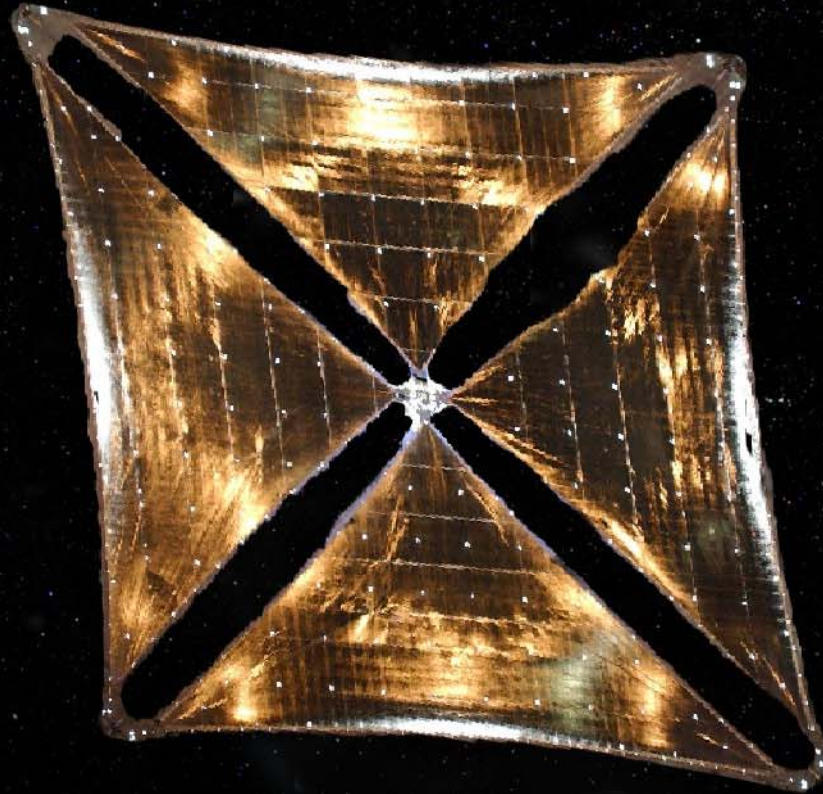


# NanoSail-D

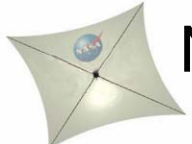
Ames/Marshall  
Technology Demonstration (AM/TD-1)  
Mission 1

2008 CubeSat Developers Workshop  
San Luis Obispo, CA  
April 11, 2008

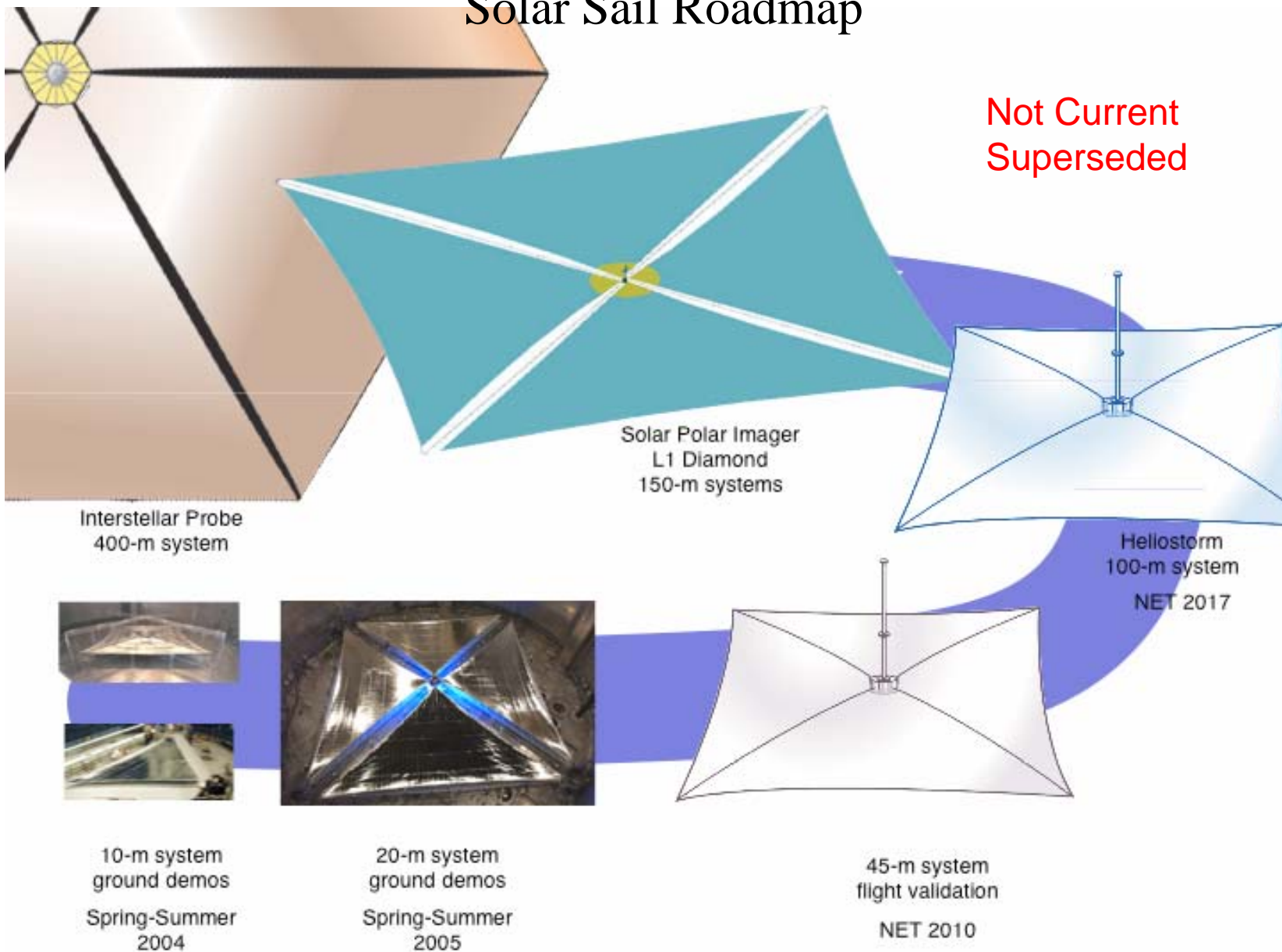


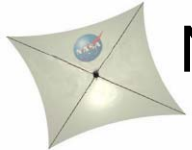
**Edward E. (Sandy) Montgomery IV**  
NASA Marshall Space Flight Center

**Charles L. Adams**  
Jacobs/ Gray Research, Inc.



## Solar Sail Roadmap





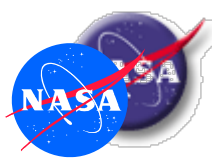
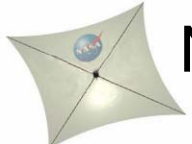
## Technology development for an 80 meter solar sail

### ATK Space Systems 20 Meter Solar Sail

First Deployment at the  
Space Power Facility  
NASA/GRC  
Plum Brook Station  
on April 22, 2005

30 minute event displayed at 120 times real time.

