National Aeronautics and Space Administration

Conjunction Assessment Requirements for NASA Spacecraft

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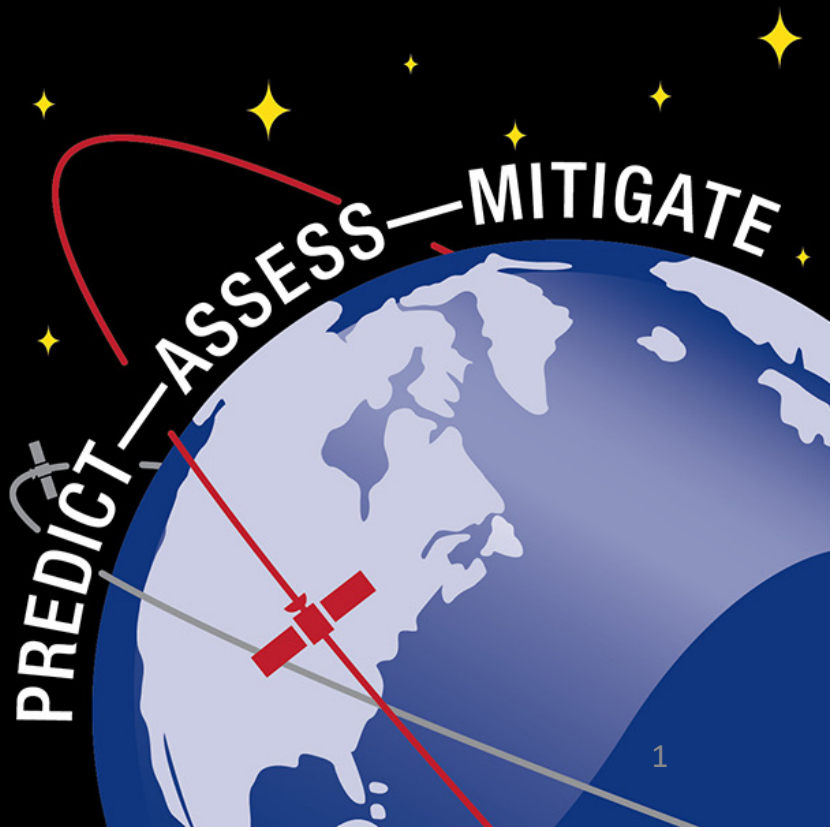
HQ Space Operations Mission Directorate

