Introduction and Pivot Technology

Space Propulsion Technology
Assessment Workshop

April 2001

Introduction

- Top Down approach to Gen 3 technologies was performed previously
  - Results of Top Down approach tends to be architectures that can achieve goals
  - Approach was to identify concepts to address functional requirements
  - Often leaves gaps in the technology portfolio
  - Funds technologies across a wide range of concepts
    - Leads to numerous concept/technology funding requirements
  - These were evaluated at an AHP workshop in Spring 2000

- Propulsion Synergy Team was asked to perform Bottom Up approach to Gen 3
  - Results of Bottom Up approach tends to be cross-cutting technologies which address impediments to achieving goals
  - Goal was to establish an efficient and affordable path to address Gen 3 requirements
  - Emphasize tractability to Gen 2 systems and technologies
    - Approach has merit in meeting cost effective transition
    - Potentially evolve Gen 2 into Gen 3 capabilities

- Result was a number of packages of technologies
  - Grouped into six categories
  - To be evaluated at an AHP workshop

Introduction

- A number of areas that produce impediments to achieving Gen 2 and Gen 3 goals have been identified
  - Within each area approaches and packages of technologies will be presented for evaluation relative to one another
  - The approaches and the technologies often have considerable overlap both within an area and across areas
- For evaluating the technologies in this workshop the pivot technology is the current state-of-the-practice
  - In general this is STS with one change
    - Gen 2 and Gen 3 systems are assumed to carry their propellant tanks to orbit and return them

Introduction

- Previous examinations have shown that among the major drivers in not achieving Gen 3 goals are operations and the facilities and logistics related to operations
  - Impacts timeline and thus the ability to achieve needed flight rates with given fleet size
  - Impacts direct costs
  - Has a leveraging impact because some operations cause the need for additional operations and because the facilities themselves require significant operations and logistics

- All of the technologies to be evaluated address these drivers in one form or another
  - Directly through technologies that reduce operations, facilities and/or logistics
    - Direct reductions in tasks to be performed
  - Indirectly through less need for tasks (e.g., longer time between overhauls)
  - Indirectly through increased margins which can in turn be used during design and development to chose design solutions requiring less operations, facilities, and/or logistics even if those solutions are heavier or larger

- These technologies sometimes also have additional benefits, but they all address these drivers

- The majority of these technologies are also applicable to Gen 2 and would have significant impact for such systems

Introduction
Technologies

Piviot Technology - Current State-of-the-Practice - STS

IVHM

100% IVHM data to identify all failures in adequate time to implement corrective action/abort.

Provide totally integrated/automated functional health verification for all systems

Automated predictive maintenance capability designed-in as part of component development

IVHM does all preflight, visible check only required

Margin

Develop all air breathing concept (including ejector rocket, subsonic LACE, combined cycle) system alternatives that have benefit measured in P/l to dry weight and with an acceptable level of complexity. Solve as an integrated solution using comparable (to rocket) techniques

Lighter weight sub-systems

Higher performance (higher Isp, lower temp, lower pump press, longer life) sub-systems

Operations

Development of critical technologies eliminating the need for support systems (e.g., self contained engine valve and TVC actuators, eliminating requirement for distributive pneumatic and hydraulic sys.)

Technology that eliminates operations associated with turnaround of propulsion system (no purging/cleaning operations). Self venting and purging engines or no need to vent/purge

Leak free joints in propulsion system (incl. H2)

Simplified mating operations technologies (automated alignments, fluid connections, interface checks

Develop technologies to utilize passive aerodynamics to minimize venting and purging requirements and eliminate the use of closed compartments

Introduction
Technologies (Cont’d)

Use same main propellants in multiple stage vehicles

Develop and mature wireless communication technology required to eliminate flight to flight & flight to ground umbilicals

Design environmentally acceptable materials/cleaning alternatives that do not substantially compromise performance

Minimize need for cryogenic conditioning to start engine

Safety

Ability to tolerate credible system failures (i.e. contain an engine blade failure)

Eliminate all pyrotechnic devices in favor of highly reliable reusable mechanical devices

Thermal Control

Ultra high temperature ceramics to eliminate active TPS and explore a wider range of TPS technologies in an operational environment including transpiration cooled, ablatives, heat sinks, passive aero techniques (search for fundamental thermodynamic technologies)

Generic technologies that eliminate active thermal management systems

Number of Systems

All Rocket Cycle

Integrated RCS, OMS, MPS, Thermal Management, & Power Generation in one system

Integrated RCS, OMS & MPS

Integrated RCS & OMS

Component development to allow use of unusable residual gases for propulsion functions

Use very low thrust Main Propulsion Sys. mode for Orbital Maneuvering Sys.