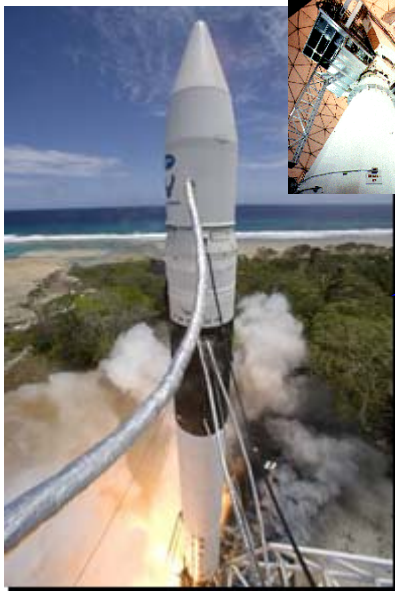
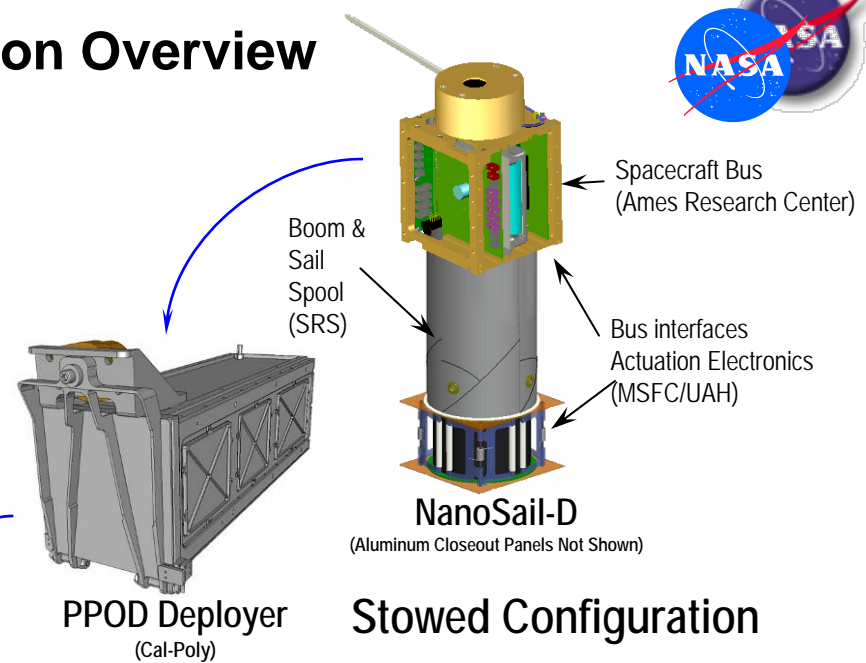
- Technology program investment of \$30M developed
  - gossamer structure design, build, and ground test maturity ✓
  - basic mission design tools ✓
  - Understanding of the difficulties of measuring performance ✓
- New Millennium ST9 Proposal addressed issues for LEO deployment of a solar sail ✗
- Key remaining hurdles
  - Solar Sail LEO GN&C Scheme ✓
  - CubeSat packaging – subscale booms ✓
  - Instrumentation ✓



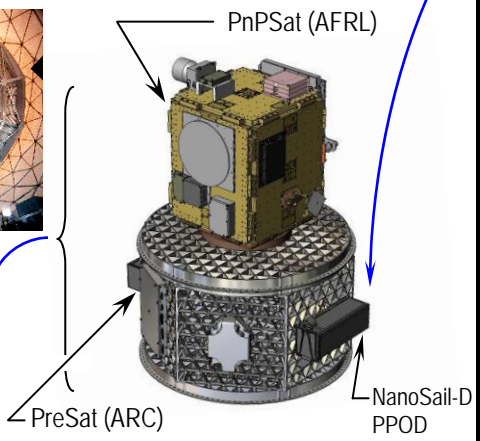
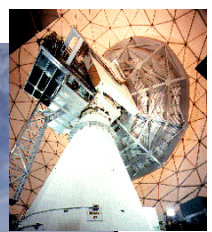
# NanoSail-D

## NanoSail-D Configuration Overview

- Objectives
  - Primary
    - Deploy solar sail leveraging directed work performed by MSFC in prior years under the SMD In-Space Propulsion Program
  - Secondary/Opportunity
    - Demo Orbital Debris Mitigation technology – drag sail
    - Ground Imaging to reduce spacecraft instrumentation
    - Add to flight experience - ARC Bus "light" experience
- Relevance
  - Planetary & Heliophysics Science missions
  - Most smallsats orbiting above 450 km struggle to meet <25 year life MOD requirement



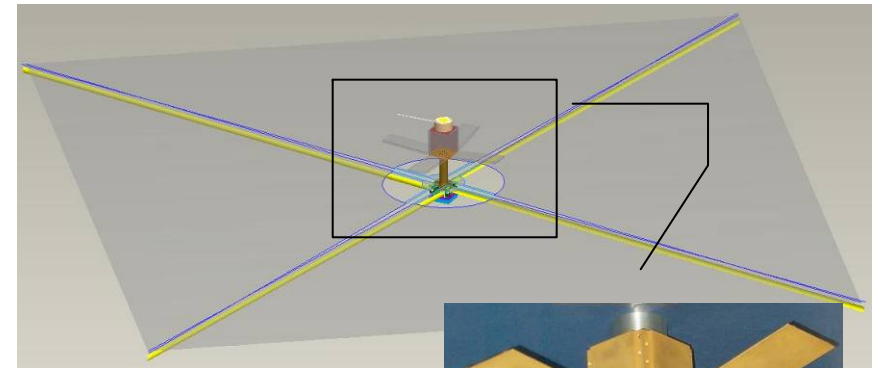
**Falcon-1**  
(SpaceX)



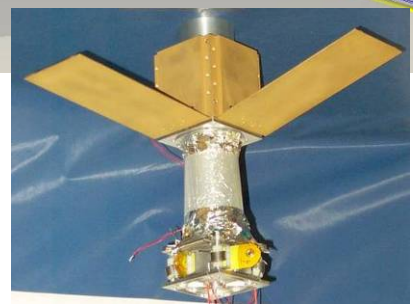
### Ride Share Adapter

(Space Access Technology)

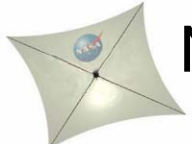
Launch Date: June 10, 2008  
 Launch site: Omelek Island, RTS (Kwaj)  
 Orbit: 685 X 330 km, 9° inclination  
 De-Orbit Period: 5 - 14 days



- 10 m<sup>2</sup> Sail Area
- 2.2 m Elgiloy Trac Booms
- UHF & S-Band comm
- Closeout Panels
- Permanent Magnet Passive Stabilization



