# "TEST VS. SIMULATION"



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JUNE 27, 1990

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## 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)

| EVALUATION CRITERIA | VEHICLE FLIGHT CATASTROPHE RISK | MISSION LOSS RISK | LAUNCH DELAY RISK | LAUNCH COMPLEX RISK | SYSTEM TEST PROVIDES DATA | REMAINING RISK AFTER 20 SECOND FRF |
|---|---|---|---|---|---|---|
| "Wrong" Component Verification | Very High | Very High | High | High | Yes | Low |
| Instrumentation Failure | Moderate | Moderate | Very High | Very High | Yes | Minor |
| Hazardous Fluid Leakage | High | High | Very High | Very High | Yes | Moderate |
| POGO Failure | Moderate | High | Minor | Minor | Can | Moderate |
| Thrust Vector Control Failure | Low | Low | Low | Minor | No | Minor |
| Propellant Loading Procedures/Operations | No | No | Very High | High | Yes | No benefit |
| Clustered Engine Performance | Minor | Minor | Minor | Minor | Yes | Minor |
| Performance Margin Uncertainty | Minor | High | No | No | Yes | Moderate |
| Stored Gas Mass, Loading, Operations | Minor | Minor | Minor | Moderate | Yes | Minor |

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|---|---|---|---|---|---|---|
| Pressurization System Performance | Moderate | High | Minor | Minor | *Yes | Moderate |
| Propellant Mass Uncertainty | Minor | Moderate | Very High | Minor | Yes | Low |
| Low Level Cutoff Sensor | Minor | Minor | Moderate | No | Yes | No benefit |
| Engine/Feed Systems Chill | Minor | Minor | High | Minor | *Yes | Minor |
| Tank Insulation | Minor | Minor | High | Minor | *Yes | Minor |
| Hardware Thermal Control | Minor | Minor | High | Moderate | *Yes | Minor |

* Mission Dependent

# ADVANCED VEHICLE SIMULATION CAPABILITY ASSESSMENT

## (NO PROPULSION SYSTEM TEST)

| EVALUATION CRITERIA | SHUTTLE | ADVANCED VEHICLE WITH SMALLER VOLUME, COMMON BULKHEAD | |
|---|---|---|---|
| | FLIGHT CATASTROPHIC/ LAUNCH DELAY RISK | ALTITUDE START | ORBITAL START |
| | | RISK | RISK |
| Pressurization Systems Performance | Moderate/ Minor | Much Higher/ Same | Significantly Higher/Higher |
| Propellant Mass Uncertainty | Minor/ Extremely High | Higher/Same | Much Higher/Same |
| Engine/Feed System Chill | Minor/High | Higher/Same | Significantly Higher/Higher |
| Tank Insulation | Minor/High | Higher/Same | Much Higher/Same |
| Hardware Thermal Control | Minor/High | Higher/Same | Significantly Higher/Higher |

Note: Risk relative to shuttle.

# SYSTEMS TESTS IDENTIFIED EVENTS

| STAGE | CATASTROPHE | | UNWORKABLE | | TOTAL PER STAGE** |
|---|---|---|---|---|---|
| | FLIGHT | PREFLIGHT | FLIGHT | PREFLIGHT | |
| SHUTTLE | 3 | 3 | 5 | 17 | 40 |
| S-1C | 4 | 0 | 3 | 3 | 13 |
| S-II | 2 | 0 | 8 | 8 | 21 |
| S-IVB | 8 | 0 | 6 | 3 | 20 |
| S-I/IB | 5 | 1 | 4 | 2 | 15 |
| S-IV* | 2 | 0 | 3 | 1 | 6 |

* Incomplete

** Includes Categories not included

### EXAMPLE

SHUTTLE
SSME NOZZLE STERN HORN RUPTURE - $H_2$ DUMPED.
MARGINAL STABILITY CHARACTERISTICS - ET/ORBITER 17" $O_2$ DISCONNECT.

SAT V
F-1 ENGINE TO STAGE BOLTS STRUCTURAL FAILURES
S-II ENGINE THRUST CHAMBER CHILL FAULTY - ENGINE STALL POTENTIAL

# MPTA TESTING EVALUATION

| ATTEMPTED FIRINGS/ABORTS | INERTING PURGE USAGE | FIRE WATER USAGE (EXTERNAL) | ABORT SOURCE |
|---|---|---|---|
| 21/9 | 5K - 12 System<br>30K - 3 System | 6 | Vehicle 2<br>Engine 8 |

# SATURN V, IB, I TESTING EVALUATION

| DEVELOPMENT STAGES | | | | | FLIGHT STAGES | |
|---|---|---|---|---|---|---|
| VEHICLE | TEST NUMBER | ABORTS | TEST INADVERTENTLY "CUT" | TEST STAGE DESTROYED | ACCEPTANCE TESTED | DESTROYED IN TEST |
| SIC<br>"ALL SYSTEMS" | 15 | 5 | 3 | | 15 | 1 |
| S-11<br>BATTLESHIP<br>ALL SYSTEMS | 54<br>9 | 29<br>6 | 1 | 1 | 15 | |
| SIV B | 21 | - | - | 1 | 27 | 1 |
| SI/IB | 23 | 6 | | | 22 | |

