



# NASA Conjunction Assessment Risk Analysis Approach

Lauri K. Newman  
NASA Robotic Conjunction Assessment Manager

27 JUN 2016

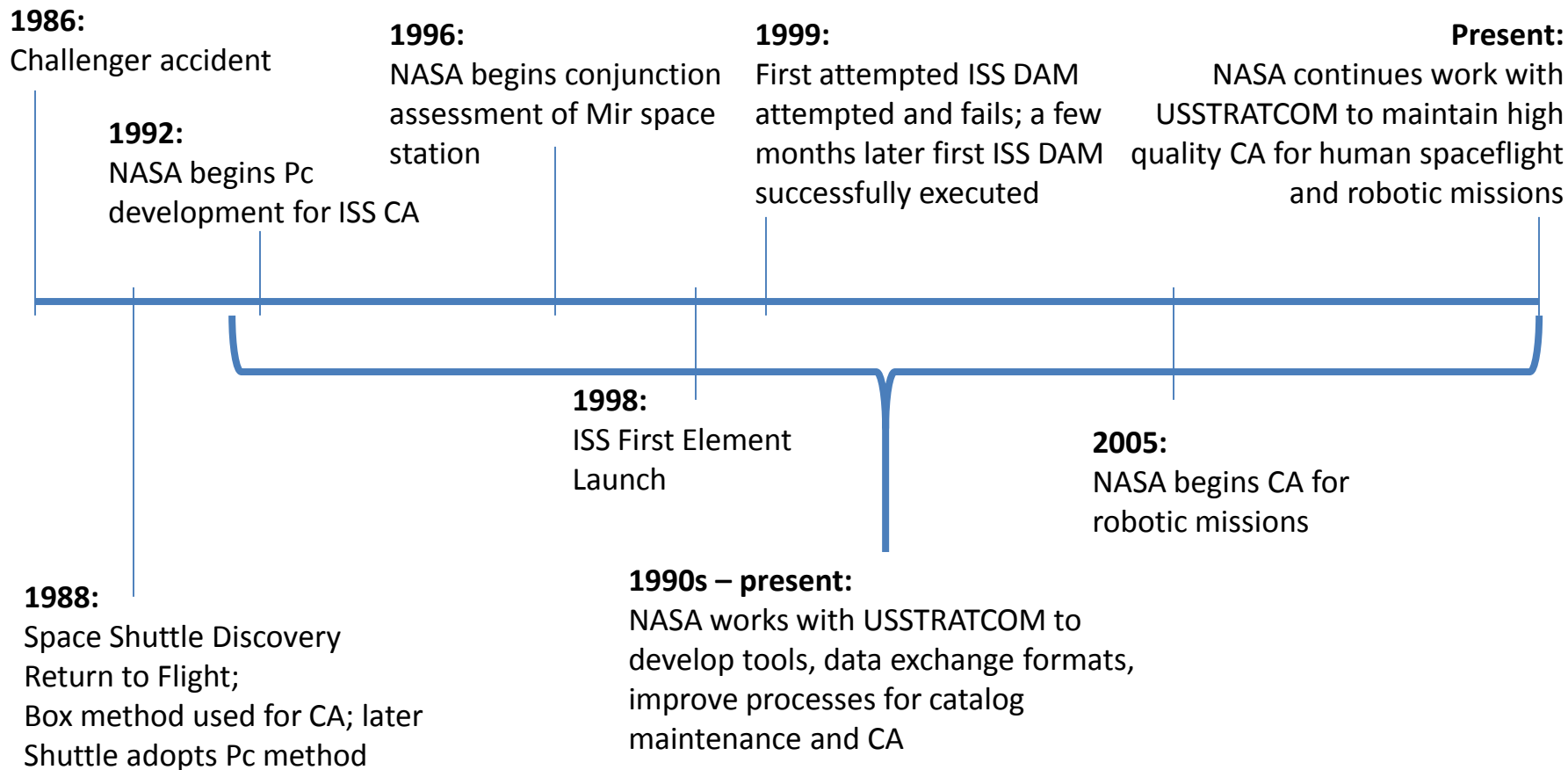
**NASA ROBOTIC CARA**

[www.nasa.gov](http://www.nasa.gov)