**Deployed Configuration**



# NanoSail-D

## NanoSail-D: A Team Effort



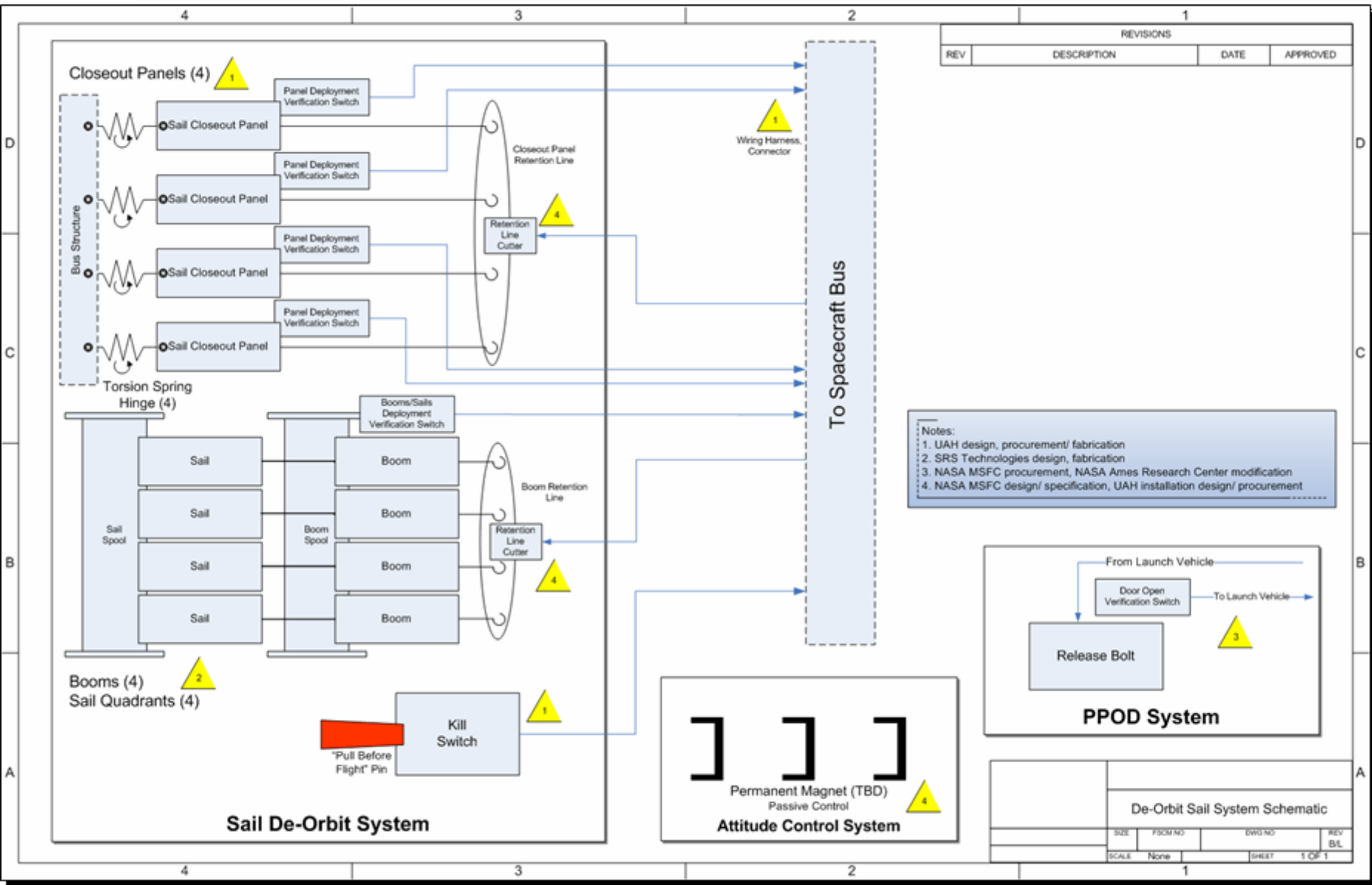
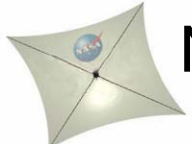
**Marshall Space Flight Center**

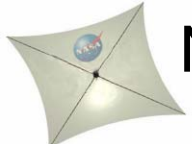
Project Manager, Elwood Agasid  
 Mission Manager, Bruce Yost  
 Principle Investigator, Mark Whorton  
 Payload Manager, Edw. E. Montgomery  
 Payload Engineer, Dean Alhorn



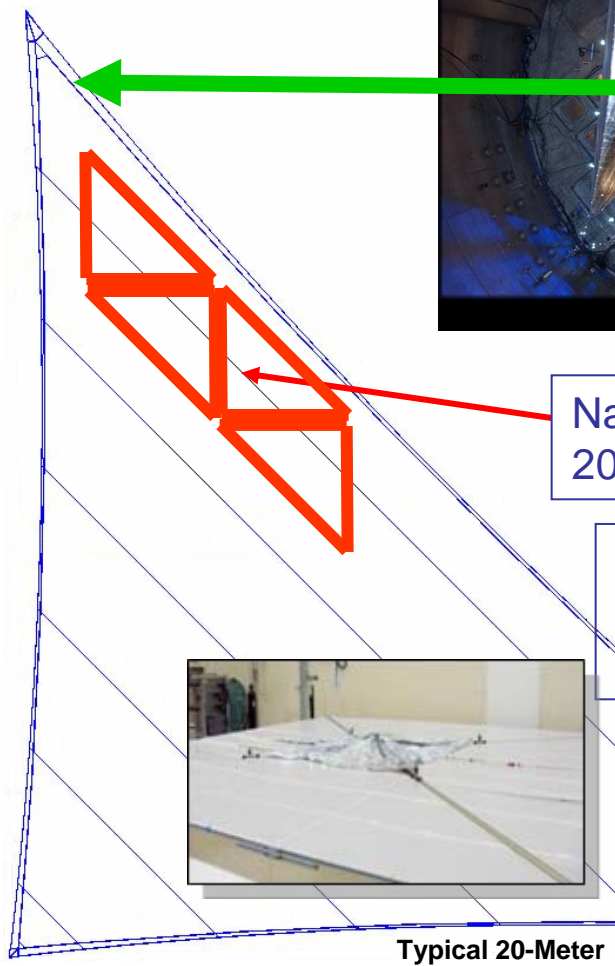
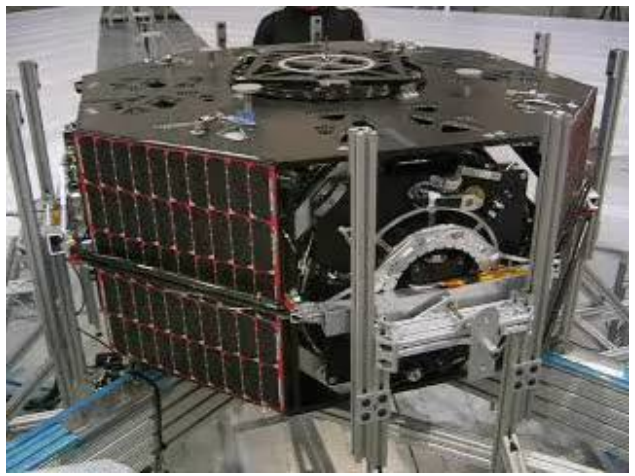
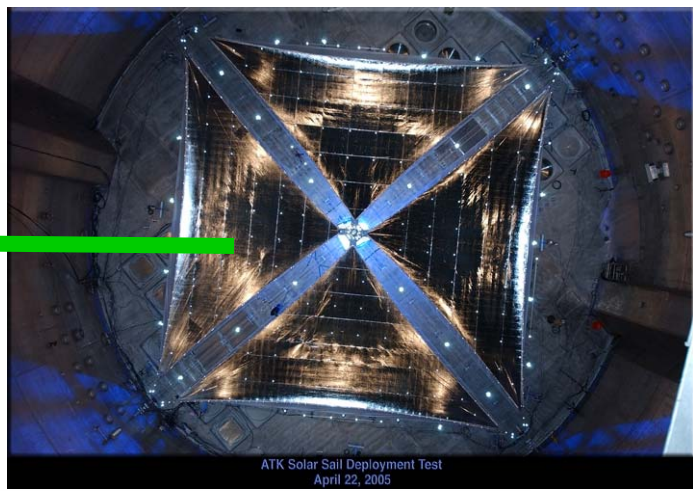
The University of Alabama in Huntsville