## *MPTA Hardware Replacement and Repair*

| MPTA Test Number | Pumps | Major Valves | EIU/MDMS | Other | LH2 Recirculation System, Pressurization System | Valves | Sensors | LH2 Diffuser, Feed Line Screens, Other |
|---|---|---|---|---|---|---|---|---|
| | ← ENGINE → | | | | ← VEHICLE → | | | |
| 1-002 | | | | 1 | 4 | 5 | 4 | 1 |
| 2 | | | | | | | 1 | 2 |
| 3 | | | | 1 | | 1 | 1 | 2 |
| 4 | | | | | | | 1 | 1 |
| 5-A | 12 | 9 | | 1 | | | 4 | 3 |
| 5 | | | 1 | | 4 | 2 | 4 | |
| 6-01 | | 9 | 1 | 1 | | | 2 | |
| 6-02/3 | 1 | 7 | | 2 | 3 | | 5 | 1 |
| 6-04 | | | 1 | 5 | | | 4 | |
| 7-01 | | 1 | | | | | | |
| 7-02 | | 2 | | | 2 | | 4 | |
| 8 | | 2 | | | 5 | 1 | | |
| 9-01 | 1 | | | | | | 4 | |
| 9-02 | 4 | | 1 | | 1 | 1 | 2 | |
| 10 | | 4 | 10 | 3 | 1 | | 2 | |
| 11-01 | 2 | 7 | | | 4 | 6 | 2 | |
| 11-02 | | | | 3 | 6 | 4 | | |
| 12 | | | | 3 | | 1 | | |
| **Total** | **20** | **41** | **15** | **20** | **30** | **21** | **40** | **10** |

Note: Hardware changes made prior to designated test number

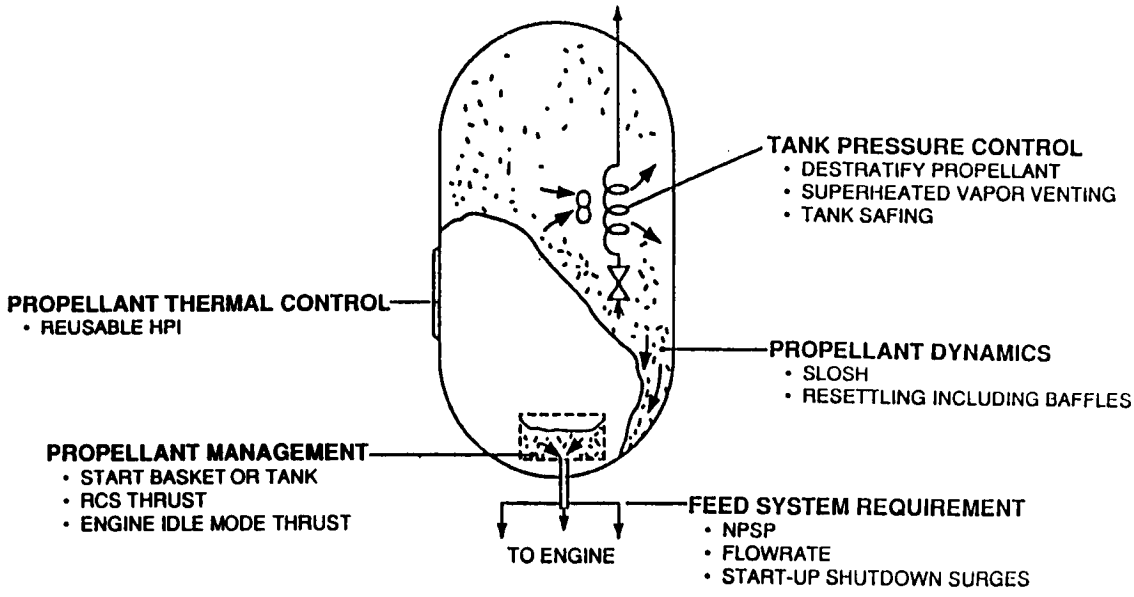
# "SPECIAL" VEHICLE SIMULATION ISSUES

## (PROPULSION RELATED)

## SPACE ENVIRONMENT EFFECTS ON:

- PROPELLANT MANAGEMENT
- PROPELLANT THERMAL CONTROL
- TANK PRESSURE CONTROL
- PROPELLANT DYNAMICS
- PROPELLANT RESUPPLY

# "SPECIAL" VEHICLE SIMULATION ISSUES




# "SPECIAL" VEHICLE SIMULATION ISSUES

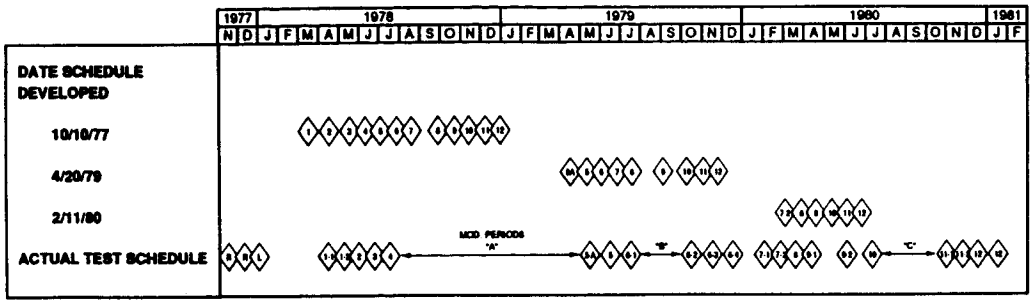
## (PROPULSION RELATED)

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




NOTE: R/L - 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.