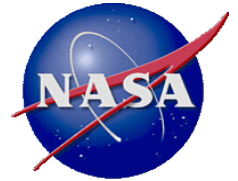


National Aeronautics and Space Administration



# **Characterizing the Space Debris Environment with a Variety of SSA Sensors**

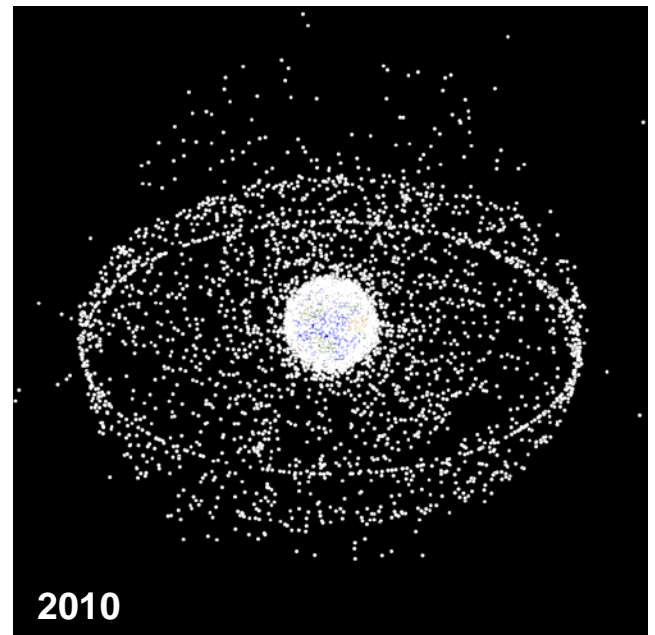
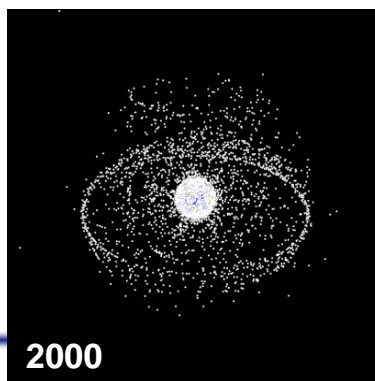
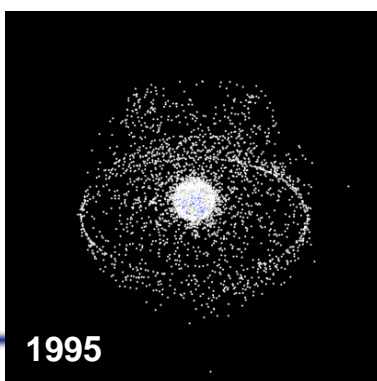
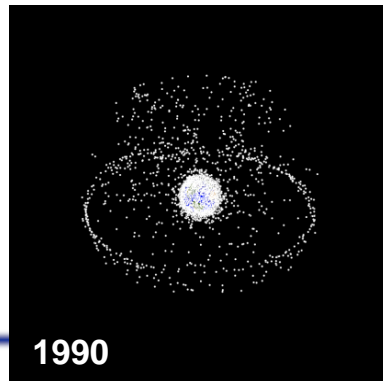
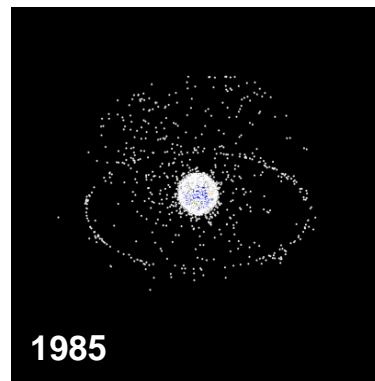
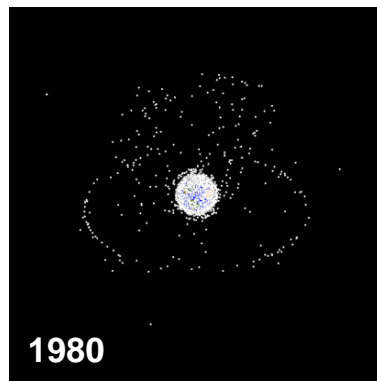
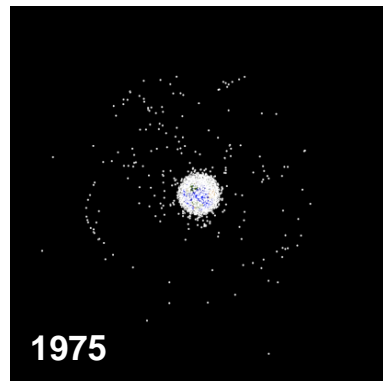
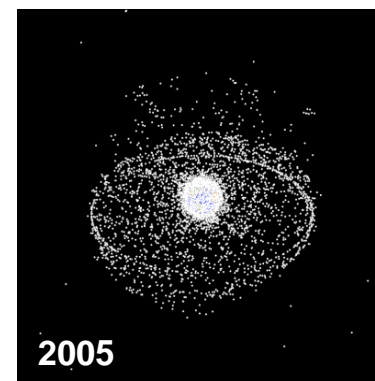
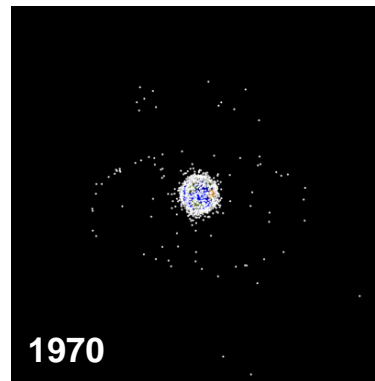
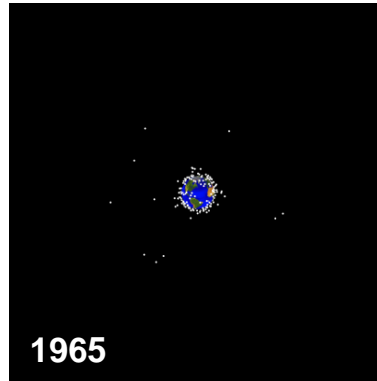
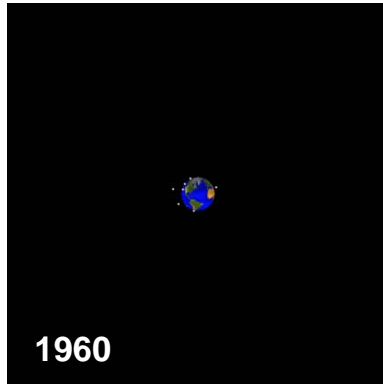
**Gene Stansbery**

