"TEST VS. SIMULATION"

BY

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Space Transportation Systems Division

INTRODUCTION

OVERVIEW: SPACE VEHICLES REQUIRE SIMULATION CAPABILITIES

PROPULSION
STRUCTURES
LOADS
AERODYNAMICS
CONTROL
OTHER

PRESENTATION SCOPE: PROPULSION SIMULATION AND PROPULSION SYSTEM TESTING

PRESENTATION OBJECTIVE/ APPROACH: THROUGH ASSESSMENT OF SIMULATION CAPABILITIES AND REVIEW OF CONTRIBUTIONS FROM PROPULSION SYSTEM TEST PROGRAMS ILLUSTRATE THAT BOTH SIMULATION AND PROPULSION SYSTEM TESTING EACH HAVE IMPORTANT ROLES IN SPACE VEHICLE DEVELOPMENT.
## Simulation Capability Assessment
(NO Propulsion System Test)

<table>
<thead>
<tr>
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<tr>
<td>Wrong Component Verification</td>
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<td>High</td>
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<td>Low</td>
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<td>Instrumentation Failure</td>
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<td>Moderate</td>
<td>Very High</td>
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<td>Hazardous Fluid Leakage</td>
<td>High</td>
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<td>Very High</td>
<td>Very High</td>
<td>Yes</td>
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<td>POGO Failure</td>
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<td>High</td>
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<td>Minor</td>
<td>Can</td>
<td>Moderate</td>
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<td>Thrust Vector Control Failure</td>
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<tr>
<td>Propellant Loading Procedures/Operations</td>
<td>No</td>
<td>No</td>
<td>Very High</td>
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<td>No benefit</td>
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<tr>
<td>Clustered Engine Performance</td>
<td>Minor</td>
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<td>Minor</td>
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<td>Yes</td>
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<td>Performance Margin Uncertainty</td>
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<td>Stored Gas Mass, Loading, Operations</td>
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<td>Minor</td>
<td>Minor</td>
<td>Moderate</td>
<td>Yes</td>
<td>Minor</td>
</tr>
</tbody>
</table>

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## Simulation Capability Assessment
(NO Propulsion System Test)

<table>
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</thead>
<tbody>
<tr>
<td>Pressurization System Performance</td>
<td>Moderate</td>
<td>High</td>
<td>Minor</td>
<td>Minor</td>
<td>*Yes</td>
<td>Moderate</td>
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<tr>
<td>Propellant Mass Uncertainty</td>
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<td>Moderate</td>
<td>Very High</td>
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<td>Yes</td>
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<tr>
<td>Low Level Cutoff Sensor</td>
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<td>Minor</td>
<td>Moderate</td>
<td>No</td>
<td>Yes</td>
<td>No benefit</td>
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<tr>
<td>Engine/Feed Systems Chill</td>
<td>Minor</td>
<td>Minor</td>
<td>High</td>
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<tr>
<td>Tank Insulation</td>
<td>Minor</td>
<td>Minor</td>
<td>High</td>
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<td>*Yes</td>
<td>Minor</td>
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<tr>
<td>Hardware Thermal Control</td>
<td>Minor</td>
<td>Minor</td>
<td>High</td>
<td>Moderate</td>
<td>*Yes</td>
<td>Minor</td>
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</table>

* Mission Dependent

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### ADVANCED VEHICLE SIMULATION CAPABILITY ASSESSMENT

(NO PROPULSION SYSTEM TEST)

<table>
<thead>
<tr>
<th>EVALUATION CRITERIA</th>
<th>SHUTTLE</th>
<th>ADVANCED VEHICLE WITH SMALLER VOLUME, COMMON BULKHEAD</th>
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<tbody>
<tr>
<td>Pressurization Systems Performance</td>
<td>Moderate/Minor</td>
<td>Much Higher/Higher</td>
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<tr>
<td>Propellant Mass Uncertainty</td>
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<td>Engine/Feed System Chill</td>
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<td>Higher/Same</td>
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<td>Tank Insulation</td>
<td>Minor/High</td>
<td>Higher/Same</td>
</tr>
<tr>
<td>Hardware Thermal Control</td>
<td>Minor/High</td>
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</table>

Note: Risk relative to shuttle.

