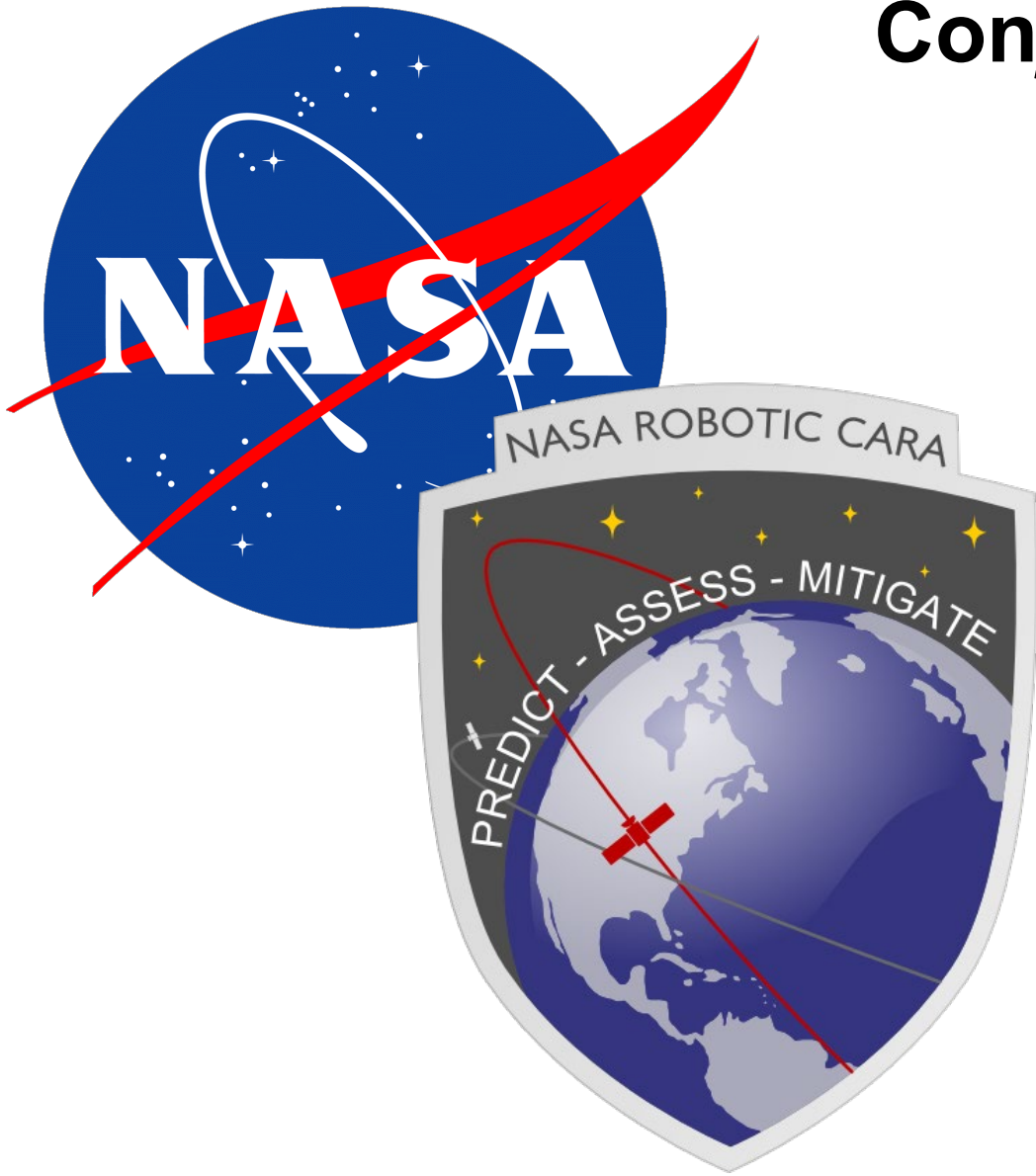
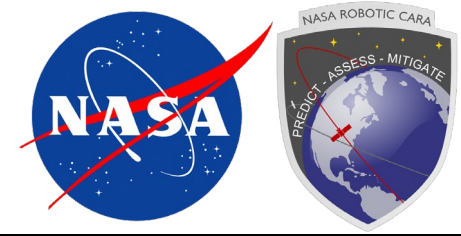


