are customers of the AMMOS are nearly always focused on cost reduction, and standards have a history of reducing non-recurring engineering costs.
- Learn from Experience: The development of international standards is informed by the experience of the those involved in the development
- Interoperability: One of the main purposes of standardization is to promote interoperability.

The AMMOS primarily supports NASA's deep space and astrophysics missions, however, the AMMOS/NMD software has been utilized in support of many international missions including ESA's Mars Express, Venus Express, and ROSETTA; JAXA's SELENE, Hayabusa-1, Hayabusa-2, and Planet-C; and ISRO's Chandrayaan-1 and Mars Orbiter Mission. Part of what makes such support possible in an efficient manner is the infusion of CCSDS international standards into the AMMOS/NMD software. Of the CCSDS flight dynamics standards, the Orbit Ephemeris Message and Tracking Data Message have been the most thoroughly infused and most utilized standards; a prototype of the Conjunction Data Message has also been created.

The proposed paper will discuss how the CCSDS flight dynamics standards have been implemented in the AMMOS Navigation and Mission Design (NMD) software, and how they are available for use in a multimission, multiagency environment. Provided will be brief overview of the CCSDS, the CCSDS standardization process, the CCSDS Navigation Working Group and its developed standards, the NASA/AMMOS ground data system and its NMD software, the infusion of the CCSDS flight dynamics standards into the AMMOS/NMD software, and a brief history the usage of these standards in flight operations. Primary ISSFD areas of interest addressed will be application of international standards in the areas of flight dynamics operations (principally tracking and orbit determination).

References

[1] Consultative Committee for Space Data Systems web site: http://www.ccsds.org

[2] NASA Advanced Multimission Operations System web site: https://ammos.jpl.nasa.gov

[3] Martin-Mur, T., et al., “Exchange of Standardized Flight Dynamics Data”, Proceedings of the 18th International Symposium on Space Flight Dynamics, Munich, Germany, 2004.

[4] Van Eepoel, J., Berry, D.S., et al., “Standardizing Navigation Data: A Status Update”, Proceedings of the 20th International Symposium on Space Flight Dynamics, Annapolis, MD, USA, 2007.

[5] Berry, D.S., “Progress in Standardizing Flight Dynamics Data Exchange” , Proceedings of the 23rd International Symposium on Space Flight Dynamics, Pasadena, CA, USA, 2012.