JSpOC Recommendations for Optimal CubeSat Operations

1 JFCC SPACE AND THE JSPOC

The Joint Functional Component Command for SPACE (JFCC SPACE) is responsible for identifying, cataloging and tracking over 23,000 man-made objects achieving orbit. JFCC SPACE executes this mission using data collected by the U.S. Space Surveillance Network (SSN) and through the expertise of its personnel at the Joint Space Operations Center (JSpOC), located at Vandenberg Air Force Base, in California. The proliferation of CubeSats (10cm x 10cm x 10cm satellites) and associated technology, have posed unique tracking and identification challenges. In light of this evolving situation, JFCC SPACE would like to share information on the current challenges it faces and propose recommendations on how to optimize operations in coordination with the JSpOC, to support the growing government, commercial, and academic CubeSat communities of interest.

2 CURRENT CHALLENGES

In late 2013, two launches presented an unprecedented challenge for JSpOC personnel. The ORS-3 mission launched STPSAT 3 and 27 CubeSats, closely followed by a DNEPR rocket hosting 31 CubeSats. Both launches involved multiple owner/operators (O/Os) from all facets of the space community; U.S. and foreign governments, academia, and commercial entities, all of whom depend on the JSpOC to a varying degree for support functions to ensure mission success. These two independent multi-payload deployment missions presented known challenges to JSpOC processes. After-action reviews completed after the launches revealed that the JSpOC and O/Os require higher levels of collaboration in order to provide optimal pre- and post-launch support. Notable points included:

- The JSpOC uses information provided by the launch entity and/or O/O as the truth-source. Without launch information from the launch entity and/or O/O, the JSpOC has limited data to inform tracking and cataloging, which delays delivery of information to satellite stakeholders.
- The JSpOC does not command and control satellites, communicate with satellites (passive or active), or provide telemetry of satellites. Many O/Os are unaware of this fact. The JSpOC relies on O/Os to perform this role and provide telemetry information that may assist with identification.
- The JSpOC depends on O/Os to provide detailed information on launch plans and payload deployment to ensure individual payload(s) are quickly identified upon separation or release from the payload deployer. Without this information and coordination, the JSpOC may have difficulty tracking and differentiating CubeSats. As a result, the JSpOC may be required to categorize the objects as unknown "analyst satellites" until more data can be collected. Analyst satellites are not publicly releasable, which makes it difficult for O/Os to conduct their missions, and inhibits collaborative identification efforts between the JSpOC and the O/O.

- The JSpOC physically tracks objects and provides assessment screenings using SSN observations and O/O-provided information, both before and after launch. These services include Launch Conjunction Assessment, Early Orbit Conjunction Assessment, and On-Orbit Conjunction Assessment. The JSpOC is dedicated to supporting spaceflight safety through all mission phases, but relies on O/O-provided information to do so consistently.

3 RECOMMENDATIONS

After extensive coordination with CubeSat O/Os, the JSpOC understands that O/Os have a wide range of requirements, spanning from pre-launch mission planning to spaceflight safety support. Accordingly, the JSpOC offers the following recommendations for CubeSat launch entities and O/Os to consider as they conduct CubeSat planning.

CubeSat Development:

- Satellite identification is extremely difficult to determine without initiative taken by the launch entity and/or O/O.
    - Identification markers, either physical or signal based, should be considered and these should be different for each object deployed in a multi-payload launch. Markers should function for at least two months to provide sufficient time for object separation and maximize the likelihood of identification.
- Satellites should have some maneuver capability to facilitate conjunction avoidance on-orbit.
- Satellites should be built to allow controlled reentry or expedited uncontrolled reentry to minimize the threat of individual CubeSats beyond the satellite's mission life.

