

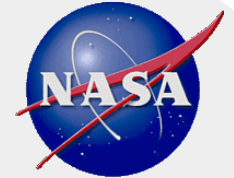
# **IT29.1 Investigation and comparison of techniques for tumbling rate assessment of massive LEO objects**

**30<sup>th</sup> IADC Meeting  
Montreal, Canada  
2012**



## **Rocket Body Rotation Analysis** **(in support of Active Debris Removal investigation)**

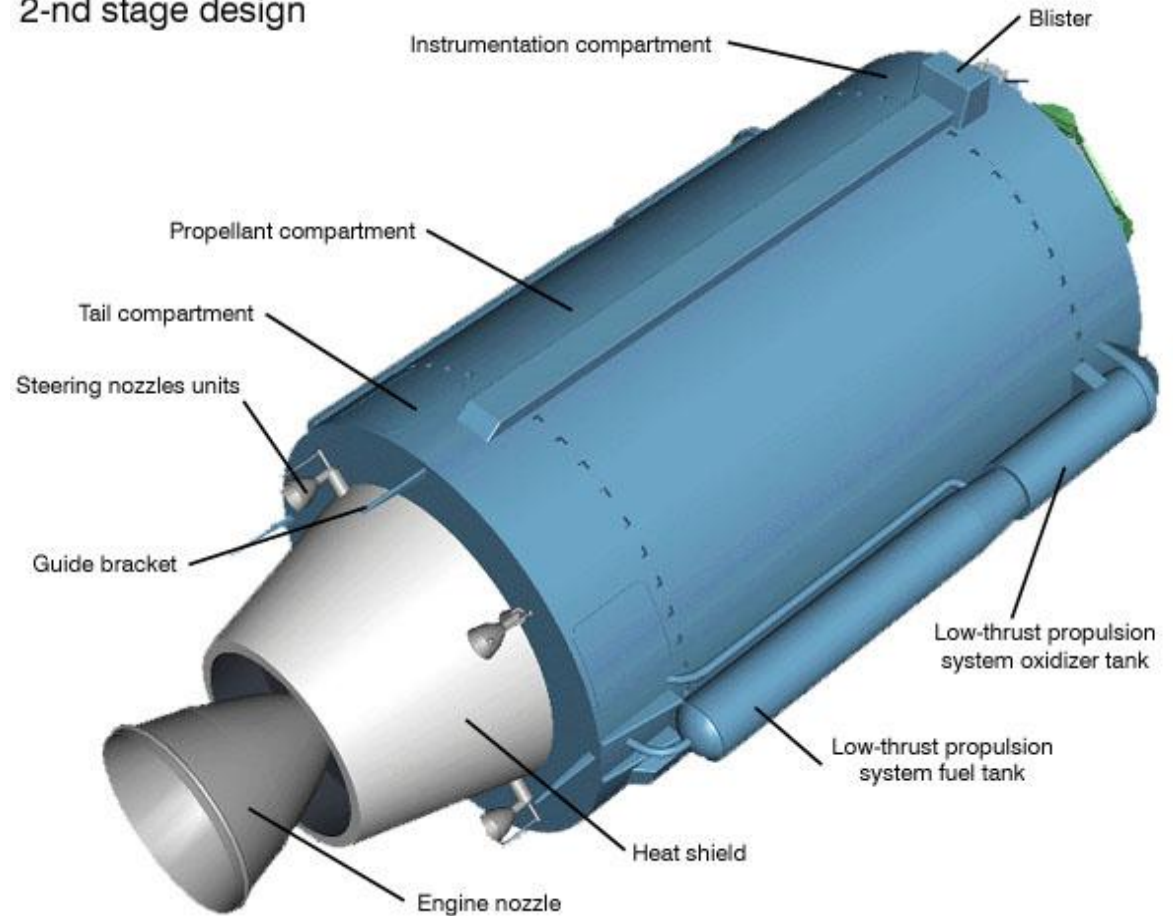
- ADR (Active Debris Removal) may help remediate the LEO environment by eliminating some significant potential debris sources (e.g. large rocket bodies)
- Must first acquire data detailing rotation rates (i.e. tumble, spin) of potential ADR targets in order to plan and develop proximity (e.g. grapple) operations
- First targets of interest are SL-8 rocket bodies (massive, intact)
- Goal: Determine rotation rates of SL-8 RBs via extended observations from multiple telescope sources and empirical laboratory data
  - Compare telescopic data with laboratory acquired data of scaled rocket bodies in order to evaluate relationship between target geometry, orientation, rotation, and the resultant time dependent photometric signature (e.g. lightcurve).
- This effort will provide essential information when designing an ADR mission



