



BSI Standards Publication

Space systems — Avoiding collisions with orbiting objects

National foreword

This Published Document is the UK implementation of ISO/TR 16158:2013.

The UK participation in its preparation was entrusted to Technical Committee ACE/68/-/3, Space systems and operations - Operations and Ground Support.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2014. Published by BSI Standards Limited 2014

ISBN 978 0 580 69952 8

ICS 49.140

Compliance with a British Standard cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 28 February 2014.

Amendments issued since publication

| Date | Text affected |
|------|---------------|
|------|---------------|

TECHNICAL
REPORT

PD ISO/TR 16158:2013

ISO/TR
16158

First edition
2013-12-01

**Space systems — Avoiding collisions
with orbiting objects**

Systèmes spatiaux — Évitement des collisions avec les objets en orbite



Reference number
ISO/TR 16158:2013(E)

© ISO 2013



COPYRIGHT PROTECTED DOCUMENT

© ISO 2013

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

| | |
|---|-----------|
| Foreword | iv |
| Introduction | v |
| 1 Scope | 1 |
| 2 Normative references | 1 |
| 3 Terms and definitions | 1 |
| 4 Collision avoidance workflow | 2 |
| 5 Perceiving close approaches | 3 |
| 5.1 Orbit data..... | 3 |
| 5.2 Initial filtering..... | 4 |
| 5.3 Eliminating infeasible conjunctions..... | 4 |
| 6 Determining potential collisions for warning and further action (close approach screening) | 5 |
| 6.1 Symmetric keepout..... | 5 |
| 6.2 Bounding volume keepout..... | 5 |
| 6.3 Probability techniques..... | 6 |
| 6.4 Maximum probability..... | 7 |
| 6.5 Bounding volume based on probability..... | 8 |
| 6.6 Comparison of techniques..... | 9 |
| 7 Probability of survival | 9 |
| 7.1 Trending..... | 10 |
| 7.2 Cumulative probability..... | 10 |
| 7.3 Bayesian assessment..... | 11 |
| 8 Additional information for judging courses of action | 12 |
| 8.1 Maneuver capability..... | 12 |
| 8.2 Spacecraft characteristics..... | 12 |
| 8.3 Quality of underlying orbit data..... | 12 |
| 9 Consequence assessment | 12 |
| 9.1 Guidance for population risk..... | 12 |
| 9.2 Traffic impacts..... | 13 |
| 10 Requirements for warning and information for avoidance | 13 |
| 10.1 Orbit data..... | 13 |
| 10.2 Minimum data required for warning of and avoiding collisions..... | 13 |
| 10.3 Optional elements of information..... | 14 |
| 11 Conjunction and collision assessment work flow and operational concept | 15 |
| Bibliography | 17 |

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 manoeuvres.

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 manoeuvres 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 outcome of past events that are similar guide courses of action.

Currently in preview, click buy full version

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

coariance

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