Introduction

- For each area to be evaluated a short briefing will be presented containing
  - Current baseline in that area
  - Problems and goals
  - Approaches to a solution
  - Technologies to implement the solution, with TRLs
  - Very rough order of magnitude cost and schedule to implement the solution

- Within the briefings, generally only direct impacts will be highlighted
  - For example, “improved reliability”
  - That “improved reliability” also means improved safety and lower costs is left unsaid since that would seem to be double counting, or at least double enthusiasm
  - Ultimately all improvements must end up in lower life cycle cost and/or greater safety to have value in a Gen 3 system

- Although each briefing will refer to a baseline, major aspects of the STS state-of-the-practice are shown in the following charts

Pivot Technology
General

- Propulsion systems
  - 5, using 4 propellants, and 19 tanks for propellants and pressurants

- Fluids
  - 51 fluids used for servicing or on the STS
  - Includes 12 process verification cleaning fluids
  - > 20 used on a flight
  - > 10 toxic fluids used, 7 on a flight

- Closed compartments
  - 6 major plus 9 vent doors

- Turnaround
  - Timeline - about 3-4 months
  - Labor - about 190,000 direct hands-on hours
    - Total labor is about 10 times direct labor

Pivot Technology
Servicing Fluid Systems

- For fluid systems, manpower intensive operations are driven in Shuttle processing by a combination of (1) high numbers of potential leakage sources for fluid systems, (2) the use of manual methods in fluid systems certification (hands on including over a dozen approaches), (3) the criticality of systems dictating high numbers of required tests and (4) the lack of reliability of components further dictating high numbers of required tests for seals as well as components removed and replaced.

- Examples of currently required fluid verifications:
  - LOX Facilities: > 1,000 per flight (leak checks), many on purging and valve actuation systems
  - LH2 Facilities: > 1,000 per flight (leak checks), many on purging and valve actuation systems
  - MPS Processing: > 40 per flight + > 30 interfaces (caused by removal of the engine pod)
  - Shuttle Main Engines: > 80 per flight per engine + > 10 interfaces

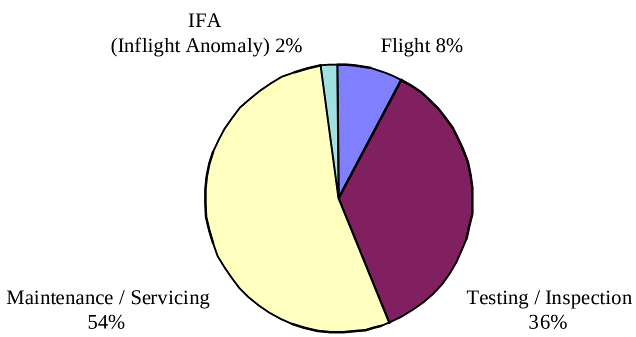
- Even systems which only check violated joints are not immune from numerous verifications given high component failure rates or required breakage into systems as part of processing such as for hydraulic systems

Pivot Technology
IVHM, BIT/BITE, Automated Testing

- Shuttle currently lacks true BIT / BITE for fluid, mechanical and structural systems and the use in electronic systems is limited in the ability to isolate problems to the lowest line replaceable unit (LRU) possible
  - Manpower intensive fault isolation of fluid systems such as propulsion contributes significantly to high turn-around times and low flight rates
  - Assuming reliability increases (addressed in other criteria) the criticality of space unique systems dictates that a significant requirement of future systems is improvement in fault isolation
    - For example, hazardous gas detection systems can indicate a leak in the ET intertank but can not specifically tell where
- The development of BIT / BITE capability for fluid, mechanical, structural and electronic systems would directly address the fault isolation which is 36% of when component failures are detected
  - Currently Shuttle relies on very manpower intensive approaches (non-BIT / BITE) for this part of turnaround activity
- The 54% of fault isolation occurring during maintenance and servicing must also be addressed by means of BIT / BITE given it's manpower intensive non-BIT / BITE nature as well
- Current remote health diagnostics emphasize the flight portion of the system

