HEXPAK*
BIG AREA FROM A
SMALL SATELLITE

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* HexPak – U.S. Patent #6,568,638 – “Modular Spacecraft Structure”
Outline

• HexPak Concept Introduction
• Hardware Testbed
• Structural and Thermal Analyses
• Conclusion
Deploying Satellite Structure

Example:
HexPak Realization of Small Satellite, 1.3 m Diameter Bays
Deploying Satellite Structure

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HexPak Realization of Small Satellite, 1.3 m Diameter Bays
HexPak: Breaks Physical Constraints of Current Space Platforms

Optimal Use of Limited Payload Fairing Volume

- Low center of gravity and large area

Key to New Mission Concepts and Unsurpassed Performance
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Permits

- Large deployable structures

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• Multiple manifest

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- Low center of gravity and large area

Permits

- Large deployable structures
- Multiple manifest
- Formations of Single-Bay Satellites

Key to New Mission Concepts and Unsurpassed Performance
HexPak: Breaks Physical Constraints of Current Space Platforms

Large Deck Area Compared to Traditional Designs

Permits

• Large Aperture Instruments
• Hosting of Multiple Cooperative or Independent Instruments

Passive IR Mission Bus Components Distributed on HexPak Platform

Key to New Mission Concepts and Unsurpassed Performance
HexPak: Breaks Physical Constraints of Current Space Platforms

New Standard for Thermal Performance
HexPak Radiating Surface to Mass Ratio is Constant, Overcoming Physical Power Limits of Traditional Structures

Highest Heat Rejection for Unit Mass

Emerging Technologies
Key to New Mission Concepts and Unsurpassed Performance
HexPak: Breaks Physical Constraints of Current Space Platforms

Architecture for On-Orbit Reconfigurability

1. Original Vehicle Launched and Deployed

2. Later Launch Augments or Replaces Elements of Existing Platform

Emerging Technologies

Key to New Mission Concepts and Unsurpassed Performance
HexPak: Breaks Physical Constraints of
Modular Structure: Reduced Manufacturing Time,
Accelerated AI&T,
Reduced Cost

Individual bays undergo AI&T in parallel

Electrical Integration

Structural Integration
HexPak: Breaks Physical Constraints of Current Space Platforms
Supports Insertion of New Technologies

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- Supports Insertion of New Technologies
- Optical Payloads

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- Supports Insertion of New Technologies
  - Optical Payloads
  - RF Payloads

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Supports Insertion of New Technologies

- Optical Payloads
- RF Payloads
- Multifunctional Structures

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Supports Insertion of New Technologies

- Optical Payloads
- RF Payloads
- Multifunctional Structures
- Plug’n’Play Fiber Network
- C&DH

Key to New Mission Concepts and Unsurpassed Performance
Example Fairing Diameters

- Falcon X 1.3 m
- Delta II 3.0 m
- Atlas V 4.4 m

Payload Fairing Circumference

2 meters (2.6 m²)
Testbed – Stowed - Mechanisms

Hinge Line 1
Aligned with Gravity
Testbed – Stowed - Mechanisms
Testbed – Stowed - Mechanisms

Latch Mechanism
Testbed – First Hinge Rotation
Testbed – First Hinge Rotation
Testbed – First Hinge Rotation
Testbed – First Latch

Latch Probe Directed to Center Of Cup
Testbed – First Latch

Latch Probe Directed to Center Of Cup
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Latch Probe Directed to Center Of Cup
Testbed – First Latch

Motor Driven Grippers Pull Probe to Seat Cup and Sphere

Latch Probe Directed to Center Of Cup
Testbed – Position Second Hinge
Testbed – Position Second Hinge
Testbed – Position Second Hinge

Hinge Line 2
Aligned with Gravity
Testbed – Second Hinge Rotation
Testbed – Second Hinge Rotation
Testbed – Second Hinge Rotation
Testbed – Final Latches

Latch Modified With Slot For Sideways Entry Of Probe
Testbed – Growth Options

Hole Patterns
Support
Testbed – Growth Options

Hole Patterns
Support
• Payload Demos
Testbed – Growth Options

Hole Patterns
Support
• Payload Demos
• Payload Mockups
Testbed – Growth Options

Hole Patterns
Support
• Payload Demos
• Payload Mockups
• C&DH Experiments
Testbed – Growth Options

Hole Patterns Support
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Hinge Plates Replaceable To Demonstrate Other Mechanisms
Testbed – Growth – Modular Network

- Subsystem Component
- Power loop through Latches
- "universal" plugs for network & power
- Optical/electrical switches
- Fiber optic interbay backbone
- Electrical intrabay lines
Plug’n’Play Network Realization
Plug’n’Play Network Realization
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Plug’n’Play Network Realization
Hardware Layout

Switches
Hardware Layout

Switches

Wireless
Hardware Layout

Switches

Wireless

Component

Mount
Small Satellite Structural Analysis

For HexPak Structural Designs Scaled for Small Satellite Launch Opportunities

- How Important are Dimensional Parameters to Stiffness and Natural Frequency?
- Is the Structural Mass Fraction Reasonable?
Small Satellite Structural Analysis
Case Study: SpaceX Falcon I

