NanoSail-D: The First Flight Demonstration of Solar Sails for Nanosatellites

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Dr. Mark Whorton, Andy Heaton, Robin Pinson: NASA Marshall Space Flight Center
Greg Laue: ManTech SRS Technologies

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NanoSail-D Mission Configuration

Launch Date: August 2, 2008
Launch site: Omek Island, RTS (Kwej)
Orbit: 330 km X 685 km, 9° inclination
De-Orbit Period: 2 - 14 days

- 3U Cubesat: 10cm X 10cm X 34cm
- Deployed CP-1 sail: 10 m² Sail Area (3.16 m side length)
- 2.2 m Elgiloy Trac Booms
- UHF & S-Band communications
- Permanent Magnet Passive Stabilization
NanoSail-D: A Team Effort

Project Manager, Elwood Agasid/ARC
Mission Manager, Bruce Yost/ARC
Principal Investigator, Dr. Mark Whorton/EV42
Payload Manager, Edw. E. Montgomery/VP52
Deputy, Charlie Adams/Gray Research
Payload Engineer, Dean Alhorn/ES32
Project Overview

- **Minimum Success Criteria**
  - Design, fabrication, test and delivery of a flight-ready satellite to the launch site within budget on an extremely tight 6 month schedule.

- **Full Success Objectives**
  - Primary: On-orbit solar sail deployment
  - Secondary
    - *Drag sail assessment*
    - *Nanosatellite component development*
    - *Pioneer new project processes*

- **Deliverables**
  - Primary Solar Sail Payload Assembly
  - Spare Solar Sail Payload Assembly
  - Payload Mockup for ARC Bus development
  - Poly PicoSat Orbital Deployer

- **MSFC Management Structure**
  - Project Management: VP
  - Lead Project Engineer: ES32
  - Principal Investigator: EV42
  - S&MA: QD22
  - ITA: EE04

- **Sponsors**
  - MSFC Center Director
  - ARC Center Director
Major Milestones

- Project Milestones
- Final Design Audit - 1/17/08
- MSFC System Acceptance - 4/17/08
- Sail payload delivery to ARC - 4/21/08
- Bus-payload integration and flight certification at ARC
  - Integration & checkout – 4/21-24
  - Satellite environmental testing - 4/25 - 5/6
  - Mission simulations completed - 5/10
- FRR at ARC – 5/13/08
- ORR at ARC– 6/9/08
- PM&PI travelling to Kwajalein
- NSSTC/1048 mission center set-up
- Launch/Mission Ops 8/2 – 8/15
  - S. Montgomery/VP52 on Kwaj
  - D. Alhorn/ES23 at NSSTC
  - M Whorton/EV42 at Kwaj
  - J. Morcone/MSFC Media Relations
  - Laurie Provin S&MS E/PO
- Initial Outbrief – 8/15/08
On-Orbit Stowed Configuration

Spacecraft Bus (ARC)
- Battery Power Supply
- Computer Controller
- S-Band Radio
- UHF Beacon Radio
- Passive Attitude Control System

Solar Sail Subsystem (MSFC)
- CP1 Solar Sail Membrane
- AFRL Trac Booms
- Gossamer Deployment Mechanisms
- Bus Interface and Actuation Electronics
On-Orbit Deployed Configuration

- **CP1 Sail Membrane** (10 m²)
- **Spacecraft Bus**
- **Trac Booms**
# Mission Milestones

<table>
<thead>
<tr>
<th>Mission Event</th>
<th>Time After Launch, L+ time (hr:min:sec)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Falcon-1 Launch</td>
<td>00:00:00</td>
<td></td>
</tr>
<tr>
<td>2. NanoSail-D Ejection from PPOD, UHF beacon on @ 10%</td>
<td>00:17:47</td>
<td>1067 seconds after launch.</td>
</tr>
<tr>
<td>3. Panels Open</td>
<td>72:17:47</td>
<td>72 hrs after ejection from P-POD.</td>
</tr>
<tr>
<td>5. S-band on, listen at 30 sec on, 30 sec off.</td>
<td>72:22:47</td>
<td>5 minutes after panel opening.</td>
</tr>
<tr>
<td>6. Optical Confirmation of Deployment (projected)</td>
<td>73:52:02</td>
<td>1 orbit after sail deployment (orbit period: 1 hr 34 min).</td>
</tr>
<tr>
<td>7. TLE Confirmation of Deployment (projected)</td>
<td>75:26:02</td>
<td>2 orbits after sail deployment.</td>
</tr>
<tr>
<td>8. Deorbit</td>
<td>168:18:02</td>
<td>Assumed 4 days after sail deployment.</td>
</tr>
</tbody>
</table>
# Mission Dashboard

## NanoSail-D Mission Dashboard

<table>
<thead>
<tr>
<th>Event Summary (times in PDT)</th>
<th>Drag Estimate from TLEs</th>
<th>Semi-Major Axis</th>
<th>Eccentricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 6/4/08 0500: Satellite leaves Ame</td>
<td>Post-launch, this will be a time history plot of the TLE drag term</td>
<td>Post-launch, this will be a time history plot of the semi-major axis (which will shrink over time)</td>
<td>Post-launch, this will be a time history plot of the eccentricity (which will circulate over time)</td>
</tr>
</tbody>
</table>
On-Orbit Performance Predictions

**Eccentricity**

**Semi-Major Axis**

**Perigee/Apogee Altitude**
On-Orbit Performance Predictions

**Orbit Decay as a Function of Sail Area (24 hr Time Period)**

**Mission Duration as a Function of Sail Area**

* 330 km x 685 km orbit