HISTORICAL PROBLEM AREAS - LESSONS LEARNED

EXPENDABLE AND REUSABLE VEHICLE PROPULSION SYSTEMS

STPSS PANEL ON DEVELOPMENT, MANUFACTURING AND CERTIFICATION

June 25 - 29, 1990

Dale A. Fester
Martin Marietta Astronautics Group

Expendable Launch Vehicle Lessons Learned

• Avoid Single String Systems

• Design Must Be Inspectable

• Qual By Flight Usage Not Acceptable
  - No Margin Demonstrated
  - Must Qualify All Components to Needed Level
  - Either Meet Specs or Change Specs

• Use All-Welded Feed Systems
  - Maintenance of Cleanliness During Changeout
  - Scavenging Components as Source of Spares
  - Multiple Checking Wears Things Out
Expendable Launch Vehicle Lessons Learned (concl)

• **Dynamic Envelope Must Accommodate**
  - Stacking of Tolerances
  - Deflections
  - Margin

• **Provide Needed Instrumentation**
  - Must Know Flight Environments for Every System

• **Overall Systems Integrator Needed (Also Applies to Reusable Systems)**
  - Interfaces Between Independent Contractors
  - Integrate 2 to 3 Sigma Parts

• **Concerns**
  - Pogo Suppression
  - Pyrotechnics Checkout
  - Proper Circuit Testing

Upper Stage/Transfer Vehicle Lessons Learned

• **Must Meet Safety Requirements**
  - Difficult for New Vehicle & Almost Impossible for Prior Design ELV-Launched Vehicle
  - Vehicle Really a Space-Operating LV
  - Across Board Two Failure Tolerance May Not Be Reasonable

• **Should Not Let Politics Drive Systems**
Shuttle Systems - Dynamics

• External Tank
  - Propellant Dynamics During ET/Orbiter Separation for RTLS
  - Required Low-g Drop Tower & KC-135 Testing
  - RCS Orbiter Translation & Aerodynamic Forces Sufficient For Separation

• External Tank
  - Had Natural Convection Recirculation System
  - Replaced With Bubbling Helium Up Feedline (Saved 400 lbm)

• RCS Tanks
  - Extensive Ground Development Program (Element, Subsystem, System)
  - Structural Fatigue and Flow Dynamics
    - Vibration Testing
    - Flow Splitting In Multiple Paths
    - Simultaneous Thruster Firing

Shuttle Systems - Reuse

• External Tank
  - One of Best Performers Since Not Reused

• RCS Tanks (OMS Tanks)
  - Specifically Developed for Orbiter
  - Extensive Ground Development Program (Element, Subsystem, System)
  - Qualified for Full 100-Mission Life
  - Included Structural Fatigue & Flow Dynamics Testing
  - Excellent Reuse History
  - N2O4 Flow Decay No Problem
    - Use Proper Purity & Handling
    - Follow Established Processes & Procedures

• Components
  - Many Were Really Expendable Component Designs
  - Others Were Exponential Extrapolations (e.g. SSME)
  - Usually Not Qualified for Full Duration & Operating Environments
  - Result: Rebuild Rather than Reliable Reuse
HIGH PRESSURE OPERATION REDUCES WEIGHT, COST

3000 PSIA

2000 PSIA

1000 PSIA

CHAMBER PRESSURE

ATLAS  SATURN V SECOND & THIRD STAGE  SATURN V FIRST STAGE  SSME

Reusable System Issues & Lessons Learned

- Material Property Database Lacking for Operational Environments
  - Both Fatigue & Flow Life
  - Data Was Extrapolated or Estimated
  - Didn't Understand Reuse & Long Life
  - Verification/Diagnostics Not Available

- Life Unknown
  - Design to Life with Margin to Cover Unknowns
  - Margin Must Include Degradation
    - Debris
    - Wear & Tear
    - Atomic Oxygen
  - Qualify for Full Duration
  - Fleet Leader Concept Has Shortcomings
Summary

• Need Materials Property Database
  Covering Operational Environments

• Need Fault Tree
  - Does Fix Ripple Through System & Cause Problem

• Need Accurate Lessons-Learned Database
  (Must Transfer to Young Engineers)

• Two Major Issues Are Long Life & Reusability
  - Need History & Diagnostics
  - Technology Process Inadequate