June 30, 2026

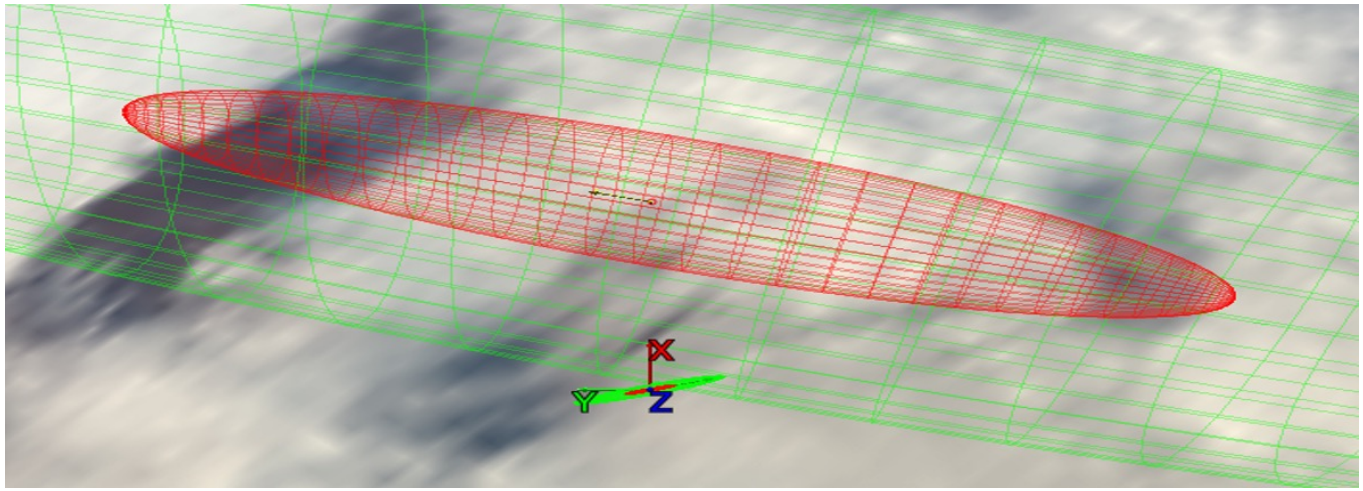


NASA **Conjunction Risk Assessment**

www.nasa.gov

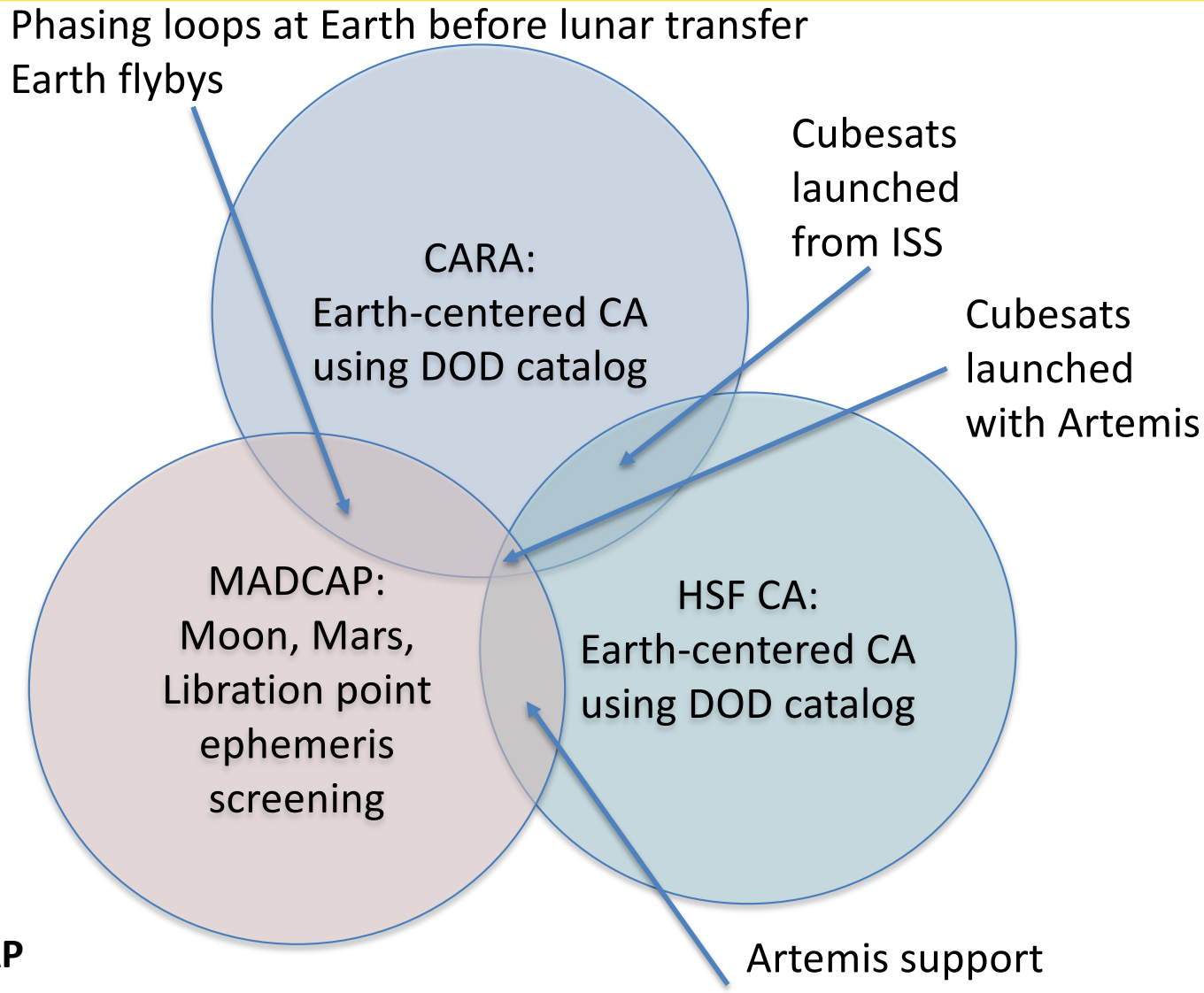
Satellite Conjunction Assessment: Basics

- High-risk satellite conjunction shown below
  - NASA satellite well maintained; small 1-σ (red/inner) / 3-σ (green/outer) error ellipses (with axes at bottom)
  - Debris object "above" it, with very large error ellipses (3-σ extends beyond image)
- Conjunction screening activities find encounters of this nature
- Risk assessment determines that actual likelihood/consequence of collision
- Mitigation planning helps select maneuver for NASA object to avoid collision

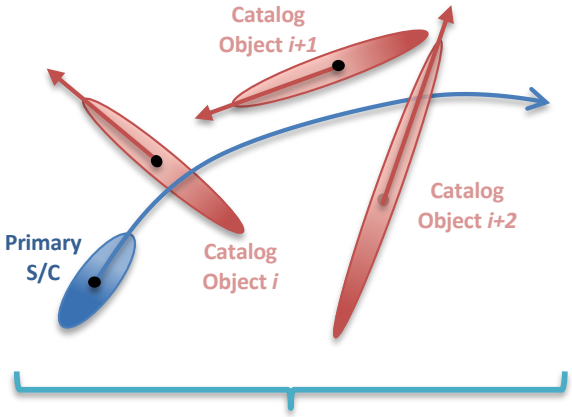


NASA Conjunction Assessment Entities

- **Human Spaceflight (HSF)**
  - **ISS and visiting vehicles**
  - **Commercial Crew**
  - **JSC-based**
- **CARA**
  - **Non-HSF, Earth-orbiting missions (~80 assets)**
  - **GSFC-based**
- **Multimission Automated Deepspace Conjunction Assessment Process (MADCAP)**
  - **Cis-lunar and beyond**
  - **JPL-based**
- **CAPO**
  - **HQ CA integrating function**
  - **Oversees CARA and MADCAP**

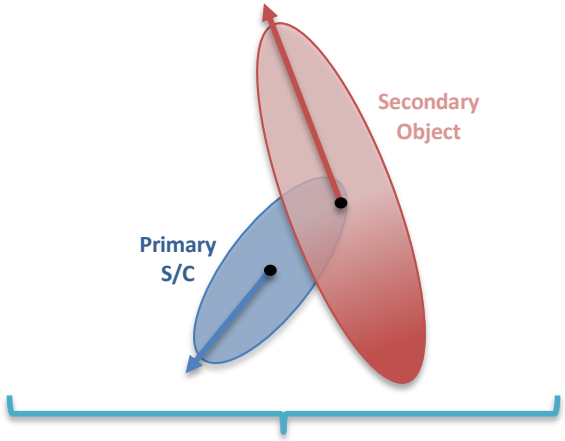


Satellite Conjunction Assessment: NASA Process Details for Earth Orbits



Conjunction Assessment (CA) is the process of identifying close approaches between two orbiting objects; sometimes called **conjunction screening**.