Conjunction Assessment Risk Analysis



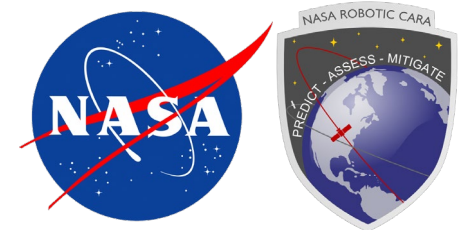
CARA Large Constellation Status

CARA Operations
NASA CARA | Spring 2021

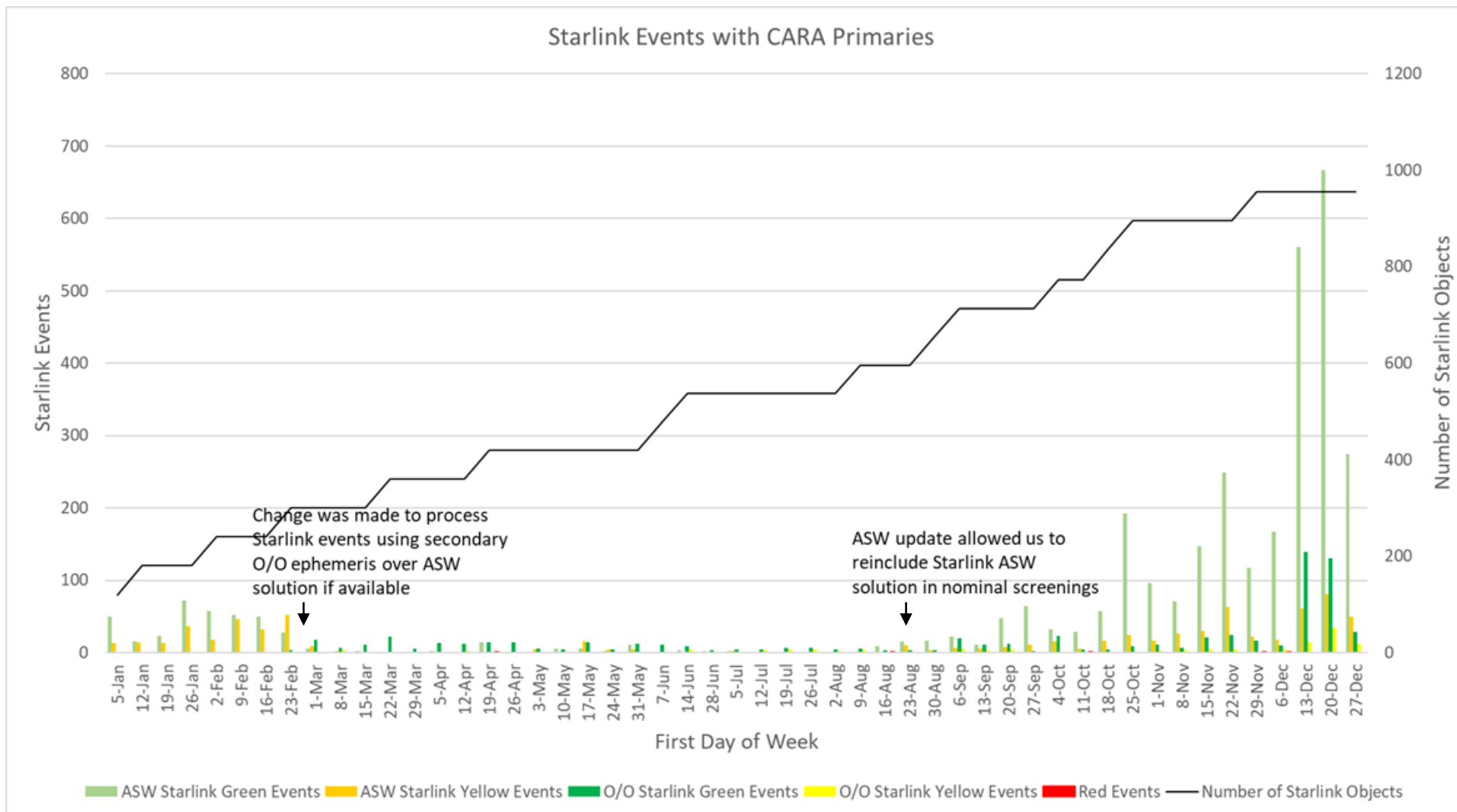


Agenda

- **Starlink and OneWeb Event Stats**
- **Known large constellations**
- **Recent Completed Work**
- **Summary of CARA CONOPS**
 - Starlink
 - OneWeb
 - Other