# Targets: SL-8 second stage rocket bodies



2-nd stage design





# Rocket Body Rotation Analysis

(Two sources utilized for telescopic data collection)

- **Source 1: United States Air Force Academy (USAFA)**

- **Telescope**

- DFM Engineering 16" Ritchey Chretien (RC)

- **Camera**

- Andor 897 Electron Multiplied CCD

- **Data Acquisition**

- Typically 200 seconds of data at 5 fps (frames per second)
    - Data rate pushed to 33 fps using 2TB solid state drive

- **Results**

- Obtained 15 nights of data from 9 Nov 2011 and 17 Jan 2012
    - Recorded 273 separate light curves on 126 unique objects
    - Pre-processed by USAFA to generate light curves

- **Data characteristics**

- Often pronounced, periodic behavior
    - Short segments that indicate possible long rotation periods

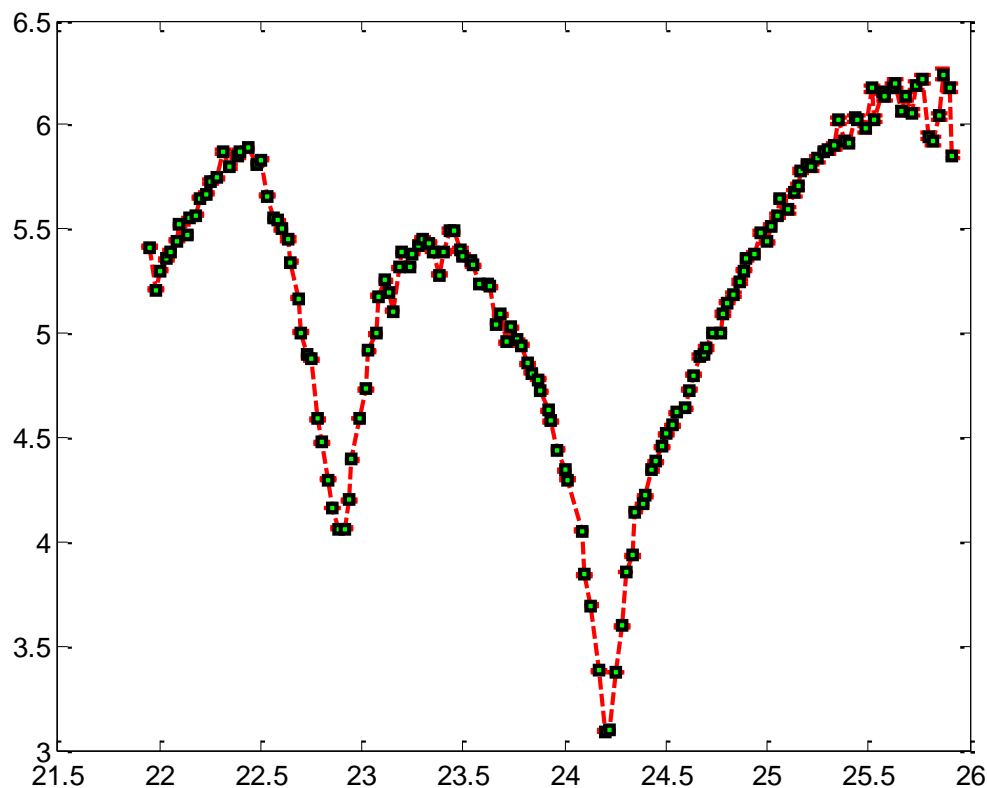


# United States Air Force Academy (USAFA)

(SL-8 SATNO 27437 Lightcurve)



Absolute Magnitude



Time (minutes)