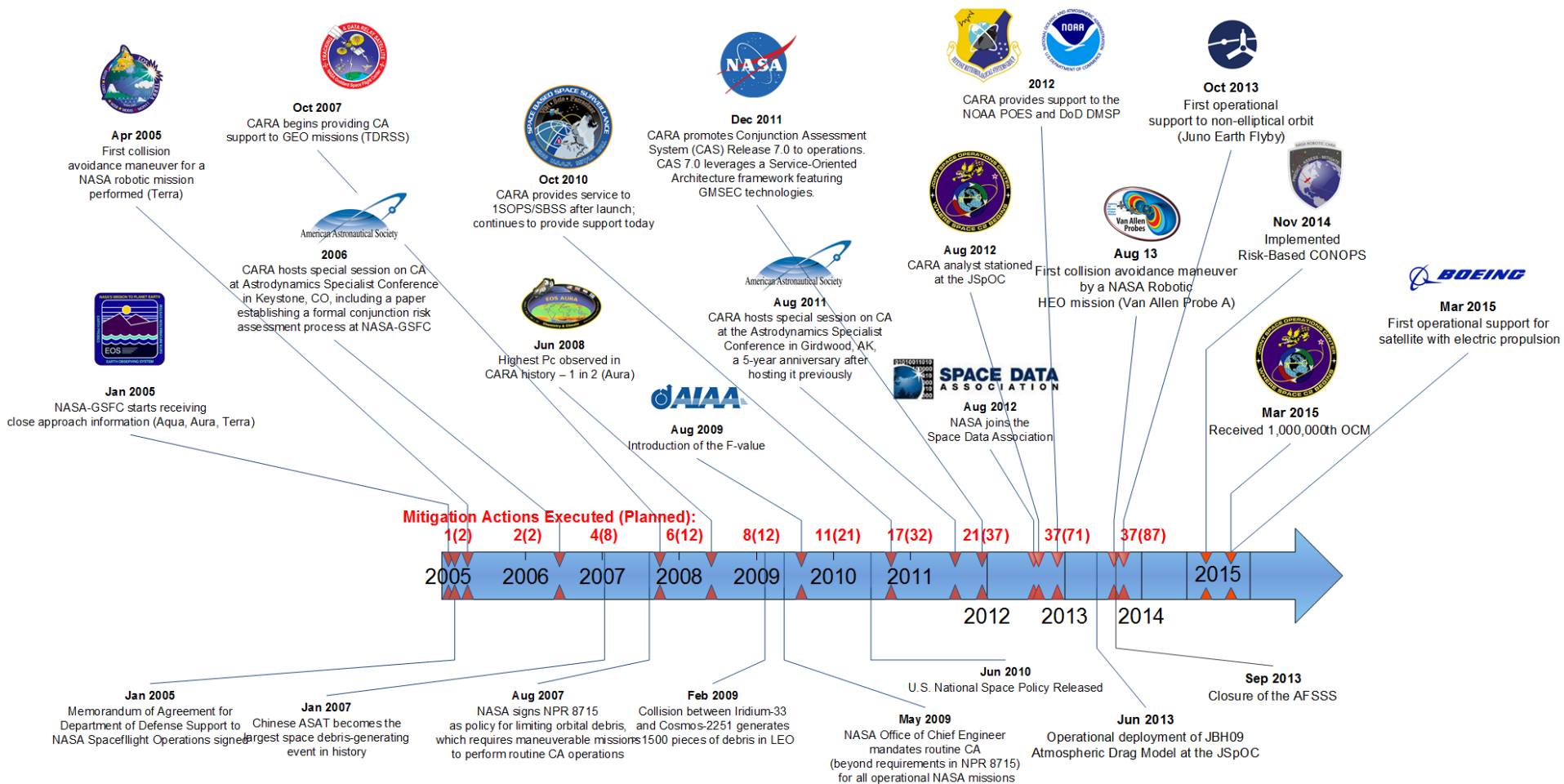


# NASA Human Spaceflight Conjunction Assessment (CA) History

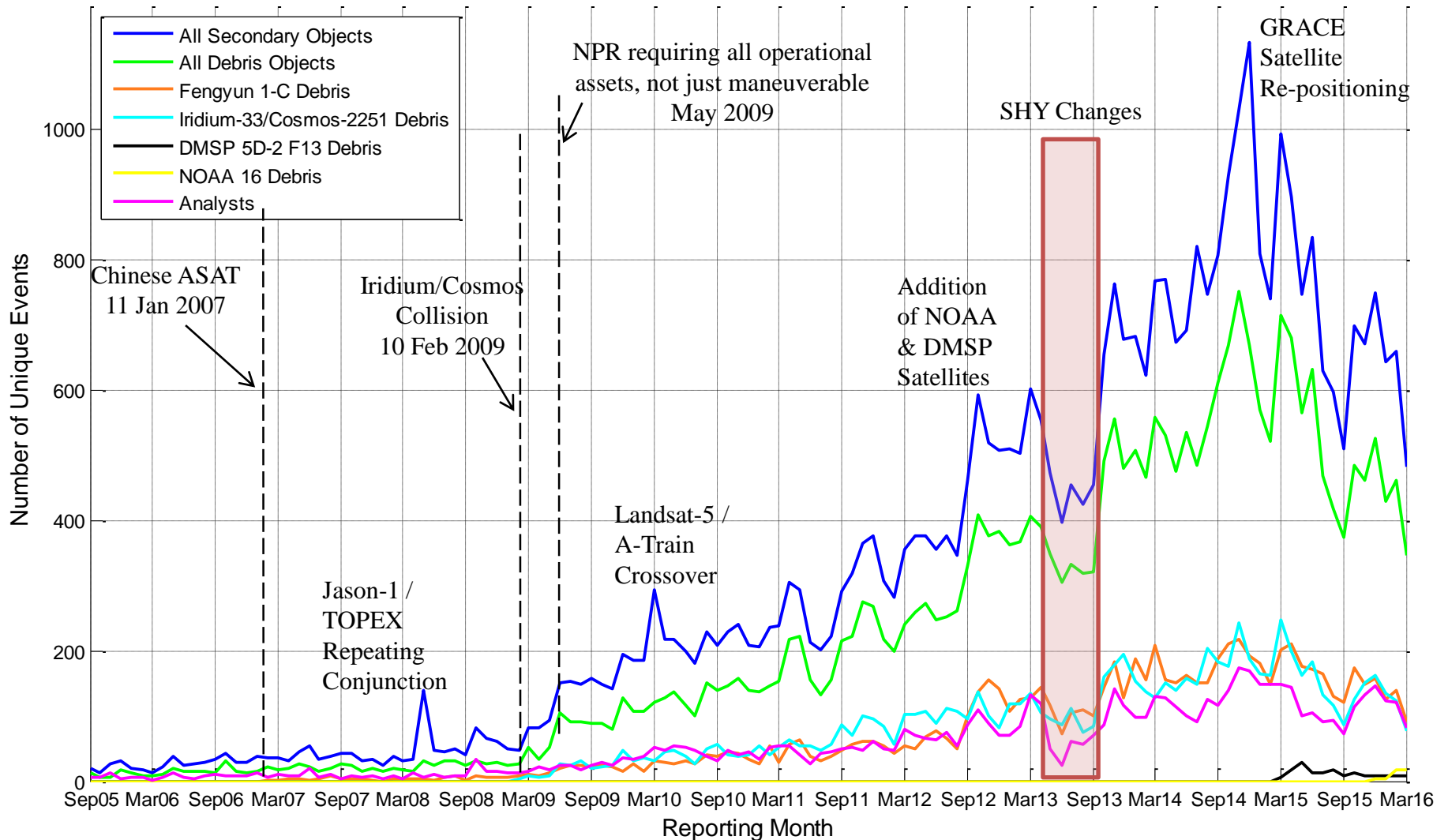
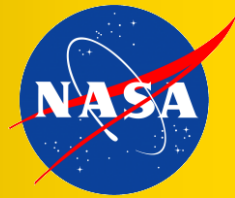


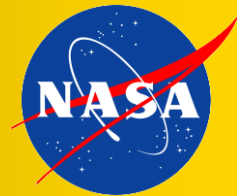
**NASA has performed CA for 25 years. Initial USSTRATCOM capability developed with NASA.**

