National Aeronautics and Space Administration

Conjunction Assessment NASA Best Practices

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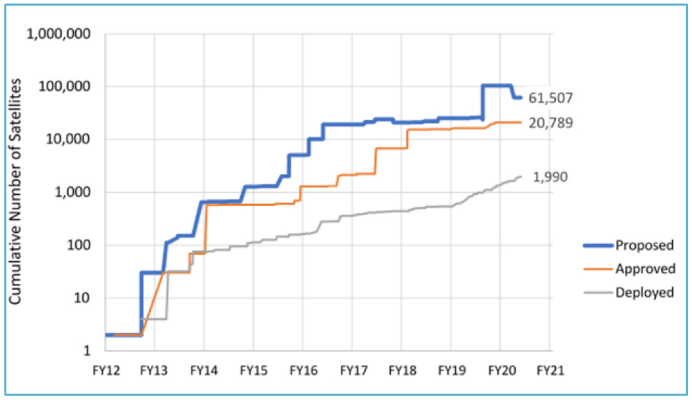
NASA **Conjunction Assessment Risk Analysis**

www.nasa.gov

Growth Trends in Earth Orbit



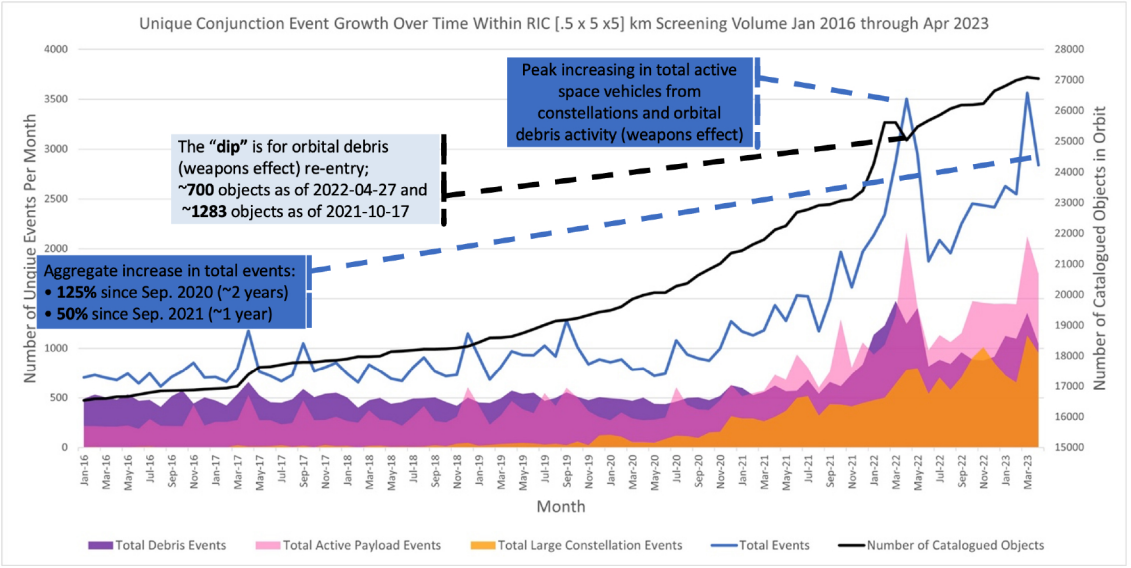
The number of satellites over time continues to grow, as shown by the graph of spacecraft counts listed in license requests to U.S. regulators.

Several ultra-large constellations (up to 30k space vehicles) have been announced (for Low Earth Orbit), though not yet deployed.

One constellation already has ~4000 space vehicles in orbit.

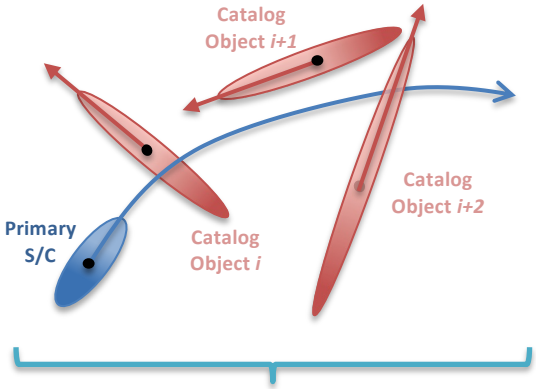
Conjunction events (**blue line**) have grown significantly, mainly due to:

- **orbital debris** (**dark purple area**) *[includes effects of anti-satellite weapons demonstrations]*
- **large constellation deployments** (**orange area**)



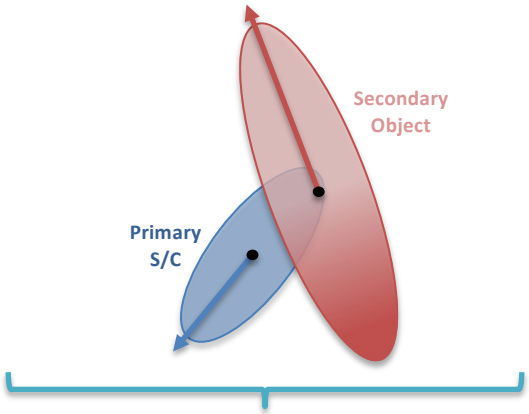
https://www.nasa.gov/sites/default/files/thumbnails/image/cara-conjunction-events-plot-apr-2023.jpg

