

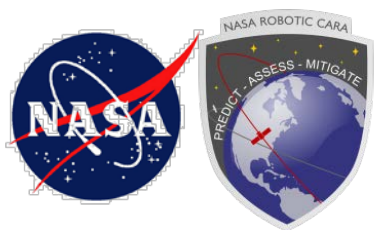
Conjunction Assessment Risk Analysis



Collision Avoidance “Short Course”

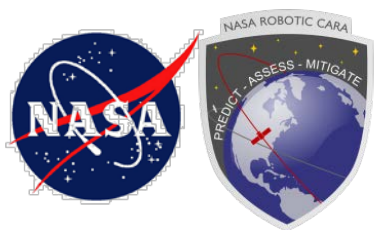
Part III: CA in Changing Space Flight Environment

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Changing Space Environment

- **Space environment has been changing, and will continue to evolve rapidly over the next few years due to the following drivers:**
 - Space Fence
 - Large constellations
 - New Space Actors
 - Smallsat proliferation
- **CA practices will need to evolve to meet growing needs**
 - New Methodologies
 - Best Practices
 - Orbital Registry
 - Data Sharing
- **Space Traffic Management**
 - Recent updates



S-Band Fence: Problem/Study Definition

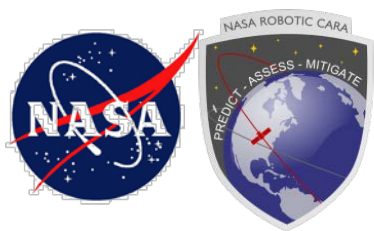
- **New Space Surveillance Network (SSN) sensor expected to increase catalog size significantly**

- Equatorial phased-array S-Band sensor
- Can track to better than 5 cm (SSN capability 10 cm)
- Initial Operations Capability currently planned for summer 2019

- **Expected issues for CA**

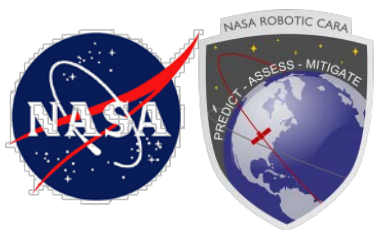
- Vastly increased quantity of new objects
- Quality of maintenance ODs
 - Newly-discovered objects likely to receive light tracking
 - May create additional ops ambiguities and affect event actionability
- If new workload is too large, current CA operations paradigm might need to be adjusted





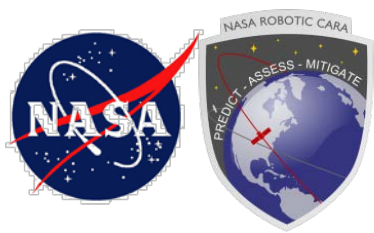
S-Band Fence: Study Composition / Timeline

- **CARA spearheaded collaborative study among the following organizations:**
 - S-Band Fence SPO (AFLCMC; Hanscom AFB), including Lockheed Martin (development contractor)
 - NASA/JSC (TOPO/FDO) and /ODPO
 - AF Space Command / A5
 - The Aerospace Corporation
 - USSTRATCOM, including CSpOC/18 SPCS and Dahlgren (Det 1)
 - FAA
- **CARA as analysis lead, with support from other organizations**
- **Purpose to determine additional workload imputed by SF deployment**
 - Number of conjunctions expected per day
 - Number of serious events per day
 - If necessary, spin-off effort to develop new CA paradigms



