Phantom Works

Miniature Deployable High Gain Antenna for CubeSats

Charles S. "Scott" MacGillivray

Office: (714) 372-1617
e-mail: charles.s.macgillivray@boeing.com

Mobile: (714) 392-9095
e-mail: zserfv23@gmail.com

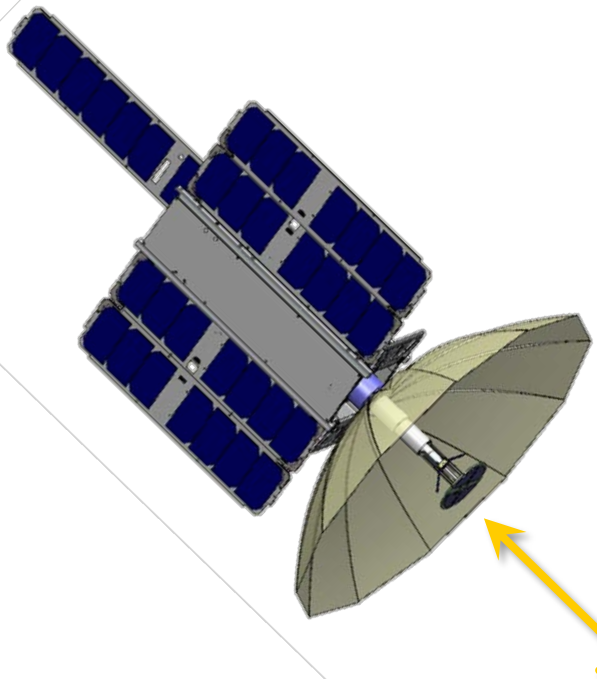
April 22nd, 2011

The Boeing Company
Boeing Defense, Space & Security (BDS) / Phantom Works
Advanced Network & Space Systems Group
Huntington Beach, CA

Developed Under Contract NRO000-08-C-0516

Miniature Deployable High Gain Antenna

- Applicable to High-Speed Communications and a Variety of Missions



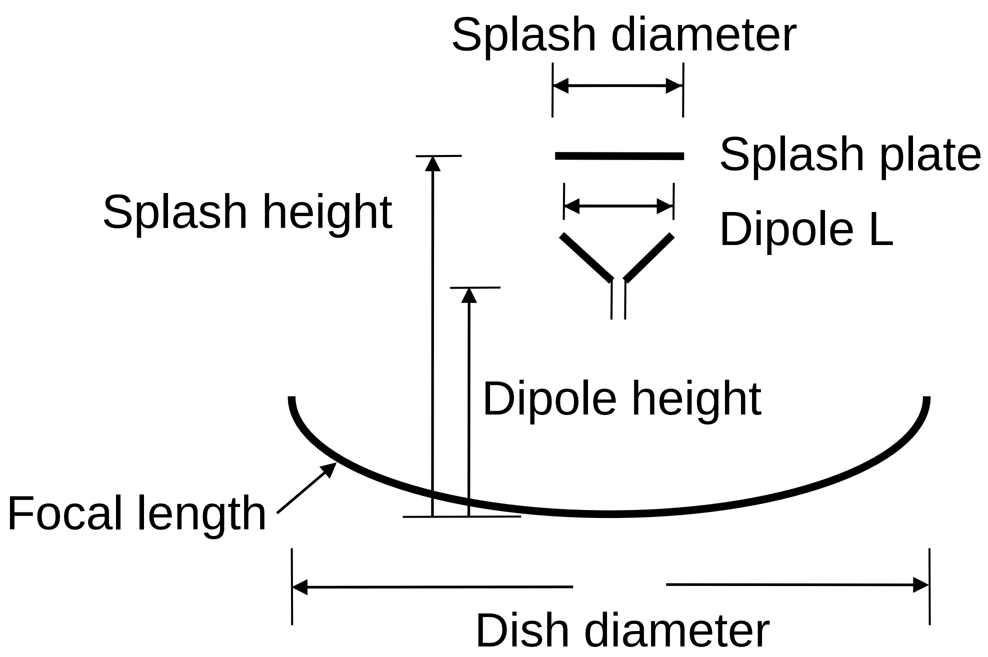
Requirement	Value	Rationale / Comments
Operating Frequency	S-Band	Represents common and popular satellite communications frequency
Gain	~18 dBi	For 400 km orbit and 5.4m Diameter Ground Terminal, supports up to 28.5 Mbps
Deployed Diameter	> 50 cm	Maximizing diameter for the given minimal stowed volume is the primary design goal
Mass	< 1.0 kg	Initial Design Goal. Mass minimized