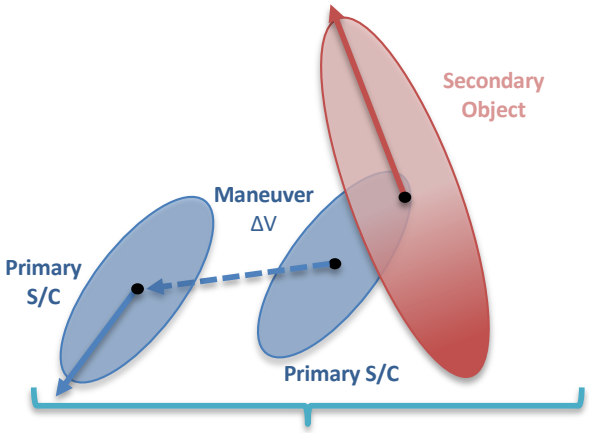
The **18th Space Defense Squadron (18 SDS)** at Vandenberg Space Force Base (VSFB) maintains the high accuracy catalog of space objects. Orbital Safety Analysts (OSAs) at VSFB screen NASA protected assets against the catalog, perform tasking requests, and generate close approach data.



CA Risk Analysis (CARA) is the process of assessing collision risk and assisting satellites in planning maneuvers to mitigate that risk, if warranted.

The NASA **CARA** program performs risk assessment for all NASA operational satellites not affiliated with Human Spaceflight (HSF), as well as for some partner missions.

JSC **Flight Operations Directorate (FOD)** performs risk assessment for all NASA HSF program assets and is the O/O for maneuver decisions and execution.



Collision Avoidance is the process of executing mitigative action, typically in the form of an orbital maneuver, to reduce collision risk.

Each satellite **Owner/Operator (O/O)** – mission management, flight dynamics, and flight operations – is responsible for making maneuver decisions and executing the maneuvers.

Satellite Conjunction Assessment: NASA Process Details for non-Earth Orbits

- **The Multimission Automated Deepspace Conjunction Assessment Process (MADCAP) was developed at the NASA Jet Propulsion Laboratory for conjunction assessment use in shared deep space environments, for which ground-based radar tracking is a challenge.**

- **MADCAP has been used to screen objects in orbit at Mars (since 2011), the Moon (since 2011), Sun/Earth Libration points L1 (since 03/2020) and L2 (since 01/2022), and in Cislunar space (since 11/2024).**

- **Due to the lack of passive tracking capability in deep space, keeping these environments safe is reliant on self-reported ephemeris and uncertainty data from mission teams**
  - There is currently no known orbital debris field at the Moon or Mars (other than a handful of inactive spacecraft) since there is no reliable method to realistically track debris from Earth
  - The creation of a debris field in these environments would complicate existing and future operations and could take many years to dissipate.

Current MADCAP-Monitored Environments

Mars
- Daily analysis initiated at 13:45 Pacific Time
- Objects within Mars SOI (range to Mars < 600,000km)

Moon
- Daily analysis initiated at 08:45 Pacific Time
- Objects within Moon SOI (range to Moon < 65,000km)

Cislunar
- Weekly analysis initiated at 15:00 Pacific Time every Wednesday
- Objects within “Cislunar zone” (range to Moon > 65,000km AND 45,000km < range to Earth < 500,000km)

Sun-Earth L1
- Weekly analysis initiated at 15:30 Pacific Time every Wednesday
- Objects within “L1 zone” (range to L1 point < 1,000,000km)

Sun-Earth L2
- Weekly analysis initiated at 16:00 Pacific Time every Wednesday
- Objects within “L2 zone” (range to L2 point < 1,000,000km)

New environments are added as soon as they become shared (>1 SC operating)
- Jupiter and Venus expected to be included in the near future

