A Geometric Analysis to Protect Manned Assets from Newly Launched Objects – COLA Gap Analysis

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A safety risk was identified for the International Space Station (ISS) by The Aerospace Corporation following the launch of GPS IIR-20 (March 24, 2009), when the spent upper stage of the launch vehicle unexpectedly crossed inside the ISS notification box shortly after launch. This event highlighted a 56-hour vulnerability period following the end of the launch Collision Avoidance (COLA) process where the ISS would be unable to react to a conjunction with a newly launched object. Current launch COLA processes screen each launched object across the launch window to determine if an object's nominal trajectory is predicted to pass within 200 km of the ISS (or any other manned/mannable object), resulting in a launch time closure. These launch COLA screens are performed from launch through separation plus 100 minutes. Once the objects are in orbit, they are cataloged and evaluated as part of routine on-orbit conjunction assessment processes. However, as the GPS IIR-20 scenario illustrated, there is a vulnerability period in the timeline between the end of launch COLA coverage and the beginning of standard on-orbit COLA assessment activities. The gap between existing launch and on-orbit COLA processes is driven by the time it takes to track and catalog a launched object, identify a conjunction, and plan and execute a collision avoidance maneuver. For the ISS, the total time required to accomplish all of these steps is 56 hours. To protect human lives, NASA/JSC has requested that all US launches take additional steps to protect the ISS during this "COLA gap" period.

The uncertainty in the state of a spent upper stage can be quite large after all burns are complete and all remaining propellants are expelled to safe the stage. Simply extending the launch COLA process an additional 56 hours is not a viable option as the 3-sigma position uncertainty will far exceed the 200 km miss-distance criterion. Additionally, performing a probability of collision (P_c) analysis over this period is also not practical due to the limiting effects of these large orbit state uncertainties. An estimated upper bound for P_c for a typical spent upper stage if nominally aligned for a direct broadside collision with the ISS is only on the order of 10^{-6}. For a smaller manned object such as a Soyuz capsule, the risk level decreases to an order of 10^{-8}. In comparison, the Air Force Range policy (AFI 91-217) for launch COLAs would only eliminate launch opportunities when conjunctions with objects exceed a P_c of 10^{-5}.

This paper demonstrates a conservative geometry-based methodology that may be used to determine if launch opportunities pose a threat to the ISS during the COLA gap period. The NASA Launch Services Program at Kennedy Space Center has developed this COLA gap analysis method and employed it for three NASA missions to identify potential ISS conjunctions and corresponding launch window closures during the 56-hour at-risk period. In the analysis, for each launch opportunity, the nominal trajectory of the spent upper stage and the orbit state of the ISS are propagated over the 56 hour period. Each time the upper stage crosses the orbit plane of the ISS, the relative radial and argument of latitude separations are calculated. A window cutout is identified if these separation differences fall within a mission-specific violation box, which is determined from the evaluation of a Monte Carlo dispersions analysis that quantifies the potential variation in the upper stage radial and argument of latitude differences. This paper details the results of these analyses and their impacts to each mission.

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A safety risk was identified for the International Space Station (ISS) by The Aerospace Corporation, where the ISS would be unable to react to a conjunction with a newly launched object following the end of the launch COLA process. NASA/JSC has requested that all US launches take additional steps to protect the ISS during this "COLA gap" period. This paper details the results of a geometric-based COLA gap analysis method developed by the NASA Launch Services Program used for three NASA missions to determine if launch window cutouts are required to mitigate this risk.