Miniature High Gain Antenna Opens up New Mission Opportunities and Represents a <u>Game Changing</u> Capability for CubeSats

Enables Direct Communication with End User

S-Band Antenna Geometry and Nomenclature

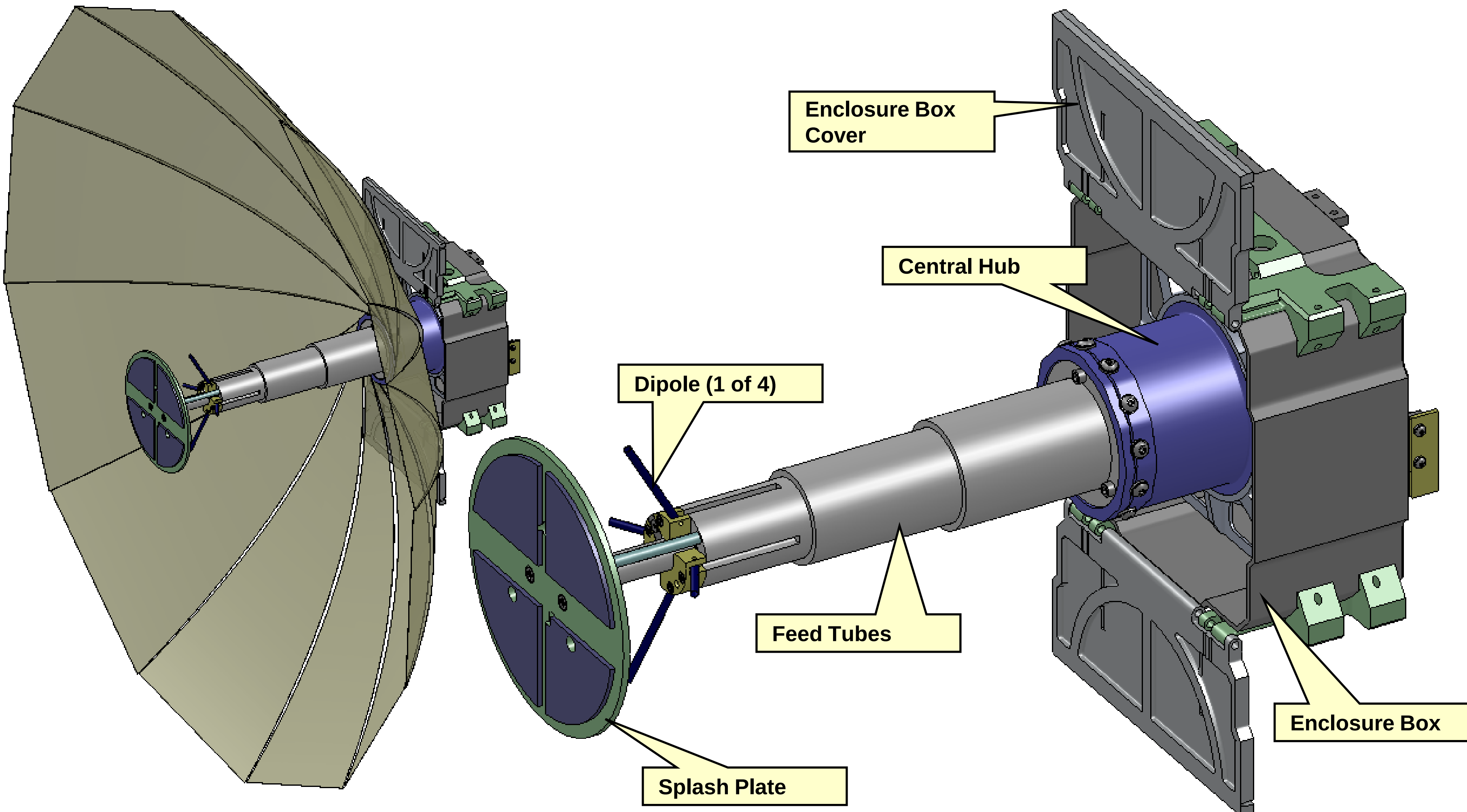
- **Antenna Simulation and Analysis Performed on a Wide Array of Different Geometries**
  - **Performance Driven by Small Packaging and Mechanical Deployment Requirements (not vice versa)**
  - **Multiple iterations to come up with feasible mechanical solution that yielded best performance**