# NanoSail-D Harvesting from 20m Plum Brook Station Test Sails



NanoSail Quadrant harvested from existing 20-meter Solar Sail

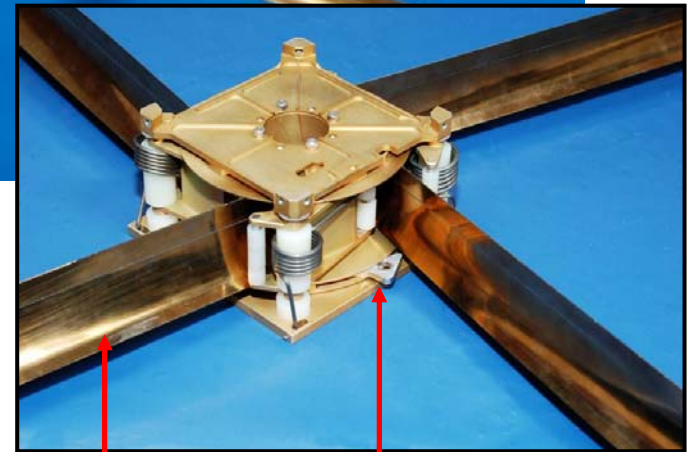
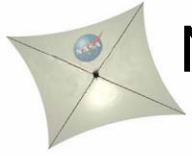
Abundant Material to create engineering models, primary and spare set of all 4 Quadrants of the NanoSail from 2 Quadrants of the 20-meter Solar Sail



Typical 20-Meter Layout

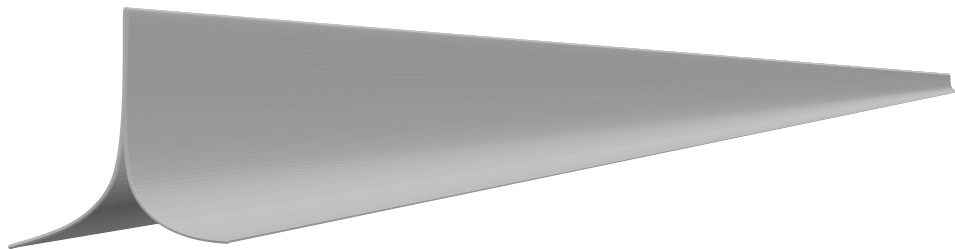


Competition Sensitive



Elgiloy "Trac" Booms

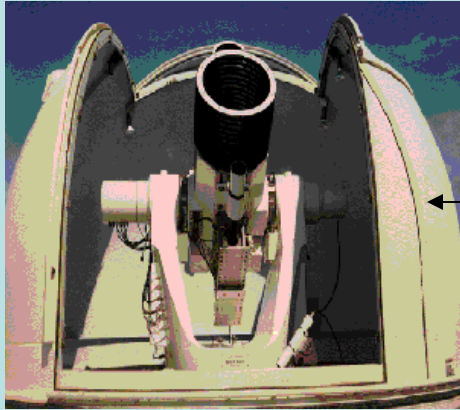
Boom Housing



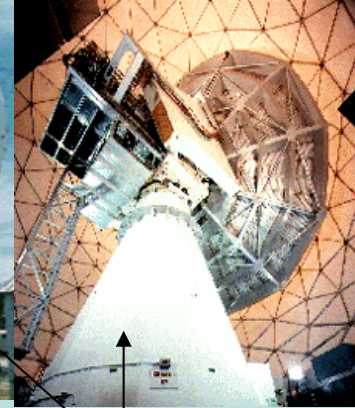
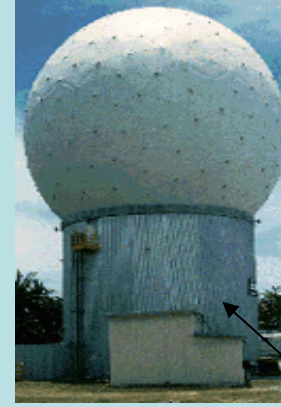
Elgiloy "Trac" Booms provided by AFRL – Pats Pending



