Collision Avoidance Plan

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AMS-1 mission involves changing altitude from its initial deployment altitude of 550 km to goal of 275 km minimum altitude. As the owner/operator, MIT LL will receive near real-time GPS-measured position and velocity data daily from the AMS-1 spacecraft over a GlobalStar downlink. Maneuvers from that present orbit will only be conducted after collison avoidance procedures for that specific maneuver are followed. Control simulations show that during maneuvers, orbit altitude can be changed by 3 km per day maximum and maintained to 1km tolerance nominal. A maneuver can be suspended by ground operations command within 12 hours maximum latency. No out of plane maneuvers will be conducted to deviate from deployment orbit at 97.4 +/- 0.1 deg.

Maneuvers are implemented on the spacecraft by executing a sequence of electric propulsion thruster firings of specific magnitudes and directions at specific times resulting in the spacecraft to gradually change from its present orbit to a new target orbit. Maneuvers are calculated using high fideilty analytical tools over a planning horizon period of time selected for that maneuver. The analtycal tools used include high precision orbital propagator and aerodynamic drag computations in the form of Praesto-2 propagator software, 12th order Gauss Jackson propagation with 10s step size, 70x70 Earth gravity model, 5x5 Moon gravity model, NRL MSIS 2000 atmosphere. The gradual continuous orbit change can be approximated by a series of slightly different discrete intermediate orbits over the same planning horizon.

For collision avoidance procedure, MIT LL ground operations will compute possible conjunctions between all the AMS discrete intermediate orbits and the latest satellite catalog information available from Joint Space Operations Center (JSpOC 18SPCS) for other space objects. Ground operations will verify that none of the discrete intermediate orbits comprising the AMS maneuver yield any close approaches to other cataloged objects. If any close conjunctions are discovered, the maneuver will be replanned and rescreened. Figure 1 shows the AMS collision avoidance logic. Once the maneuver schedule is determined to have no close conjunctions, it is uploaded to the spacecraft in the form of a Payload Activity List (PAL) valid electric propulsion thruster instruction.

It is understood that for strategic planning, according to guidance from “US Government Orbital Debris Mitigation Standard Practices” programs should estimate and limit the statistical probability of collision with objects >10 cm during orbital lifetime be < 0.001. However, in terms of specific maneuver instructions, statistical collision probabilities cannot be accurately calculated because JSpOC 18 SPCS does not report either satellite orbit covariances nor sizes.

Therefore AMS uses predicted closest point of approach (CPA) to screen for potential hazards associated wirth conjunctions. This follows the present spacecraft operator warning standard used by JSpOC / 18SPCS of satellite owner notification when CPA < 1km based on measured orbital parameters. To set a safe predictive CPA threshold for maneuvers, AMS incorporates additional contributions due to potential errors in orbital altitude calculations and tolerances in AMS altitude control during maneuvers. For error bounds, 1 km is taken as a realistic error bound for SGP4 calculations. For control tolerance, simulations of AMS maneuvers show that 1km altitude control can be maintained, as shown in Figure 2.

Therefore AMS has set CPA >2 km as a threshold for collision avoidance to insure no known non-zero probability of collision.

In addition, when AMS altitude is within 25 km of the NASA ISS, AMS maneuvers will adhere to the more restrictive CPA > 25 km to meet or exceed the standard for ISS Debris Avoidance Maneuver. Here, Trajectory Operations and Planning Officer requires notification of predicted intrustion within the volume zone of ±2 km local vertical x 25 km x 25 km local horizontal.

The efficacy of the approach is shown in Figure 3. Here, a nominal AMS discrete orbit associated with a maneuver is assumed and all objects in the catalogue within 200 km of the target altitude considered for conjunction analyses. This subset reduces the number of objects to 4092. Within the planning horizon of 7 days, the closest point of approach between AMS and any object of these 4092 possible objects is > 20 km which successfully meets the CPA >2km threshold for safety. This screening is repeated for the other discrete orbits within the maneuver. Therefire the planned maneuver to the target orbit is assessed to be safe, and approved for upload and instruction to the spacecraft.

In addition to running its own collision avoidance procedures, MIT LL will provide AMS predicted ephemerides to the JSpOC/ 18 SPCS to enable advance notification with other spacecraft operators.