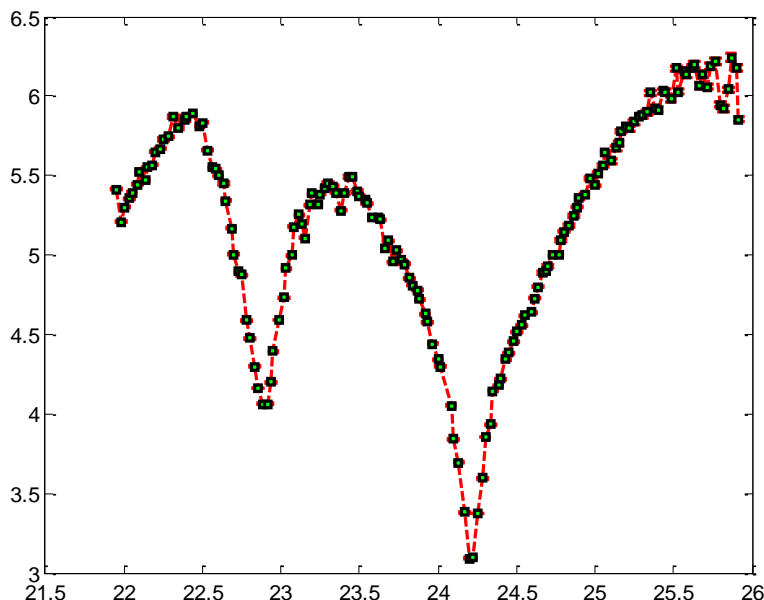
SL-8\_27437\_20110823



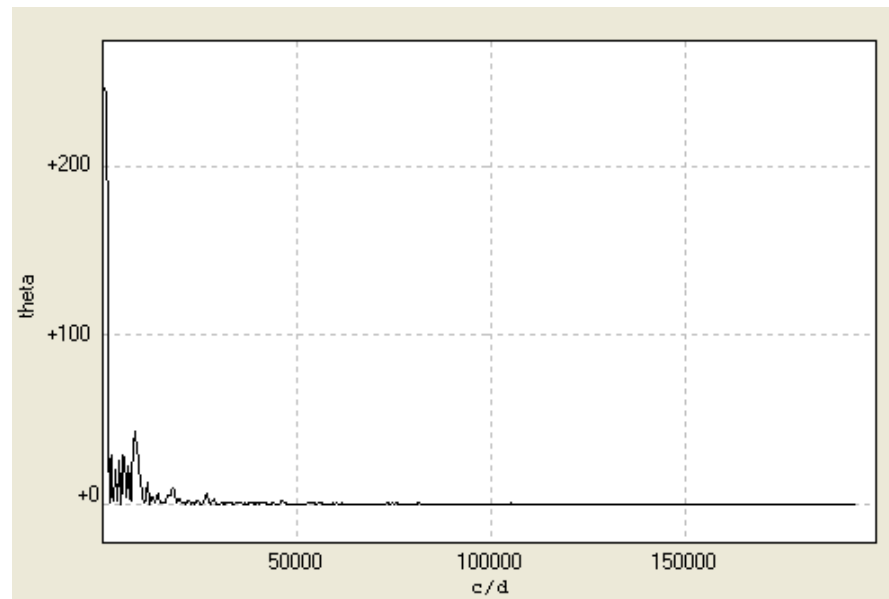
# NASA Processing of USAFA Data

## Period Extraction via Fourier Transform and Manual Measurements

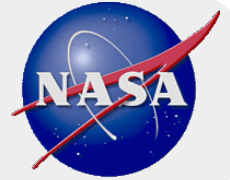
Before & After



Pre-processed data  
provided by USAFA  
(Nov 29, 2011 observations of  
SATNO 27437)



NASA FFT of lightcurve  
using Peranso Software (agrees  
with manual extraction primary period  
(80 seconds))



# Rocket Body Rotation Analysis

(Two sources utilized for telescopic data collection)

- **Source 2: New Mexico Skies Observatory Complex (NMS)**

- **Telescope**

- 80mm short tube f/4 refractor on Paramount German Equatorial mount
    - Pod 1 at the NMS facility and operated remotely from JSC
    - Telescope time is shared with Marshall Space Flight Center (MSFC)
    - Sky version 6 software from Bisque