**NASA Orbital Debris Program Office  
Lyndon B. Johnson Space Center**

**July 2010**



# Growth of the Satellite Population



**94% of Tracked Object Population are Debris**



## Space Situational Awareness

- **The term ‘Space Situational Awareness’ has many definitions, but fundamentally it means knowing all there is to know about objects in space.**
- **For space debris, this includes**
  - **Environment definition, distribution of debris**
    - Number
    - Size
    - Orbits
  - **Physical properties**
    - Size
    - Shape
    - Material composition
    - Drag characteristics



## Space Situational Awareness (cont.)

- **For space debris, this includes**
  - **Mitigation information**
    - Source
    - Fragmentation cause
    - Collision potential



# US Space Surveillance Network (SSN)



● Radar  
● Optical Telescope

LSSC = Lincoln Space Surveillance Center (Millstone, Haystack, HAX)  
AMOS = AFRL Maui Optical & Super-computing Site  
AFSSS = Air Force Space Surveillance System  
MOSS = Moron Optical Space Surveillance  
MSX/SBV = Mid-Course Space Experiment/Space Based Visible



## Discovery & Environment Definition

- **Must initially detect, or statistically sample the number and distribution of debris**
- **Implies sensors with large collecting areas**
  - **Air Force Space Surveillance System (formerly NAVSPASUR)**
    - New upgraded system in planning
  - **Phased array radars that routinely erect detection fences**
    - Eglin
    - Cobra Dane
    - Cavalier
  - **High sensitivity/High frequency radars for small debris**
    - Haystack – to 5 mm
    - Goldstone – to 2 mm
  - **GEODSS for high altitude**
  - **New wide field-of-view optical sensors in development**
    - Pan-STARRS