- **Challenges**
- **Future work**



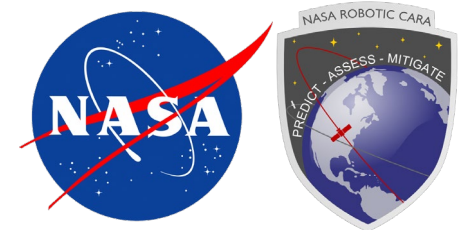
Starlink Event Stats 2020



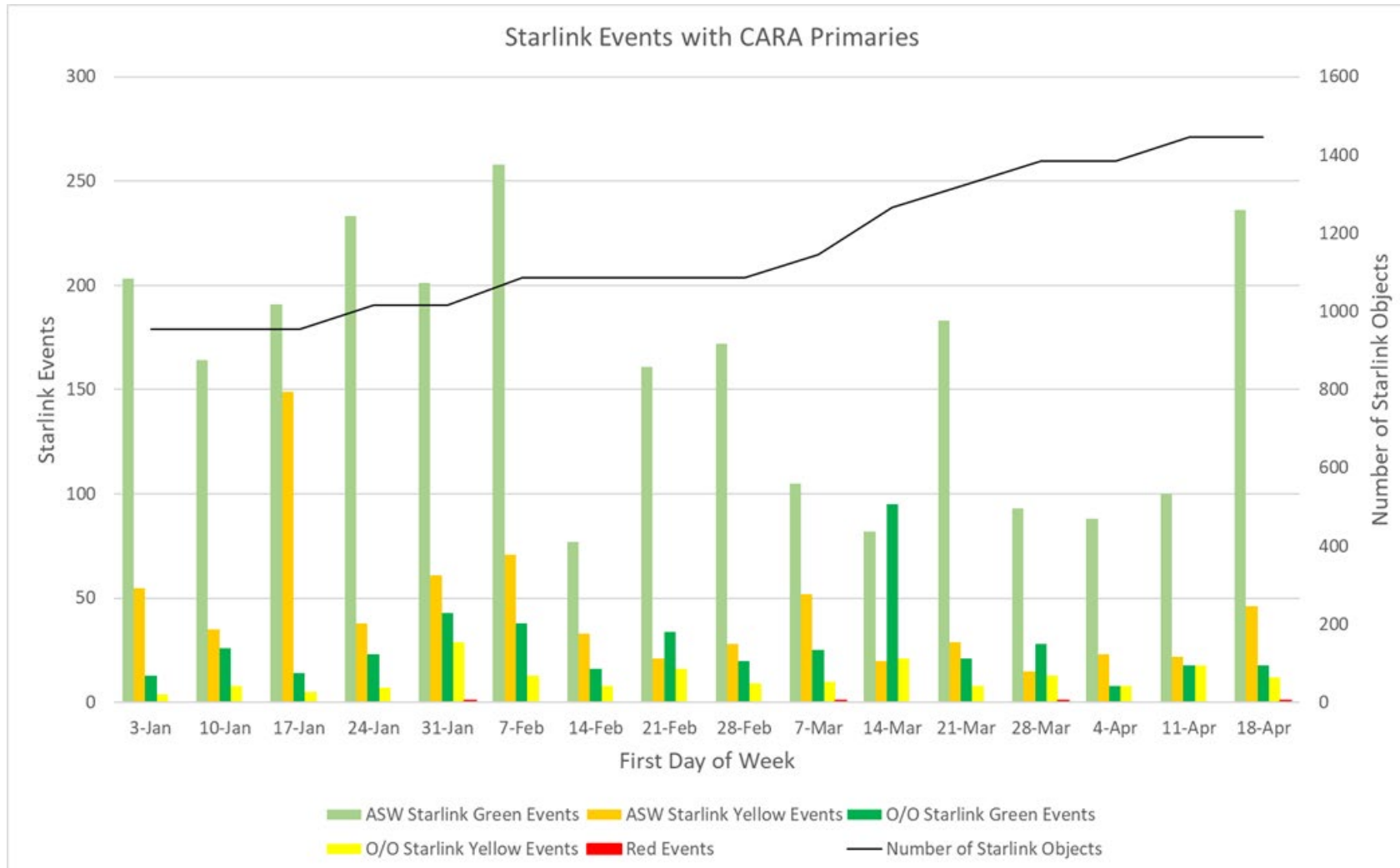
- **As of September 2020, Starlink ASW solution added to nominal screening due to improved OD solve on-orbit**
- **Increased ASW events driven by Starlink ascent to final orbit**
- **Small number (< 10) of red events observed**