- **Camera**

- Watek 902H2 Monochrome CCD video camera
    - 768 x 494 pixels
    - Video has GPS time header

- **Data Acquisition**

- Up to 500 seconds of data at 30 fps

- **Results**

- 25 nights data acquired since February 2012
    - Recorded 224 separate light curves





# SW Bisque Sky 6



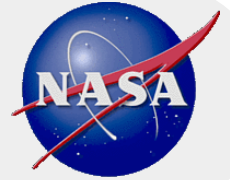
Screenshot during data acquisition mode  
(graphical map of available targets and tracking of selected)

The screenshot displays the SW Bisque Sky 6 software interface, which is used for astronomical observations. The main window shows a graphical map of the sky with various targets and their positions. The map is overlaid with a grid of lines representing celestial coordinates. The interface includes several panels and controls:

- Top Panel:** Displays the date and time: P7 03:46:06 2021 1854 31591745.
- Left Panel:** Contains a section for capturing and recording data. It includes fields for video source (AV/C Tape Recorder/Player), capture file (S:\RocketBodyVideo\To Be Processed\2012 Apr 06\23093), and a capture button.
- Bottom Left Panel:** Shows tracking offset information, including Range (1407.16), Phase angle (4.000), and a tracking offset size of 30 arcminutes. It also includes a status section with "Status: Tracking", "Last Error: No error.", and "Cycles/Second: 4.9".
- Bottom Right Panel:** Displays a table of object data for the selected object (SL-8 R/B 23093). The table includes fields for Object name, Magnitude, Equatorial coordinates (RA, Dec), Horizon coordinates (Azim, Alt), Phase (%), Hour angle, RA rate, Dec rate, and Click distance.
- Right Panel:** Shows a graphical map of the sky with various targets and their positions. The map is overlaid with a grid of lines representing celestial coordinates.

Item	Value
Object name	SL-8 R/B 23093
Magnitude	0.0
Equatorial	RA: 23h 02m 26s Dec: +66°56'12" (current)
Equatorial 2000	RA: 23h 01m 58s Dec: +66°52'14"
Horizon	Azim: 26°24'53" Alt: +28°31'40"
Phase (%)	0.00
Hour angle	-06h 15m 30s
RA rate (arcsecs...)	-1477.0652
Dec rate (arcsec...)	-375.5182
Click distance	1.0000