# NASA Robotic CARA History

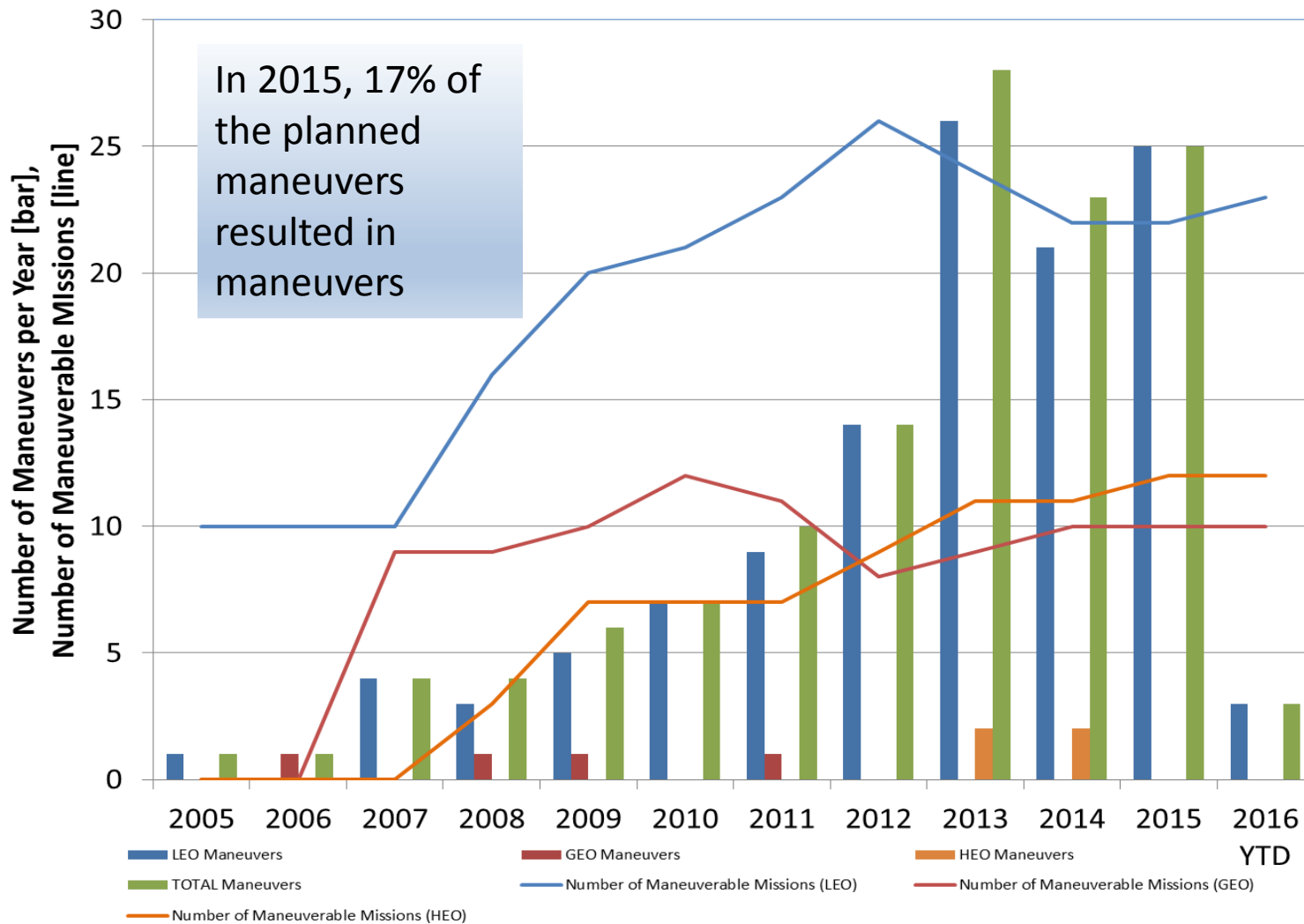


# Mission Context: Number of Conjunctions in LEO

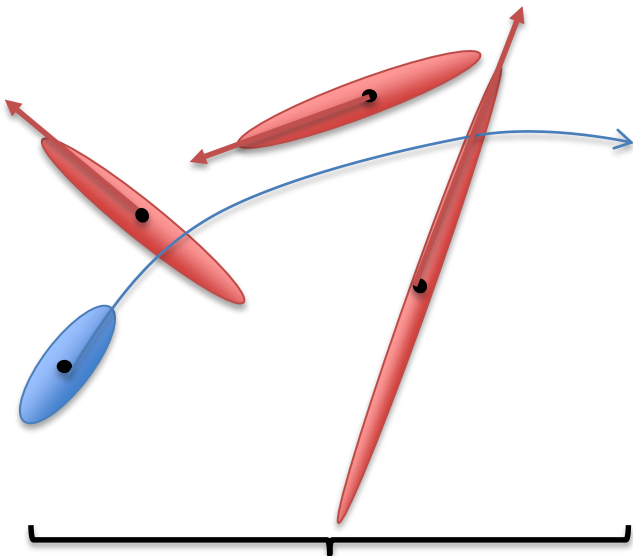
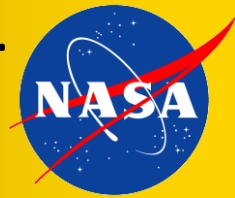