2020 Red Threshold = $4.4\text{E-}4$

2021 Red Threshold = $1\text{E-}4$

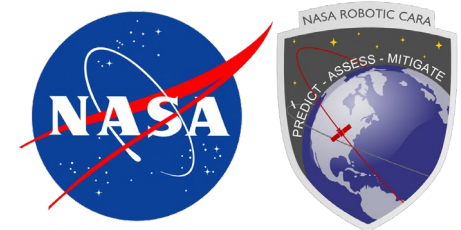


Starlink Event Stats (2021 YTD)



- SpaceX has signed a Space Act Agreement with NASA and has committed to maneuvering for high-risk events against CARA-protected assets
- CARA continues to meet routinely with the Starlink team to discuss CONOPS and other items of interest
- Overall, number of events has not grown linearly with the number of Starlink payloads launched; number of high risk events has remained low

2020 Red Threshold = $4.4\text{E-}4$
2021 Red Threshold = $1\text{E-}4$



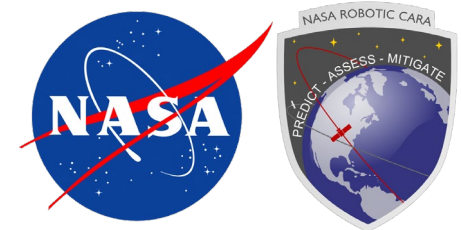
Starlink Payloads (as of 2 May)

- **SpaceX continued to have frequent Starlink launches with 9 launches YTD in 2021**
- **1383 Starlink payloads in orbit as of 15 April**
- **64 Payloads have reentered**
- **Approximately 23 Starlink payloads on-orbit are not currently maneuvering**
 - Could be active or dead (see slide 9)
- **As of 27 April, FCC approved another 2,824 Starlink payloads at 570 km**
 - These payloads were originally approved at 1,100 km

