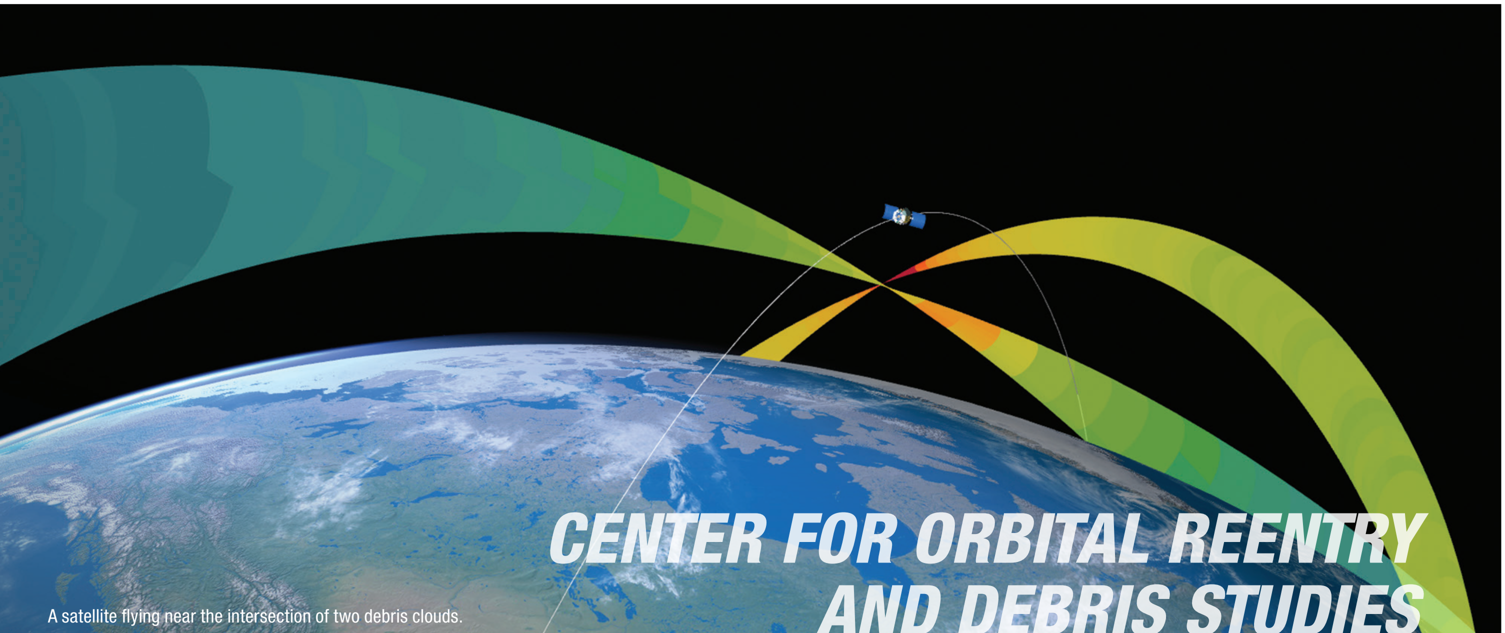


A satellite flying near the intersection of two debris clouds.

The Problem of Space Debris

Increased space debris traffic equals increased collision risk for launch vehicles and satellites on orbit. Objects in space — even tiny objects — can inflict grave harm to critical sensors and spacecraft components and potentially result in a loss of capability. If a satellite must maneuver to avoid being hit by space debris, the maneuver can endanger the spacecraft by forcing it to expend valuable propellant and potentially limit its life expectancy.

As low Earth orbit (LEO) constellations grow larger, the density of the near-Earth environment will grow markedly and unevenly. A space population boom creates the potential for enormous, unworkable numbers of collision avoidance actions, shrinking launch windows and influencing constellation architecture design and satellite replenishment strategies.

High-accuracy assessment and prediction tools are essential for reducing risk to current systems as well as future launches. Aerospace's Center for Orbital and Reentry Debris Studies (CORDS) is addressing these threats head on by developing tools and techniques for analyzing potential collision scenarios, studying reentry breakups of upper stages and spacecraft, and modeling debris objects in space. These efforts are critical given the predicted population growth in launch efforts and LEO satellite constellations.

