Launch Vehicle Design Process Characterization Enables Design/Project Tool

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Purpose

• Provide an overview characterization of the launch vehicle design process

• Delineate design/project tool to identify, document and track pertinent data
Launch Vehicle Design Process
Features

• Vehicle Life Cycle

• Fundamental premises
  – Industrial specialization
  – T-model

• Compartmentalization
  – Hardware subsystems
  – Design functions
  – Discipline functions

• Technical integration
Vehicle Life-Cycle Flow Chart
Design Process Life-Cycle Evolution
Influence of Aerospace Infrastructure and Specialization on Design

**Capabilities and Knowledge Base**

**Industry**
- Design
- Manufacturing Capability
- Technology

**Institutes and Government**
- Knowledge Base
- Test and Launch Facilities
- Methodology
- Technology

**Academia**
- Disciplines
- Research
- Technology

**State of the Art**
- Standards
- Monographs
- Technologies
- Manufacturing Capabilities
- Advanced Technology

**Divide**
- Compartmentalization

**Synthesize**

**Analyze and Assess**

**Design Product**

Iterate
**T-Model for Technical Integration**

- **Systems**
- **Formal**
- **Top Level**

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- **Specific Discipline to Specific Discipline**
- **Informal**
- **Indepth**

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- **Discipline**
- **Component**

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- **Discipline**
- **Component**
Compartmentalization and Reintegration
STS Compartmentalization

1.0 STS

2.0 Launch Vehicle

3.0 Payload Interfaces

4.0 Operations Systems
Compartimentalization

Launch Vehicle Hardware Subsystem Compartimentalization

1.0
STS

2.0
Launch Vehicle

2.1
Propulsion Systems

2.2
Vehicle Structures

2.3
Thermal Systems

2.4
Avionics Systems

2.5
Other Systems

3.0
Payload Interfaces

4.0
Operations Systems

2.2.1
Thrust Structure

2.2.2
Aeroshell

2.2.3
Tankage

2.2.4
Intertank Structure

2.2.5
Payload Bay Structure

2.2.3.1
Oxygen Tank

2.2.3.2
Fuel Tank

2.2.3.2.1
Tank Structure

2.2.3.2.2
Tank Thermal System

2.2.3.2.3
Propellant Utilization System

2.2.3.2.4
Propellant Conditioning System

(Selected compartmentalized subsystems shown as an example)
Compartmentalization
(continued)

Launch Vehicle Hardware
Subsystem Compartmentalization

2.0
Launch Vehicle

2.1
Propulsion Systems

2.2
Vehicle Structures

2.3
Thermal Systems

2.4
Avionics Systems

2.5
Other Systems

2.2.1
Thrust Structure

2.2.2
Aeroshell

2.2.3
Tankage

2.2.4
Intertank Structure

2.2.5
Payload Bay Structure

2.2.3.1
Oxygen Tank

2.2.3.2
Fuel Tank

2.2.3.2.1
Tank Structure

2.2.3.2.2
Tank Thermal System

2.2.3.2.3
Propellant Utilization System

2.2.3.2.4
Propellant Conditioning System

Launch Vehicle System Design Functions

2.0.1
Launch Vehicle System

2.0.2
Aerodynamics

2.0.3
Trajectory/Performance

2.0.4
GN&C

2.0.5
Structures

2.0.6
Thermal

2.0.7
Propulsion

2.0.8
Avionics

2.0.9
Materials

2.0.10
Manufacturing

2.0.11
Other

(Selected compartmentalized subsystems shown as an example)
Compartmentalization
(continued)
Typical Design Functions

(Selected compartmentalized subsystems shown as an example)
Technical Integration of System, Design, and Discipline Functions
System Design Function
Systems Plane Overview

Technical Integration

Subsystems
- Launch Vehicle System
- Propulsion Systems
- Structures Systems
- Thermal Systems
- Avionics Systems
- Other Systems

Design Functions

Compartamentalization

Requirements Formulation
- Understand User Requirements, Develop Systems Concept and Acceptance Plan
- Develop System Performance Specification and System Verification Plan
- Expand Performance Specifications into CI "Design-To" Specifications and CI Verification Plan
- Evolve "Design-To" Specifications into "Build-To" Documentation and Inspection Plan

System Requirements Document
- System Requirements and Design
- PDR
- SR

Reintegration

Operations
- Demonstrate and Validate System to User Acceptance Plan
- Integrate System and Perform System Verification to Performance Specifications
- Assemble CI's and Perform CI Verification to CI "Design-To" Specifications
- Inspect to "Build-To" Documentation

System Verification and Validation
- AR
- DCR
- Compliance Document
- Verification Requirements and Specifications Document

