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National Aeronautics and Space Administration



NASA Conjunction Assessment Risk Analysis Approach

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NASA's Process: CARA



- NASA is committed to safety of flight for all of its operational assets
 - Performed by CARA at NASA GSFC for robotic satellites
 - Focus of this briefing
 - Performed by TOPO at NASA JSC for human spaceflight
- The Conjunction Assessment Risk Analysis (CARA) was created to offer this service to all NASA robotic satellites
 - Currently provides service to ~65 operational satellites
 - NASA unmanned operational assets
 - Other USG assets (USGS, NOAA)
 - International partner assets



NASA Human Spaceflight Conjunction Assessment (CA) History

1986: Challenge 19 N. de		ser accident 1 992: NASA begins Pc levelopment for ISS		1996: NASA begins conjunction assessment of Mir space station		on ce	1999: First attempted ISS DAM attempted and fails; a few U months later first ISS DAM qua successfully executed			Present: NASA continues work with SSTRATCOM to maintain high ality CA for human spaceflight and robotic missions
		l			1998: ISS First E Launch	Elemo	ent	20 N/ ro	105: ASA boti	begins CA for c missions
1988: Space Shuttle Discovery Return to Flight; Box method used for CA; later Shuttle adopts Pc method				1990 NASA deve impr main	1990s – present: NASA works with USSTRATCOM to develop tools, data exchange formats, improve processes for catalog maintenance and CA					

NASA has performed CA for 25 years. Initial USSTRATCOM capability developed with NASA.

NASA Robotic CARA History





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Mission Context: Number of Conjunctions in LEO



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Collision Avoidance Maneuver History





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The CARA Process Helps Manage On-Orbit Collision Risk

 P_c

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

The Joint Space Operations Center (JSpOC) – a USAF unit at Vandenberg AFB, maintains the high accuracy catalog of space objects, screens CARA-supported assets against the catalog, performs OD/tasking, and generates close approach data **CA Risk Analysis (CARA)** is the process of assessing collision risk and assisting satellites plan maneuvers to mitigate that risk, if warranted

 $\overline{2\pi [\det(\mathbf{C})]^{1/2}}$

 $\frac{1}{2}X^{\mathrm{T}}\mathbf{C}^{-1}X$

dA

The **CARA** Team at NASA-GSFC provides CARA for all NASA operational robotic satellites, as well as a service provider for some other external agency/organizations **Collision Avoidance (COLA)** is the process of executing mitigative action, typically in the form of an orbital maneuver, to reduce collision risk due to a conjunction

ΛV

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

CARA Operational Process: Close Approach Predictions at the JSpOC



- The JSpOC maintains an accurate state for all trackable objects
- In support of CARA, the dedicated Orbital Safety Analysts (OSA)
 - Perform routine screenings 3x day for LEO, 1x for GEO/HEO
 - Against JSpOC's Astrodynamics Support Workstation (ASW) solution and the O/O solution if available
 - Inspect orbit determination; perform manual orbit determination, if warranted
 - Adjudicate tasking level of secondary objects; request increased tasking, if warranted
 - Generate and deliver necessary data products
- JSpOC is staffed by Goddard-dedicated OSA 20 hours/ day

The **Screening Duration** is the "lookout" period of time for which conjunctions are identified. This is 7 days for LEO assets and 10 days for GEO/HEO assets

The **Screening Volume** is the geometric volume placed around the asset during the conjunction screening process; any objects that violate this volume trigger data products to be generated and delivered. The screening volumes are re-sized annually by CARA using a 95% capture of the relative uncertainties in each orbital regime based two-year moving window historical conjunction data

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CARA Operational Process: NASA Robotic Collision Risk Analysis



- CARA is responsible for assessing, communicating, and assisting with mitigation of on-orbit collision risk
- As data is received, the CARA system automatically processes that data, and generates & delivers
 - CARA Summary Reports to O/O
 - Work List to JSpOC OSAs
- CARA team performs routine risk analysis
 - Pc; Pc sensitivity
 - Conjunction Geometry
 - OD Evaluation / Solution Consistency
 - Space Weather Sensitivity
 - Maneuver planning & evaluation
- For high-risk conjunctions, CARA builds and delivers a High Interest Event (HIE) briefing with detailed analyses, and planning & decision information



The **Collision Probability (Pc)** is the probability that, given the uncertainty in the two objects' positions as described by their covariance matrix, that the actual miss distance is less than the hard-body region

Maneuver Planning

- A trade-space contour plot shows the effect that a range of phase times and delta-v magnitudes have on miss distance
 - Single conjunction event (top)
 - Multiple events (bottom)
- Assists with initial maneuver planning
 - Save time-expensive iteration cycles for high fidelity maneuver planning
 - Does not presume any constraints about satellite maneuver capability or conjunction mitigation strategies—allows flight support teams to decide on course of action



NASA ROBOTIC CARA