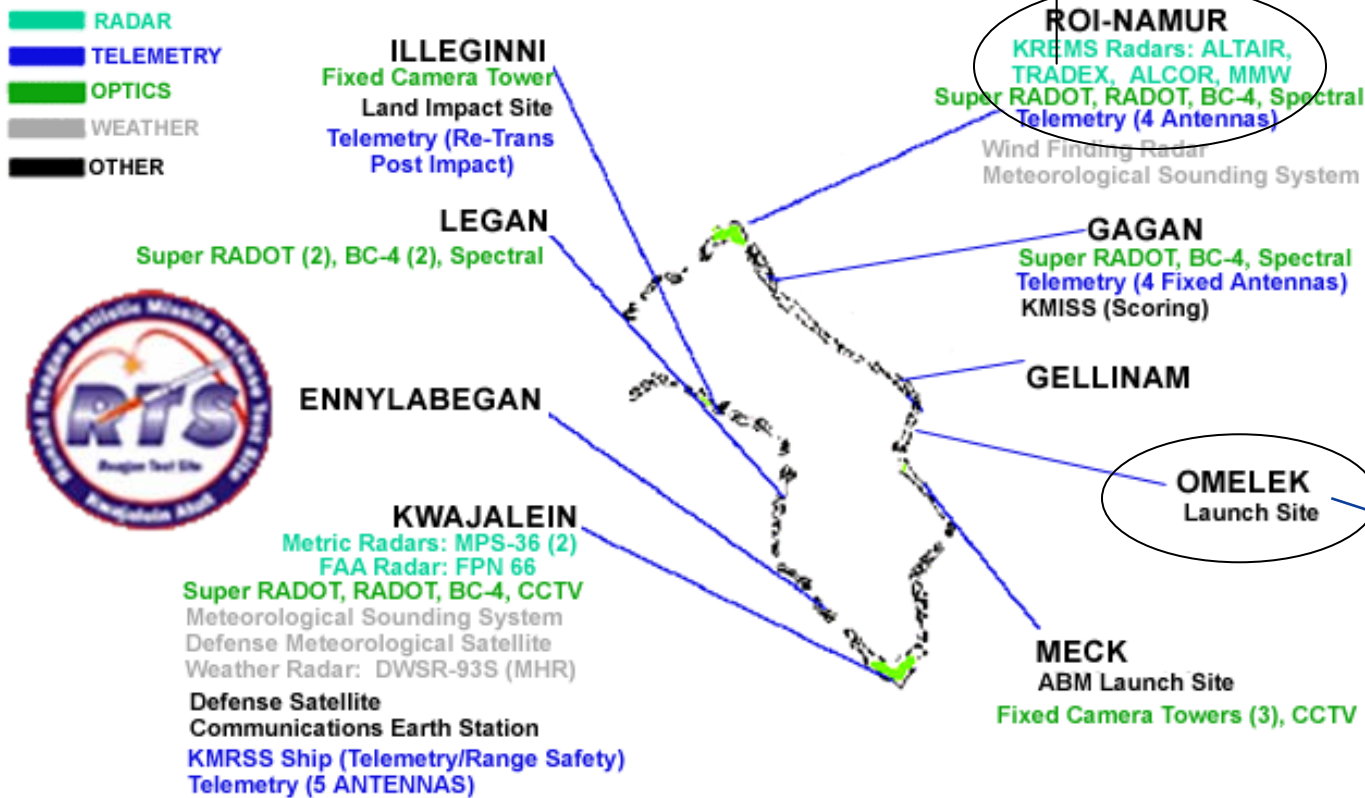
# Reagan Test Site (Kwajalein): Launch and Payload Ops

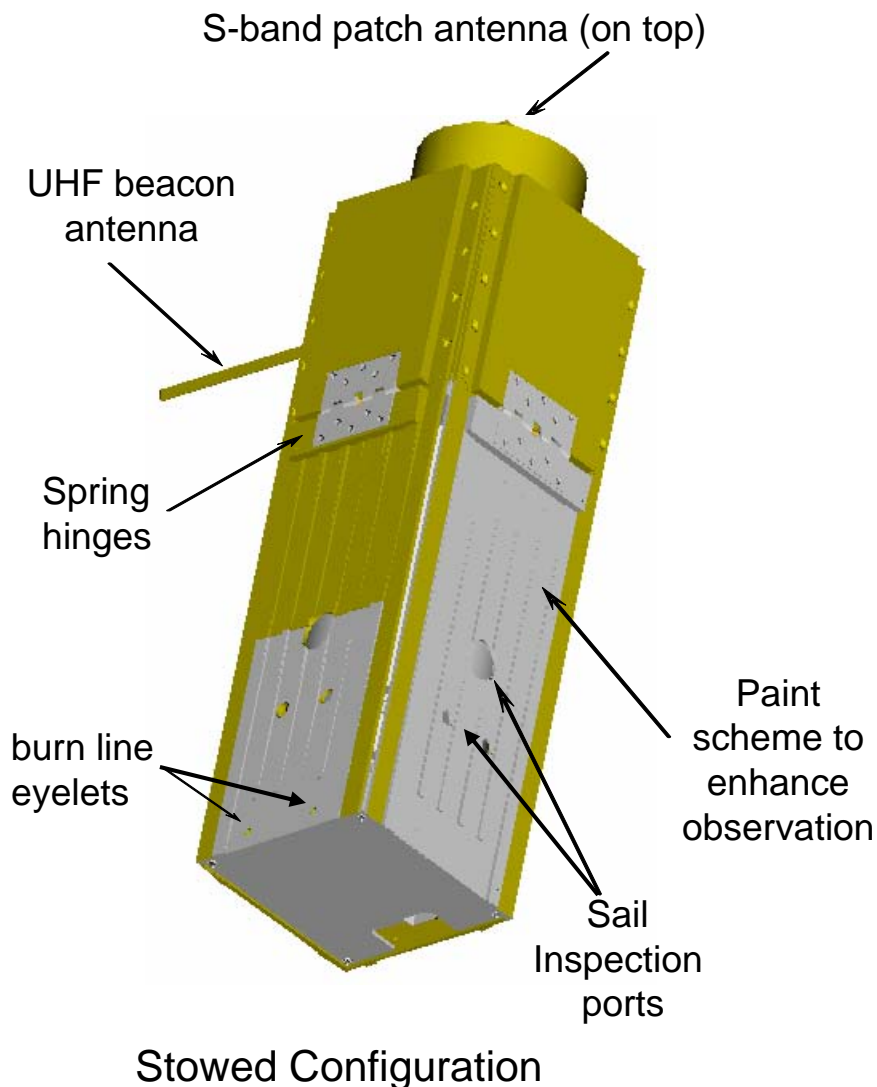


The Super RADOT (Recording Automation Digital Optical Tracker) is designed for closed-loop tracking and acquisition of long-range metric data.

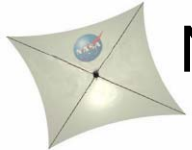


The Millimeter Wave Radar (MMW) is a dual frequency (Ka- and W-Band) monopulse tracking radar. It is characterized by high range and Doppler resolution, high sensitivity, precise pointing and tracking, waveform flexibility, and a high degree of computer control for real-time ops.