Pre-launch Planning:

- JFCC SPACE highly encourages early engagement between the launch entity and/or CubeSat O/O(s) and the JSpOC. Early engagement includes exchanging mission briefs, discussing mission support requirements, and establishing formalized communication channels prior to launch. This will allow the JSpOC to provide an honest assessment of how they can support the O/O's mission, and provide recommendations on how to best achieve mission success.
- Orbit and mission parameters should be tightly scrutinized and controlled by O/Os.
    - With some margin, operational life should be proportional to orbit life. For example, a satellite's operational life should be greater than 2/3 of the orbital life.
    - Satellites that have a projected orbit 100km or less in the radial component from the ISS should be reevaluated to identify alternatives that don't threaten the ISS or to determine if overall mission objectives and parameters outweigh the risk to Human Space Flight (HSF) objects. In general, O/Os should deploy CubeSats below or from the ISS.
    - Satellites should be placed into high inclination orbits. Early engagement will allow the JSpOC to review the launch plan, and provide recommendations that will ensure maximum sensor coverage to optimize tracking and identification, as well as spaceflight safety.

- To expedite cataloging and identification, the launch entity and/or O/O should provide the following to the JSpOC (preferably through the R-15 Form, 10-30 days prior to launch):
    - Orbital regime of the satellite(s)
    - Deployment sequence of launch vehicle and all payloads
        - Satellites should be deployed at multi-second intervals during burns to facilitate CubeSat separation and JSpOC detection/identification/tracking. Detailed development of supporting deployment scenarios such as minimum propulsion thrust (km/s) recommendations and timed satellite deployments will enable observations. This will lead to greater probability of individual CubeSat identification.
        - If deployment during boost is not an option then deployments during non-powered flight should be no closer than 60 seconds apart.
    - Satellite characteristics, including size, maneuverability, and deployment plans (i.e. solar panels, parachutes, shedding, etc.)
- To ensure spaceflight safety, the launch entity or satellite O/O(s) should request launch conjunction assessment.
    - The launch entity should submit the launch trajectories and analysis requirements through the Form 22.
    - The JSpOC will screen the trajectories against the space catalog and inform the launch entity and/or O/O of any possible conjunctions.

Launch

- Immediately after launch, the JSpOC will use the information provided by the launch entity and/or O/O to confirm a nominal launch, and catalog and identify the launched satellites.
- If the JSpOC is able to catalog and identify a satellite according to provided information, they will provide the initial element set to the O/O.
- If cataloging and identification is complicated due to lack of information or a complex launch sequence, the JSpOC may be forced to catalog the objects as analyst satellites.
    - If the O/O pre-coordinated with the JSpOC, the JSpOC will provide information on analyst satellites and ask the O/O for assistance in identifying their asset.
    - It the O/O has not pre-coordinated, the JSpOC will maintain the object as an analyst satellite until sufficient tracking data is collected to confidently catalog the object.

Post-Launch

- For multi-payload launches, satellites that are CubeSats or smaller, or complex deployment sequences, ongoing communication with the JSpOC is critical to identifying satellites and providing timely and accurate conjunction assessment.
    - If available, O/O tracking or position data should be provided to the JSpOC to assist in identification.
    - If the O/O cannot provide tracking data, the JSpOC will provide potential positional data and ask the O/O to confirm successful communication.
- During the early orbit phase of operations, the JSpOC relies on O/O information and predicted ephemeris to provide accurate conjunction assessment for maneuverable missions.

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- o The O/O can provide ephemeris pre- and post-launch for early orbit conjunction assessment to assist in maneuver planning.
- If the CubeSat mission is non-maneuverable, the JSpOC will rely on SSN data to provide conjunction assessment. In this case, information from the launch provider and/or O/O is absolutely critical to cataloging the object as soon as possible so that the JSpOC can provide conjunction assessment based on high-accuracy catalog data.

4 GETTING STARTED

The JSpOC would like to engage as early as possible with all CubeSat launch entities and O/Os to discuss mission requirements, negotiate optimal support, and establish lasting relationships that will ensure mutual operational success.

- Visit JFCC SPACE's public website, Space-Track.org, for a description of SSA Services
    - o Available at no cost to all satellite O/Os
    - o https://www.space-track.org/documentation#odr
    - o Includes links to all launch planning and support forms (R-15, Form 22, Orbital Data Request)
- Consider an SSA Sharing Agreement with USSTRATCOM
    - o Protects proprietary information
    - o Entitles signatory to advanced SSA services
    - o Contact j513@stratcom.mil for more information
- Contact the JSpOC's SSA Sharing Cell to discuss your mission and coordinate immediate support
    - o Email: jspoc.ssasharing@us.af.mil
    - o Phone: 805-606-2675