## **Follow Up Orbit & Source (Parent Body) Definition**

- **Once Discovery is made, follow-up observations refine the orbit & eventually the debris is cataloged**
  - Identifying the parent body part of cataloging process
- **Enables future conjunction assessments**
- **Not possible for small debris**
  - **Sensitivity limits of most SSN sensors**
    - 10 cm for most of the SSN
    - 5 cm for Cobra Dane
    - 2 cm at low altitudes for future upgraded AFSSS
    - 1 m at geosynchronous altitudes
  - **Large numbers of small objects**
    - ~500,000 1-cm & larger debris in low Earth orbit



# Physical Properties

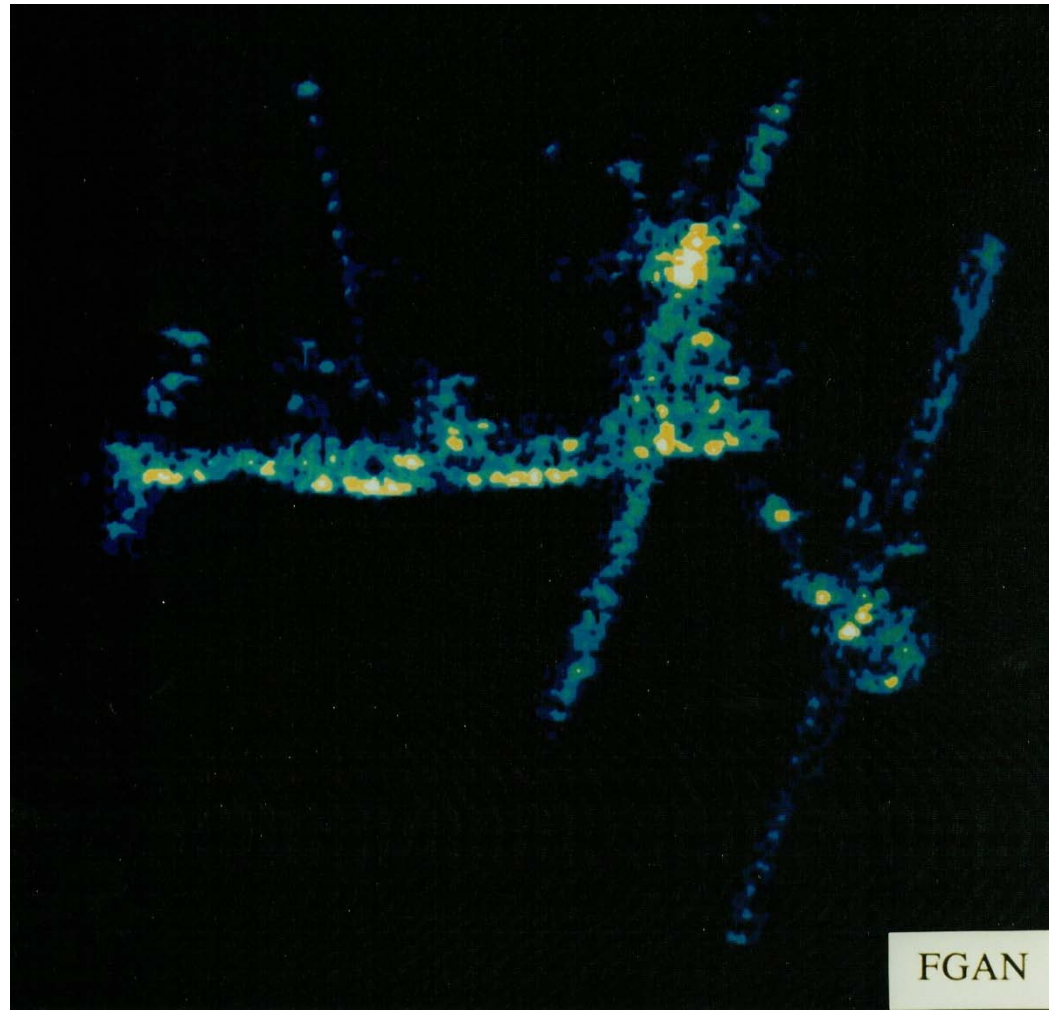
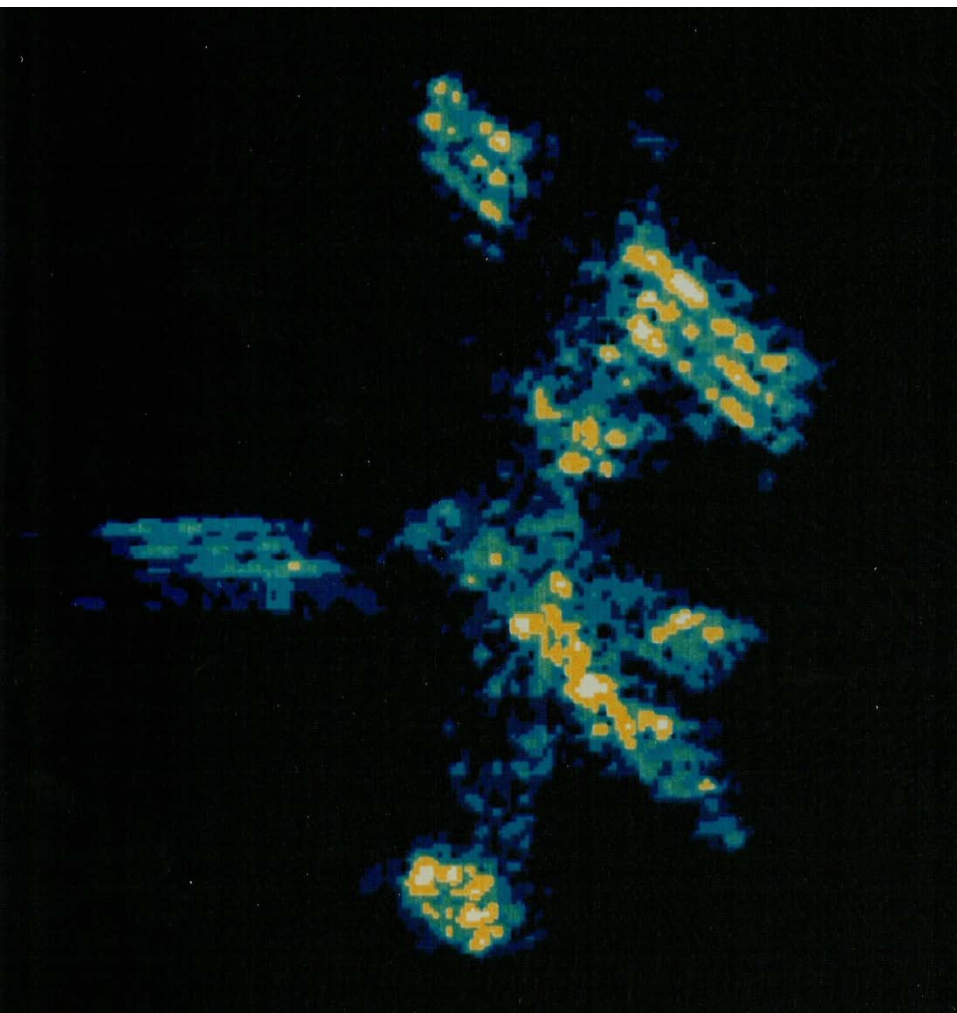
- **Imaging**