CORDS Capabilities

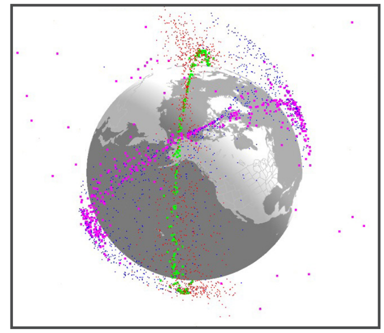
CORDS-developed tools encompass a vast array of operations, from predicting possible collisions during launch and on orbit, to predicting hazards to spacecraft after collisions in space, simulating the breakup of reentering debris, estimating the survivability of satellite components reentering Earth's atmosphere, and determining risk to life and property. CORDS provides information on when a reentry might occur, and Aerospace collects and analyses material that survived reentry. Results of these analyses are published, enhancing risk prediction models worldwide.

CORDS capabilities

- Real-time and long-term debris risk management and assessment
- Debris minimization standards and best practices
- Analysis of population growth of objects in low Earth orbit
- End-of-life support for on orbit and reentry disposal
- Prediction of reentry hazards
- Launch collision avoidance

Collision Avoidance and Space Traffic Management

The single most important contribution to managing space debris is to avoid making more. One method to accomplish this is to predict and help prevent catastrophic collisions between existing objects. For nearly two decades, CORDS has pioneered new techniques and processes to provide probability-based mission assurance launch collision avoidance analysis for all national security space launches and has supported the Space Surveillance Network for nearly sixty years. Our team has worked to improve the accuracy of the catalog of resident space objects and how to apply this knowledge to achieve effective collision avoidance. Aerospace's Debris Analysis Response Team provides realtime debris risk assessment for on-orbit collisions and breakups.

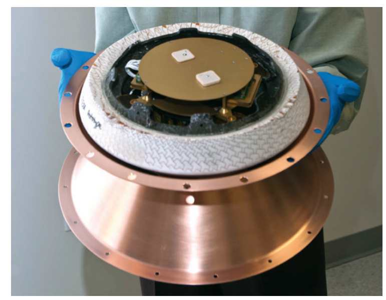


This image models the debris from the 2009 collision of the Iridium-33 (green) and Cosmos2251 (purple) satellites. Overlaid in red and blue are Aerospace models of estimated untrackable debris.

Debris Analysis

High-energy breakups of objects in space generate a cloud of debris that creates risk to other spacecraft. Aerospace has accumulated over thirty years of data from on-orbit breakups and ground tests, partnering with the Air Force and NASA to conduct tests and model high-energy breakups and collisions. Recently, with the sponsorship of the Air Force's Space and Missile Systems Center (SMC) and in partnership with NASA, Aerospace helped conduct the DebriSat test, where custom-built test objects using modern materials and construction techniques were subjected to a hyper-velocity breakup. After impact, fragments were collected and analyzed to improve future models.

Prior to launch, a new spacecraft is assessed for reentry risk. By modeling the amount of material that is likely to survive reentry, Aerospace can make accurate models of how material behaves in response to reentry heating and loads. This knowledge can then be applied by industry during the design process to minimize future risk. In support of SMC, CORDS enlists the public's help in locating reentered space debris by tracking and publishing both past and upcoming reentries.



The first Reentry Breakup Recorder (REBR) successfully recorded data as it plunged through the atmosphere aboard a disintegrating Japanese HTV-2 spacecraft. Data was transmitted to ground systems via the Iridium satellite system.

The Reentry Breakup Recorder

CORDS developed the Reentry Breakup Recorder (REBR)—a small, lightweight, self-contained, autonomous, survivable, and locatable data-recording device—to measure the effects of atmospheric reentry on space objects. Attached to a host vehicle, this device "sleeps" until the point of atmospheric reentry, where it wakes up to record temperature, acceleration, rotational rate, and other data, as well as the subsequent breakup of the space hardware due to atmospheric drag, aerodynamic heating, and loads. REBR is released during breakup, and protected by its heat shield, survives reentry and "phones home" recorded data via the Iridium system. Five REBR devices have been launched to date, providing innumerable insights into the atmospheric reentry and breakup of spacecraft.

The Essential Role of Debris Management

Protection of U.S. warfighters and interests as well as protection of civilian life and property on the ground are of paramount importance. Staunch debris management is essential to prevent increasing risk to on-orbit assets, shrinking launch windows, and the potential loss of satellite capability. CORDS analyzes space debris and reentry risk reduction via high-accuracy space surveillance, well-designed satellite conjunction prediction, and cutting-edge assessment tools.

The Aerospace Corporation

Aerospace is a nonprofit corporation that operates a federally funded research and development center (FFRDC) for the United States Air Force. This FFRDC spans the entire space domain for government as well as civil space and other federal agencies. With a world class workforce of roughly 3,000 engineers and scientists, Aerospace is able respond with agility to the unique challenges posed by national security space requirements, delivering well-defined, innovative solutions that assure mission success.