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Introduction

This document collects a variety of potential questions and answers related to NASA's collision avoidance policies and guidance. Included below are references to the source documents, various points of contact, and the various questions and associated answers. The document may be updated periodically to add additional information.

For questions not sufficiently covered in this document, please email one of the points of contact. For questions requiring the context of a specific space flight mission, please start with the JSC Flight Operations Directorate (for human space flight missions) or Conjunction Assessment Risk Analysis (CARA) for all other space flight missions.

Document References

- NASA Procedural Requirement (NPR) 8079.1: NASA Spacecraft Conjunction Analysis and Collision Avoidance for Space Environment Protection
  https://nodis3.gsfc.nasa.gov/npg_img/N_PR_8079_0001_/N_PR_8079_0001_.pdf
- NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook (a.k.a. the CA2 Handbook)
  https://www.nasa.gov/wp-content/uploads/2023/07/oce-51.pdf

Points of Contact

- Overall policy, guidance, and process questions:
  - ca-policy-feedback@nasa.onmicrosoft.com

- Feedback on general technical and handbook topics:
  - ca-handbook-feedback@nasa.onmicrosoft.com

- Support to specific space flight missions:
  - Human spaceflight (HSF) missions: JSC Flight Operations Directorate (FOD)
  - Non-HSF missions: Conjunction Assessment Risk Analysis (CARA) program

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Background and Context

What is the problem NASA is attempting to address?

The near-Earth orbit environment is becoming congested due to the success of government and commercial space endeavors. Having more spacecraft in similar orbits naturally leads to increased conjunctions. All space operators need to be proactive in planning, coordination, and operations to protect not just their own systems, but also the space environment. We need to operate within a framework of standard practices that includes appropriate protocols for inter-operator coordination.

How big a problem is posed by on-orbit conjunctions?

On-orbit conjunctions are frequent, and as more satellites are placed in orbit will become even more frequent. This is a natural consequence of a diverse and vibrant space enterprise. Space operators need robust processes to be proactive in predicting and mitigating close approaches. NPR 8079.1 establishes NASA's internal requirements, and the CA2 Handbook identifies the necessary elements of a mature set of conjunction assessment processes.

What federal agency has responsibility for space traffic management and conjunction avoidance in the U.S.? Is there a United Nations or international group that has overall responsibility?

The U.S. has promulgated Space Policy Directive 3 (SPD-3), the National Space Traffic Management Policy. Implementation of the goals associated with SPD-3 are underway, which assigns a leadership role for Space Situational Awareness (SSA) and Space Traffic Management (STM) activities to the Department of Commerce (DOC) for commercial and international entities. The NOAA Office of Space Commerce is currently implementing a Space Traffic Coordination system called the "Traffic Coordination System for Space" or TraCSS.

What is the NASA conjunction assessment process?

At a high level, NASA uses a three step process for Conjunction Assessment (CA):

1. **Conjunction assessment** – The process of comparing trajectory data from the asset to be protected against the trajectories of the objects in the space object catalog to predict when a close approach will occur within a chosen protective volume placed about the asset.
2. **CA risk assessment** – The determination of the likelihood of two space objects colliding and the expected consequence if they collide in terms of lost spacecraft and expected debris production.
3. **Conjunction mitigation (aka collision avoidance)** – An action taken to remediate conjunction risk, including a propulsive maneuver, an attitude adjustment (e.g., for differential drag or to minimize frontal area), or providing ephemeris data to the secondary operator to enable an avoidance maneuver.

NASA Policy Information

Why was the NPR issued?

NASA's interests are best served by proactively implementing protocols and best practices to minimize collision risk. We are in a position to lead by example and demonstrate an effective approach to protect the space environment.
In order to ensure NASA is proactively managing collision risk, additional planning requirements are established to focus attention on conceptual and pre-implementation actions that will manage operational impacts. For contracts and partnerships, the NPR provides additional guidance to help ensure NASA continues to lead in protecting the space environment through managing collision risk.

How were the technical elements of the NPR reviewed?

The technical components of the NPR were peer reviewed by a group of inter-agency experts in conjunction assessment.

Is there overlap between the OCAP (from the NPR) and the ODAR or EOMP (from NPR 8715.6)?

The Orbit Collision Avoidance Plan (OCAP), Orbital Debris Assessment Reports (ODAR), and End of Mission Plans (EOMP) are distinct documents addressing different perspectives with the overall goal of protecting the space environment. The ODAR and EOMP work to reduce the potential for unmanaged introduction of new or enduring orbital debris from space flight missions (including launch). The OCAP is a newer required plan that applies to the early design phase of a space flight mission, documenting study and analysis tasks and design considerations that affect how the mission's operations phase appropriately mitigates conjunctions.

How should NASA levy the requirements in the NPR on contractors or partnerships?

For contracts that will result in the implementation of a spaceflight mission, the appropriate requirements from the NPR should be included. The specific approach should be tailored to the contract and its objectives. Incorporating the requirements in a planned contract modification, as opposed to initiating a new modification solely to incorporate the NPR's requirements, is generally sufficient.

