STAR ONE C4 Space Debris Mitigation Plan (Prepared for the Federal Communications Commission)

TABLE OF CONTENTS

1. Introduction

The Star One C4 satellite was built by Maxar and it is fully compliant to the FCC ruling and ESA requirement on orbital debris. This orbital debris assessment report describes the design, mitigation, and plan to meet the requirement. The satellite is owned and controlled by Embratel/Star One, part of the Claro Brasil group.

This plan includes specific elements of orbital debris mitigation: spacecraft hardware design in control of debris released, minimizing debris generated by accidental explosions, safe flight profiles and post mission disposal. In addition, this plan also covers the best practices adopted to operate the satellite in safety conditions.

2. Related Documents

2.1. Applicable Documents

The following documents are applicable to the extent specified herein:

1. Claro Internal Debris Mitigation Procedure. IT_MECCEL_G20
2. FCC. Orbital Debris Mitigation Standard Practices.

2.2. Reference Documents

The following documents, though not formally part of this document, were also used in preparing this plan:

1. IADC Space Debris Mitigation Guidelines IADC-02-01 Rev. 3. 23 June 2021.
2. Space Product Assurance. Safety. ECSS-Q-40A. 17 May 2002
3. Mitigation of Orbital Debris in the New Space Age. FCC 04-130. IB Docket No. 18-313. April 2, 2020
4. NASA Process for Limiting Orbital Debris. NASA-STD-8719.14B. April 2019
5. Environmental Protection of the Geostationary-Satellite Orbit. ITU-R S.1003-2. 2010.
6. UNCOPUOS. Technical Report on Space Debris. 1999, New York.
7. U. N. Article VI and VII of The Outer Space Treaty.
8. Claro Quality Manual.

3. STAR ONE C4 Design

Star One C4 was designed to minimize the amount of debris released during normal operations. Maxar was the satellite manufacturer and has performed a careful debris generation assessment on the satellite platform. The result confirms no intentional debris will be released by the spacecraft during normal on-station operations except the following: the only part of the mission in which portions of the spacecraft are released from the main spacecraft body is during deployments. Release and deployment mechanisms are intended to contain the debris generated when activated. There are several reflector hold-down and release mechanisms that are actuated by EEDs (Electro-Explosive Device) that have the potential to expel a small amount of debris, i.e. up to 3mg of titanium debris from the hold-down and 2mg of "soot" per firing. These EEDs are space standard items and have flown on over 35 Maxar spacecraft with no failures. The assessment found no other source for debris throughout the mission.

The satellite owner and the manufacturer have taken measures to ensure a safe operational configuration of its satellite system through a flight heritage hardware design and flight proven operational procedures. Each section below addresses specific measures taken, as required by the Commission's rules, to limit the possibility of this satellite's operations generating orbital debris.

The satellite is based on an all Bi-Propellant chemical propulsion subsystem.

3.1 Collisions with small debris and meteoroids

Maxar has also assessed the probability of the satellite becoming a source of debris due to collisions with small space debris or meteoroids that could cause loss of satellite control and prevent post-mission disposal. Collisions with the background environment, including meteoroids, are considered as part of the satellite design on a statistical basis to determine collision risk. Maxar includes meteoroid environments as part of the satellite Environmental Requirement Specifications.

The available literature was reviewed for large size space objects, particularly technical papers that present collision probability estimates for orbital conditions of interest. The satellite requirement was derived from these technical papers, as well as NASA models, and include debris and meteoroids of various sizes. Satellite design includes steps to limit the effects of such collisions through shielding, the placement of components, and the use of redundant systems.

The structural elements of the satellite act as part of the debris/meteoroid shield to protect sensitive electronics, thermal control elements and propellant systems located inside the satellite's body. Placement of components has been considered, such as the propellant tanks and propulsion lines, which are located inside the platform structure.

Redundancy is part of the overall design of the satellite to preclude failure of functions, including the ability to control each subsystem's functions against unintentional debris collision.

3.2 Minimizing Accidental Explosions

The satellite design has limited the probability of accidental explosions during and after completion of mission operations. In designing this GEO satellite, the satellite manufacturer has taken steps to ensure that debris generation will not result from the conversion of energy sources on board the satellite into energy that fragments the satellite. In particular, the satellite manufacturer advises that no structural failures of pressurized volumes have occurred on its satellites to date. Burst tests are performed on all pressure vessels during qualification testing to demonstrate a margin of safety against the MEOP (Maximum Expected Operating Pressure). Bipropellant mixing is avoided by the use of valves that prevent backwards flow in propellant lines and pressurization lines. Batteries have cells with low internal pressure and do not retain a charge at the end of the mission. Pyrotechnics are nominally only used in the mission as part of the initial propulsion subsystem priming and reflector deployment processes.

To minimize the chance of accidental explosion, Maxar has designed the satellite to operate safely and allow for monitoring of the satellite health during operation. The satellite has redundancy in units/functions for reliability. Satellite design provides sufficient amount of telemetry data for health and safety monitoring. Propellant tanks are monitored for pressure or temperature variations during satellite operations. Alarms in the Satellite Control Center inform controllers of any excessive variations.