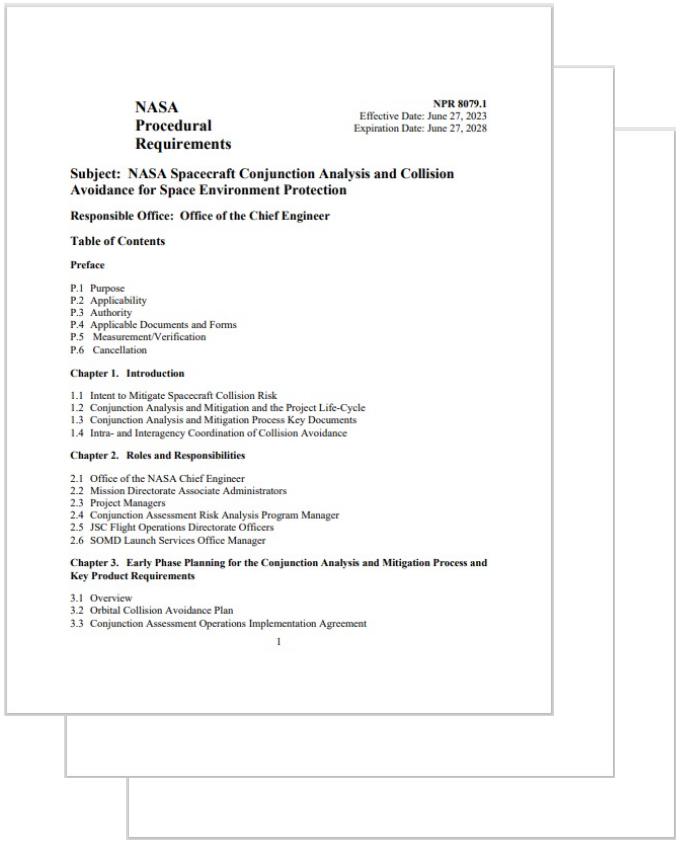
CA Requirements

- **NPR 8079.1 documents CA requirements for the Agency**
  - **FAQ that accompanies the NPR and Handbook: https://www.nasa.gov/sites/default/files/atoms/files/faq-nid-and-hbk-collision-avoidance.pdf**
- **NPR Applicability statement**
  - **The requirements of this directive apply to NASA programs and projects with spacecraft that are owned, developed, or operated by NASA. For …other spacecraft, MDAAs share the intent of this directive and associated best practices and seek to understand the partners' operational procedures for conjunction risk assessment.**
- **NASA-owned or -operated spacecraft NPR definition:**
  - **A spacecraft owned, developed, or operated by NASA or operated principally for NASA.**
  - **OCE Intent – NPR applies to PI-led missions**

Rationale

- **Spacecraft that maneuver (including changing trajectory without propulsion like differential drag or altering ballistic coefficient with a drag chute) need to provide predicted trajectory data for CA screening to prevent collision**
  - Protects other operators' spacecraft and the environment
- **Non-maneuverable spacecraft must be trackable/tracked through demise in order to be included in the CA process**

NASA Procedural Requirement (NPR) 8079.1



NASA
Procedural
Requirements

NPR 8079.1
Effective Date: June 27, 2023
Expiration Date: June 27, 2028

Subject: NASA Spacecraft Conjunction Analysis and Collision Avoidance for Space Environment Protection

Responsible Office: Office of the Chief Engineer

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2.2 Mission Directorate Associate Administrators
2.3 Project Managers
2.4 Conjunction Assessment Risk Analysis Program Manager
2.5 JSC Flight Operations Directorate Officers
2.6 SOMD Launch Services Office Manager

Chapter 3. Early Phase Planning for the Conjunction Analysis and Mitigation Process and Key Product Requirements

3.1 Overview
3.2 Orbital Collision Avoidance Plan
3.3 Conjunction Assessment Operations Implementation Agreement

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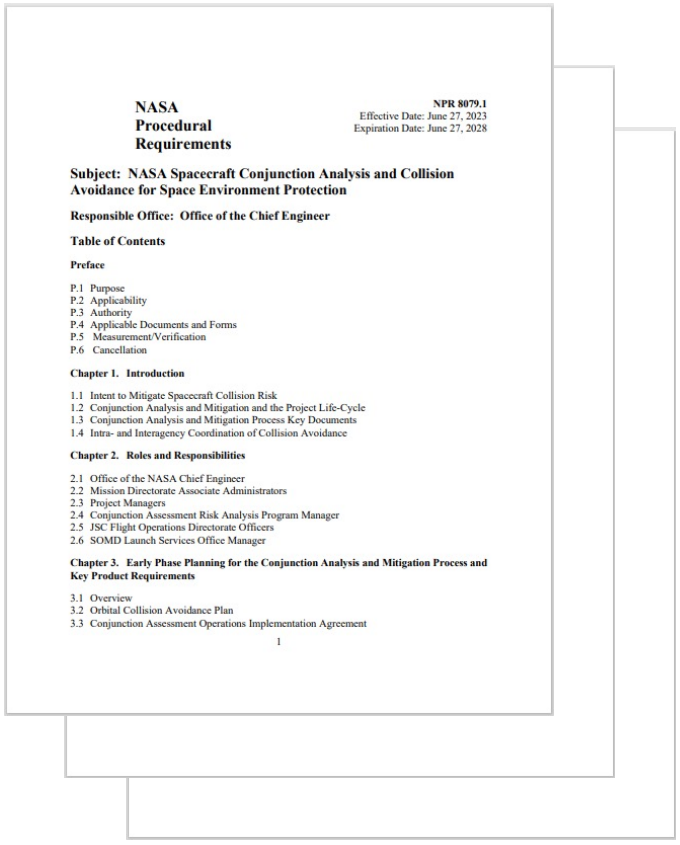
NPR Goal

Protect the space environment and reduce the risk of collision to an acceptable level by establishing the minimum collision avoidance requirements and associated operational protocols for NASA.

NPR Effective June 27th, 2023

NASA Procedural Requirement (NPR) 8079.1



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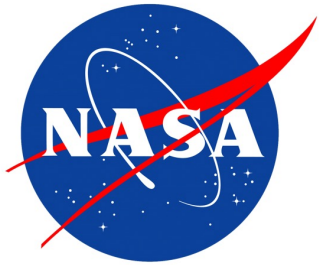
<u>This goal is accomplished by:</u>

Two-fold approach to analyze the **satellite design process** with **conjunction assessment** and **risk mitigation** in mind, during the **pre-launch phase**.