Predicted Performance of Baseline Design

Frequency	Peak Directivity
GHz	dBic
2	16.96
2.1	17.74
2.2	18.28
2.3	18.12
2.4	18.59
2.5	18.95

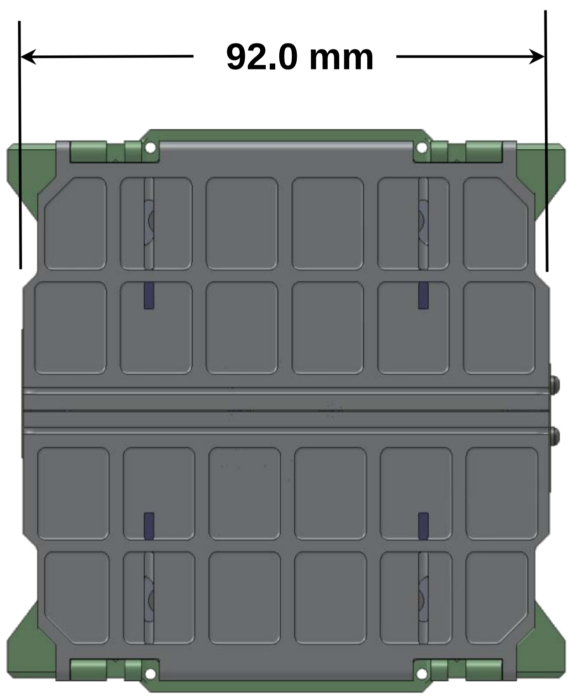
Final Baseline Design
- Deployed

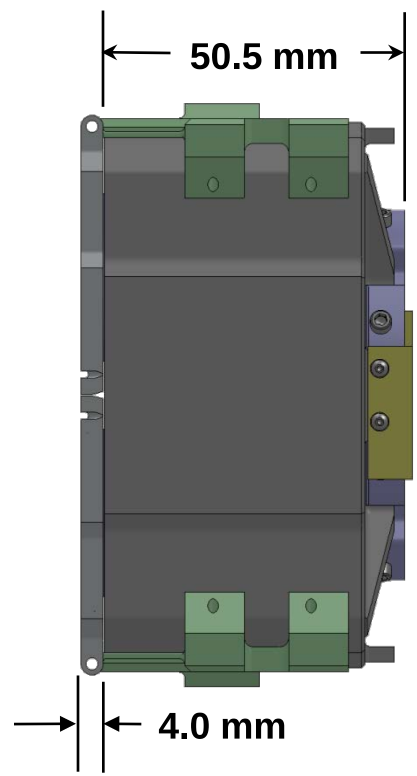


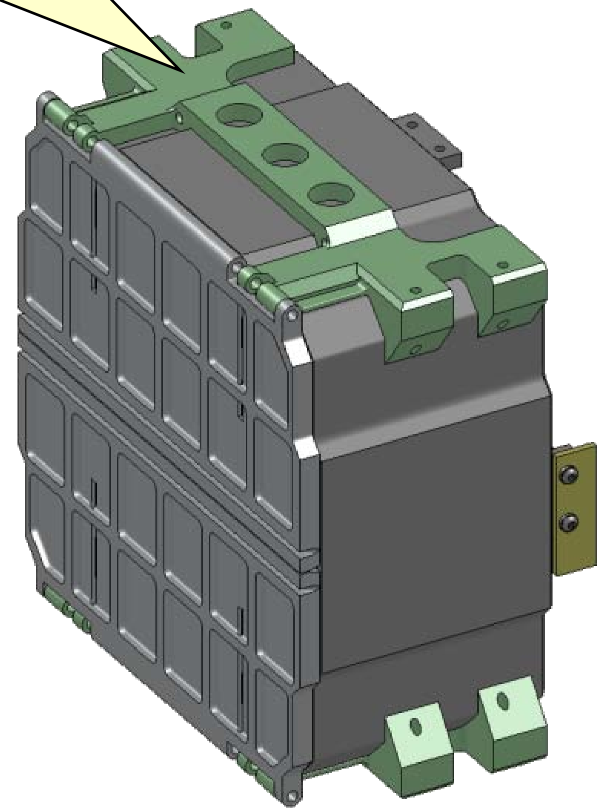
Reflector Dish and Arms Omitted for Clarity

