BUSINESS NOT AS USUAL

Presented to
Program Development and
Cultural Issues Panel
at the
Space Transportation Propulsion
Systems Symposium

June 27, 1990

UNITED TECHNOLOGIES
PRATT & WHITNEY

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GENCORP
AEROJET
CONCLUSION

Manage the problems together (Government/Contractors)

Don't resist cultural change
TYPICAL DESIGN SIMPLIFICATION IDEAS WHICH REDUCE COSTS

ELIMINATE BOOST PUMPS
ELIMINATE FAIL-OP IN CONTROL SYSTEM
ELIMINATE THROTTLING AND CLOSED LOOP CONTROL
LOWER CHAMBER PRESSURE
ELIMINATE POWER HEAD/DUAL PREBURNERS (GG CYCLE)

COMBUSTION CHAMBER DESIGN SIMPLIFICATION

SSME CC Design

4 Overlays + 2 closures = 6

15 Parts & 32 Weldments

ALS CC Design

Coolant Inlet

6 Parts & 0 Weldments

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CASTINGS VS. MACHINED AND WELDED FORGINGS

One Piece INCO 718
Machined Forgings
I-718

SSME Turbopump Volute
IR&D Cast Volute

Cost Savings of >10:1

AUTOMATED INSPECTIONS AND FUNCTIONAL CHECKS

Data Reduction & Maintenance Decisions
Flush & Purge
Visual Inspection

Sequence Test
Automated Leak Check

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Two Thirds Of Total Life Cycle Cost Is Determined By The End Of Concept Design*

* Richman Associates, Design To Cost Seminar, Aerojet 1977
Our Approach To The TCA: Maintain Flexibility

- Establish A Point Of Departure Design (a)
- Evaluate Competing Low Cost Designs/Approaches (b)
- Examine Technical And Process Issues And Alternatives (c)
- Select Final Approach Based On Rigorous Cost Comparisons (d)
- Demonstrate The Final Concept At MSFC (e)

Our Cost Model Embodies TQM

**OQFD**
- Respond To Customer's Desire For:
  - Low Cost Design
  - Understanding Of Factors Affecting Cost

**Juran**
- Identify Avoidable And Unavoidable Costs
- Evaluate, Early In The Design Process:

**TQM**
- Form: Touch Labor And Material Costs To Manufacture The Hardware

**SPC**
- Fit: Manufacturing Process Yields

**Taguchi**
- Function: "Warranty" Costs - Reliability And Spares
Summary

• High Reliability And Low Cost Are Obtainable
  - Inherent In Design And Manufacturing Processes:
    Fewer Parts  Advanced Processes
    Low Cost Materials  Reduced Inspection
    Wider Margins  Efficient Manufacturing

• Contractors Are Committed

• TQM Is In

• Consortium + Government + Prime Contractors = Partnership

• Government Role Is Key
  - Fix The Requirements
  - Avoid Gold Plating
  - Limit Specifications
  - Maintain Funding And Schedule

Low Cost Approaches To Engine Controller

• Modular, Flexible Architecture Results In 70% Decrease In Controller Life Cycle Cost

• Standard Modules, Interfaces, Software

• Adaptable To Various Engine Requirements
Low Cost Approaches To Propellant Control Effector

- Electromechanical Activation
- Ox And Fuel Valve Commonality
- Integral Electronics
- Digital Control And Interface
- Integral Valve Position Resolver

Low Cost Approaches To Turbopump Design

- Two-Stage Pump
- Self-Compensating Hydrostatic Bearings
- Cast Turbine Manifold
- Cast Pressure Vessel
- Integrally Machined Turbine Hub And Blades (Blisk)
- LCF And HEE-Resistant Turbines
  - No Coatings Or Platings
- Cast Impellers
- Reusable With Minimum Inspection And Refurb
Injector Assembly and Subscale Chambers Will Provide the Data Base for the 3-D Subscale Impinging Injector

Workhorse Chamber

- w/wo Ablative Stability Ring
- Bomb Testing
- Long Duration Tests
- Performance Testing

Calorimetric Chamber

- Stability Demonstration
- Bomb
- Fuel Temperature
- Chug

L' Ablative Chamber

Nozzle

w/wo L' Section
Heat Flux Profile
FFC Effects

Impinging Element Injector Offers Lower Cost and Acceptable Isp

<table>
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<tr>
<th>Parameter</th>
<th>Baseline Swirl Cost Element</th>
<th>Alternative Impinging Element</th>
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<tr>
<td># Parts</td>
<td>2200</td>
<td>15</td>
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<tr>
<td># Operations</td>
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<td>Injection ΔP_{FUEL} (Pa)</td>
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<td>Injection ΔP_{CO2} (Pa)</td>
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<td>Predicted Isp (sec)</td>
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<td>438.5</td>
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Concurrent Engineering Design Approach Addresses All Major Design Objectives

- Downstream Functions Actively Participated in the Design Process
  - Suppliers
  - Reliability
  - Productibility
  - Safety
  - QA
  - ILS

- Approach to High Reliability Formulated
- Approach to Low Cost Formulated
- Cost Model Constructed

Ongoing Advanced Development Programs Are Focused on High Reliability and Low Cost

- Combustion Devices
  - Thrust Chamber Assembly
  - Gas Generator Assembly
- Hydrogen Turbopump Assembly
- Propellant Control Effector (GGA Valve)
- Engine Controller