- **Only for large objects**
- **Sometimes used to look for the cause of a fragmentation**
- **Radar**
  - Haystack – up grading to HUSIR
  - HAX (Haystack Auxiliary)
  - ALCOR (ARPA-Lincoln C-band Observables Radar)
  - MMW (Mili-Meter Wave)
  - FGAN/TIRA (non US SSN)
- **Optical**
  - AMOS/AEOS (Air Force Maui Optical Station/Advanced Electro-Optical System)





# Imaging Sensors - Radar



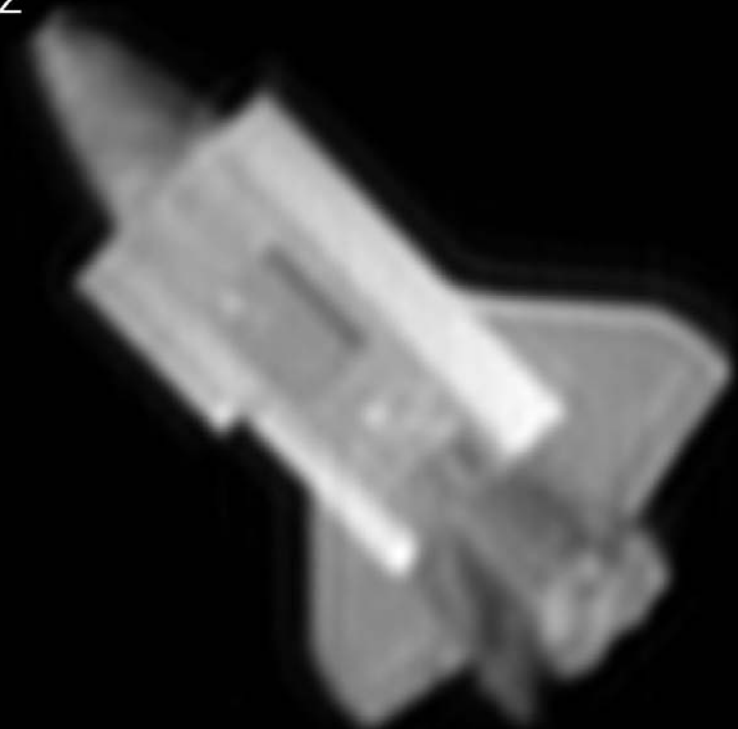


