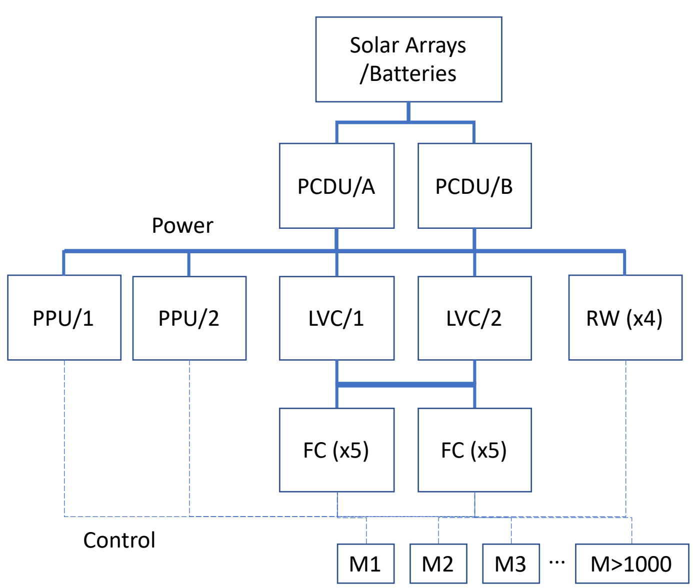
AST&Science – Further Orbital Debris Analysis
SAT-PDR-2020043-00034

AST&Science ("AST") is providing further information and responses following the FCC's letter request to give additional information regarding the reliability of the propulsion capabilities of the SpaceMobile satellites, including in-orbit collision risk if these propulsion capabilities are lost.

As explained, AST will launch a test satellite, the Blue Walker 3 ("BW3") prior to the launch of the constellation. This will provide AST with information concerning flight heritage because the propulsion unit for the BW3 is the same as the units used for the constellation. In addition to the electric propulsion system, AST has incorporated an attitude and orbital control system ("AOCS") with full redundancy and flight heritage that can be used to orient the spacecraft into a high-drag configuration. The orbital lifetime for a satellite that fails and has no propulsive capability at the operational altitude can be varied depending on the orientation of the spacecraft using the AOCS components. With a failed propulsion system, it will take 20.14 years to deorbit by using the high-drag orientation of the spacecraft. This calculation assumes a 24 m diameter array oriented such that the exposed surface area is 450 m^2, 735 km starting altitude, and uses the NRLMSISE-00 atmospheric model to determine the atmospheric densities in the determination of the drag profile of the spacecraft.

The probability of not meeting this 20.14 year deorbit is then determined by the probability that not only the propulsion system fails but also the attitude control system fails. Because the array attitude control is a highly distributed system consisting of over 1000 elements, each having separate power, processing, sensing and actuating, it is extremely robust and degrades gracefully over time in the event of failures. The most likely failure scenario by orders of magnitude is therefore a failure of the central AOCS computers that coordinate this control. A diagram of the major components of the power management and flight control subsystems is provided below.



A conservative system-level reliability analysis assumes a drop in component reliability of 1% per year for most major components, each reaching 90% reliability after 10 years. An exception to this is the reaction wheel assembly, since each wheel is expected to have a 95% reliability at 10 years. De-orbit using the propulsion system requires 1 (of 2) power conditioning unit (PCDU), 1 (of 2) low voltage controller (LVC), 1 (of 2) propulsion unit (PPU), 1 (of 10) flight computer (FC) and 3 (of 4) reaction wheels (RW) to be remain operational and communicating. De-orbiting using attitude control only requires 1 PCDU, 1 LVC and 1 (of the 5) FC to remain operational and communicating, since the contribution of the highly distributed array elements to failure of the control system is effectively zero over maximum time on orbit of 30 years (10 operational + 20 for de-orbit). The high redundancy in the FC units is driven by supporting communications to the >1000 array elements. Applying the failure probabilities to the architecture as shown puts the overall reliability of the system to successfully de-orbit at 96% for propulsive de-orbit at end of life (6 years of de-orbit after 10 years of operation), and at 98% for high-drag de-orbit (20.14 years of de-orbit starting from operational altitude after 10 years of operation). Propulsive de-orbit is driven by reaction wheel reliability, and high-drag de-orbit time is reduced to only 13 years if the satellite can first be brought propulsively down do an altitude of 700 km.

The operational strategy for safe de-orbit is to decommission a satellite once the failure of any major component puts the satellite in an "at risk" state, where it is only 1 fault away from an inability to initiate and maintain de-orbit. Under consideration of the various failure scenarios and reliabilities, a very conservative estimate indicates that only ~5 satellites out of the 243 total in the constellation may be required to de-orbit using the high-drag maneuver, and of those, the expected value of the number of satellites that might violate the 25-year rule is less than 1.

Using the NASA ORDEM 3.1 software, the probability of an impact occurring in less than 20.14 years is 0.0112 if all ability to maneuver is lost. One method to maneuver is the onboard propulsion system, but another is the attitude control system using the same method of changing the ballistic coefficient by changing the projected area. The end-of-life pitch-up maneuver would allow for the satellite to be moved in-track by as much as 740 m within a 2-day period during a solar minimum, and by as much as 7.4 km within a 2-day period during a solar maximum. From the de-orbit analysis above, the probability of a satellite losing all maneuverability is less than 1 in 243, so the probability of an impact occurring due to failure of both propulsion and attitude control under the conservative failure probabilities given above is 0.0112 / 243 or 0.005%.

CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this application, that I am familiar with Part 25 of the Commission's rules, that I either prepared or reviewed the engineering information submitted in this application, and that it is complete and accurate to the best of my knowledge and belief.

Dr. Raymond Sedwick
Chief Scientist, Space Systems
AST&Science LLC
Midland Int'l Air & Space Port
2901 Enterprise Lance
Midland, TX 79706
432.276.3966