Final Baseline Design (Continued)
- Stowed

Mounting Adapter Can be Modified to Accommodate Other CubeSat Frames

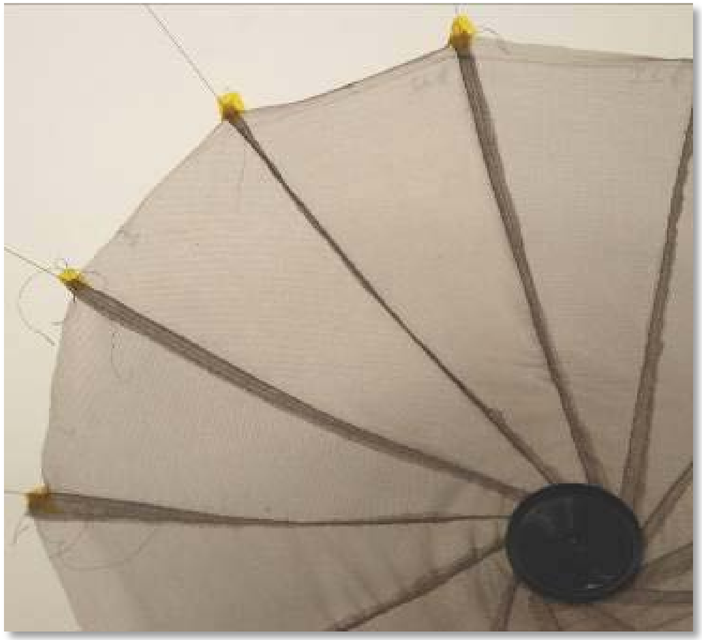






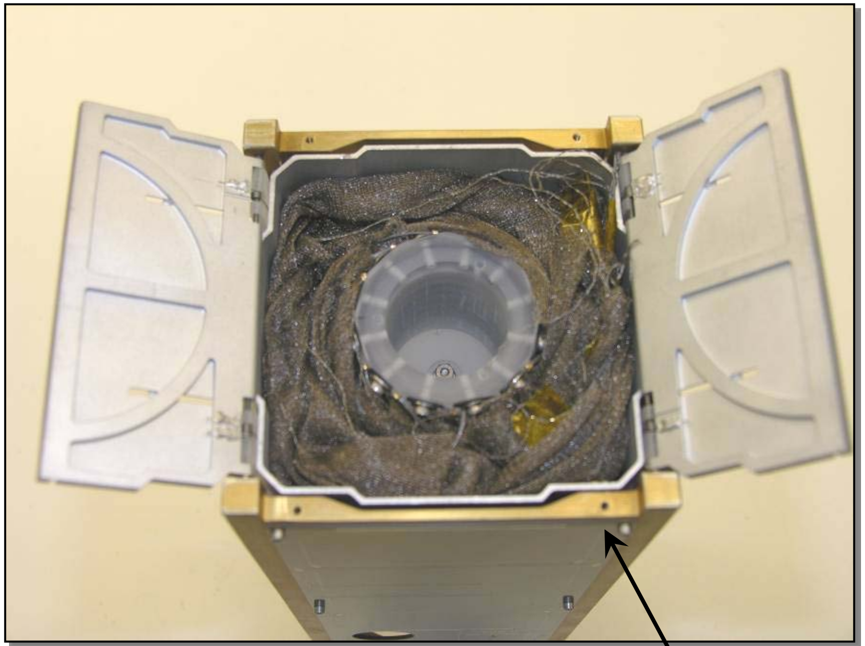
Mesh Dish Prototype Hardware
- Utilizes Conductive Mesh Fabric

