
# 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
  - Increasing on-board autonomy
  - 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

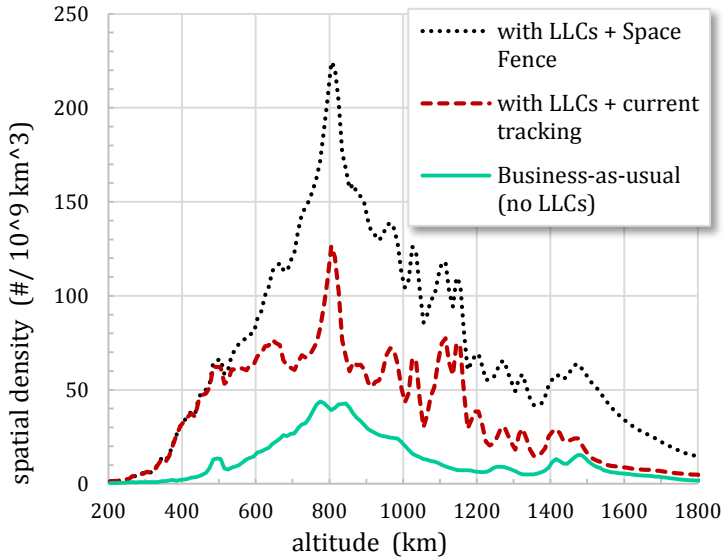
# Space Fence: Problem/Study Definition

- **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 late CY 2019

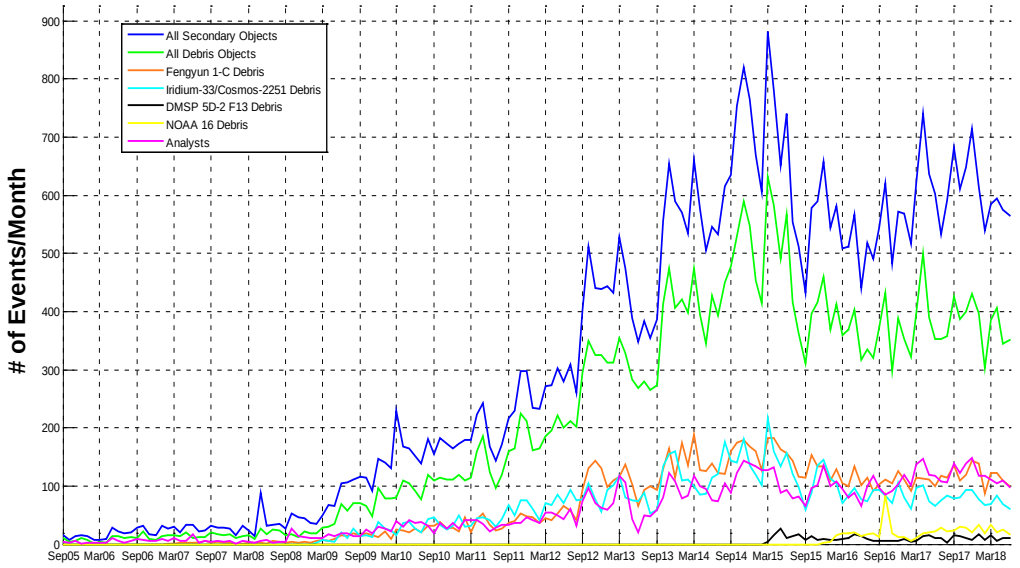
- **Expected issues for CA**
  - Substantially increased quantity of new objects
    - Overall CA workload increase estimate: factor of 3 to 3.5
  - Quality of maintenance ODs
    - Newly-discovered objects likely to receive light tracking
    - May create additional ops ambiguities and affect event actionability
  - Should be addressable by current ops paradigms, but workload increases will be felt both by CA practitioners and individual missions

# Increasing Workload-Space Fence and Large Constellations

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
- **Current constellation information available at** https://www.newspace.im/