# Analysis of NMS Data

## – Processing

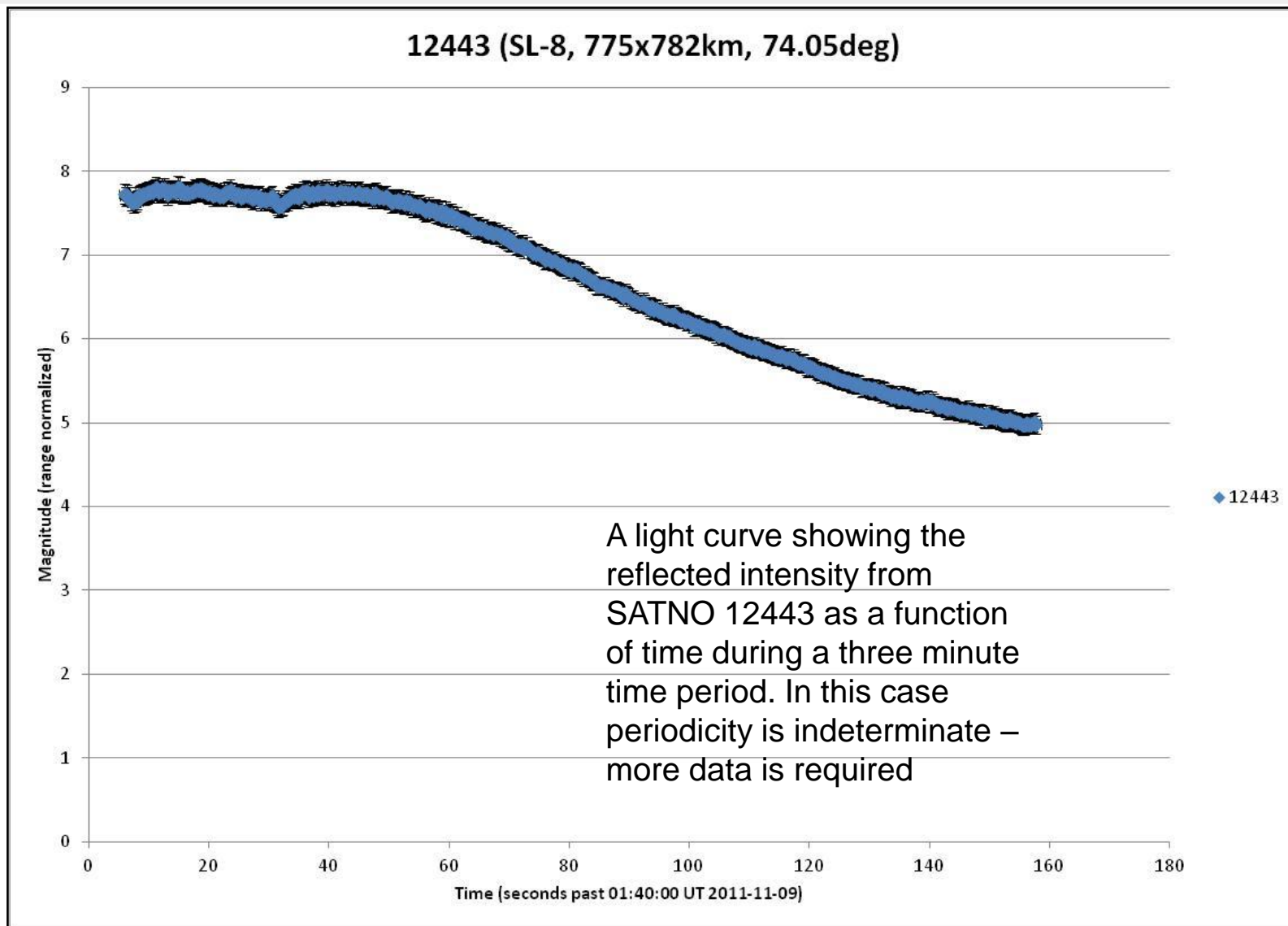
- Photometric calibration utilizes Landolt (equatorial declinations) and Oja (northern declinations) standard stars
- Airmass Extinction correction applied
- Range normalized to 1000 km

## – Post-processing

- Employed Matlab code or LiMovie to search for centroid of brighter point source in FITS images
- Apply FFT (Peranso SW) and manula assessment to obtain rotation period (primary,secondary, tertiary, etc)
- Correlate observations with laboratory analysis to confoirm target rotation states



## Processed Light curve for SATNO 12443





## Ongoing Activities

- NMS data collection will continue through 2012
- Phase Functions will be evaluated and corrections applied
- Comprehensive laboratory data acquisition is underway to model SL-8 behavior at all orientations and phase angles
- Final analysis will provide observed and inferred rotation states and rates for each object observed



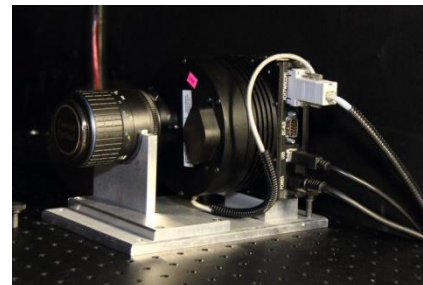
# NASA Optical Measurement Center (OMC)

- The OMC simulates space-based illumination conditions using equipment and techniques that recreate telescopic observations and source-target-sensor orientations.
- Able to generate:
  - Optical signatures
  - BRDF measurements
  - Spectroscopic measurements

Lamp located  
on rotary arm  
(green)