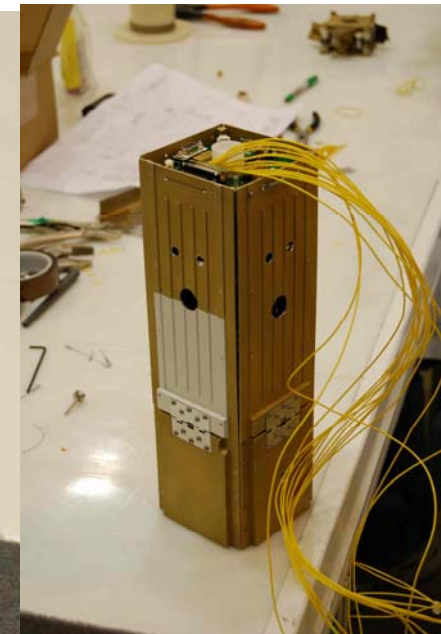
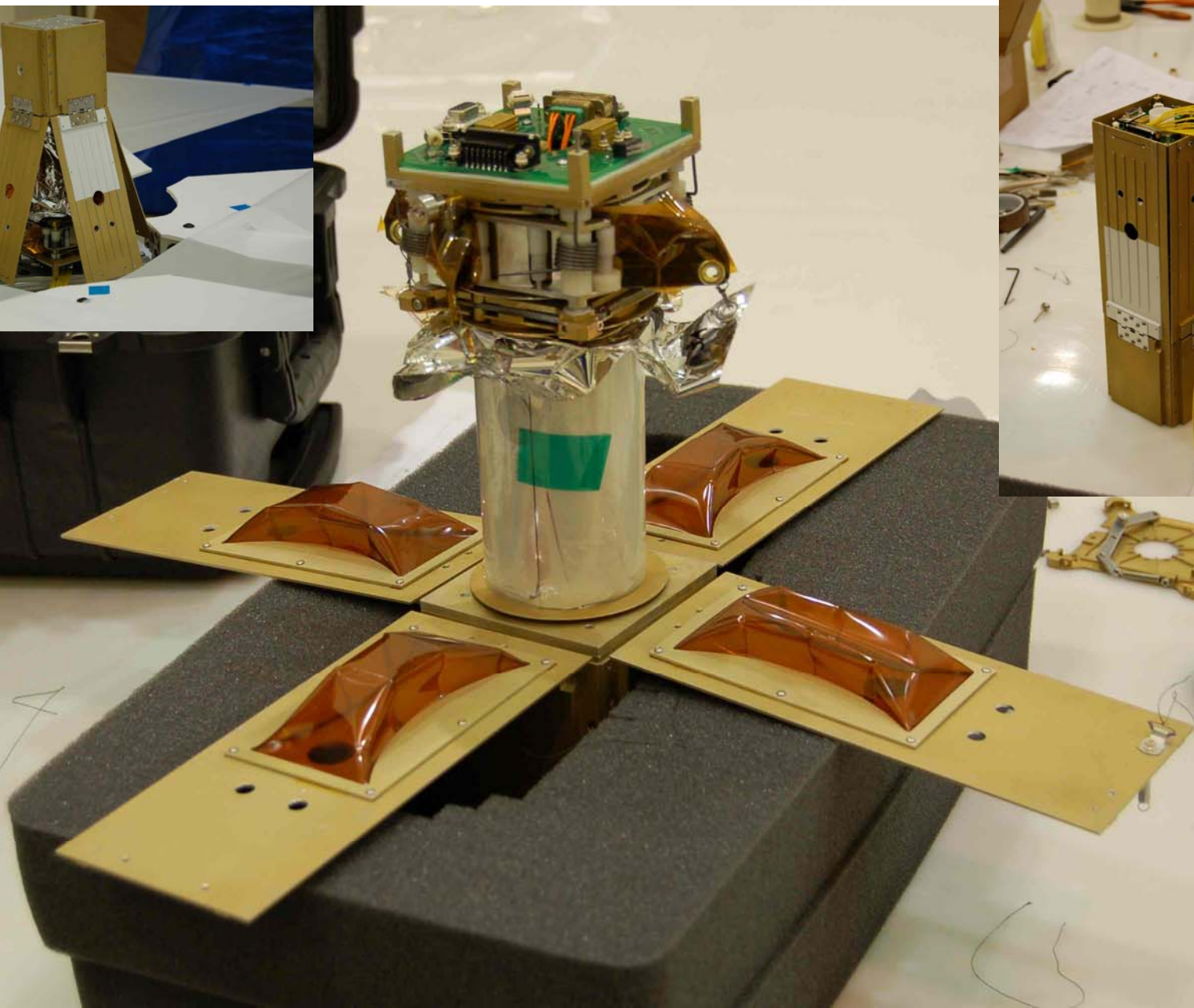
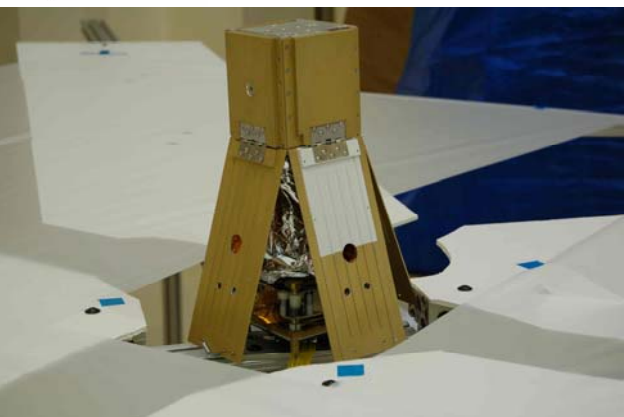


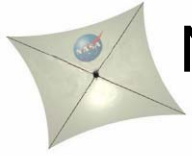
- NanoSail-D sail subsystem delivery to Ames Research Center on 4/20/08.
- Currently bus and payload undergoing separate integration and testing.
- Integrated spacecraft testing through 5/10/08.
- Delivery to launch site on 5/23/08.
- Falcon-1 launch scheduled on 6/10/08.

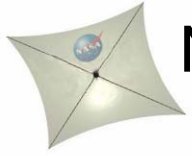


NanoSail-D

# NanoSail-D







# MythBuster Conclusions



The CubeSat Myth :

**CONFIRMED**

- Spectators one year -> sweating launch the next
- Real mission value -> science enabling
- Cost/Schedule/Mission Assurance -> reduced
- Safety/Value -> not sacrificed

The Solar Sail Myth:

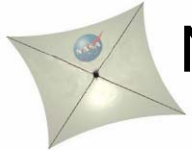
**PLAUSIBLE**

NASA is “Jurassic Park” myth:

**BUSTED**

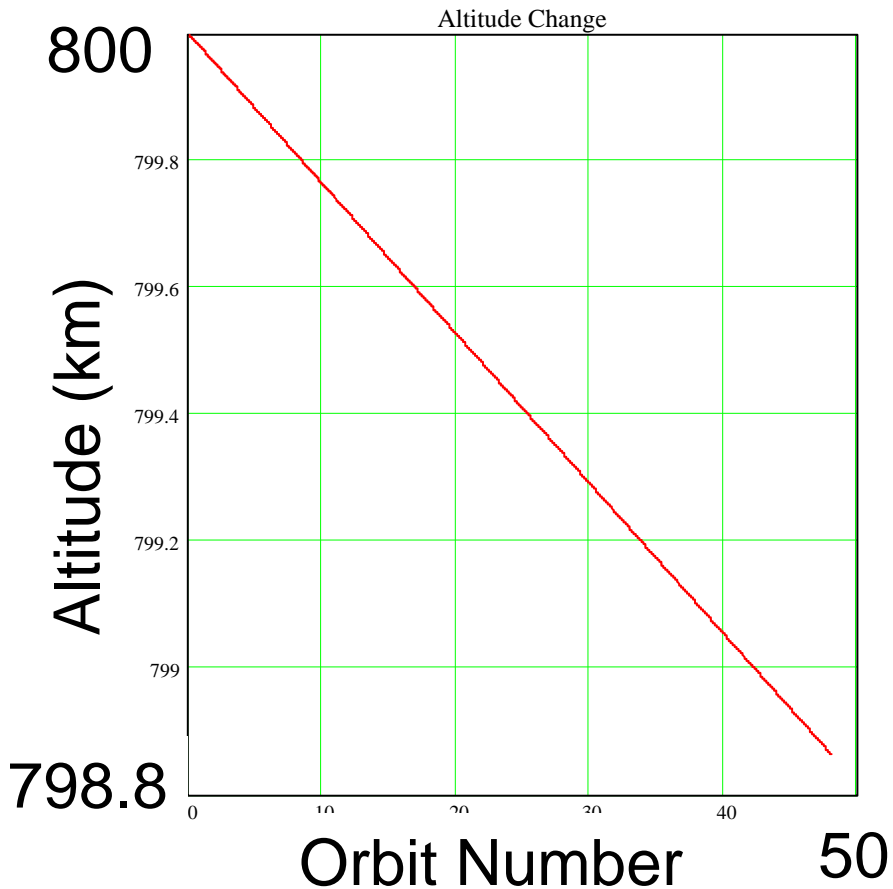
Questions ?



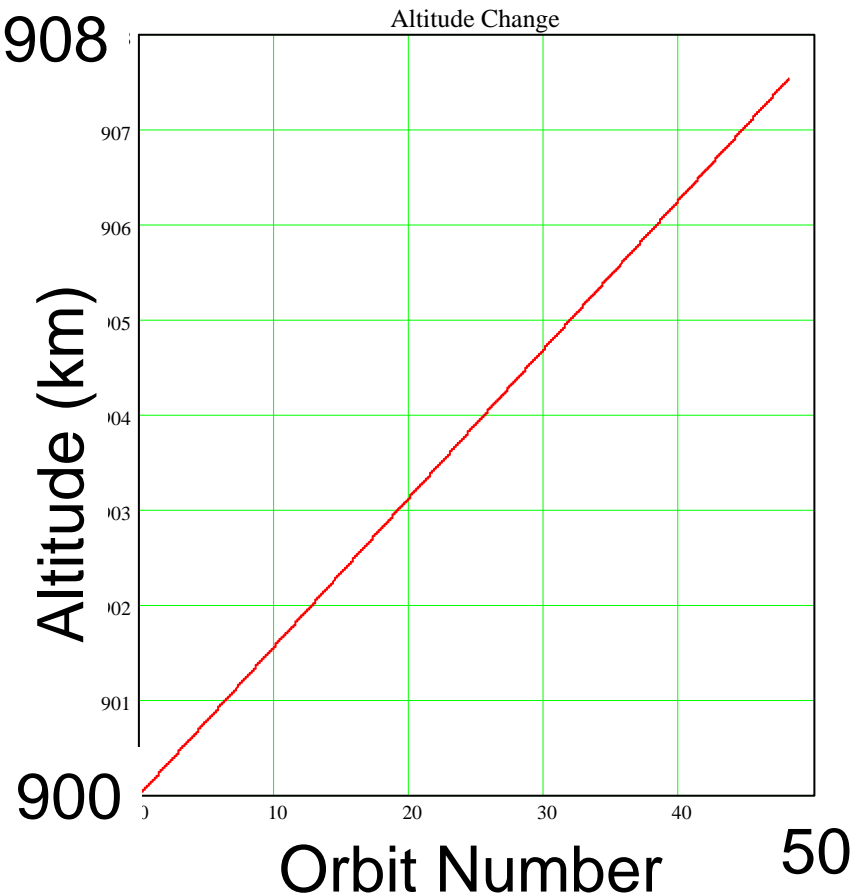


# NanoSail-D

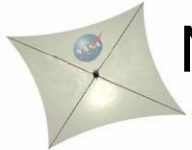
## LEO Solar Sail Orbit Raising Performance (Sunsynchronous, Inertially pointed, circular orbit, average sun cycle, 40 m<sup>2</sup> cubesail)



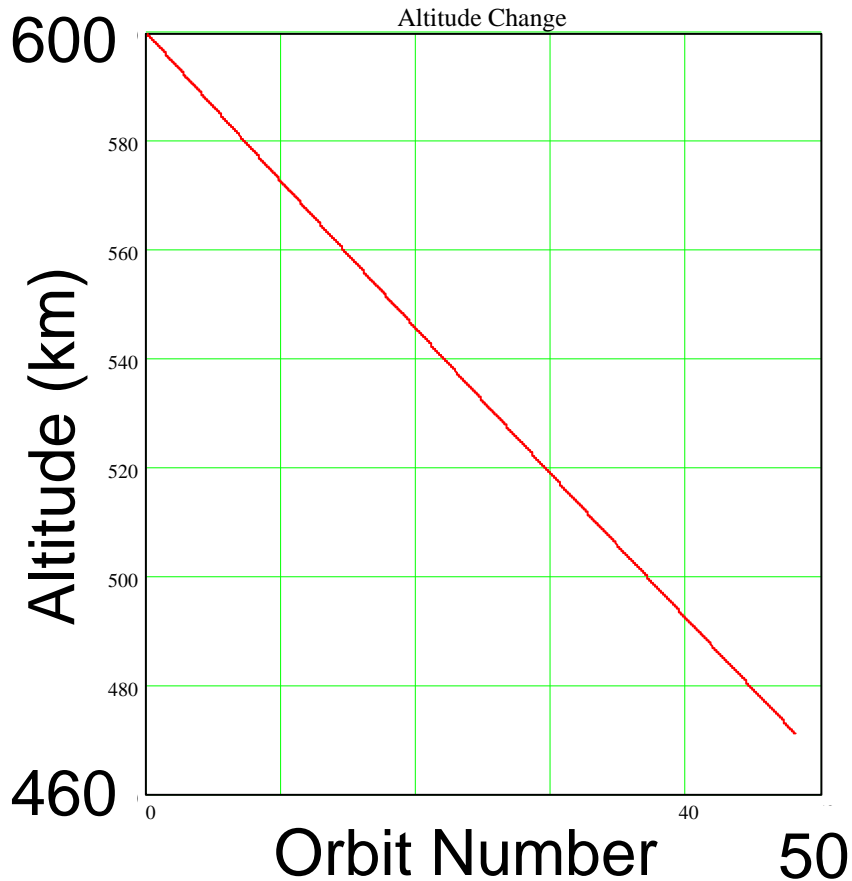
800 km Start Altitude  
(-24 m/orbit)