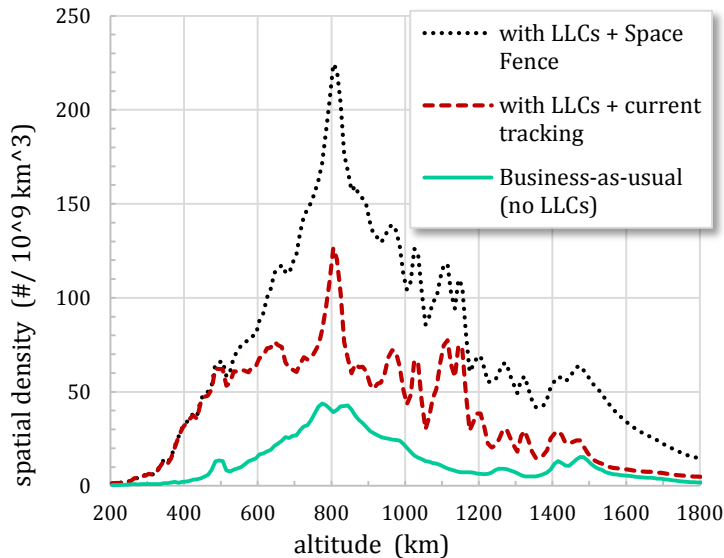
S-Band Fence Study: Results

- **Overall number of conjunction reports per day expected to increase by about a factor of 3**
 - Depends on Orbit altitude – varies between 2x and 4x
- **This value not so large that new CA paradigms required**
 - Some adjustment to thresholds and timelines; but existing algorithm set can continue to be used
- **Results expected to be publically released in paper at AIAA Conference in Maui in January 2019**
- **Once data flows, will check actual workload and data quality against simulated results**

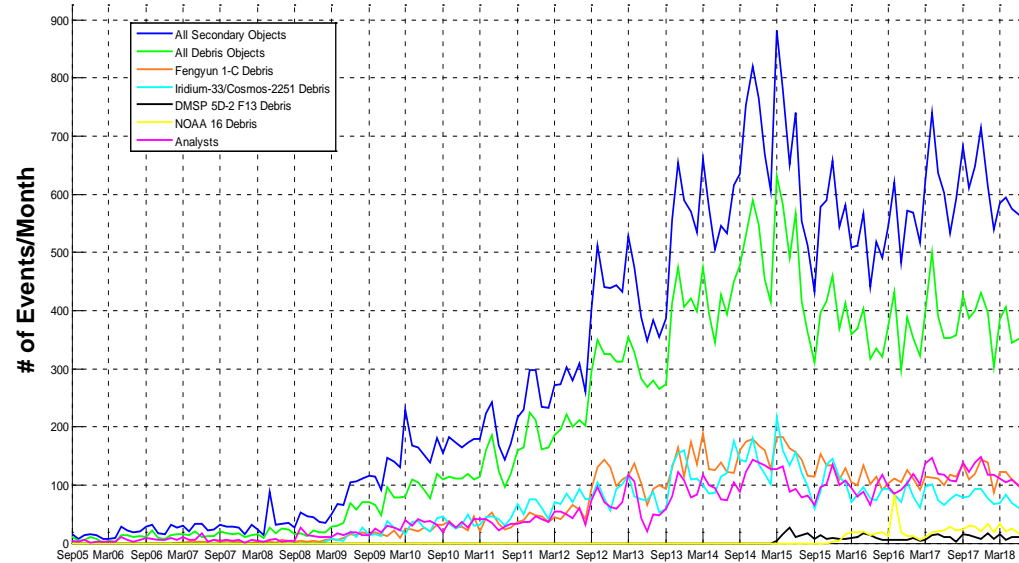


Increasing Workload

Predicted Tracked Object Density by Altitude in 2030

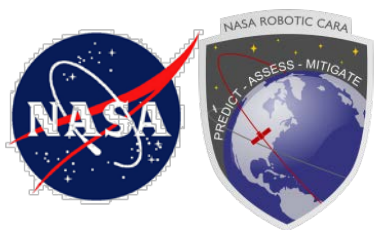


Unique Events within 0.5x5x5-km Volume by Object Type, LEO



- **Current CA workload is large and expected to grow**

- Across the LEO fleet, NASA CARA sees about 700 unique conjunctions each month
- About one conjunction per month per LEO spacecraft requires further analysis and mitigation planning
 - Requires ~1 staff week of work for the CARA team for risk assessment as well as support from the mission flight operations team for maneuver planning
 - Only about 15% of analyzed events result in a maneuver

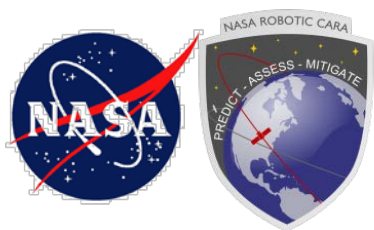


Large Constellations

- **Planned large constellations will add thousands of objects to catalog**
 - Analysis of some proposed constellations has indicated a fresh conjunction event every 3 days vs 1-2 fresh events/month in current operations
- **Operations impact is large**
 - Effort to analyze the data will require more manpower
 - Hopefully the development of robust automated risk assessment tools will follow to reduce operations impact

