Design Space Exploration/Identification In Elegant System Design and Operation

Michael D. Watson
NASA Marshall Space Flight Center

Michael D. Griffin
Chief Executive Officer, Schafer Corporation
Principles of Elegance

• Elegant Systems are
  ▪ Effective
  ▪ Efficient
  ▪ Robust

• Elegant Systems Manage and Minimize
  ▪ Unintended Consequences
Elegant Systems are achieved through:

- Understanding the Mission Context
- Managing the Physical and Logical System Interactions among the system components and with the system environment
  - Physics (Structural, Thermal, Fluid, Electrical)
  - Logical (Data and Information)
- Managing the Organizational Structure and Information Flow
- Understanding the Policy and Law Constraints
  - Federal Aviation Administration (FAA) Regulations
Properties of Elegance

- Simplicity in Function and Operations
- Espalier: Seamless integration of secondary functions
- Efficient Configuration within the Mission Context
- Robust in Operation and Application
  - Evolve in a graceful manner
- Minimize Unintended Consequences
Design Space Exploration/Identification is:
- Defined by the Mission Context
- Defined by the System Physics
- Constrained by schedule, budget, policy, and law
- Influenced by organizational dynamics

Focus is on finding the most efficient system configuration.
Design Space Exploration/Identification

- **Mission Context**
  - How is the system to be used?
    - Loiter time
  - What are the operational constraints?
    - Deployment location
  - What is the operational environment?
    - Dedicated operator or field soldier
    - Remote operations center or field operated
  - What is the maintenance philosophy?
    - Single flight
    - Field maintenance, depot maintenance
  - What is the post mission assessment approach?
    - Local field assessment, strategic assessment
Design Space Exploration/Identification

- **System Physics**
  - Aerodynamics
  - Propulsion System
  - Launch System
  - Recovery Systems

- **System Efficiency defined by System Physics**
  - System Exergy provides a complete thermodynamic efficiency of the integrated system to examine all possible system configuration options
    - Provides an integrated analysis of all system interactions within the system and with the environment
    - Has been shown to identify discontinuous design solution spaces with improved system characteristics
Design Space Exploration/Identification

• Design Space is constrained by Budget, Schedule, Policy, and Law
  ▪ Budget limits configuration options
    – Development
    – Production and Operations (includes sustainment)
  ▪ Schedule limits configuration options
    – Development
      » How soon does the system need to be to market or fielded?
    – Production and Operations
      » Production pipeline
      » Operations support
        • Team size
      » Maintenance Approach
        • Field maintenance or depot maintenance
Design Space Exploration/Identification

- Design Space is constrained by Budget, Schedule, Policy, and Law
  - Organizational Dynamics
    - Defines the efficiency with which a specific organizational structure can achieve a specific configuration
  - Policy and Law constrains configuration options
    - Federal Aviation Administration (FAA) Regulations
Design Space Exploration/Identification

- Be Aware of Unintended Consequences
  - Error (Mistakes)
  - Ignorance (Not Knowing or Not Understanding)
  - Bias
    - Cultural
    - Historical
  - Short Sightedness (Imperial Immediacy of Interest)
  - Self Defeating Prophecy

- Early design space exploration needs to have assumptions well grounded
Summary

- **System Elegance starts in Design Space Exploration/Identification**
  - Design Space Exploration/Identification is defined by Mission Context and System Physics
    - Identify the most efficient configuration for the system
    - System exergy analysis potentially allows broader design space exploration
  - Design Space is constrained by Budget, Schedule, Policy, and Law
    - Sets the local conditions within which to find the most efficient option
  - Design Space is influenced by the organizational dynamics
    - Sets the efficiency with which the organization may achieve the most efficient option
Acknowledgement

• Information on UAV/UAS provided by
  ▪ U.S. Army Program Executive Office (PEO) Aviation
    – Lars Ericsson
    – James Springer