1. Orbital Collision Avoidance Plan (OCAP)
2. Conjunction Assessment Operations Implementation Agreement (CAOIA)

NASA Procedural Requirement (NPR) 8079.1

[NAME] ORBITAL COLLISION AVOIDANCE PLAN



Orbital Collision Avoidance Plan (OCAP):

Detailed study and analysis of various mission design parameters and CONOPS related to conjunction assessment and mitigation capabilities.

OCAP Requirement & Timeline

- NASA Procedural Requirement (NPR) 8079.1
  - Requires signed OCAP and compliance matrix document at PDR/Project Approval
  - Start working with CARA ASAP in Pre-Formulation/Formulation Phase
  - OCAP is completed iteratively and signed by mission and CARA
    - Documents the structured <u>study of aspects of mission design</u> ***that affect*** <u>close approach prediction and mitigation during mission operations</u>

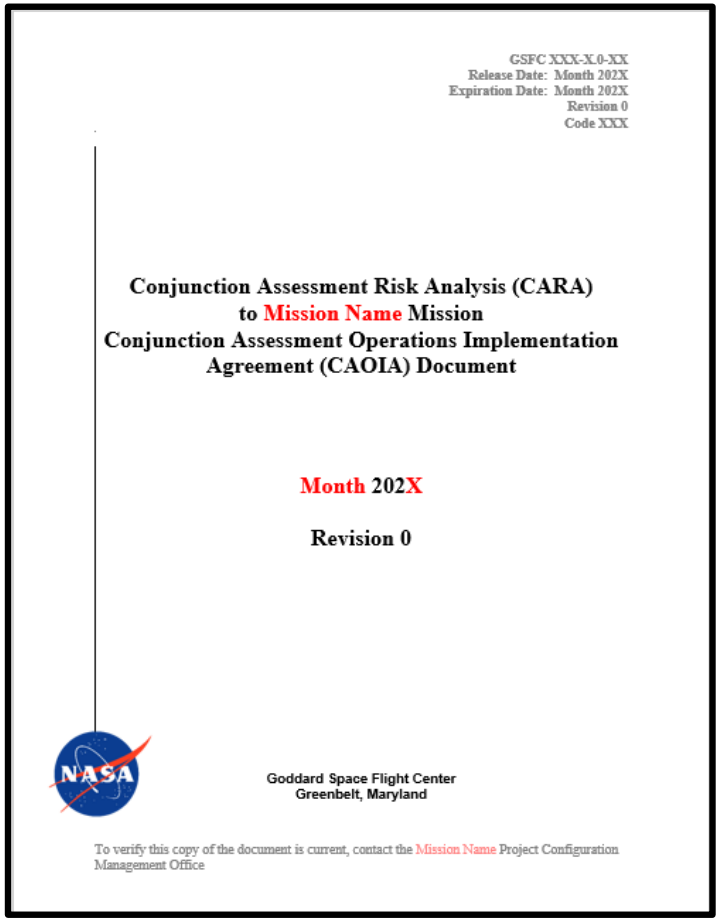
Objective: To ensure that all the needed conjunction assessment components ae supported by the mission design

Life-Cycle Phase	Pre-Formulation	Formulation	
7120.5 Life-Cycle Gates	MCR ▽	SRR ▽ SDR ▽	PDR ▽
Conjunction Assessment Products		① Initial OCAP inputs (required)	② Baseline OCAP (required)
NPR-Related Activities	• As concepts develop, project manager coordinates with CARA (non-HSF) or JSC FOD (HSF) for orbit selection options	• Project manager demonstrates application of this NPR • Project manager provides initial OCAP inputs to CARA/JSC FOD review • CARA/JSC FOD begins OCAP analyses	• Project manager baselines OCAP and provides OCAP to CARA/JSC FOD for review and concurrence and subsequent final approval by the program manager

Notes: ① Project provides initial inputs for OCAP
② Iteration of OCAP content with CARA or JSC FOD
③ Achieve OCAP concurrence (Baseline)

7120.5 Timeline

NASA Procedural Requirement (NPR) 8079.1



GSFC XXX-X.0-XX
Release Date: Month 202X
Expiration Date: Month 202X
Revision 0
Code XXX

Conjunction Assessment Risk Analysis (CARA)
to Mission Name Mission
Conjunction Assessment Operations Implementation
Agreement (CAOIA) Document

Month 202X

Revision 0

Goddard Space Flight Center
Greenbelt, Maryland

To verify this copy of the document is current, contact the Mission Name Project Configuration Management Office