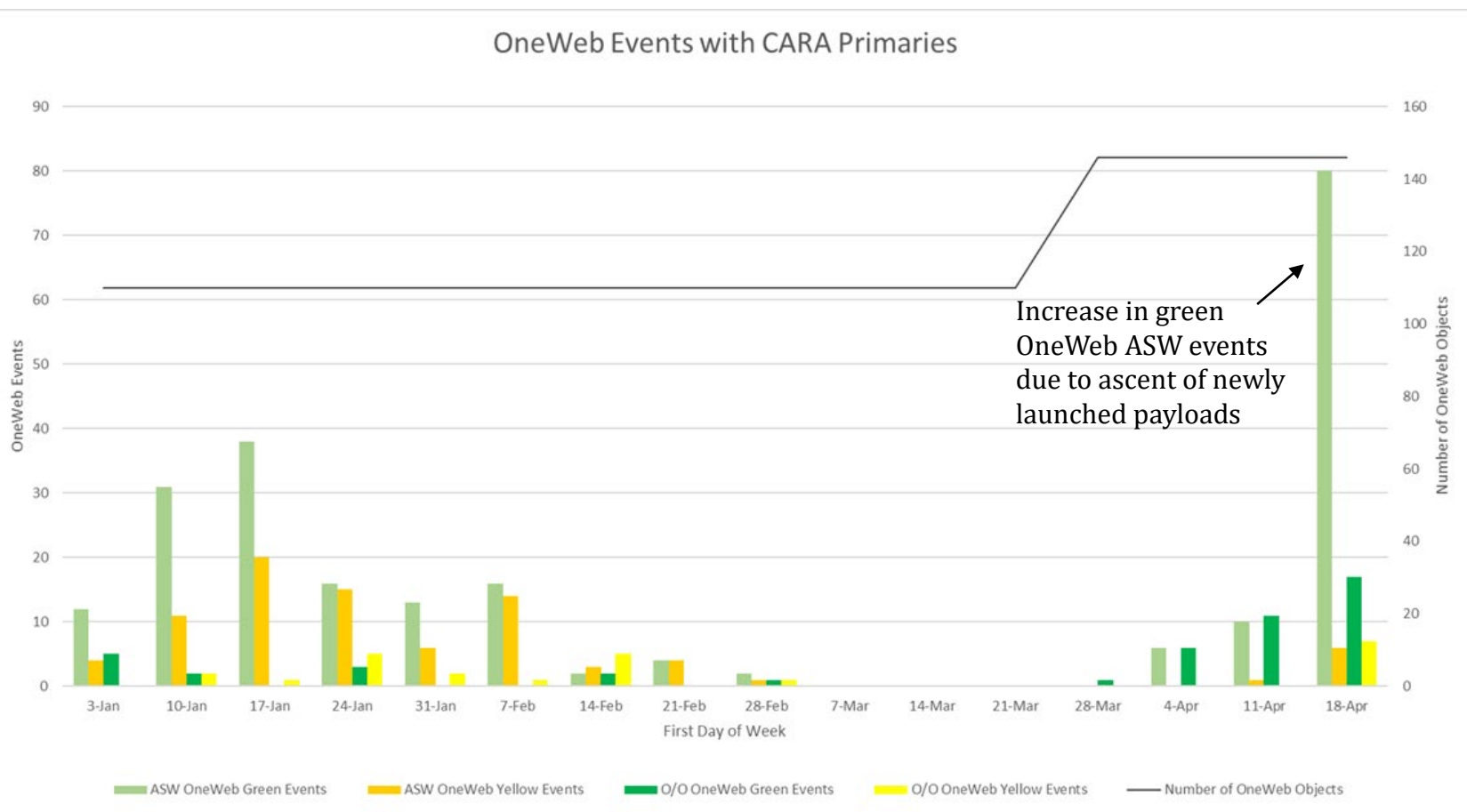
April 15, 2021

Orbit Type	Orbit Parameters (km)	Number of Spacecraft
Initial Orbit	≤ 380 apogee	319
ISS Regime	> 400 and ≤ 425 apogee	18*
Transit to Final Orbit	> 380 and ≤ 545 apogee	189
Final Orbit	> 545 and ≤ 555 apogee	871
Non-Standard Orbit	≥ 550 apogee	4
Total		1383

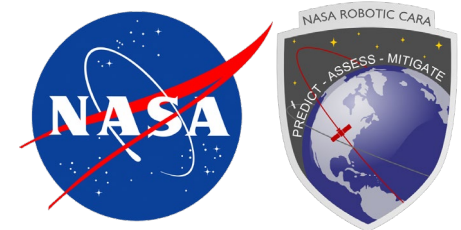
*ISS Regime payloads also counted as in transit



OneWeb Event Stats (2021 YTD)

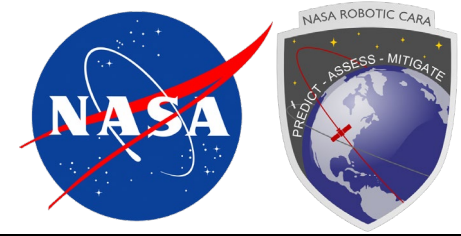


- **OneWeb has resumed monthly launches in early 2021**
- **Each launch has 36 payloads that ascend through many CARA assets to their final orbit at 1,200 km**
- **CARA continues to meet every M-W-F with the OneWeb operations team to discuss any conjunction events identified**
- **OneWeb team modifies ascent maneuvers to mitigate events**
- **No high-risk and few moderate-risk events have been identified thus far**