BDS | Phantom Works

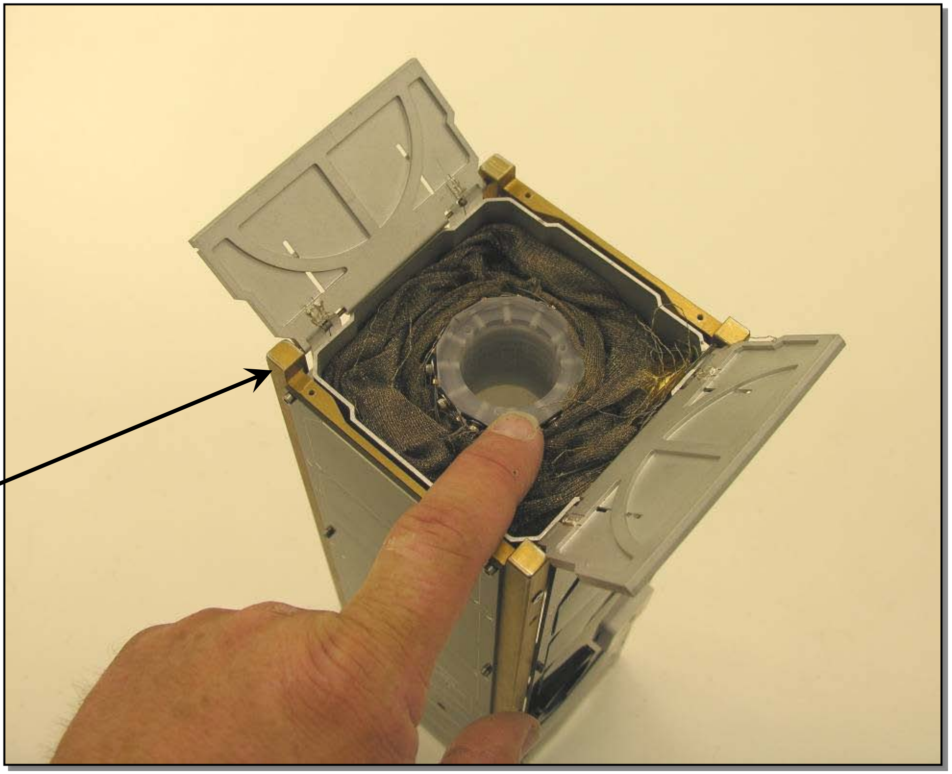


Stowed Packaging

- Feed Tube and Splash Plate Removed to Show Internal Packaging

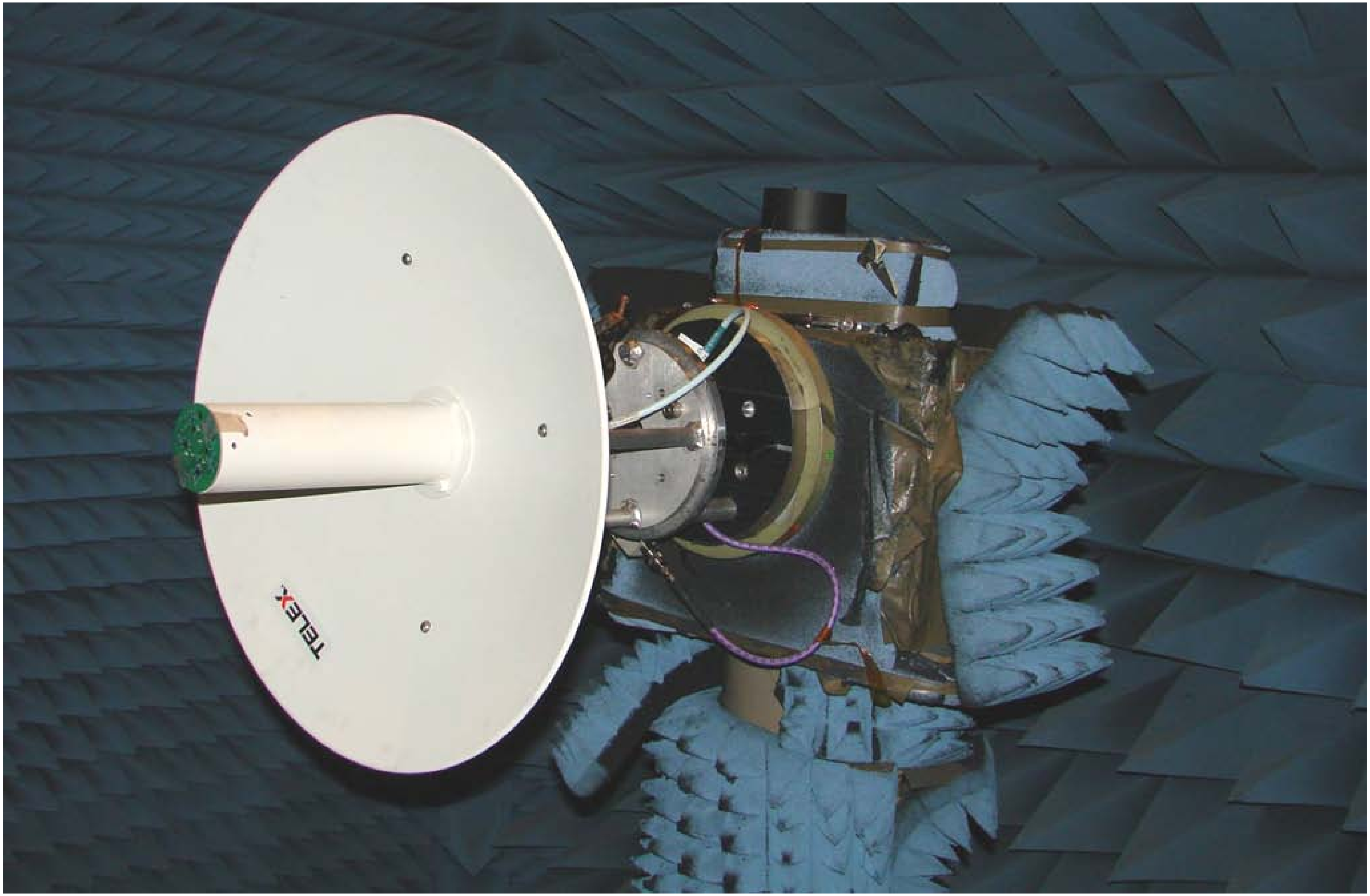


- **Stowed Dish Packaging Efficiency was Better Than Expected**
  - **Allows for Dish Diameters Greater than 0.50 m**



