TECHNICAL REPORT

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Space systems — Avoiding collisions with orbiting objects

Systèmes spatiaux — Évitement des collisions avec les objets en orbite

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

This Technical Report describes the work flow for perceiving and avoiding collisions among orbiting objects, data requirements for these tasks, techniques that can be used to estimate the probability of collision and guidance for executing avoidance maneuvres.

The process begins with the best possible trajectory data, provided by satellite operators or sensor systems developed for this purpose. The orbits of satellites must be compared with each other to discern physically feasible approaches that could result in collisions. The trajectories so revealed must then be examined more closely to estimate the probability of collision. Should a collision be likely within the criteria established by each satellite operator, the spectrum of feasible maneuvers must be examined.

There are several different approaches to conjunction assessment. All have merits and deficiencies. Most focus on how closely satellites approach each other. This is often very uncertain since satellite orbits generally change more rapidly under the influence of non-conservative forces than observations of satellites in orbit can be acquired and employed to improve orbit estimates. Spacecraft operators require the fullness of orbit data in order to judge the credibility and quality of conjunction perception. This information includes the moment of time of the last elaboration of orbit (the epoch) and the standard time scale employed, state vector value or elements of orbit at this moment of time, the coordinate system description that presents the orbital data, the forces model description that was used for orbital plotting, and information about the estimation errors of the orbital parameters. Essential elements of information for this purpose are specified in ISO 26900.

There are also diverse approaches to estimating the probability that a close approach might really result in a collision. This is a statistical process very similar to weather forecasting. Meteorologists no longer make definitive predictions. They provide the probability of precipitation, not whether it will rain. All conjunction assessment approaches are in some way founded in probabilities. Probability of collision is also a highly desirable element of data. It must be accompanied by metadata that allows operators to interpret the information within their own operational procedures.

How near satellites might be to each other and the probability they might collide if they were that close are only two discriminants of potentially catastrophic events. Since the objective is that the satellite survives despite many potential close approaches, cumulative probability of survival is also important information. Responding precipitously to the close approach nearest at hand might only delay the demise of the satellite or even contribute to a subsequent more serious event. The evolution of orbits toward close approaches and the cumulative probability that a satellite might survive for a period of time are also important.

Finally, the state of each of the conjunction partners, their ability to maneuver or otherwise avoid contact, and the outcomes of past events that are similar guide courses of action.

Space systems — Avoiding collisions with orbiting objects

1 Scope

This Technical Report is a guide for establishing essential collaborative enterprises to sustain the space environment and employ it effectively. This requires diligent collaboration among all who operate satellites.

This Technical Report describes some widely used techniques for perceiving close approaches, estimating collision probability, estimating the cumulative probability of survival, and manoeuvring to avoid collisions.

NOTE Satellite operators accept that all conjunction and collision assessment techniques are statistical. All suffer false positives and/or missed detections. The degree of uncertainty in the estimated outcomes is not uniform across all satellite orbits or all assessment intervals. No comparison within a feasible number of test cases can reveal the set of techniques that is uniformly most appropriate for all.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TR 11233, *Space Systems — Orbit determination and estimation — Process for describing techniques*

ISO 26900, *Space data and information transfer systems — Orbit data messages*

ANSI/AIAA S-131-2010, *Best Practices in Astronautics: Propagation*

AIAA G-043-1992, *Guide to Developing Operational Concepts*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
conjunction
apparent meeting or passing of two or more objects in space

3.2
collision
act of colliding; an instance of one object striking another

3.3
covariance
measure of how much variables change together

Note 1 to entry: For multiple dependent variables, a square, symmetric, positive definite matrix of dimensionality $N \times N$, where N is the number of variables.

3.4
encounter plane
plane normal to the relative velocity at the time of closest approach

3.5
false alarm
statistical Type I error, when a statistical test fails to reject a false null hypothesis