- 500 kg total launch mass
- 1.3 m internal diameter
- >25 Hz natural frequency
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Case Study: SpaceX Falcon I

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4 Bay Stack Using Composite Facesheets

Vertical drumming mode
Lateral cantilever mode
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4 Bay Stack Using Composite Facesheets

Vertical drumming mode
Lateral cantilever mode
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4, 8, and 12 Bay Stacks

Structural Mass Fraction

Natural Frequency (Hz)

Vertical drumming mode

Lateral cantilever mode
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Case Study: SpaceX Falcon I

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Graph showing:
- 4, 8, and 12 Bay Stacks
- Natural Frequency vs. Structural Mass Fraction

Modes:
- Vertical drumming mode
- Lateral cantilever mode
Area Advantage

What can you get out of a 1.3 m fairing?

- 0.9 m²
- 1.1 m²
- 1.7 m²

4 x 1.3 m dia
4.4 m²

4 x 1.3 m dia
8.8 m²

4 x 1.3 m dia
7.8 m²
Thermal Analysis

• Created Model
  - M55J/Al honeycomb sandwich panel floor
  - Ag/teflon surface, .23 EOL absorptivity, .81 emissivity

• Inert Bay Run – (Ex: LEO SunSynch, 10:30 ascending node)

Animation removed for PowerPoint version compatibility
Thermal Progress

- Created Model
  - M55J/Al honeycomb sandwich panel floor
  - Ag/tetlon surface, .23 EOL absorptivity, .81 emissivity
- Inert Bay Run – (Ex: LEO SunSynch, 10:30 ascending node)
- 400 W/m^2
- 800 W/m^2
- Hottest and Coldest Temperature Seen On Deck
- Practical Limit ~ 400 W/m^2
Thermal Control Strategies

- Decoupled from Deck
Thermal Control Strategies

- Decoupled from Deck

4x Flux
Thermal Control Strategies

- Decoupled from Deck

4x Flux

Needs 4x Area
Thermal Control Strategies

- Decoupled from Deck
- Coupled to Deck
Thermal Control Strategies

- Decoupled from Deck
- Coupled to Deck
- Thermal Spreader
Thermal Control Strategies

- Decoupled from Deck
- Coupled to Deck
- Thermal Spreader
- Heat pipes
Thermal Control Strategies

- Decoupled from Deck
- Coupled to Deck
- Thermal Spreader
- Heat pipes
- Exotics ...
Modular Thermal Design – At the Bay Level

• Individual Bays Are Thermally Decoupled
  – Can Be Designed for Different Operating Temperatures
  – Changes in Thermal Design Are Localized Rather than Systemic
Modular Thermal Design – At the Component Level

- Different Components Merit Different Strategies
- But Strategy Can be Orbit Environment Specific Rather than Spacecraft Specific
Modular Thermal Design –
At the Component Level

- Different Components
  Merit Different
  Strategies

- But Strategy Can be
  Orbit Environment
  Specific Rather than
  Spacecraft Specific

- Effective “Thermal
  Footprint”
Modular Thermal Design – At the Component Level

- Different Components Merit Different Strategies
- But Strategy Can be Orbit Environment Specific Rather than Spacecraft Specific
- Effective “Thermal Footprint”
- Enables
  - Thermally Decoupled Layout
  - Modularization of Thermal Design At the Component Level
Continuing 2006 HexPak Activity

- Further Analysis of Thermal Capability and Control Strategies
- Plug’n’Play C&DH Demonstrations and Interface Testing
- Exploring Flight Demonstration Opportunities
Conclusion

- HexPak Advantages for Small Satellites
  - Efficient Use of Payload Fairing
  - Efficient Multiple Manifest
  - Large Deck Area
  - Modular Structure
  - Modular Thermal Design
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Modular Structure

- Simple Design
  - Small Part Count
  - Scaleable Geometry
  - Scaleable Performance

- Dense Packing
  - Near Optimal Use of Fairing
  - Accommodates Range of Component Sizes
Mission Validates HexPak Technologies, and Supports Two Bays for Partner Payloads

Demo Concept Supports

- 115 kg mass
- 200 W avg power
- 2 X 1.1 m dia hexes (1.5 m² deck area)
- TBD data rate
- TBD pointing control
Configuration Trades
Multiple Manifest

- HexPak stacking is naturally extensible to multiple satellites. Simpler, lower mass interface than traditional approaches.
- Useful feature for responsive space missions:
  - Single launch to populate planes for theater-specific constellations.
  - Single launch of formations.

Constellation

Formation

1. Target
2. Assess Damage
Rapidly Deployable Avionics

- HexPak Geometry provides flexibility in SC configuration
- 2D Wiring Network and Power Harness Simplifies Layout
  - Simple network topologies
  - “Circuit board” layout
- Ideal for Implementation of Plug’n’Play
  - Substitution of different payloads, subsystem components
  - Self-discovery of spacecraft properties
Rapid Response Scenario

- Select from S/C Inventory
  - Payloads
  - Structure
- Select bus template
- Electronic Layout
- Simulation
- Assembly
- Software
- Launch
- Operations

Inventory → Layout → Predesign

Simulate → Assemble

Launch → On-Orbit Ops