# Collision Avoidance Maneuver History

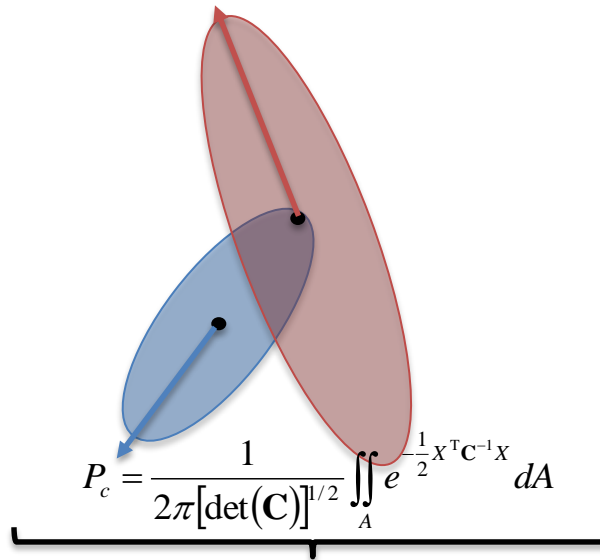


# The CARA Process Helps Manage On-Orbit Collision Risk



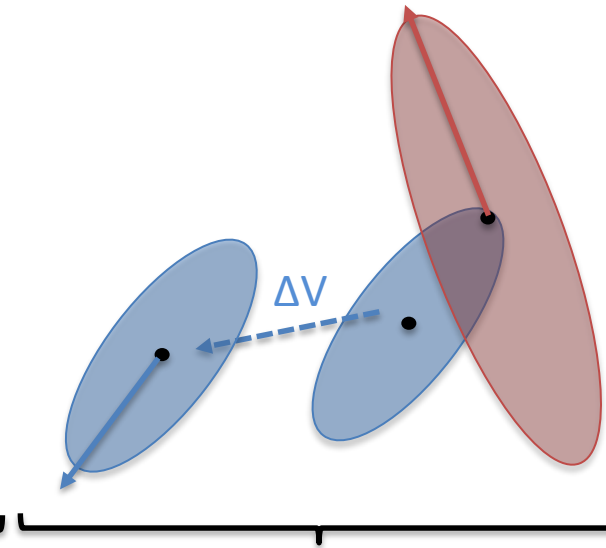
**Conjunction Assessment (CA)** is the process of identifying close approaches between two orbiting objects; sometimes called conjunction “screening”

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

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



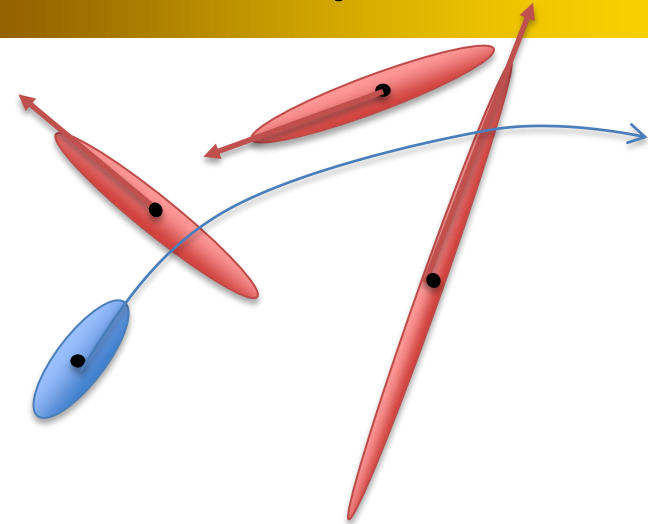
**Collision Avoidance (COLA)** is the process of executing mitigative action, typically in the form of an orbital maneuver, to reduce collision risk due to a conjunction

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

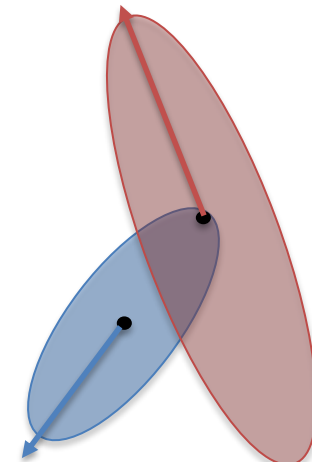
The **Screening Volume** is the geometric volume placed around the asset during the conjunction screening process; any objects that violate this volume trigger data products to be generated and delivered. The screening volumes are re-sized annually by CARA using a 95% capture of the relative uncertainties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



# 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
  - $P_c$ ;  $P_c$  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



$$P_c = \frac{1}{2\pi[\det(\mathbf{C})]^{1/2}} \iint_A e^{-\frac{1}{2}\mathbf{x}^T\mathbf{C}^{-1}\mathbf{x}} dA$$

The **Collision Probability ( $P_c$ )** 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