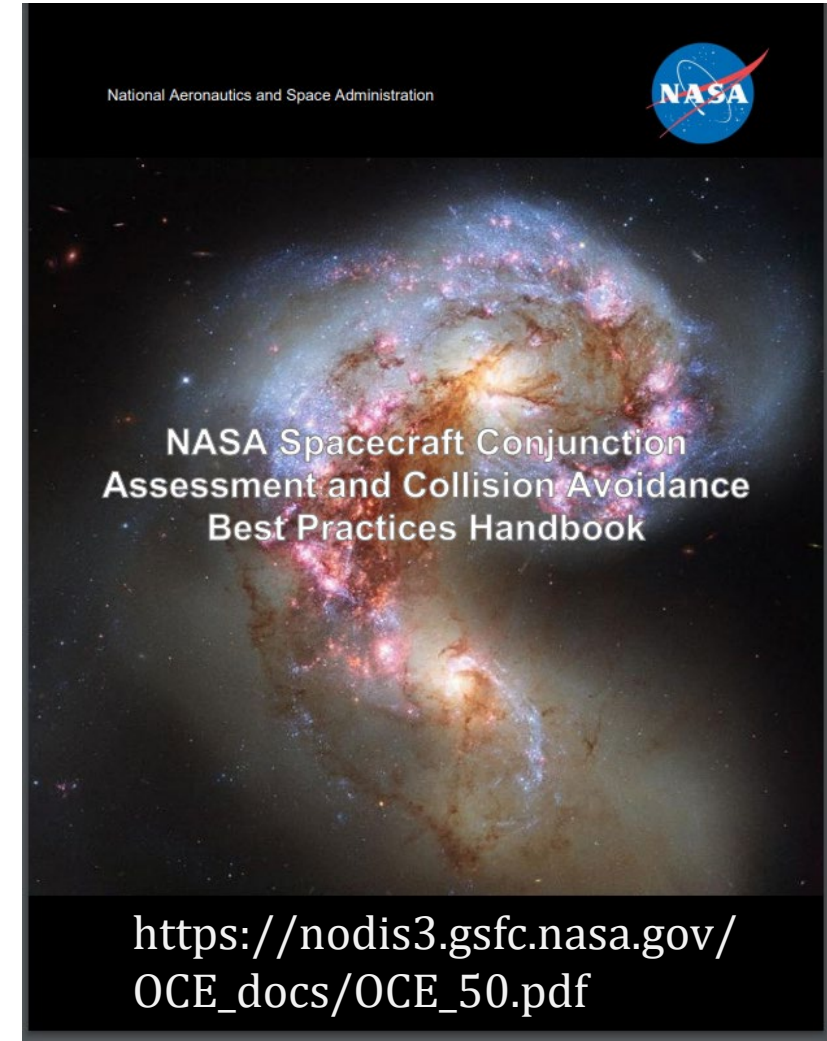
Known Large Constellations

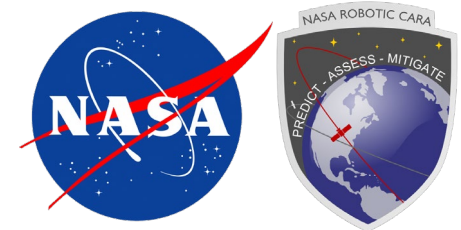
Large Constellations	Current Status
SpaceX	1,500 launched (1383 on orbit) Planned 12,000+ (4,800 near 550 km)
OneWeb	600+ at 1200 km
Project Kuiper	3,000+ at LEO
Viasat	20+ at 8200 km
TeleSat Canada	117+ at 1000 km & 1250 km
Kepler Communications	140 at 520-600 km
LeoSat MA	108 at 1400 km
SpaceBees (Swarm)	150 at 460-580km (~87 currently on orbit)
Flock (Planet)	396 at 410km & 605 x 620 km (more planned?)
SpaceMobile (AST)	243 at 720km



