

Standard

Aerodynamics – Propagation Specifications, Technical Definitions, and Recommended Practices

American National Standard

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Aerodynamics—Propagation Specifications, Technical Definitions, and Recommended Practices

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American Institute of Aeronautics and Astronautics

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Abstract

This document provides the broad aerodynamics and space operations community with technical standards and lays out recommended approaches to ensure compatibility between organizations. Applicable existing standards and accepted documents are leveraged to make a complete—yet coherent—document. These standards are intended to be used as guidance and recommended practices for aerodynamics applications in Earth orbit where interoperability and consistency of results is a priority. For those users who are purely engaged in research activities, these standards can provide an accepted baseline for innovation.

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Foreword

One of the most significant scientific and technological accomplishments since the beginning of the space era is the successful deployment of space systems and the necessarily ingenious application of astrodynamics to support these systems. Astrodynamics has been developed by extending the knowledge accumulated since the first recorded investigations into the motions of heavenly bodies.

The outgrowth of civilian and military rocket system developments has led to the establishment and implementation of numerous space systems, related physical models, and astrodynamics theories, algorithms, and procedures. With the proliferation of different and independent space systems and advancements in technology and astrodynamics sciences, the interfacing needed to ensure interoperability within space operations has become more complex.

The ASD/CoS charter is to *“Identify, establish, and publish astrodynamics standards, guides, and recommended practices to ensure the continued enhancement of aerospace-wide efficiency and productivity to meet the scientific, technological and operational demands.”* To accomplish the chartered goals, the strategy is to:

- Research and establish the up-to-date status of the astrodynamics standards and practices currently available.
- Identify scientific, technological, and operational programs and system elements that have a need for astrodynamics standards and consensus practices.
- Perform in-depth analyses of the existing standards and practices and develop recommendations for possible adoption and/or modifications as AIAA standards or practices.
- Develop definition of standards and adopt formal guidelines and requirements of standardization.
- Recommend and propose the areas where new standards, guides, and recommended practices are required. Additionally, identify areas where standards are currently not appropriate.
- Identify, develop, and document candidate new astrodynamics standards, guides, and recommended practices for consideration.
- Perform independent verification and validation, including solicitation of in-depth reviews within industry, academia, and government laboratories for all proposed and documented standards, guides, and recommended practices.
- Submit proposed standards, guides, and recommended practices to the Standards Executive Council for approval and publication.
- Maintain all relevant technical materials and standards.
- Maintain technical coordination with scientific and astrodynamics communities nationally and internationally.

To help provide coherent direction for its activities in identifying and selecting topics, the committee approved a set of criteria. Fundamentally, the committee has taken the view that the objective of an astrodynamics standard is to provide guidance on practices that will ensure and enhance interoperability between organizations. Following are the criteria that have been useful in selecting topics that achieve this objective:

- Scope: Does the topic relate to processes associated with describing the motion of orbiting bodies? Although rather evident, the committee has occasionally found itself considering topics that really fall within the purview of a different area or responsibility.

- Utility: Is the topic of wide concern to the majority of the astrodynamics community, and does it deal with the process of information exchange among members of that community? If a topic is of only minor relevance to the community, developing standards may not be particularly useful. Thus, such standards should aim at facilitating the broadest information exchange across the community.
- Alternatives (Ambiguity): Does the topic involve alternative ways of performing a process or accomplishing an objective? In cases where multiple alternatives exist, we tried to give guidance on the variability of applications, indicating what the community consensus is. Where only one commonly accepted alternative existed, we determined if there was any potential confusion in its application.
- Practicality: Can agreement be achieved on standardization? Despite meeting all the above criteria, insufficient consensus may demand not treating the topic.

The ASD/CoS initial effort, *Recommended Practice, Astrodynamics—Part I*, was chaired by Dr. Joseph J. F. Liu. A *Part II* document was initiated by Dr. Hamilton Hagar, but was never officially finished in its original form. The current document supersedes the *Part I* and *Part II* and forms a unified document, including specific treatment of standards and recommended practices. The current version focuses on propagation for Earth orbiting satellites.

At the time of approval, the members of the AIAA Astrodynamics Committee on Standards were:

David A. Vallado, Chair	Center for Space Standards & Innovation
Rich Burns	NASA
David Finkleman	Center for Space Standards & Innovation
Michael Gabor	Northrop Grumman
Felix Hoots	The Aerospace Corporation
T.S. Kelso	Center for Space Standards & Innovation
Steve Nerem	University of Colorado
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Glenn Peterson	The Aerospace Corporation
Paul Schumacher	U.S. Air Force Research Laboratory
John H. Seager	Analytical Graphics, Inc.
P. Kenneth Weidemann	University of Virginia
Fred Stone	Space Infrastructure, Inc.
Jerome R. Vetter	Johns Hopkins University Applied Physics Laboratory

The above consensus body approved this document in August 2010.

The AIAA Standards Executive Council (Vice President, Wilson Felder, Chairman) accepted the document for publication in August 2010.

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Introduction

The American Institute of Aeronautics and Astronautics (AIAA) Astrodynamics Committee on Standards (ASD/CoS) has developed this open set of voluntary standards and recommended practices applying to propagation of orbits about the Earth. This document provides the broad astrodynamics and space operations community with technical standards and lays out recommended approaches to ensure compatibility between organizations. Applicable existing standards and accepted documents are leveraged to make a complete—yet coherent—document. These standards are intended to be used as guidance and recommended practices for astrodynamics applications in Earth orbit where interoperability and consistency of results is a priority. For those users who are purely engaged in research activities, these standards can provide an accepted baseline for innovation.

This document describes the technical specifications and requirements that comply with established and accepted guidelines, practices, and technical intent for propagation in Earth orbit. There are numerous examples of recommendations for implementation and approved variations. Accompanying resources will include algorithm and software code examples, as well as corresponding test cases, to establish confidence in the resulting products.

The remainder of this document is organized to provide a complete picture of the Earth orbit propagation application:

- Section 4 provides a glossary of terms used in the standards document.
- Section 5 lists the accepted and agreed upon units, constants, coordinates, and time systems, as well as consideration of conversions and precision.
- Section 6 describes the accepted force models used for Earth orbit propagation applications. These force models include gravity, atmospheric drag, third-body perturbations, solar radiation pressure, tides, and other perturbative forces.
- Section 7 describes application of analytical, numerical, and semianalytical approaches to orbit propagation.
- Section 8 summarizes the references used in the development of this set of standards and Annex A provides informative references.