For partnerships and other agreements, the specific agreement goal and structure should guide the involved NASA organization(s). Agreement goals and structure tend to vary widely across NASA. Agreements that do not involve the development or operation of a space flight mission generally do not require attention. For agreements involving a space flight mission, the NASA organization(s) should consider the nature of the agreement in context with overall risk to the space environment from collision risk. Where appropriate and possible, the NASA organization should invite the partner to adopt the technical requirements from the NPR, and possibly update the agreement to reflect this.

Are templates available for the NPR-required OCAP and CAOIA documents?

Non-human space flight missions should contact CARA for a copy of the latest baseline template for the CAOIA. The OCAP is intended to be a repository for results of applicable analyses; so while CARA can provide a template, this document is written largely by CARA or MADCAP and not the Program or Project.

When should work begin on the OCAP?

The intent of the OCAP is to coordinate analyses that help the Program/Project to identify and mitigate any issues related to minimizing anticipated close approaches over the life of the mission. This includes mission attributes such as choice of orbit, which is typically done very early, often before selection/award. Spacecraft teams are encouraged to reach out to CARA or MADCAP at award or even earlier for assistance in identifying potential issues so that they can be addressed as early as possible in design, when it is cheapest and easiest.

Is there an altitude below which the NPR requirements do not apply?

No. Operational spacecraft traverse all orbital altitudes, and space safety is important everywhere.

Does the NID apply to all classes of space flight missions? What about smallsats and cubesats?

Yes, the NID applies to all classes and sizes of space flight missions. Any collision affects the involved objects, and likely will generate risk to other objects through new debris. While NASA can accept risk to our own assets, we will not attempt to impose risk on other operators. All space operators need to be proactive in identifying and mitigating close approaches.

What does "NASA Owned and Operated" mean?

The NPR applies to "NASA owned and operated" spacecraft. Whether the NPR applies to a particular NASA spacecraft should be a conversation between the Program/Project manager and CARA/FOD as soon as possible after selection, as this determination determines whether analysis and deliverables are required and affects CARA funding levels. While there are unique cases, in general the criteria for determining NPR applicability are as follows. The NPR is applicable to spacecraft that:

- Are built in-house at a NASA facility
- NASA has contracted to an entity to build and deliver a spacecraft that will be operated by NASA or a NASA contractor (appropriate language should be included in the contract)
- NASA is operating the spacecraft (if another entity has an interest in the collaboration, this may require additional agreements with those entities)

The NPR is not directly applicable to:

- Contracts in which NASA is procuring data only, not hardware
- Spacecraft for which NASA is providing an instrument but is not operating the spacecraft
- Spacecraft provided under a grant. NASA has no ability to require constraints under a grant framework. However, the grantee should be STRONGLY encouraged to apply the NASA best practices for CA as listed in the CA2 Handbook.

The intent is to ensure that the NASA Administrator is aware of any open risk tacitly accepted by using NASA funds for a spacecraft -- the Administrator is answerable to the President and the Congress for any collision involving this spacecraft. The Administrator will need to explain what orbital safety rules applied to that spacecraft and why they may have been waived or not followed.

What does "maneuverable" mean?

Certain requirements in the NPR are applicable to "maneuverable" spacecraft. A "maneuverable spacecraft" is defined in the NPR glossary as "A spacecraft that has capability permitting the manipulation

of the spacecraft's trajectory in a non-Keplerian fashion". This means that spacecraft that use non-propulsive methods to change their trajectory (e.g. differential drag), are considered "maneuverable" for purposes of the NPR requirements. During development of the OCAP, CARA/FOD will work with the Program/Project to determine whether the spacecraft will be considered "maneuverable" based on its capabilities.

What if the miss distance is low but the *Pc* is also low?

If the predicted Euclidean miss distance is smaller than the hard-body radius for the conjunction, then the NPR requirements mandate a mitigation action, regardless of *Pc* value. If the *Pc* is lower than the mitigation requirement of 1E-04 and in the opinion of the mission, the miss distance is disturbingly small, the mission may elect to pursue a mitigation action. As with any mitigation maneuver (see NPR 5.3), a planned maneuver must be screened and analyzed by CARA to ensure risk to other objects can be identified.

Why are the requirements for producing and furnishing ephemerides more demanding than past practice?

An ephemeris is the best way to represent planned trajectory changes and produce durable future predictions that include uncertainty estimates, and that is the methodology needed to perform conjunction assessment. NASA wishes to emphasize the responsibility that owners/operators must assume to produce and distribute ephemerides that enable actionable CA decisions. Based on interagency experience with using ephemerides for conjunction assessment, the requirements specify the ephemeris generation frequency, density, length, covariance realism, and format needed for use in the CA enterprise.

NASA Conjunction Assessment and Collision Avoidance Best Practices Handbook Information

Who should use the Handbook?