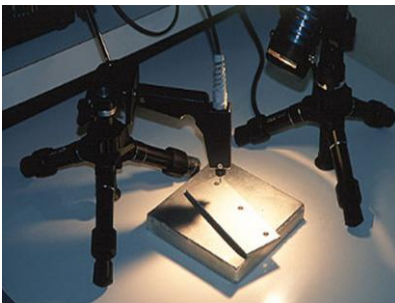
Camera

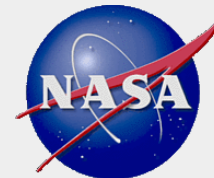


Robot



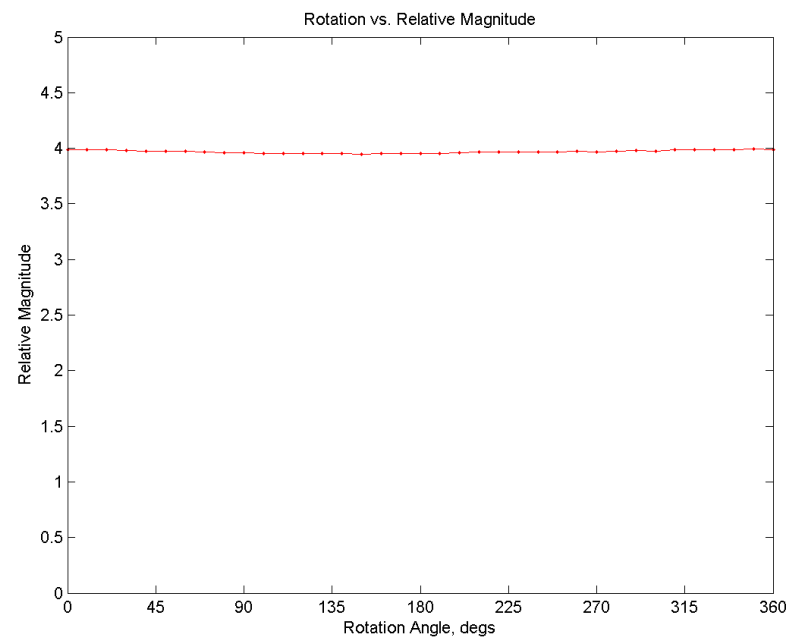
Spectrometer



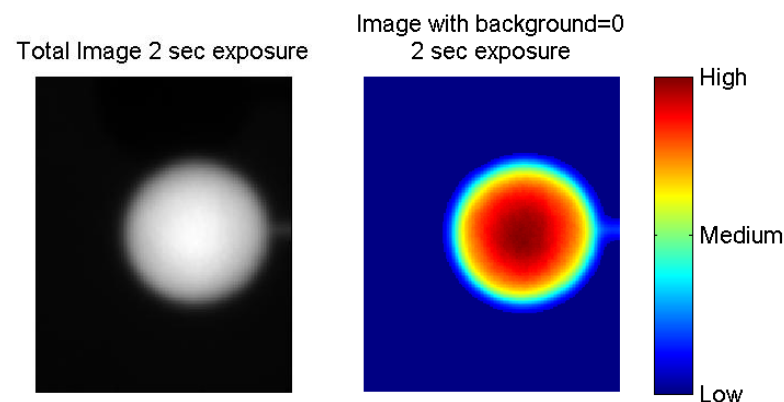


# OMC

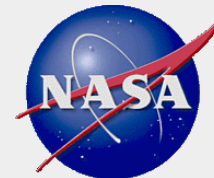
- Preliminary results of 1.5" Lambertian sphere shown to right, 360 degree rotation at 3 degree phase angle.
- Data used to determine phase functions for ground-test debris used to best simulate the orbital debris environment
- Next task: acquire photometric lightcurves of scaled rocket body models in laboratory for comparison to telescopic data



