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Space systems — Avoiding collisions among orbiting objects

Systèmes spatiaux — Évitement des collisions entre objets en orbite

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

This second edition cancels and replaces the first edition (ISO/TR 16158:2013), which has been technically revised.

The main changes compared to the previous edition are as follows:

— improved figures for clarity;

— added plot of maximum probability;

— switched to “decimal comma” per ISO editorial rules;

— simplified operational concepts figures;

— added informative annexes containing collision probability relational nomograms;

— added collision probability topology in both graphical and tabular look-up formats;

— reordered the bibliography.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

This document describes the workflow 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 manoeuvres. Diligent collaboration is strongly encouraged among all who operate satellites.

The process begins with the best possible trajectory data, provided by satellite operators or sensor systems developed for this purpose. The orbits of satellites can be compared with each other to discern physically feasible approaches that can result in collisions. The trajectories so revealed can then be examined more closely to estimate the probability of collision. Where the possibility of a collision has been identified within the criteria established by each satellite operator, the spectrum of feasible manoeuvres is 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 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 can 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 can be accompanied by metadata that allows operators to interpret the information within their own operational procedures.

How near satellites can be to each other and the probability they can 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 can only delay the demise of the satellite or even contribute to a subsequent more serious event. The evolution of close approaches and the cumulative probability that a satellite can survive are also important.

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

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Space systems — Avoiding collisions among orbiting objects

1 Scope

This document is a guide for establishing essential collaborative enterprises to sustain the space environment and employ it effectively.

This document 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

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
collision
act of colliding; instance of one object striking another

3.2
conjunction
apparent meeting or passing of two or more objects in space

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
ephemeris
time-ordered set of position and velocity within which one interpolates to estimate the position and velocity at intermediate times

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3.6
false alarm
statistical Type I error, when a statistical test fails to reject a false null hypothesis

3.7
interface control document
ICD
specification that describes the characteristics that can be controlled at the boundaries between systems, subsystems, and other elements

3.8
operational concept
roles, relationships, and information flows among tasks and stakeholders and the way systems and processes will be used

3.9
orbital elements
parameters that describe the evolution of the trajectory and which can be used to estimate the trajectory in the future

4 Collision avoidance workflow

The avoidance process begins with orbit data, the content of which is specified in ISO 26900. The data can be provided by collaborating satellite operators and from observers who are capable of viewing satellites. It is also important to know the nature of each object if possible. This information includes size, mass, geometry, and the operational state (e.g. active or inactive). Finally, collision probability estimates consider the inevitable imprecision associated with orbit determination and other hypotheses and measurements. Figure 1 depicts this top-level workflow.

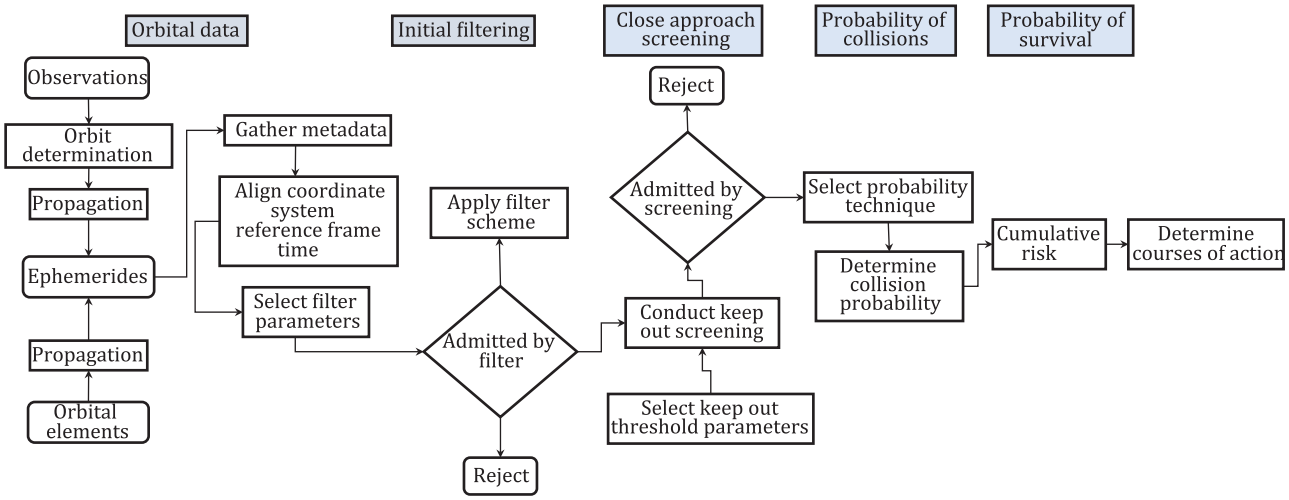

Figure 1 — Top-level collision avoidance workflow

5 Perceiving close approaches

5.1 Orbit data

5.1.1 Inputs

Inputs to conjunction assessment are principally data that specify the trajectories of the objects of interest. These are one of three types of information: orbital elements, ephemerides, or observations of satellites. Orbital elements in this context include parameters that describe the evolution of the

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