Iridium Deorbit of Block 1 Constellation
Iridium Communications
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I. SHORT DESCRIPTION OF OUTERSPACE ACTIVITY

Iridium completed the most significant technology refresh in space history, replacing its entire constellation of Low Earth Orbit (LEO) satellites. As part of that endeavor, Iridium developed and implemented a deorbit program for its original (Block 1) satellites to remove them from orbit and ensure space is safer for future generations. During Block 1 operations, Iridium became acutely aware of the risks that derelict spacecraft pose: notably the destructive collision of Cosmos-2251 and Iridium-33 in 2009[1]. This event opened the eyes of the space community and certainly strengthened Iridium's resolve to take all steps necessary to assume a leading role in space stewardship. The Iridium deorbit program can be used as a model for best practice ideas and concepts for future satellite programs and space stewardship.

Several objectives guided investment and development efforts for the deorbit program. Iridium committed to a deboost plan that would accomplish a 25-year or better deorbit profile. Through that plan, Iridium maintained direct control of the satellites, guiding them through a safe passage from mission to final controllable orbits. In order to accomplish these objectives, flight software enhancements and operational improvements were necessary to achieve orbit targets reliably. Once fuel was exhausted, propellant tanks were depressurized, to avoid explosion risk. At the end of life, satellite passivation was performed, which de-spun momentum wheels to remove kinetic energy, re-oriented solar arrays to a high drag configuration, and discharged the batteries to put the satellite into an inert configuration.

The deboost of Iridium satellite SV097 in December of 2019 was the final active event of the Iridium deorbit program. The result was the deboost of 65 satellites, 60 of which have already re-entered Earth's atmosphere with a median time to reentry of just 19 days. The sum of material removed from space exceeds 33 metric tons. End of life deboost maneuvers and full transparency to other space actors/entities were critical to the success of the deorbit program. Given the state of the constellation, Iridium invested substantially in software modifications to optimize deboost, provide options for challenged SVs, and provide extra levels of fault tolerance and reliability.

In the 1990's, when Iridium was designed, space cleanup initiatives were just becoming a topic of interest. NASA and Inter-Agency Space Debris Coordination (IADC) guidelines for a 25-year burn-in was not a commercial standard. As one of the first satellite constellations, Iridium foresaw the need to remove satellites from LEO and minimize the potential for future debris generation. Therefore, Block 1 satellites had design and operational requirements for end-of-life management. This included a significant propellent allocation for orbit lowering (deboost) and some flight software to support end-of-life maneuvers.

With deboost capability built into each satellite, a reader might get the impression that executing a deboost would be a simple task. Iridium engineers found that responsible space cleanup was far more than just sending a "deboost" command. Twenty years of Iridium flight experience provided invaluable insight into how the satellites performed under various conditions. They understood what modes and algorithms worked best for satellite performance, risks that existed for old hardware, and upgrades that could ensure reliability and success in deorbit. Management provided the resources for engineering and operations to take the right steps in every aspect of the deorbit program.

The Iridium program had seven objectives for the satellite deorbit:

- Deboost: Use remaining propellant to maneuver the satellites as low as possible
- Drag: Configure satellite for high drag at the end of deboost
- Direct: Guide and maintain active control of the satellite throughout maneuvers
- De-spin: Reduce onboard kinetic energy of the momentum wheel
- Depressurize: Vent any remaining propellent & pressurants from tank
- Discharge: Drain the battery and electrical energy
- Demise: Maximize disintegration of satellite upon reentry

These objectives are intuitive, though some technical details are worth noting:

- NASA and the IADC recommend a 25-year reentry orbit for LEO satellite disposal[2]; however, Iridium Block 1 satellites were designed with a more aggressive goal: a one-year reentry timeframe. Iridium found many satellites had enough fuel remaining to reach altitudes low enough that Iridium set an aspirational goal of a four-week reentry post-deboost phase.
- Orbit experience showed drag differences due to solar array positions. Empirical data showed that solar array position could decrease the satellite ballistic number, reducing on-orbit dwell times once deboost was complete.
- Directing the deboost was limited to maintaining custody/control of the satellite while it was actively maneuvered through deboost. Maneuver plans were shared with all interested parties. Unfortunately, thruster capability and control authority did not allow for a controlled or targeted reentry.

II. CONNECTION WITH THE LONG-TERM SUSTAINABILITY (“LTS”) GUIDELINES

In conjunction with guideline D.2, Iridium implemented advanced measures for spacecraft passivation and post-mission disposal and designs to enhance the disintegration of space systems during uncontrolled atmospheric re-entry. Iridium developed, tested, and executed efforts to ensure a successful deorbit campaign. Further, Iridium committed the necessary resources to develop new satellite software, operational procedures, and simulation capabilities and the efforts were endorsed throughout Iridium to ensure efforts were made to enhance space sustainability.

Iridium’s deorbit program also supported the LTS guidelines B.1 & B.9 by providing updated contact information and sharing information on space objects and orbital events. Iridium’s close communication with the Combined Space Operations Center (CSpOC) was imperative to its deorbit program successes especially since the satellites needed to traverse the area currently being utilized for human spaceflight. CSpOC and other civil and commercial bodies helped facilitate communications between Iridium, and other space actors. Iridium’s ephemerides and maneuver OPMs uploaded to *space-track.org* were marked as “public” so that the satellite owner/operator community would have access to the information, allowing for greater situational awareness. Iridium highly recommends that all members of the space community follow suit. Additionally, Iridium provided multiple points of contact on *space-track.org* to streamline communication and coordination between satellite operators.

Aiding the coordination effort further was a key feature of Iridium Block 1 satellites, as they were equipped with automated burn planning software. However, they did not have the ability to screen plans against a database of objects in space. Iridium simulated burn plan generation, verified that plan on the ground, then submitted the proposed plan to CSpOC. Once the plan was cleared for execution, the SV was commanded to generate the actual onboard plan, which was verified against the original plan and modified as necessary as actual burn performances slightly differed from the planned maneuvers. Iridium managed its burn plans with the right individuals and chose to use known and pre-coordinated plans to ensure active ownership of the maneuvers.

III. LESSONS LEARNED

Iridium is acutely aware of the on-orbit risks posed by derelict satellites and has been a vocal advocate of responsible space operations. Based on our experience deorbiting our Block-1 satellites, space asset management should be done in accordance with international standards of execution coordination, utmost transparency and in such a way to ensure spacecraft passivation and post-mission disposal and designs to enhance the disintegration of space systems during uncontrolled atmospheric re-entry.

Iridium's end-of-life disposal started in the vehicle design phase, but that was only the beginning framework. Engineers and operators took all the experience they gained operating the first generation satellites and applied those skills and techniques to refine that framework into a successful deorbit program. Engineering challenges were encountered as the satellites aged, and resources were applied to overcome those obstacles. The processes and procedures used to extend the life of the mission were also applied to improve disposal reliability. In short, the design and execution of an end-of-life disposal program should be considered early in the design phase, enhanced during the operational phase and then executed with full transparency to ensure a successful campaign.

Iridium developed a full deorbit plan and executed it successfully. We committed to using space for our operations and then leaving it as we found it by properly deorbiting and disposing of our constellation. We believe this sets a high standard for the global space industry and endeavor to share our deorbit plans to help others achieve similar results.

[1] Shepperd, R., Ward, D. McKissock, D. "A Review of the Collision between Iridium 33 and Cosmos 2251", International Conjunction Assessment Workshop, Paris, France, 2019.

[2] Inter-Agency Space Debris Coordination Committee. "Space Debris Mitigation Guidelines," IADC-2002-01, Rev 1. 2007.