Fabrication Assembly and Code to "Build-To" Documentation

Systems Plane Responsibility: Ensure the system will satisfy all requirements and constraints for the entire life cycle.
Structures Design Function

System
Aerodynamics
Trajectory/Performance
GN&C
Structures
Thermal
Propulsion
Avionics
Materials
Manufacturing
Other
System Plane Responsibilities

- Provide technical leadership
- Define and allocate requirements
- Define system philosophies
- Develop activities plan
- Synthesize architectural alternatives
- Compare and screen with historical database
- Compartmentalize and reintegrate subsystems/design function
- Define and manage interfaces and interactions
- Integrate design and discipline functions for balanced design (technical integration)
- Perform system trade studies to balance system attributes
- Develop plans for verification, manufacturing, and operations
- Track critical technologies and issues
- Track technical performance parameters/margins
- Perform risk assessment
- Provide configuration control
- Orchestrate reviews
- Document results.

Other Design Function Plan Responsibilities

- Requirements
- Acquire and assess allocated requirements
- Develop natural and induced environments for all mission events
- Develop derived requirements
- Determine supporting discipline criteria
- Configure requirements for verification
- Design
- Synthesize design alternatives
- Compare and screen with historical database
- Determine and evaluate critical technologies
- Perform design analysis and test (stability, transient, and quasistatic analysis for contributing disciplines)
- Determine attributes (performance, cost, reliability, operability, and safety)
- Trade and compare attributes
- Identify failure modes
- Perform uncertainty and sensitivity analysis
- Perform risk assessment
- Iterate, select, and mature design
- Develop drawings, specifications, and databases.
- Manufacturing
- Develop manufacturing plan
- Determine and certify critical processes
- Build.
- Verification
- Develop verification plan (test, analysis, similarity, etc.)
- Perform verification at appropriate levels
- Certify hardware/software.
- Operations
- Develop operations plan (assembly, checkout, launch, flight, return, refurbishment/maintenance)
- Determine operations database
- Establish operations constraints and procedures.
Categories of Compartmentalization

- Discipline Functions (Example Disciplines Supporting Structures Design Function)
- Design Functions (Example Launch Vehicle System)
- Hardware/Software Subsystems
Matrices of Input/Output Data Flow

Subsystems

Design Functions

Disciplines

I x I Matrix

N x N Matrix

Input/Output Data Flow Associated With Physical, Functional, and Informational Interfaces of Hardware Elements

Input/Output Data Flow Associated With Design Function and Discipline Activities
I x I Matrices
Interactions Among STS Subsystems

| X | Matrix for STS |
1 x 1 Matrix for Launch Vehicle

Interactions Among Launch Vehicle Subsystems
Matrices of Input/Output Data Flow

Subsystems

Design Functions

Disciplines

Input/Output Data Flow Associated With Physical, Functional, and Informational Interfaces of Hardware Elements

Input/Output Data Flow Associated With Design Function and Discipline Activities
**N x N Matrix for Launch Vehicle**

**LAUNCH VEHICLE SYSTEMS DESIGN FUNCTIONS**

- 2.0.1 Launch Vehicle System
- 2.0.2 Aerodynamics
- 2.0.3 Trajectory/Performance
- 2.0.4 GN&C
- 2.0.5 Structures
- 2.0.6 Thermal
- 2.0.7 Propulsion
- 2.0.8 Avionics
- 2.0.9 Materials
- 2.0.10 Manufacturing
- 2.0.11 Other

**EXAMPLE MATRIX ENTRY**
- Ascent Aero Heating Histories
- Entry Aero Heating Histories
- Compartment Flow Rates
- Plume Heating Environments

**Outputs**

- Cost/Reliability/Operability/Safety/Other-ilities
Integrated Information and Communication System (I^PCS)
Need and Approach

Need: Improve the efficiency and fidelity of the launch vehicle design process through all stages.

Approach: Provide the means to—

1. Connect all process participants in the design process to archive valid/correct design information and ensure interactions are accounted

2. Implement advanced tools
Typical Features

1. Residence and/or place holder for the design description and specifications, associated attributes, ICD's, and supporting data (this tool could be based upon the design process characterization model along with the N x N and I x I diagrams)

2. Real-time interactive communications system

3. Management related information system (this tool would include the WBS, cost-spending profiles, allocations, reserves, schedule, etc.)

4. Electronic mockup with fidelity consistent with the design stage

5. Flight performance simulation with fidelity consistent with the design stage that displays key performance indicators versus flight time

6. Advanced interactive MDO synthesis system that can search for architectures per given requirements and constraints but be driven by an optimization algorithm

7. Virtual reality design system that can focus on the vehicle system, element, subsystem, or part where the design participants can assess the realization of their design decisions in real time

8. Interactive synthesis tool with design-to models that include performance, cost, reliability, safety, operations, etc.