Enclosure Box Integrated with CubeSat Structure Frame

Deployable Feed Element Assembly RF Testing
- RF Test Results Showed Excellent Performance



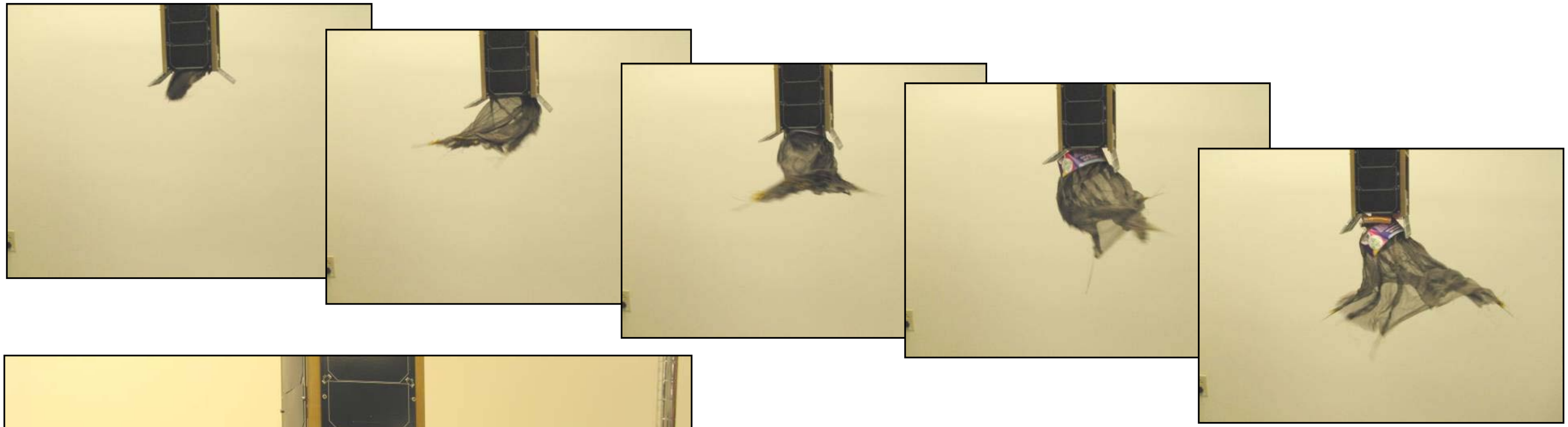
Mechanical Deployment Testing
- Verified Initial Deployment Motions