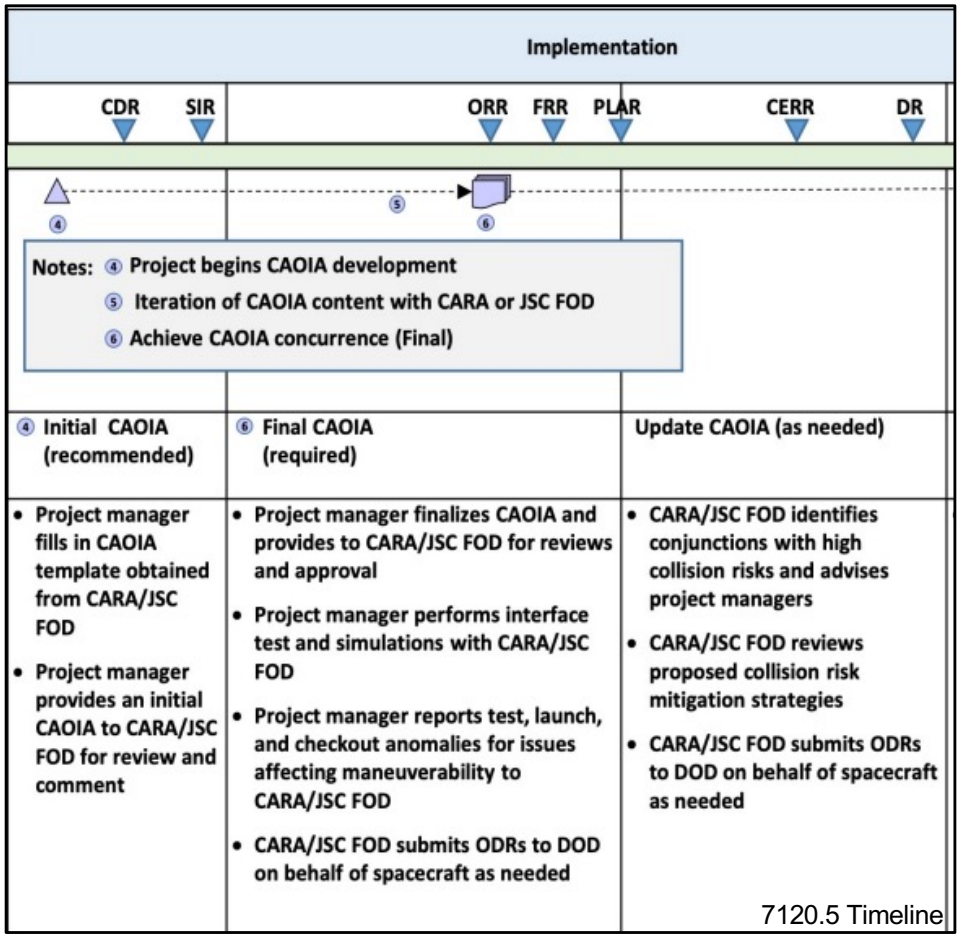
Conjunction Assessment Operations Implementation Agreement (CAOIA):

Agreement between missions and CARA documenting the specific operational processes the project plans to implement to protect the spacecraft and space environment.

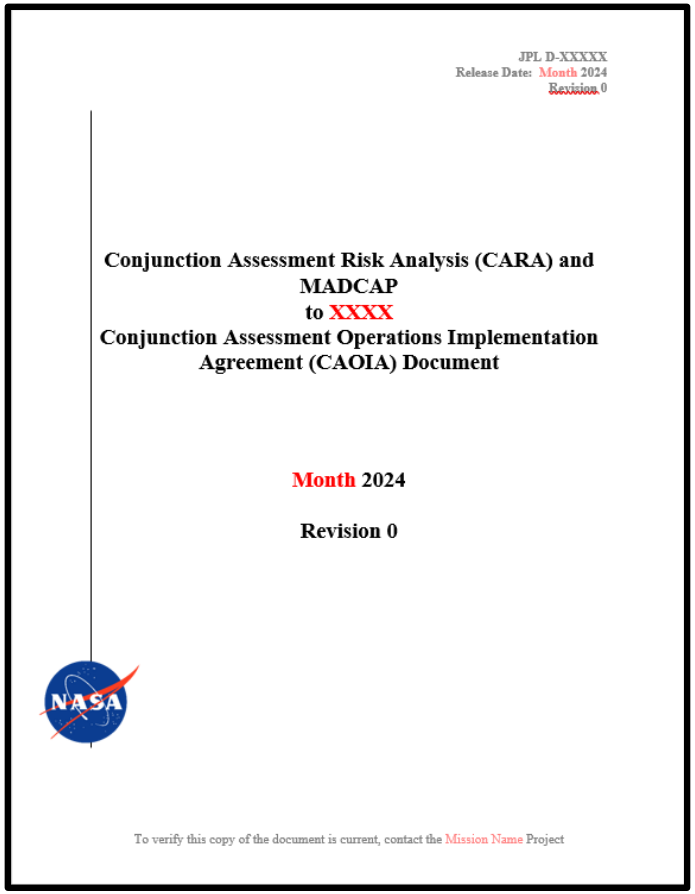
CAOIA Requirement & Timeline

- **NASA Procedural Requirement (NPR) 8079.1**
  - **Requires completion by ORR/ORR equivalent**
  - **Start working with CARA in the Implementation phase**
  - **CAOIA is completed iteratively, and can be updated as needed by the missions**

Objective: To ensure that all necessary operational processes will be in place prior to launch.