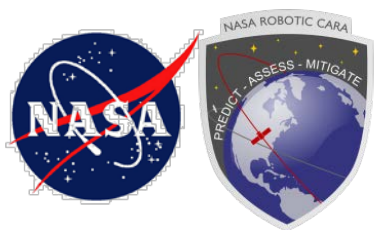
Some Planned LEO Constellations

Operator	Num sats	Alt (km)	Country
SpaceX V-band	7518	335-345	US
Planet Swift	6	350-650	US
Capella	48	350-650	US
Black Sky	60	450	US
Kepler	140	550	US
Skybox	30	576	US
Yalini	135	600	Canada
Spire	100	651	US
Planet Doves	150	675	US
Orbcomm	31	750	US
Iridium	72	780	US
Theia	112	800	US
Lucky Star	156	1000	China
Telesat LEO	72	1000	Canada
Boeing	1008	1025	US
Hongyan	300	1100	China
SpaceX Starlink	4425	1110-1325	US
OneWeb	720	1200	ESA
Telesat LEO	45	1248	Canada
Boeing	1948	1275	US
LeoSat	108	1400	US
Astrome Tech	600	1400	India
Globalstar	40	1412	US



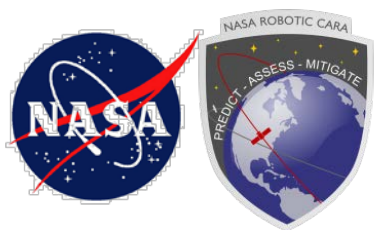
New Space Actors

- **The space environment today is very different from what it was 10 years ago and continues to evolve with technology**
 - Historically, space operations were domain of large governmental entities.
 - Commercial space operators are becoming commonplace and have different business models than government actors
 - Cubesats are cost effective and accessible for everyone down to elementary schools
- **Challenge in educating new space actors on best practices and availability of data and tools**

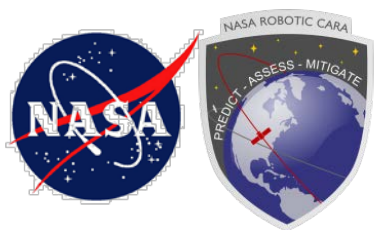


New Methodologies

- **Potential new CA paradigms to handle workload**
 - CA remediation against “grouped” events using an aggregate P_c
 - Station-keeping burn strategy to minimize conjunction risk, without actually remediating individual events unless an extremely high P_c
 - Consideration of consequence in addition to risk to determine which events to remediate
- **Automation/artificial intelligence**
 - Investigate methods to automate more of the process
 - Ensure that maneuvers are screened before performing
 - OD must be verified and new tracking requested
 - Determine usefulness of machine learning, neural nets, etc. in decision-making

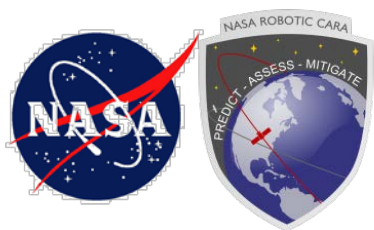


- **CA industry is evolving rapidly**
 - Guidelines/standards are needed to enable healthy growth
- **New methodologies will be needed for safety of flight**
 - Safety of Flight best practices should be adapted universally
 - Best practices are available on Space-Track.org website
 - Secure World Foundation publishes “Handbook for New Actors in Space”
 - NASA CARA to publish CA Handbook as well; focus will be more on technical/scientific foundations of best practices
 - Existing operators can share experience and lessons learned



