Abortability Metrics: Quantifying Intact Abort Mode Availability for Reusable Launch Vehicles
AIAA-2006-7293

Revision A
19 September 2006

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Background
SEI has identified the need for a system capable of rapidly assessing possible abort scenarios for a wide variety of transportation concepts. Such a system is applicable for use in the early stages of design and execute fast enough to enable design trades and decision making “in-the-loop”.

The ‘Abort Simulation Modeler’ (or ASM) assesses possible failure modes, mitigation options, and flight scenarios possible along the nominal flight path and identifies sensitive areas during the mission when intact abort options are lowest or non-existent for a proposed or existing launch asset.

The ASM does not simulate the cause of a system failure event. It simply assumes one has occurred and attempts to determine trajectories that correspond to the available abort modes.

**Output:** ‘Abort Options Map’ for Specific Launch System plus a quantitative score
Abort Options Map

Objectives:  1) Provide quantitative data on the abort capability for a particular launch system
            2) Enable direct comparison of different launch assets
            3) Enable ability to modify a design to close “gaps” through rapid and routine assessment capability.
Quality of Coverage (QoC) is calculated based on:
- User-provided weightings on the different abort modes based on the desirability of the mode
- Percentage of flight time during which each of the abort modes is available
- Percentage of flight time during which abort mode availabilities overlap

The QoC metric is used to gauge how well a vehicle concept is able to provide intact abort modes throughout the nominal trajectory.

A QoC score will fall between 0 and 1 with 1 representing a perfect score.
Completeness of Coverage (CoC) is calculated based on:
- Percentage of flight time during which gaps in abort mode availability exist
- Normalizing reference time

The CoC metric provides insight into whether a vehicle concept has periods of time during its nominal ascent trajectory during which no intact abort modes are available.

A CoC score will fall between 0 and 1 with 1 representing a perfect score.
Prototype ASM
PROTOTYPE Abort Simulation Modeler (ASM): Program Structure
PROTOTYPE Abort Simulation Modeler (ASM): ModelCenter® Implementation
PROTOTYPE Abort Simulation Modeler (ASM): ModelCenter® Implementation
Case Study #1: ACRE-92
Advanced Concept Rocket Engine (ACRE)-92 RLV

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
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<tbody>
<tr>
<td>GLOW</td>
<td>2.3 Milbs</td>
</tr>
<tr>
<td>Dry Weight</td>
<td>224Klbs</td>
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<tr>
<td>Length</td>
<td>163.0 ft</td>
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<tr>
<td>Thrust,sls</td>
<td>2.76 Milbs</td>
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<tr>
<td>Upper Stage GLOW</td>
<td>N/A</td>
</tr>
<tr>
<td>Payload</td>
<td>20Klbs LEO</td>
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ACRE-92 Abort Coverage Map

Completeness of Coverage (CoC) Score : 0.805
Quality of Coverage (QoC) Score : 0.604

Note: The red shaded area indicates a gap in the abort coverage that would result in a Loss of Vehicle event.
Case Study #2: Sentinel MSP
Sentinel Military Space Plane (MSP)

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<thead>
<tr>
<th>Parameter</th>
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<td>Length</td>
<td>143.3 ft</td>
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<td>Thrust,sls</td>
<td>953Klbs</td>
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<td>Upper Stage GLOW</td>
<td>78.7Klbs</td>
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<tr>
<td>Payload</td>
<td>13Klbs to LEO</td>
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Completeness of Coverage (CoC) Score : 0.735
Quality of Coverage (QoC) Score : 0.227

Sentinel Abort Coverage Map

Note: The areas shaded red indicate gaps in the abort coverage that would result in a Loss of Vehicle event.
Case Study #3: Quicksat MSP
Nominal Configuration

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<td>Thrust,sls</td>
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<tr>
<td>Upper Stage GLOW</td>
<td>89.5Klbs</td>
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<tr>
<td>Payload</td>
<td>13Klbs LEO</td>
</tr>
</tbody>
</table>

Quicksat Military Space Plane (MSP)

Takeoff from Military Space Port

Mach 9 Staging Point

SMV Orbit Delivery to 70x197 nmi. @ 28.5°
Completeness of Coverage (CoC) Score : 0.800
Quality of Coverage (QoC) Score : 0.261

Quicksat Abort Coverage Map

Note: The area shaded red indicates a gap in the abort coverage that would result in a Loss of Vehicle event.
Case Study Summary Results
Case Study Comparison
- ACRE-92 scored better than both other vehicles in both the QoC and CoC metrics
- *Quicksat* scored nearly the same as ACRE-92 in CoC
- ACRE-92 scored considerably better than either *Sentinel* or *Quicksat* in the QoC metric
Summary
One of the main goals of the ASM is to significantly decrease the amount of time required to complete an abort analysis.

Without the prototype ASM, each case study abort map would require on the order of one to two weeks.

Using the prototype ASM reduces this time to one or two days.

The ultimate goal for the ASM is to provide this capability in one to two hours.

General Observations
The prototype ASM successfully simulated all four potential abort modes (ATO, AOA, DRL, and RTLS).

Using the tool, SEI assessed propulsion system failures for three (3) very different launch vehicle classes

- All-Rocket SSTO
- TSTO MSP with RBCC propulsion
- TSTO MSP with TBCC and DMSJ propulsion

POST was not robust and required a lot of user interaction during analysis.

With a more efficient trajectory routine, we can accomplish goal of computing abort mode options for a variety of failures with required setup and execution time consistent with conceptual-level design studies.

The user interface and logic controllers must be specialized for the ASM application.

Summary
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