### SYSTEMS TESTS IDENTIFIED EVENTS

**

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<tr>
<th>STAGE</th>
<th>CATASTROPHE</th>
<th>UNWORKABLE</th>
<th>TOTAL PER STAGE</th>
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<tr>
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<td>FLIGHT</td>
<td>PREFLIGHT</td>
<td>FLIGHT</td>
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<tr>
<td>SHUTTLE</td>
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<tr>
<td>S-IC</td>
<td>4</td>
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<tr>
<td>S-II</td>
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<tr>
<td>S-IVB</td>
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<td>0</td>
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<td>S-I/IB</td>
<td>5</td>
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<td>S-IV*</td>
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* Incomplete

** Includes Categories not included

** EXAMPLE **

** SHUTTLE **

SSME NOZZLE STERN HORN RUPTURE - H₂ DUMPED.
MARGINAL STABILITY CHARACTERISTICS - ET/ORBITER 17° O₂ DISCONNECT.

** SAT V **

F-7 ENGINE TO STAGE BOLTS STRUCTURAL FAILURES
S-II ENGINE THRUST CHAMBER CHILL FAULTY - ENGINE STALL POTENTIAL
### MPTA Testing Evaluation

<table>
<thead>
<tr>
<th>Attempted Firings/Aborts</th>
<th>Inerting Purge Usage</th>
<th>Fire Water Usage (External)</th>
<th>Abort Source</th>
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<tbody>
<tr>
<td>21/9</td>
<td>5K - 12 System</td>
<td>6</td>
<td>Vehicle 2</td>
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<tr>
<td></td>
<td>30K - 3 System</td>
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<td>Engine 8</td>
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### Saturn V, IB, I Testing Evaluation

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Test Number</th>
<th>Aborts</th>
<th>Test Inadvertently &quot;Cut&quot;</th>
<th>Test Stage Destroyed</th>
<th>Acceptance Tested</th>
<th>Destroyed in Test</th>
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<tr>
<td>SIC &quot;All Systems&quot;</td>
<td>15</td>
<td>5</td>
<td>3</td>
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<td>S-11 Battleship All Systems</td>
<td>54</td>
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## MPTA Hardware Replacement and Repair

<table>
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<th>MPTA Test Number</th>
<th>Pumps</th>
<th>Major Valves</th>
<th>EJMMDS</th>
<th>Other</th>
<th>LH2 Recirculation System</th>
<th>Valves</th>
<th>Sensors</th>
<th>LH2 Delivery, Feed Line, Sockets, Other</th>
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</tbody>
</table>

**Total** | 20 | 41 | 15 | 20 | 30 | 21 | 40 | 10

Note: Hardware changes made prior to designated test number

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"SPECIAL" VEHICLE SIMULATION ISSUES

(Propulsion Related)

**SPACE ENVIRONMENT EFFECTS ON:**

- Propellant Management
- Propellant Thermal Control
- Tank Pressure Control
- Propellant Dynamics
- Propellant Resupply

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"SPECIAL" VEHICLE SIMULATION ISSUES

(TANK PRESSURE CONTROL
- DESTRATIFY PROPELLANT
- SUPERHEATED VAPOR VENTING
- TANK SAFING)

PROPELLANT THERMAL CONTROL
- REUSABLE HPI

PROPELLANT DYNAMICS
- SLOSH
- RESETTLING INCLUDING BAFFLES

PROPELLANT MANAGEMENT
- START BASKET OR TANK
- RCS THRUST
- ENGINE IDLE MODE THRUST

FEED SYSTEM REQUIREMENT
- NPSP
- FLOWRATE
- START-UP SHUTDOWN SURGES

TO ENGINE

"SPECIAL" VEHICLE SIMULATION ISSUES
(Propulsion Related)

Simulation Assessment:

For some issues -

- Necessary technology does not exist
- Demonstration of technology necessary
- Orbital experimental data necessary
- Development stage ground test possible/desirable
- Special development ground facilities required
### MPTA Test Schedule

<table>
<thead>
<tr>
<th>DATE SCHEDULE DEVELOPED</th>
<th>ACTUAL TEST SCHEDULE</th>
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<tbody>
<tr>
<td>10/10/74</td>
<td></td>
</tr>
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<td>4/20/79</td>
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</tr>
<tr>
<td>2/11/80</td>
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**NOTE:** RL - Resonant/Loading Tests

### Conclusions

- Propulsion system testing has prevented catastrophe and mission loss events and launch delays.

- The complexity of interactive characteristics of various subsystems/defies accurate simulation. System testing provides for model basing and enhances simulation.

- Some advanced/"special" vehicles may have equal or greater requirements for propulsion system testing and unusual test facilities/methods may be required.

- A ground propulsion "system test" program is the logical approach for proving design characteristics/methods where flight catastrophic failures or other failures can best be understood and controlled.

- Advancement in technology and technology demonstration in some areas is necessary to satisfy future mission requirements.