WHEN ARE COMPONENT FAILURES DETECTED

3 FLOW ANALYSIS: STS-67, 71 AND 70



Pivot Technology
Wires and Lines

SSME

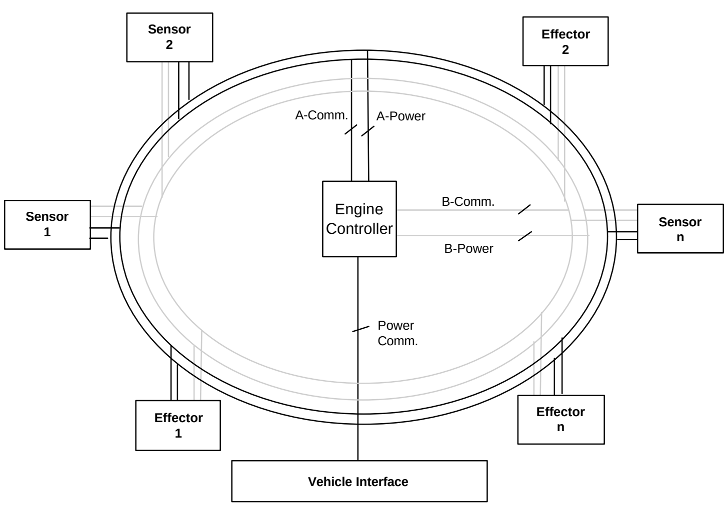
Sensors	
Type	Number
Pressure	18
Temperatures	15
Speeds	3
Flow	2
Igniter Monitors	3
Position	14

Effectors	
Type	Number
Servovalve Drivers	6
Servoswitch Drivers	12
Igniters	3
Solenoids	13

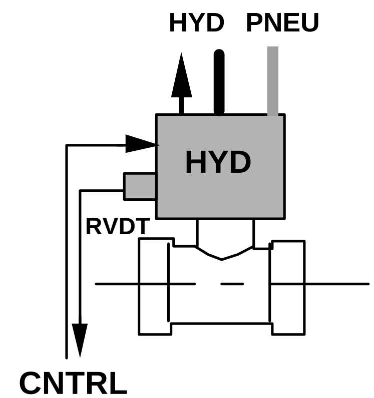
Notes:

(1) Sensors Are Dual Output to 2 Channels Providing Full Redundancy

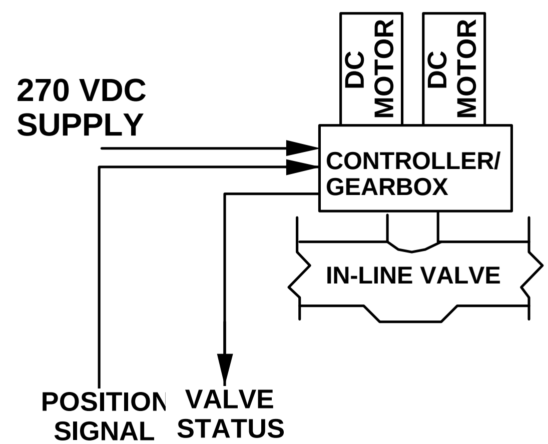
(2) 20 Harnesses Required Per Engine



Current SSME



EMA



Pivot Technology
Umbilicals

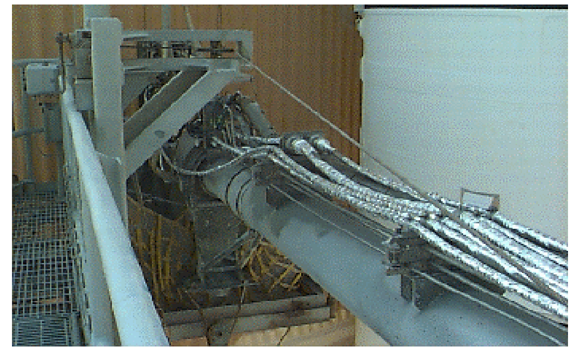
- The STS has over 100 umbilicals

- Most critical umbilicals have pyro disconnects
  - Only replaced near flight time
  - Hazardous mechanisms require stopping other work and serial processing

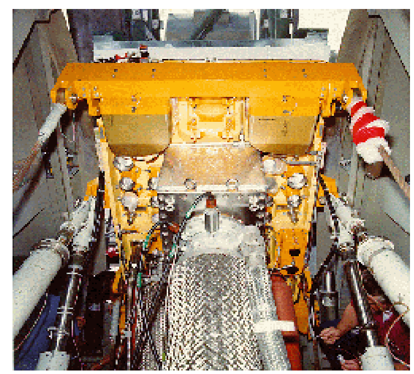
- Must be cleaned after launch
  - Currently most are cleaned by disassembly, cleaning, refurbishment, reassembly, and verification

- In general
  - Days to refurbish
  - Expendable hardware
  - Days to install
  - Days to checkout
    - Example: 6 shifts (approximately 75-100 hours) per GUCP for fluids only
  - Highly manual operations
  - Many serial operations
    - Checkout part of system, reconfigure, checkout remaining

- To save weight, hardware on ground instead of vehicle requiring additional interfaces
  - Sensor, valve actuation



Shuttle H2
Vent Arm



Shuttle LOX T-0 Interior View