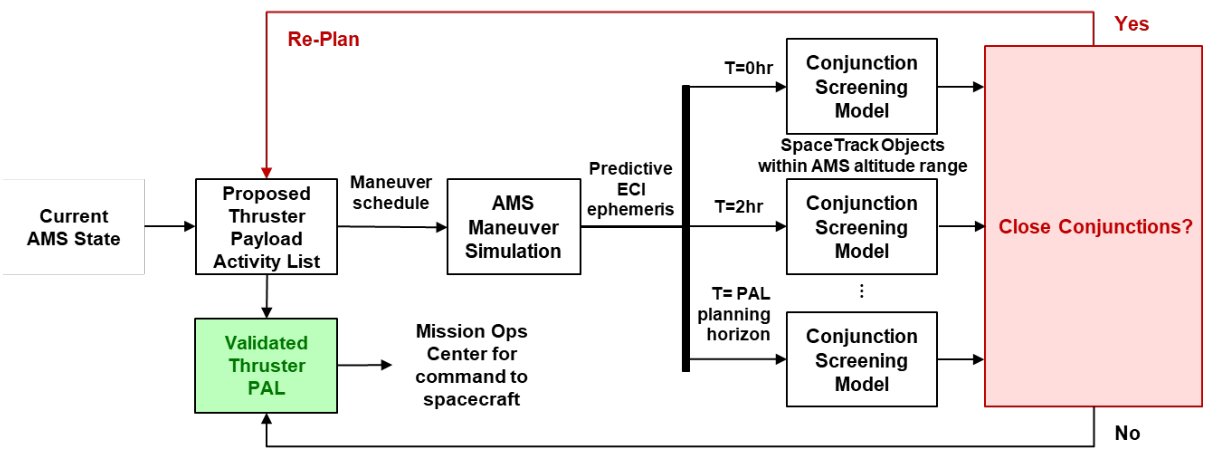

Figure 1. AMS Collision Avoidance Logic

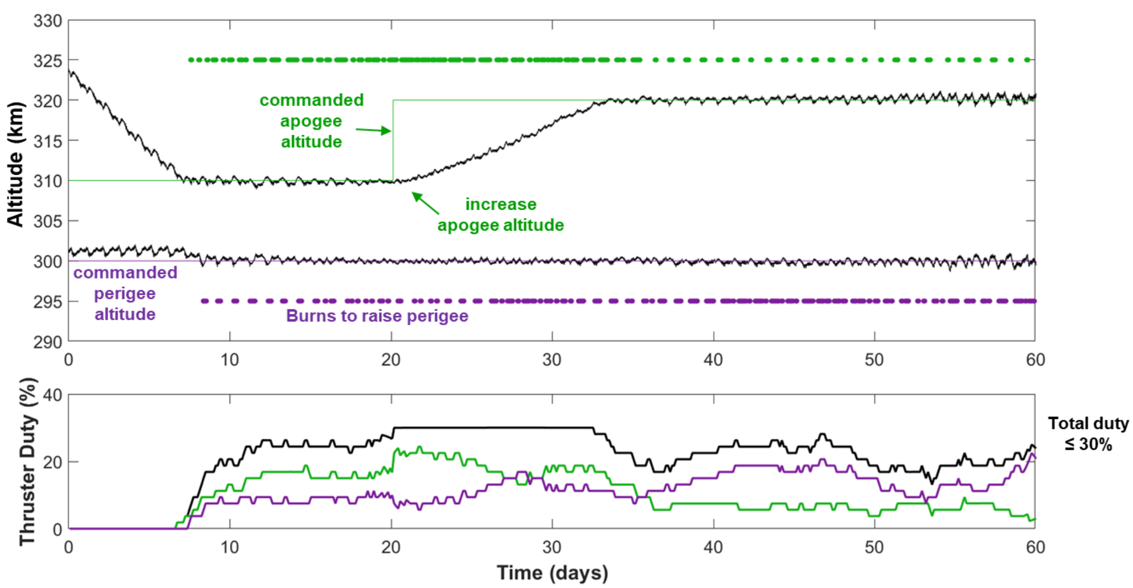

Figure 2. Simulation of AMS altitude control accuracy

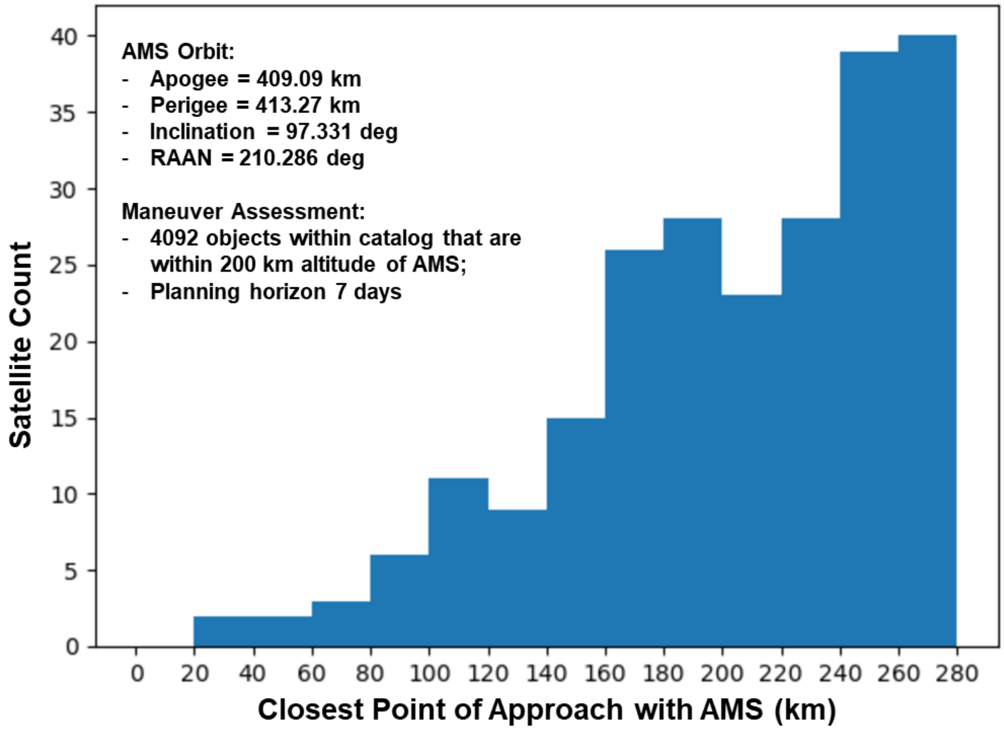

Figure 3. Efficiacy of the AMS collision avoidance