LESSONS LEARNED FROM PAST REUSABLE LAUNCH SYSTEM DESIGNS

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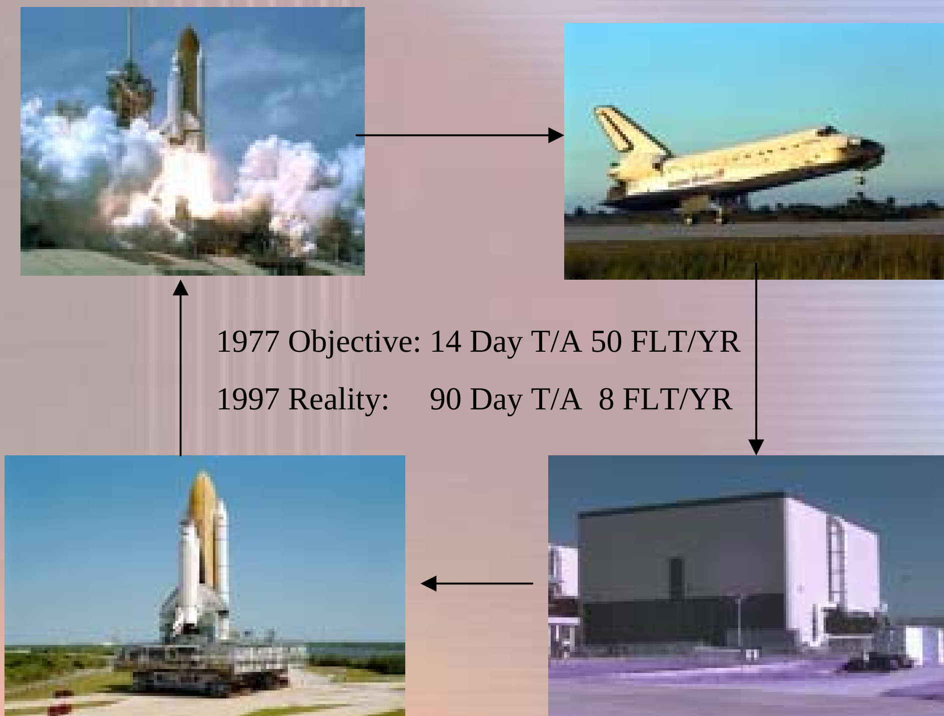
Introduction

- STS Operations History
- X-33 Phase II Development Perspectives
- Future Launch Systems
- Conclusions

STS Operations History



1977 Objectives

•14 Working Days/160 Hr Ground Elapsed Time

•Aircraft Like Operations/reusable Hardware

•50 Flights/year

1981 Reality

•Inherited Apollo Program Gov/industry Infrastructure

•Major DDT&E Program

•Mission Oriented, Not "Cost" Oriented Goals

1984 STS Operations

•Shuttle Processing Contract Operability Goals

•Consolidation of Contracts

•DDT&E Continues on a Per Flight Basis

1986 Challenger Accident

•Mission Goals Changed (Eliminated DOD/commercial Payloads)

•Vehicle Checkout Philosophy Changed Adding more checks and balances

•Major operations and Infrastructure Cost Increases

2003 Columbia Accident

•TBD

1998 STS Operations

•Space Flight Operations Contract Initiatives to Reduce Costs

•STS Upgrades to Reduce Costs/counter Obsolescence

•DDT&E/Recertification Continues on a Per Flight Basis

•Goals to Reduce Payload Costs From $7,500+/lb to $3,000/lb (LEO)

X-33 Advanced Technology Demonstrator

X-33 Advanced Technology Demonstrator Phase II Cooperative Agreement Contract

– Flight Demonstrator

– RLV Ground Technology Development

– Commercially Developed RLV (*VentureStar*) Design Definition/Business Plan

Aggressive NASA Approach to Developing New Launch System

–Fast Track Project, 33 Months from Go-Ahead to First Flight

–Over Population Flight Trajectory

–Dramatic Operations Improvements

Ultimate Objective: Produce Data to Enable Business and Government Decisions to Proceed With a Privately Funded Reusable Launch System to Replace Space Shuttle