The Handbook has two distinct audiences. First, for NASA program and project managers the CA2 Handbook serves as a consolidated reference and aid during the development of future space flight missions, providing context and support for the NPR's implementation requirements. Second, for any other space operator, the Handbook details the technical basis for our conjunction assessment processes. NASA's conjunction assessment processes have been developed over the past 30 years and may serve to help other space operators in developing their own mature approach.

Did NASA work with any other agencies on the development of the handbook?

While the Handbook outlines NASA's current practices, it was developed with the help of several U.S. agencies including the Department of Defense.

What is the difference between the Handbook and DOD's 18th Space Defense Squadron (18 SDS) *Space Safety Handbook*?

The 18th Space Defense Squadron (18 SDS) is responsible for maintaining the space object catalog for the U.S. The 19th Space Defense Squadron uses the catalog to perform the first step of the process: conjunction assessment, also referred to as "screening".

The *Space Safety Handbook* available on the US Space Force Space Delta 2's website, Space-Track.org, describes how to receive support from DOD, including CA screening data. DOD does not perform CA risk assessment for its customers, and this must be performed by the Owner/Operator once the screening data is received.

The NASA CA2 Handbook describes NASA's best practices for risk assessment, and partly overlaps with the Space Safety Handbook as appropriate to fully describe the end-to-end CA process. NASA missions receive CA services directly from CARA or FOD and do not need to use the 18th SPCS *Space Safety Handbook* for CA purposes.

NASA Conjunction Assessment Risk Analysis (CARA) Information

What is CARA's baseline support and how is it funded?

The support that CARA provides to mission customers in terms of mitigation thresholds and products exchanged is defined by the NPR and documented in the Conjunction Assessment Operations Implementation Agreement (CAOIA) between CARA and the mission. Support at this level is included in the staffing levels that CARA is funded for through the Agency. Missions desiring support beyond the baseline should contact CARA to make a request and determine whether additional resources would be required to provide the requested support. In order to ensure the availability of CARA staff to support high interest events for all missions, additional requests may require dedicated staff.

Office of Space Commerce Space Traffic Coordination (STC)

What is OSC's role in Conjunction Assessment?

The NOAA Office of Space Commerce (OSC) was tasked in Space Policy Directive-3 to take on the Space Traffic Coordination role on behalf of the US Government. OSC is implementing a Traffic Coordination System for Space (TraCSS) to perform this service, and it is expected to exit beta testing and become operational in late FY25. There is currently a transition activity in works to shift standard Conjunction Assessment screening support for commercial and international customers from the DOD to OSC.

Will NASA use TraCSS?

NASA will continue to use the screening services provided by the CARA Orbital Safety Analysts (OSAs). TraCSS will be replacing the screening capability at DOD for non-NASA and non-DOD users. As TraCSS develops and new capabilities are added, NASA will evaluate whether to take advantage of any of the TraCSS services, such as incorporating commercial tracking data into screenings.

Will CARA go away once TraCSS is operational?

No. TraCSS will be replacing the screening capability at DOD but does not currently plan to provide risk assessment. CARA will still be needed to assist NASA spacecraft with risk assessment analysis and recommendations.

Additional Technical Information

Why was the Pc chosen as the risk assessment metric?

As a collision likelihood metric, the *Pc* presents a number of advantages. The metric considers the miss distance, the two satellites' positional uncertainties, and the combined object sizes, all within the same calculation. The parameter is useful as a statement of relative conjunction severity and as a test statistic to compare to a threshold for requiring mitigation action, even if it is not best interpreted as a statement of expected event frequency. Issues of "probability dilution" and risk understatement bias, which have been raised in the critical literature as a criticism of the *Pc*, are minimized by the way that CARA has set the null hypothesis for risk assessment and selected the mitigation threshold (this issue is treated at some length in the Handbook). Finally, *Pc* is the standard collision likelihood calculation within the CA community, thus aligning the NASA with this emerging industry standard.

Can a space flight mission use a different collision likelihood metric?

Yes, but the *Pc* calculation is that which will be used by CARA to assess when mitigation actions are recommended. Missions are free to employ a different risk assessment methodology to identify situations that, although not high-risk according to a *Pc* calculation, may be of concern to the mission and therefore candidates for mitigation.

Why was the baseline Pc threshold of 1E-04 selected for recommending a mitigation maneuver?

The NASA Office the Chief Engineer considered a number of different possible thresholds and concluded that the 1E-04 value provided the desirable balance between safety and mission facilitation/enablement. This threshold also aligns with the level that most space safety organizations have embraced as a collision likelihood threshold for requiring mitigation (1 in 10,000 chance of collision).

Why was the *Pc* mitigation recommendation of 1.5 orders of magnitude lower than the 1E-04 high-risk threshold, which equates to a conjunction Pc reduction to 3.1E-06, selected?

A CARA study concluded that, by reducing high-risk events to this *Pc* level, they no longer contribute appreciably to the satellite's cumulative lifetime risk of collision.