CARA – MADCAP Joint Support



JPL D-XXXXX
Release Date: Month 2024
Revision 0

Conjunction Assessment Risk Analysis (CARA) and MADCAP to XXXX Conjunction Assessment Operations Implementation Agreement (CAOIA) Document

Month 2024

Revision 0

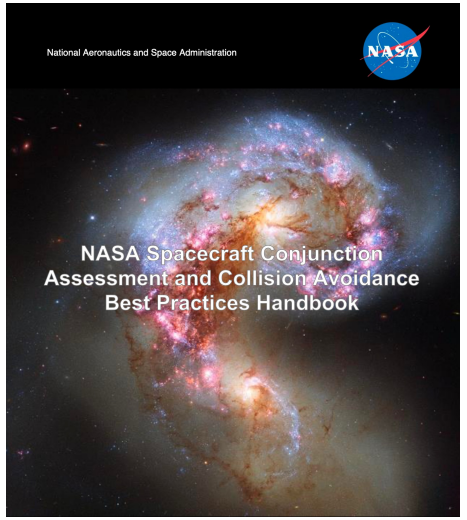
To verify this copy of the document is current, contact the Mission Name Project

CARA – MADCAP Joint CAOIA

- CARA supports NASA assets in Low Earth Orbit (LEO), Geosynchronous Orbit (GEO), and Earth Gravity Assist (EGAs) for greater than 3 hours
- Multimission Automated Deepspace Conjunction Assessment Process (MADCAP) supports non-Earth orbiting NASA assets
- CARA and MADCAP can provide joint support for missions who require **both** LEO/GEO/EGA and non-Earth orbiting CA screenings

Best Practices: NASA Handbook

- **NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook https://nodis3.gsfc.nasa.gov/OCE_docs/OCE_51.pdf**
- **Helps space system operators understand existing capabilities and processes**
  - **Includes related US Space Command (USSPACECOM) and the US Space Force 18th Space Defense Squadron (SDS) best practices**
- **Provides technical background on NASA CA processes, including why requirements were levied and how to implement them**
- **Offers best practices for use by any spacecraft Owner/Operator to help protect the space environment**
- **Companion software repository contains many of the tools used by NASA: *https://github.com/nasa/CARA_Analysis_Tools***



Summary

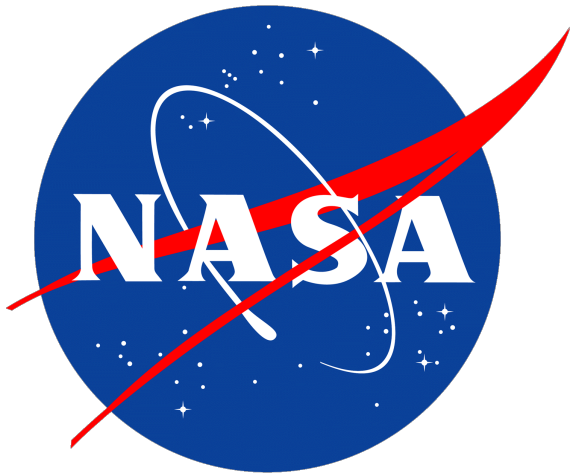
- **Increasing congestion of space accentuates need for robust CA practice**
- **NASA is committed to refining and sharing appropriate best practices**