Some Planned LEO Constellations

| Name | Number | Altitude (km) | Inclination (deg) |
|---|---|---|---|
| ISS | 1 | 400 | 51.6 |
| Starlink | 1584 | 550 | 53 |
| OneWeb | 600 | 1200 | 88 |
| Hongyan | 320 | 1094 | 50 |
| Iridium | 75 | 780 | 86.4 |
| GlobalStar Block 2 | 30 | 1410 | 52 |
| Amazon Kuiper | 3236 | 630, 610, 590 | 51.9, 42, 33 |
| Telesat Polar | 72 | 1000 | 99.5 |
| O3B | 20 | 8063 | 0 |
| Telesat Inclined | 45 | 1248 | 38 |
| Envisat | 1 | 773 | 98.4 |
| Hongyun | 156 | 1000 | 97.4 |
| Synspective | 30 | 600 | 97.8 |
| Orbcomm Block 2 | 18 | 750 | 47 |
| Flock | 217 | ~489 | 97 |
| Lemur | 76 | ~496 | 97 |

Table excerpted from Shepperd, Ryan, "How Big is Big? Better Metrics for Defining Constellation Size regarding Space Sustainability," International CA Workshop, Paris, France, June 2019.

# Trending Concern: Excessive CA Streamlining

- **Desire among satellite O/Os to streamline CA process**
  - Understandable, given additional expected CA loading
- **Proposed streamlining: eliminating pre-maneuver screenings**
  - If screening volume large enough, all possible conjunctions, even with primary ephemeris altered due to a maneuver, should be represented by CDMs
  - Can use state and covariance information in current CDM set to perform equivalent of maneuver screening
  - Eliminates need to send maneuver ephemeris to 18 SPCS for screening
- **Fallacy: ignores potential maneuvers of other primary objects**
  - "Regular" screenings consider only the submitted primary ephemeris or DoD primary solution against remainder of catalogue
  - "Ephemeris on ephemeris" screenings are conducted in order to consider potential maneuvers of secondary objects, but only if ephemeris submitted
  - Current streamlining proposal thus leaves category of potential secondary objects (*i.e.,* other primaries) unaddressed

# Trending Concern: Autonomous, On-Board CA

- **Some satellite operators have implemented autonomous, on-board CA**
  - 18 SPCS CDMs uploaded at regular intervals
  - On-board algorithms identify and plan needed maneuvers autonomously
  - No notifications to anyone about intended maneuvers in advance
- **Issue 1: cannot know maneuver intentions of other spacecraft**
  - Maneuver plans often changed with little lead time
  - Presently O/Os work together to address such situations; impossible here
- **Issue 2: "Kantian Universality" failure**
  - One must act only in a manner that can become a universal law
  - Cannot have more than one constellation with autonomous CA
    - If two satellites autonomously reacting to avoid collision with each other, and neither knows how the other is planning to react, no way to know whether a collision is being avoided
    - Result might be for both satellites to maneuver into each other

# New Space Actors

- **The space environment today is very different from a decade ago and continues to evolve very rapidly**
  - 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, even down to elementary schools
- **Challenge in educating new space actors on best practices and availability of data and tools**
- **May require space "regionalizaiton" rules**
  - E.g., altitude < 350km a "Wild West" region for cubesats with little flight dynamics experience or orbital control
  - Allows inexperienced actors to access space without threatening high-value assets

# New Methodologies

- **Potential new CA paradigms to handle workload**
  - CA remediation against “grouped” events using an aggregate Pc
  - Station-keeping burn strategy to minimize conjunction risk, without actually remediating individual events unless an extremely high Pc
  - Consideration of consequence in addition to risk to determine which events to remediate—already moving towards implementation at NASA
- **Automation/artificial intelligence**
  - Investigate methods to automate more of the process while retain key safety elements
  - Determine usefulness of machine learning, neural nets, etc. in decision-making

# Best Practices

- **CA industry is evolving rapidly**
- **Guidelines/standards are needed to enable healthy growth**
  - 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”
    - Global VSAT Forum (GVF) - commercial communications operators consortium has developed set of best practices that include some for CA
    - CONFERS for Proximity ops
    - 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
  - AIAA recently initiated a Space Traffic Management working-group to investigate various topics. One is best practices.
    - Above items and others being collected to be made available on public website
    - For information contact Dan Oltrogge or Moriba Jah

# 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**
  - Currently-maintained RSO catalog will lack up-to-date data on these satellites' locations
- **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