X-33 Advanced Technology Demonstrator

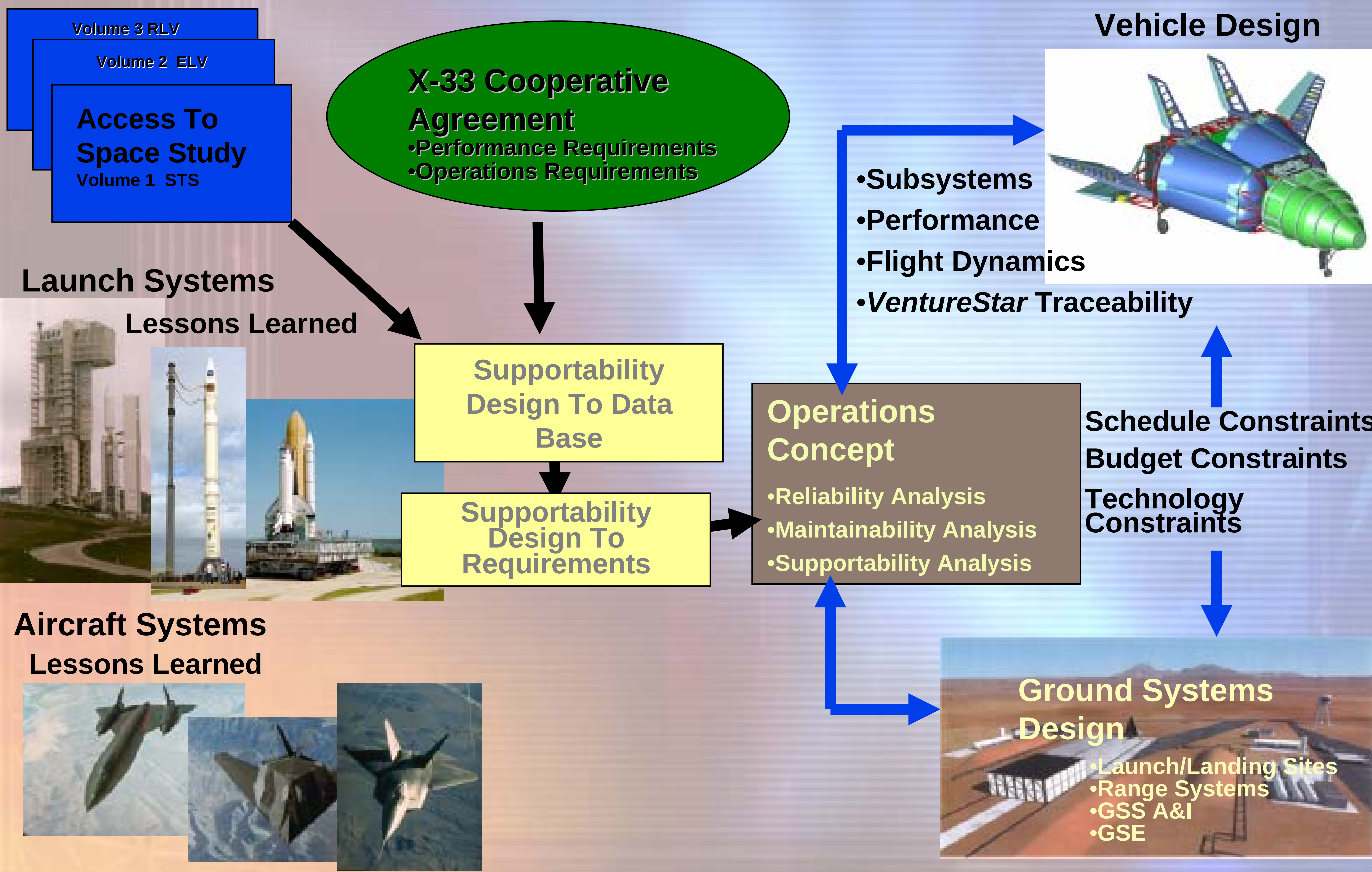
Initial X-33 Program Technology Performance Goals:

- Aerodynamics under real gas effects
- Lifting body flight dynamics validation
- Structural load paths with an internal payload bay
- Reusable TPS thermal performance
- Reusable composite multilobe liquid hydrogen tanks
- Linear Aerospike engine performance
- Thrust vector control via differential engine thrusting
- Subsystem performance in a flight environment

Initial X-33 Program Operations Goals:

- Flight at speeds exceeding mach 15
- 50 personnel touch labor
- 3 consecutive 7 day turn arounds
- A 2 day turn around
- Demonstrate vehicle certification to allow over population flight path

Design to Operations Process



X-33 Advanced Technology Demonstrator

X-33 Vehicle Performance Update (Program Realignment)

Design Challenges
- •Flight dynamic stability resolution
- •O2/H2 Gassification System design
- •Weight growth
- •CG location
- •Composite LH2 Tank design

