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Determination of the Performance-Optimum SSF Orbital Inclination for SSP Support Missions

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Objective

To determine the SSF orbital inclination which minimizes the required SSP yaw steering propellant for rendezvous while maintaining the equivalent range safety launch window.

Background

- SSP SSF support missions are rendezvous missions and therefore target an inertial orbital plane.
- Intersection of the launch site and the target orbital plane is referred to as the "in-plane" launch time. Launch at any other time requires steering to the target plane which costs performance.
- Rendezvous missions require maximizing the range safety launch window/ rendezvous phasing window overlap time.
- The range safety launch window is determined by disposal restrictions on the External Tank (ET).
- Disposal of the ET is limited in the Pacific Ocean to an area bordered by Palmyra Island at window open and Hawaii at window close (Figure 5).

How Varying Inclination Impacts Performance

- The performance-optimum inclination at the in-plane time is the latitude of the launch site. This maximizes the contribution from the Earth's rotational velocity to the vehicle's velocity (Figure 2, top illustration).

- Reducing the target orbital inclination below the latitude of the launch site:
  - oo results in no in-plane launch opportunities;
  - oo increases the performance requirements across the launch window and steepens the performance penalty curve (Figure 3).

- Increasing the target inclination above the latitude of the launch site:
  - oo results in two in-plane opportunities, one ascending and one descending (Figure 2, bottom illustration);
  - oo changes the optimized performance penalty curve from a somewhat parabolic to a W-shaped curve (Figure 4).

Methodology

- Four inclinations were studied: 28.05, 28.80, 29.45 and the initial SSF baseline inclination of 28.45 degrees.
- Trajectory data for the study were generated by 3 degrees of freedom (DOF) Simulation and Optimization of Rocket Trajectories (SORT IV) and 6-DOF Space Vehicle Dynamics Simulation (SVDS) software. Figure 7 compares the SORT and SVDS results for the 28.80 inclination case.
- Trajectories were optimized at the range safety launch window open and in-plane times.
- Performance penalty values are relative to the 28.45 degree in-plane performance. Also, the performance penalty curves are aligned relative to the launch window open time instead of the in-plane time.

Results

Inc.	Window Length (Min.)	Minimum Performance Penalty (lbs)	Margin to Cover the Window (lbs)	Comments
28.05	56	590	3160	Penalty higher across the launch window (Fig. 3)
28.45	55	0	1300	Window not centered on the in-plane time (Fig. 1)
28.80	53	210	470	Optimized at the launch window open time (Fig. 1)
29.45	50	810	3430	Minimum penalty at the window open time

Conclusions and Recommendations

- Two options have been identified to reduce yaw steering performance requirements for SSP SSF support missions:
  - Reduce the range safety launch window length and keep SSF at an orbital inclination of 28.45 degrees;
  - Place SSF in a slightly higher inclination orbit and maintain an equivalent launch window.

- The second option is recommended to maximize the range safety launch window length, and thereby maximize the rendezvous phasing window/range safety window overlap.

- The performance-optimum inclination is 28.80 degrees. This inclination reduces the yaw steering performance requirement to cover the launch window by about 800 lbs.

- The results have been presented to and accepted by the JSC Missions Operations Directorate (MOD) and Space Shuttle Program Office (SSPO).