Recent Completed Work

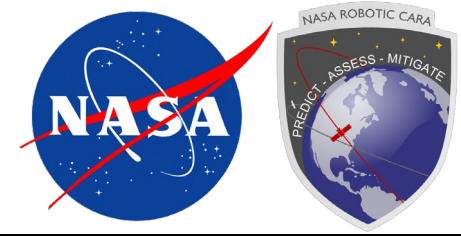
- **NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook**
 - Published December 2020
- **Covers many topics**
 - USSPACECOM CA Process
 - Spacecraft and Constellation Design
 - Pre-launch Prep and Early Launch Activities
 - On-Orbit Collision Avoidance
 - Automated Trajectory Guidance and Maneuvering
- **Living document will be updated as best practices for CA evolve**





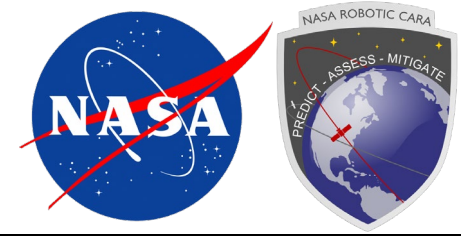
Summary of Large Constellation CONOPS

- **CARA Reviews ASW and O/O solutions for secondary payloads and will determine which solution is preferred on a case-by-case basis**
 - See Future Work (Slide 12)
- **For known ascending missions such as identified Starlink and OneWeb CARA defers to the O/O ephemeris reflecting ascent maneuvers**
- **For non-maneuverable Starlink payloads, CARA will recommend/assist in maneuver planning**
 - Identified via Space-Track Maneuverability Flag
 - If a Starlink payload has “Unknown” maneuverability per Space-Track CARA will reach out to determine status
- **Daily Starlink email sent to all CARA missions with latest Space-Track active/maneuverable flag information**



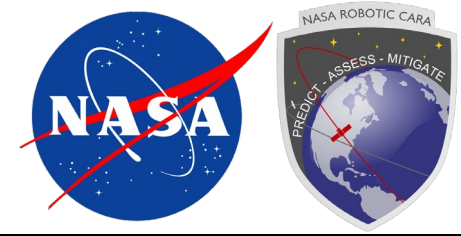
Summary of Large Constellation CONOPS

- **CARA utilizes the Automated Maneuver Screening (AMS) script**
 - Allows automatic repeated screenings of special maneuver ephemerides every 8 hours
 - Only needed for maneuvers planned and executed within 24 hours i.e. emergency situations for missions within Starlink ascent or final orbit altitudes (~280 – 570 km)
- **CARA Supports routine meetings with OneWeb team to discuss conjunction events**
 - OneWeb team replans ascent maneuvers as needed
- **Secondary Payload Contact procedure used for high interest events**
 - CARA reaches out to secondary payloads on behalf of supported missions
 - Determines further maneuverability and ephemeris information directly from O/O whenever possible



Challenges

- **Large effort to coordinate with numerous large constellation operators and secondary O/Os in general**
- **Each O/O has their own CONOPS and have various levels of CA CONOPS sophistication**
- **O/O ephemeris quality evaluation is important in order to determine the efficacy of the O/O solution for decision-making**
- **Need to continue nominal operations while incorporating new large constellation and other secondary payload evaluation and work**



Future Work

- **Continue dialog with Starlink and OneWeb teams to identify any potential issues and develop mitigation strategies as needed**
- **Work with future secondary O/O missions to understand their CONOPS and how CARA can continue to support and protect NASA missions**
- **CARA reviews all FCC and FAA licenses and provides feedback where applicable as part of the standard review process**
 - CARA provides technical comments but cannot require CONOPS and/or propulsion
- **CARA Operations developing secondary O/O ephemeris use CONOPS to determine appropriate action for events**
 - Considers availability of O/O ephemeris, maneuverability, and covariance size
 - Reviewing ability to evaluate accuracy and covariance realism