Additionally, long term trending analysis are performed to monitor for any unexpected trends.

After orbit-raising to the disposal orbit, all unfired pyrotechnics (EEDs) will be fired as part of the final satellite decommission. Upon reaching the final disposal orbit, all propellant tanks will be close to empty. The pressurant tanks can always be isolated from the propellant tanks by ground control.

All propellants and pressurants will be vented utilizing the on-board thrusters.

4. STAR ONE C4 Operations

- Star One C4 was successfully launched on July 15, 2015;
- It has been operated by Claro since August 2015;
- It has chemical propulsion for attitude and orbit control;
- Star One C4 is controlled at 70 +/- 0.5°W longitude.

- Star One C4 shared the station longitude with Star One C2 between August 2015 and October 2021. Currently, it shares the station longitude with Star One D2. Both satellites are controlled by Claro.
- Claro uses the same flight dynamic system to all satellites to minimize source of errors in orbit determination and propagation.
- Claro keeps the eccentricity-inclination strategy to operate the satellites in the same orbital slot safely. To ensure the safety, Claro keeps the satellites that share the same longitude at least 5 km apart from each other.
- Claro monitors any approximation with Star One C4 through Space Data Association (SDA) daily reports.
- Claro shares ephemeris with SDA to be used for close approach analysis.
- Also, Claro exchanges ephemeris regularly with ViaSat, that has a controlled satellite at 69.9°W.
- Claro has also an agreement with USSTRATCOM to use their Space Situational Awareness support.
- Claro monitors all close approaches notifications 24 hours per day and act to mitigate any risk of collision with Star One C4 when needed.

Claro uses 5 km as threshold to perform collision mitigation maneuvers.

5. STAR ONE C4 End of Life Disposal

5.1 Deorbit maneuvers

Star One C4 has propellant reserved to perform the orbital maneuver at the end of life in order to take it to the graveyard orbit, with an altitude of at least 300 km above the geostationary arc.

Claro will coordinate with other operators controlling nearby satellites to avoid interference during the orbit raising maneuvers.

5.2 Energy Depletion

The following will be performed to deplete all energy sources on Star One C4 to the maximum extent possible:

1) All previously unfired pyros are fired.

2) All earth deck thrusters are fired until all thrusters indicate the bipropellant fuel and oxidizer have been depleted. During this step the satellite is oriented so that the earth deck thruster firings are raising the satellite orbit as much as possible.

3) All anti-earth deck thrusters are fired to deplete the remaining bipropellant fuel.

4) After it has been determined that only one of the bipropellants are remaining, the Helium in the pressurant tank is depressurized to the lowest practical pressure by transferring the gas to the propellant tanks. Then the Helium isolation valve is closed to isolate the pressurant tanks. A small amount of propellant will not be expellable and will remain in the propulsion system.

5.3 Orbital Debris Generation

The spacecraft does not generate orbital debris. Only gas is expelled, nothing is cast off from the spacecraft.

5.4 Deactivate Spacecraft Electronics

The following will be performed to deactivate the spacecraft electronics. This overview does not include the detailed command plan; a detailed command plan will be generated, reviewed and validated by the satellite owner and the manufacturer closer to the intended de-orbiting.

1) Turn off all payload units including TWTAs, LCAMPs, Receivers, LNAs, Downconverters, Beacon Transmitters, Master Oscillators etc. This will ensure no Payload RF radiation will interfere with other spacecraft.

2) Turn off Momentum Wheels.

3) Deactivate Electrical Power System.

- a) Turn OFF all the Battery Chargers to keep the batteries from recharging.
- b) Open Battery Relays to further preclude the ability to recharge the batteries.
- c) Turn OFF all Power Control Unit Battery Dischargers to ensure no battery power is applied to the bus.
- d) Deplete charge from all batteries.

4) Disable Telemetry Subsystem.

Command Off Telemetry transmitters to ensure no RF radiation will interfere with other spacecraft.

6. Notifications

Claro undertakes the responsibility to provide to the relevant entities and agencies, as required (e.g. UNCOPUOS, FCC, Anatel, ITU etc.), with all appropriate notifications, as required by laws or regulations, about Claro satellites including, but not limited to, those concerning initial entry of service, current station location, relocations, inclined orbit operations and deorbiting operations.

7. ISO 9001:2015 Certified Company

Claro S.A. is an ISO 9001:2015 certified company and received its certificate of conformance on 22 July 1998 (Certificate Number: 33784) from ABS Quality Evaluations, Inc., applicable to the PROVISION OF SATELLITE CONTROL, TRACKING AND LAUNCH SUPPORT SERVICES.

ISO 9000 is a set of international standards on quality management and quality assurance developed to help companies effectively document the quality system elements needed to maintain an efficient quality system. It also can help a company satisfy its customers, meet regulatory requirements, and achieve continual improvement.