Conjunction Assessment: Basic Definitions and Responsibilities



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

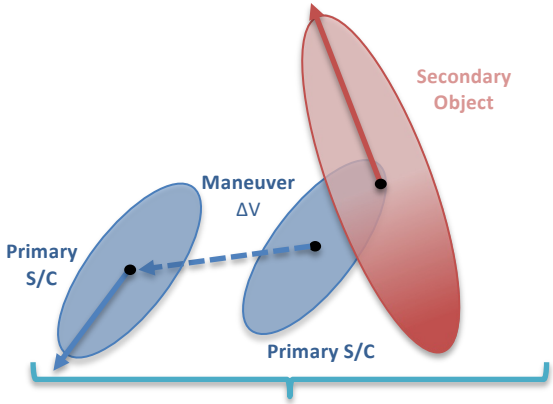
The **18th Space Defense Squadron (18 SDS)** at Vandenberg Space Force Base (VSFB) maintains the high accuracy catalog of space objects. Orbital Safety Analysts (OSAs) at VSFB screen protected assets against the catalog, perform tasking requests, and generate close approach data.



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 non-HSF satellites, and some partner missions.

JSC **Flight Operations Directorate (FOD)** performs risk assessment for all NASA Human Spaceflight (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.

Resources

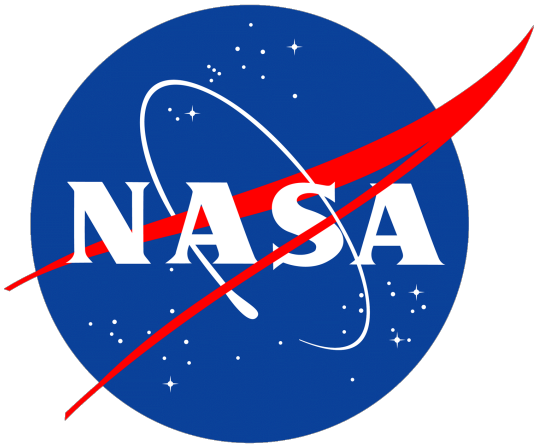
- NASA is committed to refining and sharing appropriate best practices
  - Best practices document available to the public
  - NASA tool sets with test data available to the public
- NASA spacecraft are required to follow best practices
  - Requirements documented in NID 7120.132/NPR 8079.1
- Accompanying FAQ: https://www.nasa.gov/sites/default/files/atoms/files/faq-nid-and-hbk-collision-avoidance.pdf

NASA CA Handbook

CARA Tool Repository

NASA CA website

Questions?



Backup

NID: Project Deliverables During Formulation and Implementation

Orbital Collision Avoidance Plan (OCAP) contents:

- Orbit selection
- Ascent / descent Plan
- Space Surveillance Network trackability and cataloging
- Ephemeris generation
- Conjunction mitigation action resources
- Spacecraft flight control and navigation paradigm
- Autonomous flight control

Lifecycle Integration:

- Baseline plan prior to approval to proceed to the Implementation Phase
- NPR 7120.5 missions baseline the plan prior to proceeding into the Implementation Phase
- When updated, provide OCAP for reviews and decisions points during the Implementation Phase

Approval:

- Reviewed and concurred by JSC FOD (for HSF) or CARA (for non-HSF)
- Approved by Program Manager

Conjunction Assessment Operations Implementation Agreement (CAOIA) contents:

- Ephemeris sharing (post-launch, continuing), for maneuverable spacecraft, specifications for ephemeris sharing
- Maneuver considerations (24-hr advance notice, yield right-of-way to on-station objects, close approaches, mitigations, anomalies)
- Autonomous flight control and navigation (ground awareness, ephemeris planning, abort)
- Deorbit / Descent considerations (coordinate with JSC FOD to avoid ISS)

Lifecycle integration:

- Approved agreement required before proceeding to Operations
- NPR 7120.5 missions provide the agreement at Operational Readiness Review (ORR)
- NPR 7120.8 missions provide the agreement at an appropriate pre-launch review (e.g., continuation assessment, periodic project review), determined in coordination with the program manager

Approval:

- Approved by project and CARA (for non-HSF)
- Implemented and approved within existing procedural requirements for HSF missions (not a separate plan)

Spacecraft Design Considerations

- It is important (and efficient) to make plans for conjunction assessment during spacecraft planning and design
  - CA process needs can be accommodated more easily prior to spacecraft fabrication
  - All processes and tools must be developed and validated well in advance of launch
- Key items to consider during design:
  - Orbit selection
  - Trackability
  - Deployment plan
  - Ephemeris generation process and tools
- Lesson learned example:
  - A NASA spacecraft assumed that two-line elements (TLEs) would be available from DOD for use as acquisition data for tracking radars.
  - After launch, it was discovered that the orbit was too low an inclination for DOD CA sensors to track and maintain it appropriately, so TLEs were not regularly available
  - This situation could have been prevented through pre-launch analysis

Cis-lunar CA

- Catalog of non-cooperatively/passively tracked objects used in CA includes only Earth-orbiting objects
- Activity at Moon, Mars, and Libration points increasing risk of collision; screening of orbits in these regimes now needed
  - NASA MADCAP provides ephem-on-ephem screening for missions
  - Relies on sharing of data
  - Open to non-NASA entities
- DoD developing cis-lunar catalog and screening capability
  - Requirements not yet defined
  - Implementation is still in early stages of development
- NASA continues to work with DoD on beyond GEO SSA capabilities.