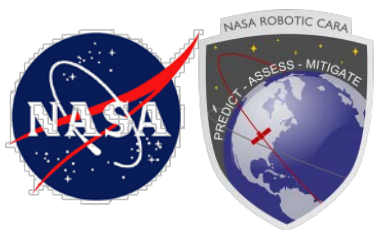
Orbital Registry

- **Propose an “Orbital Registry” service as part of STM that would:**
 - **Deconflict orbital placement:** provide evaluation of mission orbit selection during design phase to determine impact from close approach perspective and offer trade space of alternative orbits
 - Similar to filing flight plans; during license evaluation is too late to change orbit selection – should be during design
 - Tweaking orbits by a few km can make a big difference in reducing the number of close approaches with neighbors
 - Allows for advance notice of potential co-locations so that they can be avoided or managed smartly.
 - **Maintain database of operator contact information**
 - **Enable protected data sharing:** Sharing ephemerides is critical for powered flight/low-thrust modelling. Operators need to be ensured that their sensitive data is protected.
 - Centralized screening service would allow trusted agent to do this screening while keeping data secure
 - **Provide access to best practices/guidelines**
 - Initial best practices available include Space-Track.org, Secure World Foundation Handbook for New Space Actors



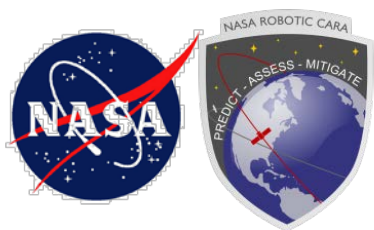
Importance of Data Sharing

- **Many spacecraft now using electric propulsion and/or automated onboard maneuver planning and execution**
 - The currently-maintained RSO catalog won't have up-to-date data on where these objects are
- **These missions will need to share powered flight ephemerides to all for CA**
 - Other operators have no way to tell where these assets are without shared data
 - Users would have to change their practice to screen these ephemerides against their own instead of relying solely on CSpOC/18 SPCS
 - Sharing should be through a trusted/protected mechanism, like Space-Track.org or SDA.
 - Missions will have to have mechanism for screening these ephemerides
- **Issue**
 - How does an operator know that another operator exists, or know where to find ephemeris data for other assets?



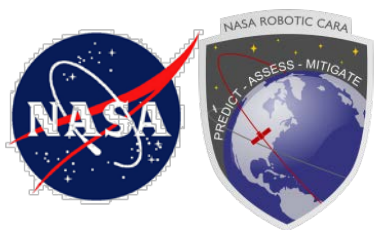
Space Traffic Management [1 of 2]

- **The potential need for a Space Traffic Management Architecture has been the subject of debate internationally for several years.**
 - Need for rules of the road to help operators efficiently use space
- **National Space Council**
 - Re-established in June 2017 by President
 - Created interagency working group to look at STM issue
- **Space Policy Directive-3**
 - Signed June 18, 2018 by President at 3rd NSpC meeting
 - First US Space Traffic Management Policy
 - Department of Commerce will make space safety data and services available to the public
 - Department of Defense will continue to maintain the authoritative catalogue of space objects
 - Implementation plan still being worked



Space Traffic Management [2 of 2]

- **American Space SAFE (Situational Awareness and Facilitation of Entity) Management Act**
 - Approved by U.S. House Science, Space, and Technology Committee on June 27, 2018
 - This bill will establish the Department of Commerce as the civilian agency to provide civil space situational awareness and traffic coordination. Further, the act:
 - Directs NASA to develop a plan for science and technology R&D activities to improve space situational awareness (SSA) and space traffic coordination capabilities
 - Establishes a NASA Center of Civil Space Situational Awareness Science and Technology Excellence
 - Establishes a civilian Space Situational Awareness Program at the Department of Commerce to provide information and services to spacecraft operators
 - Requires a basic set of SSA information and services for no charge and allows fees for additional information and services
 - Promotes opportunities for U.S. private sector SSA data and service providers to participate in and contribute to the Program
 - Establishes an SSA data testbed to provide public access to certain SSA data
 - Provides for NASA technical expertise to be leveraged by the Department of Commerce on a reimbursable basis
 - Directs the Secretary of Commerce to develop voluntary civil space traffic coordination guidelines and facilitate the development of industry standards
 - Creates a five-year space traffic coordination pilot program at the Department of Commerce to facilitate communication, negotiation, and resolution by civil spacecraft operators



Summary

- **Exciting growth offers opportunities that will change society, but needs to be done safely to ensure that we have continued use of the space environment for future generations**

- **References:**

- The Aerospace Corporation, “*Space Traffic Management In The Age of New Space*”
 - https://aerospace.org/sites/default/files/2018-05/SpaceTrafficMgmt_0.pdf