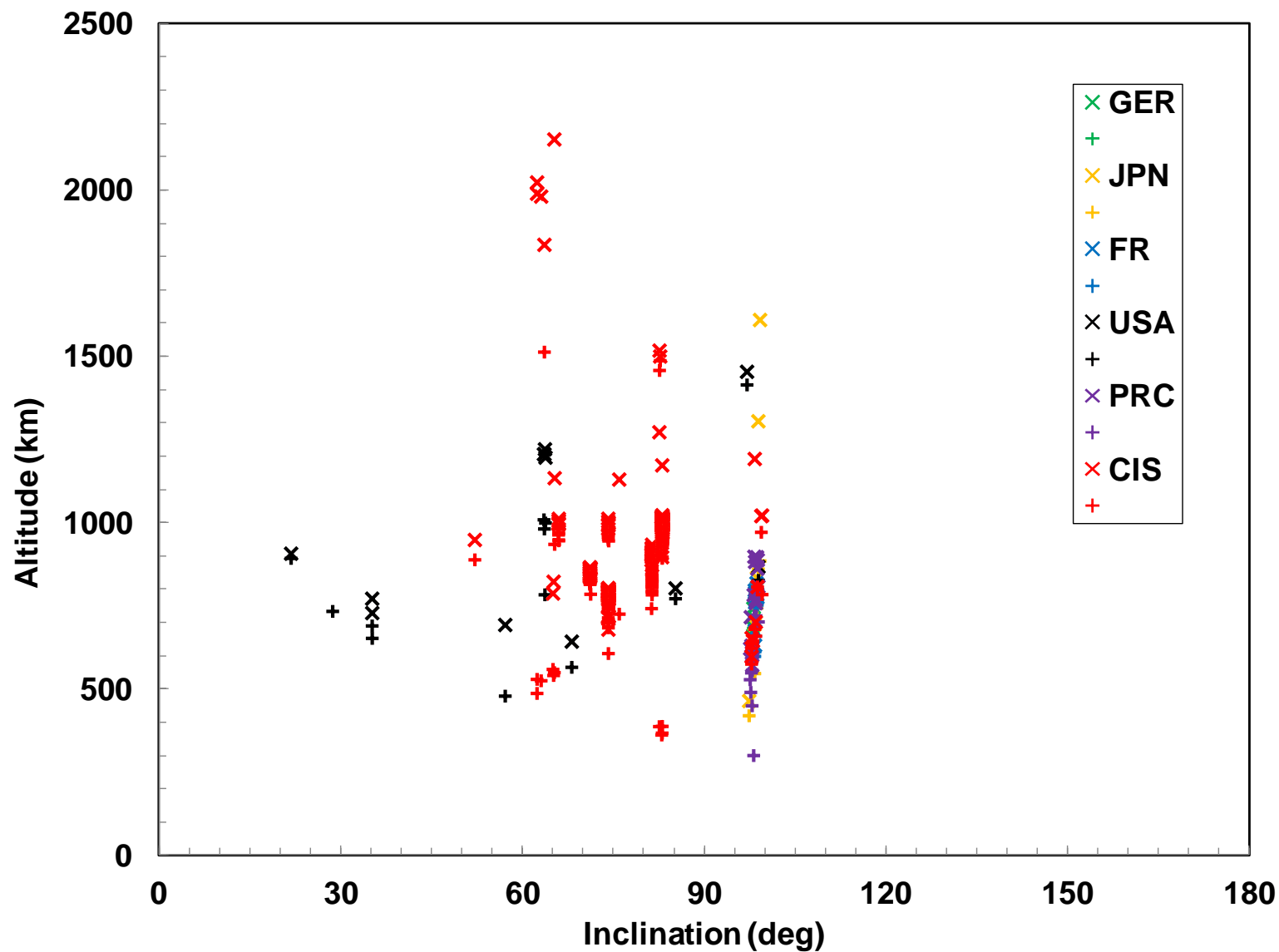
First scaled model is SL-8 second stage with a simple, gray color scheme, 1:48 scale

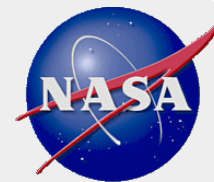






# Rocket Body Candidates





## Subset

ssn	perigee (km)	apogee (km)	inc		
21950	804.9	773.8	85.13	TITAN 2 R/B	US
28538	1198.2	1001.5	63.65	ATLAS 3B CENTAUR	US
27432	898.6	797.5	98.59	CZ-4B R/B	PRC
19468	890.3	883.8	98.71	CZ-4 R/B	PRC
24279	1307.4	862.7	98.81	H-2 R/B	JPN
20491	1611.9	887.3	99.09	H-1 R/B	JPN
27940	694.8	673.2	97.97	RUBIN 4/SL-8	GER
28898	717.3	679.9	98.04	MOZ.5/SAFIR/RUB	GER
28499	677.2	600.6	98.22	ARIANE 5 R/B	FR
27422	820.8	777	98.51	IDEFIX/ARIANE 4	FR
4965	2154.8	551.7	65.11	SL-11 R/B	CIS
10918	1000.6	955.7	82.91	SL-8 R/B	CIS