BUDGET IMPACT

Rebaseline Vehicle Design Impacts
- •Replaced Turboalternator with Batteries
- •O2/H2 Gassification System eliminated
- •Removable Payload Container eliminated
- •Utilize ceramic TPS on aft areas
- •Mold line frozen
- •Descoped IVHM

Rebaseline Decision Philosophy:
- •Deleted RLV traceable flight items moved to ground test projects
- •Maintain all RLV traceable technology validations

OPERATIONS/SCHEDULE IMPACT

Rebaseline Operations Impacts
- •Deleted IHMS
- •Deleted Integrated Operations Maintenance System demonstration
- •Deleted Payload Container demonstration
- •Battery replacement between flights
- •Ceramic TPS waterproofing required
- •First flight date slipped 4 months (7/99)

Rebaselined System Supports VentureStar Decision Criteria

X-33 Advanced Technology Demonstrator

Certification Methodology

- The X-33 Certified for Flight for the Entire Flight Test Program Prior to First Flight
- Utilize Aircraft Certification Methodology As Much As Possible
- Reliability Analysis Performed As Part of Design
  - Because of Limited Life Flight Test Program the "System" Was Designed to .9865 Probability Safe Recovery
  - Low Probability of Ground Casualties From Over-Flight Allowed EIS Approval (< 30 per 1Million Flights)
- Integrated Avionics Test Bed
  - Vehicle Brass Board to Test Flight Avionics Subsystems and Systems
  - Final Validation of Flight and Ground Software
  - Ground/flight Test Operations Simulation and Training
- Integrated Vehicle Ground Test Program
  - Fast Track Program Doesn't Allow Systems Level Verification With a Ground Platform
  - Utilized Flight System (assets) to Perform Dual Functions
    - Verify Flight/ground Systems Integrity
    - Validate the Design
- Flight Readiness Approval Process
  - Launch Safety Review Board @ L-60 Days
  - Program Readiness Review @ L-30 Days
  - Flight Test Readiness Review @ L-10 Days

Future Systems Development

Future Reusable Launcher Programs Must Build on Lessons Learned From Previous Attempts at Demonstrating Operability

STS Upgrades

X-33/RLV Phase II
DDT&E

Methods To Achieve Operability

- Design To Operations
  - Technology Infusion
  - Increase Design Margins
  - COTS Technologies
- Minimize Operations Infrastructure
  - Certification Prior To Operational Implementation
  - Efficient Procedures
  - Reliability, Maintainability, Supportability Implementation

Design/Certify Total System To Meet Operations Requirements

VentureStar Phase III

Advanced Concepts

Military Space Plane
DDT&E/Operations

Because of the Investment Commitments Required, Vehicle and Ground Systems Must Be Fully Qualified Prior to Initiating the Operational Implementation.

Future Systems Development

Vehicle/Ground System Issues	***Solutions***
High Maintenance Components	•Robust TPS (eliminate re-water proofing and normal debris damage and thermal barrier checks) •Low Maintenance Engines (eliminate between flight intrusive inspections, increase design margins, eliminate post flight bearing drying) •Minimize wiring
System Level Complexity	•Self Contained Reusable Propulsion •Minimize electrical power and cooling requirements •Simplified Fluid Systems (minimum number/types of fluids, eliminate hazardous fluids.) •Maximize health management/BIT to the component level •Maximize commonality of hardware (ie. Universal Signal Conditioners)
Operational Complexity	•Single Level Access of components •Standardization of Payload Interfaces •Payload containerization •Automated integrated work control •Eliminate unique/hazardous systems (pyrotechnics, ablatives, etc.)
Labor Intensive Operations	•Automated Interfaces and umbilicals •Self -Verifying Interfaces (Mechanical, fluid & Electrical) •Autonomous interface systems retest capability •Quick release mechanical fasteners

Conclusions

- Historically, launch systems development programs had operability goals, which were compromised to meet mission performance requirements.
- DDT&E infrastructures were created as integral parts of the program operations and eventually never shed from the system over the life of the program
- The combination of “design to performance” and developmental program operations infrastructure has resulted in the operations intensive launch delivery systems today
- If future programs are to meet overall life cycle cost goals total system (ground, mission and programmatic) performance must be optimized.

Therefore government investment must be directed toward operations certification of new system technologies as much as it is on traditional performance qualifications. Tremendous improvements can be made in system operations, which will translate into program efficiencies and lower overall system cost from the first launch and continuing through the life of the program