NASA CA Handbook

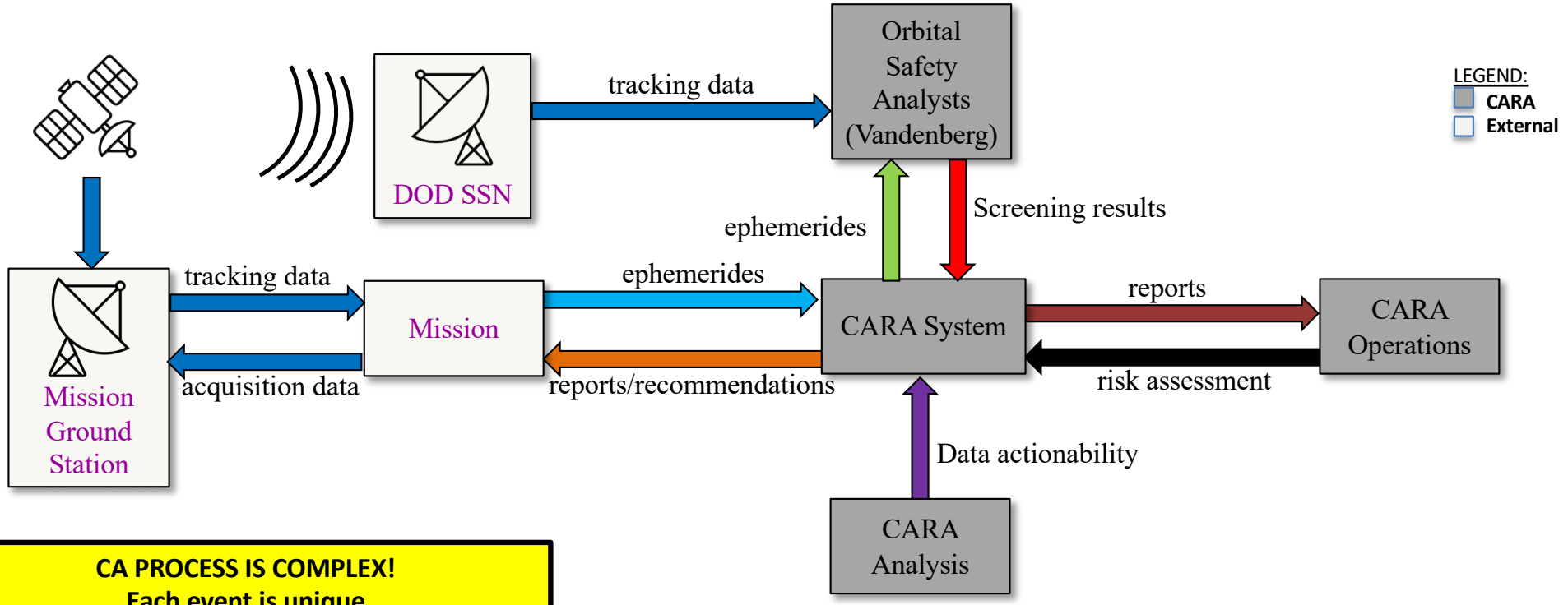
CARA Tool Repository

NASA CA website

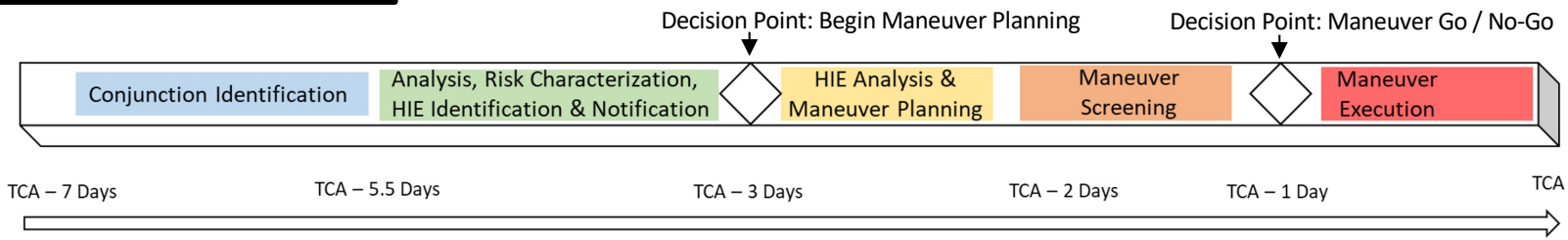
Questions?



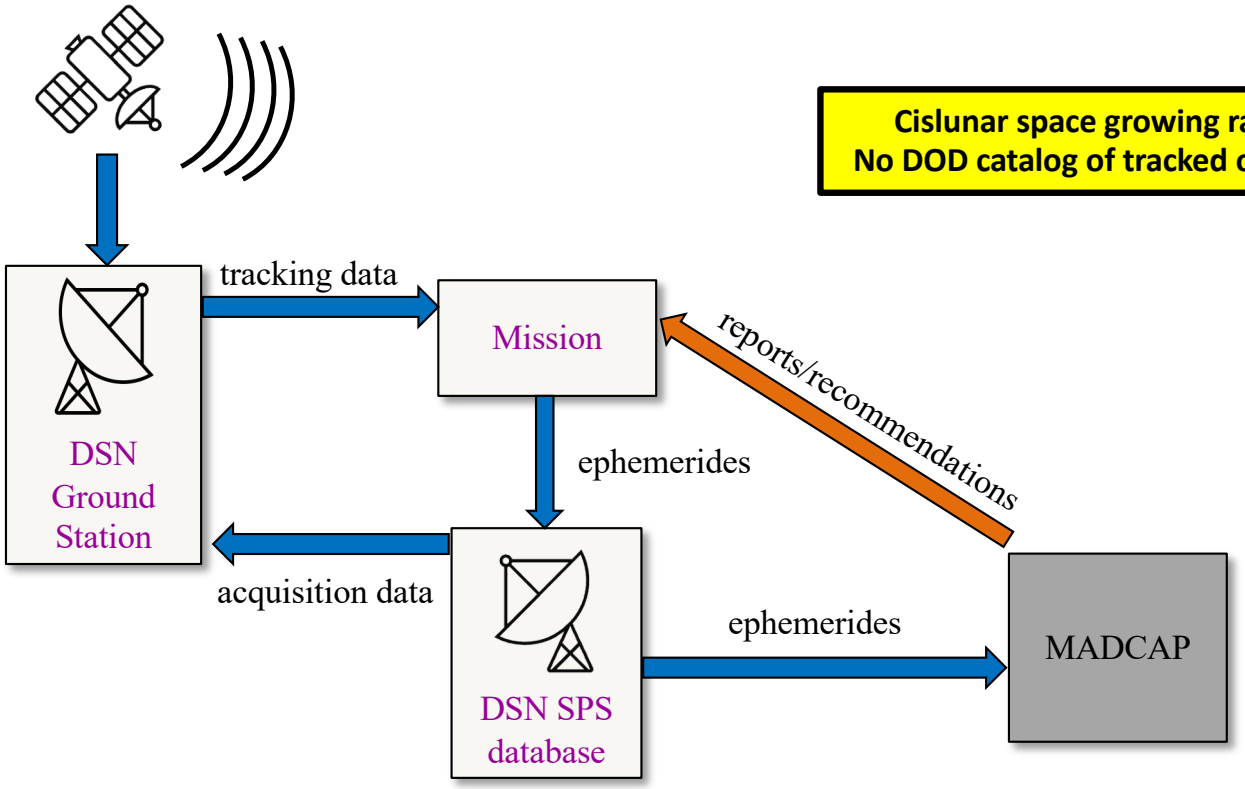
CARA Real-Time Process



CA PROCESS IS COMPLEX!
Each event is unique
Automated system still requires manual analysis



MADCAP Process



Cislunar space growing rapidly (Artemis cubes, CLPS, etc)
No DOD catalog of tracked objects – rely on ephemeris sharing