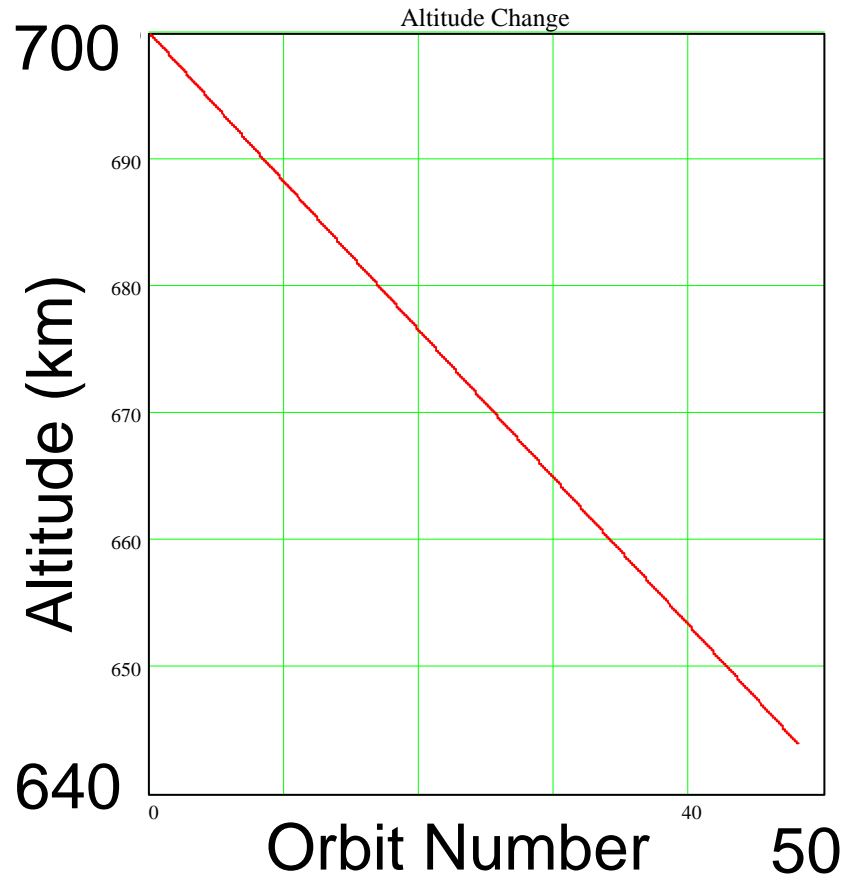
900 km Start Altitude  
(+157 m/orbit)



## LEO Solar Sail Orbit Lowering Performance (Sunsynchronous, Inertially pointed, circular orbit, average sun cycle, 40 m<sup>2</sup> cubesail)

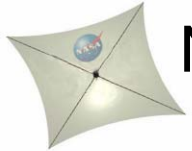


600 km Start Altitude  
(-2.8 km/orbit)



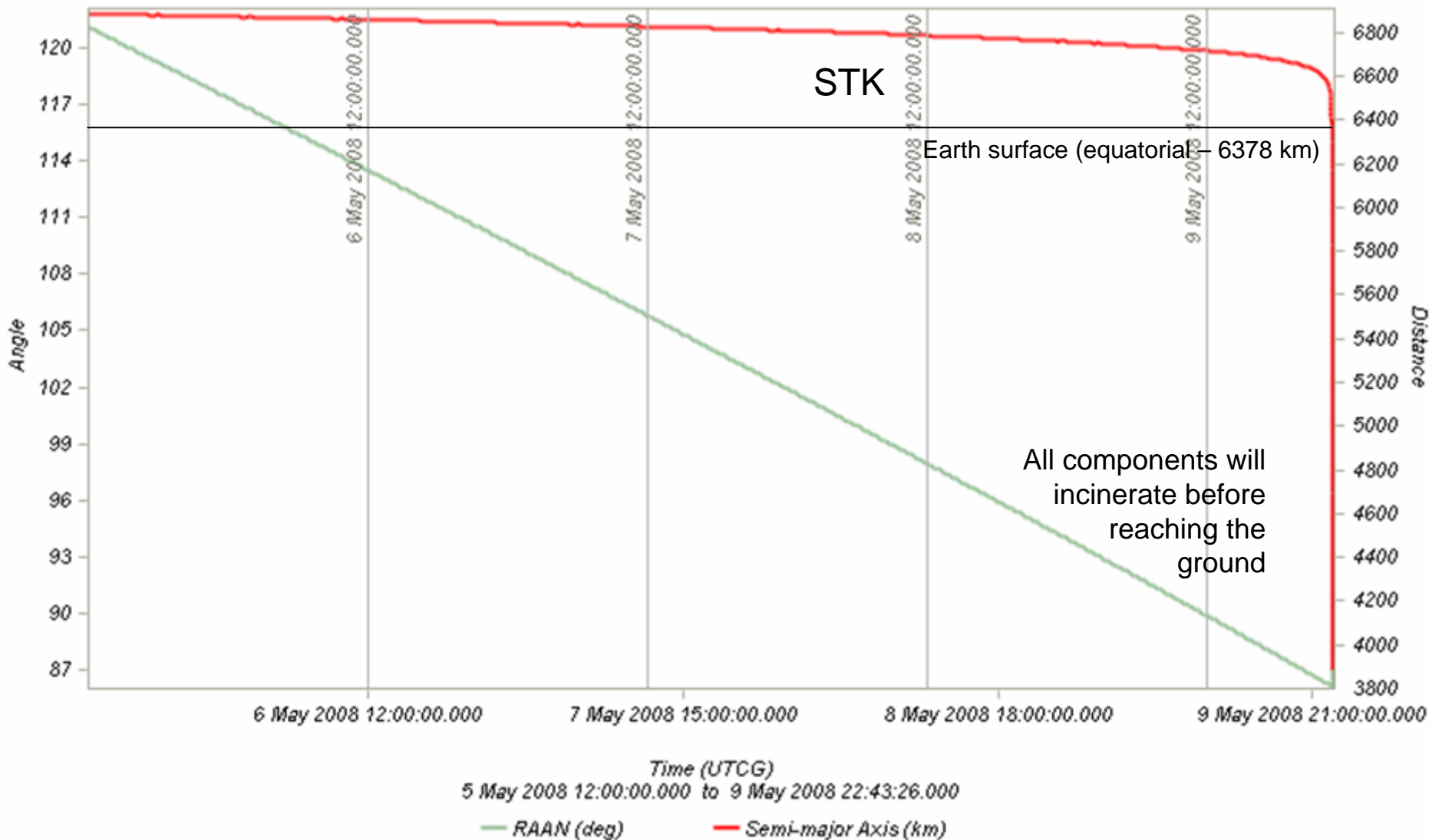
700 km Start Altitude  
(-1.2 km/orbit)

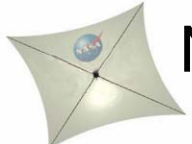




## An Unfortunate Orbit – Initial Deorbit Predictions

Satellite-NanoSail: J2000 Classical Orbit Elements - 09 Feb 2008 16:16:35





# NanoSail-D



## NanoSail-D Hardware