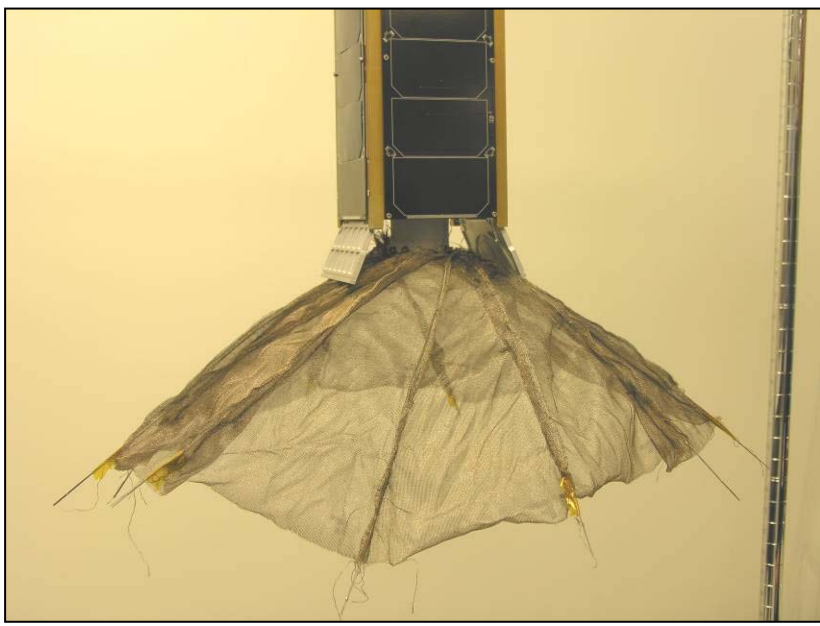
- **Enclosure Box Testing Successfully Demonstrated That:**
  - **Boeing "standard" burn wire PCB consistently cut monofilament restraint line**
  - **Enclosure Box doors consistently open when restraint line is cut**
  - **"First Motion" of hub moving out of box and dish arms deploy without entanglement**

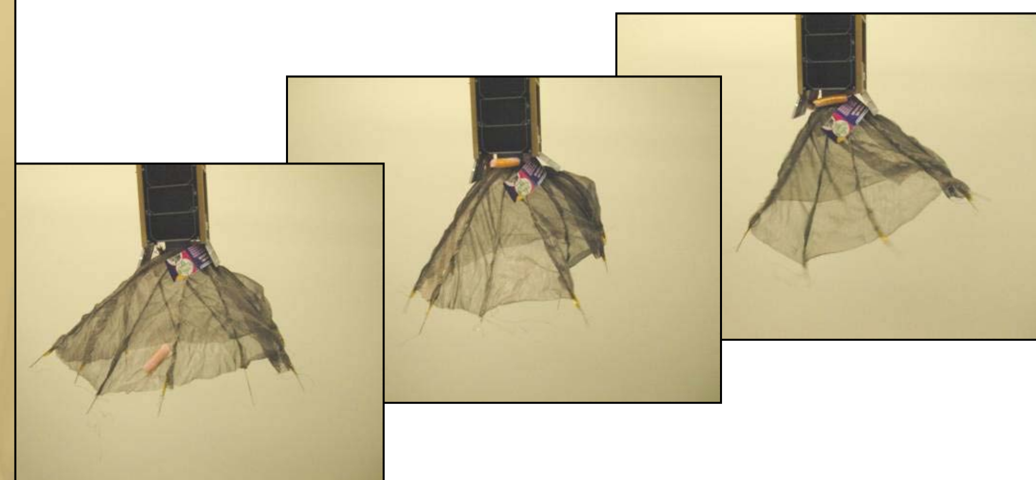
- **Deployment Tests of Feed Tubes Performed**
  - **Manually testing identified areas for minor improvement that can easily be incorporated in next design revision**

Mechanical Deployment Test

- Slow Motion Frame Sequence of Hub and Mesh Dish Deployment







**Total Deployment Time
Approx 3 seconds**

Summary
- Development Proved Very Successful

- **Developed Deployable Antenna Design from Initial Concept to a Working Prototype**
  - **Proved that design concept is fundamentally sound**
  - **Validated deployment approach and that packaging of a high gain antenna is possible within CubeSat shape and size restrictions**
  - **New novel RF Balun design shown to provide excellent performance**
  - **Packaging efficiency of mesh dish and radial arms is better than expected**

- **Deployable Feed Tube Design Represented Significant Portion of Development Effort**
  - **Telescoping Tube approach is straightforward**
  - **Stowed packaging height a function of feed length**

Current Design Lays Successful Foundation for the Final Design to Support Flight Demonstration