# Imaging Sensors - Optical

STS-107  
28 JAN 2003  
21:49 Z

Visible Camera STS-107  
28 JAN 2003  
13:53 Z

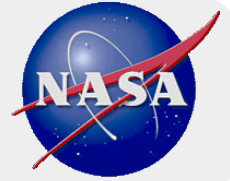
Infrared Camera



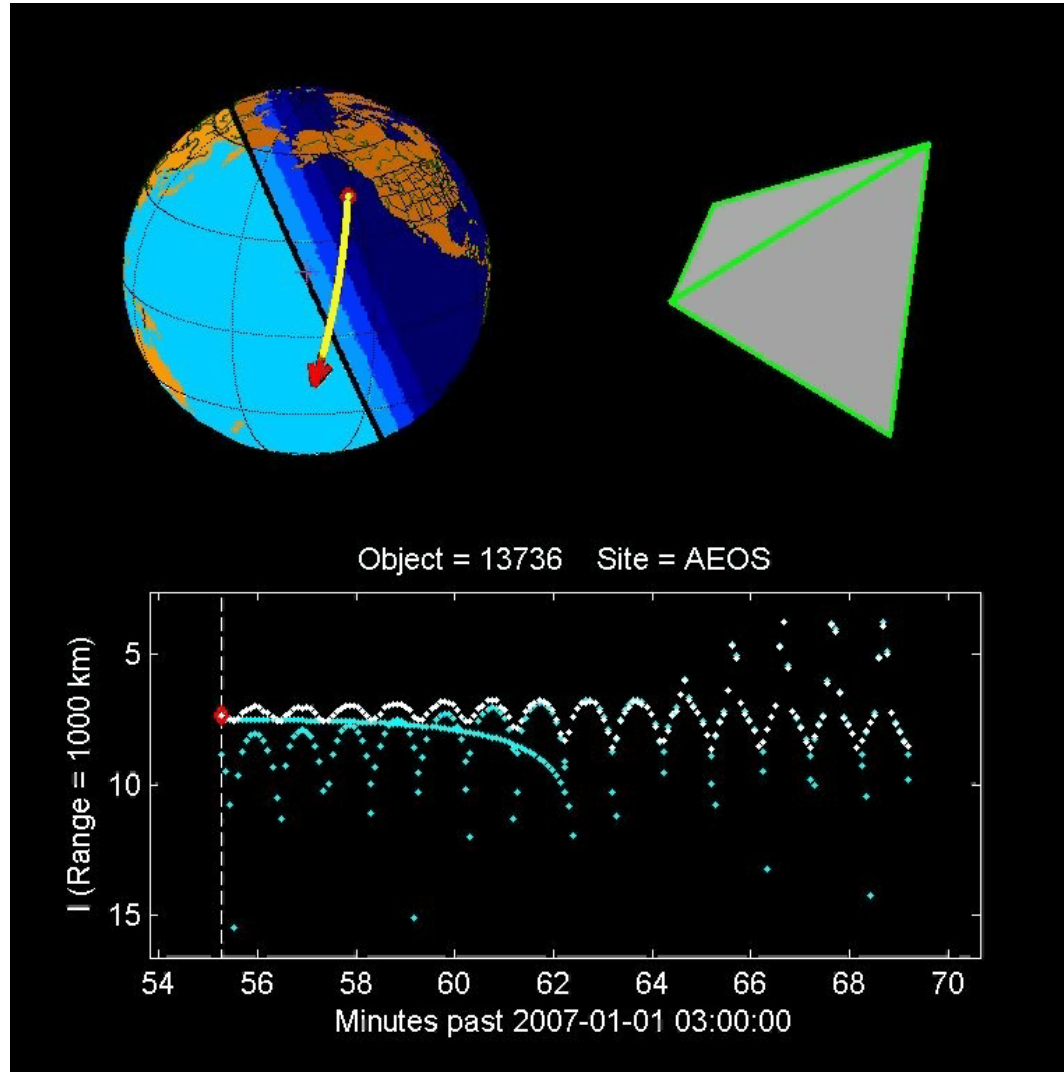


# Physical Properties

- **Non - Imaging**
  - **Shape**
    - Optical – Light curve analysis
    - Radar – Polarization
      - Spheres
      - Dipoles
  - **Material composition**
    - Optical – spectral analysis



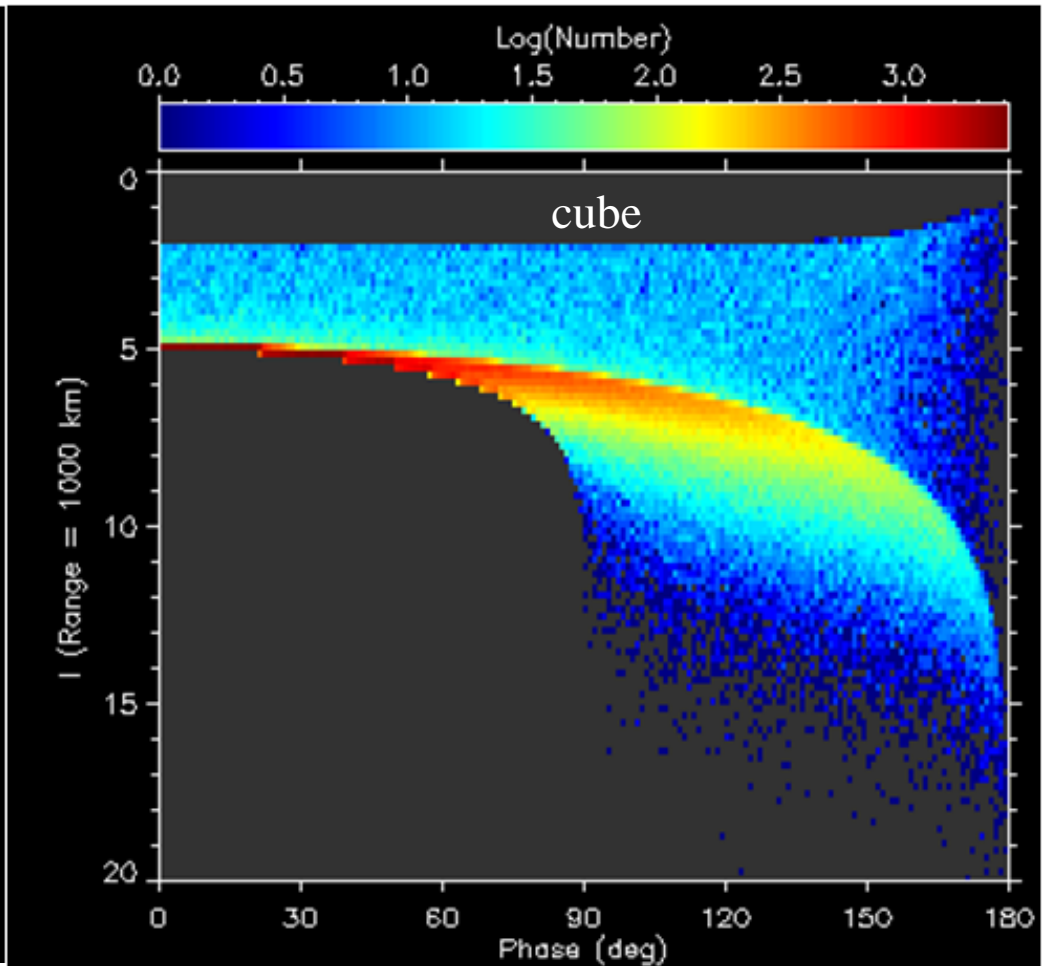
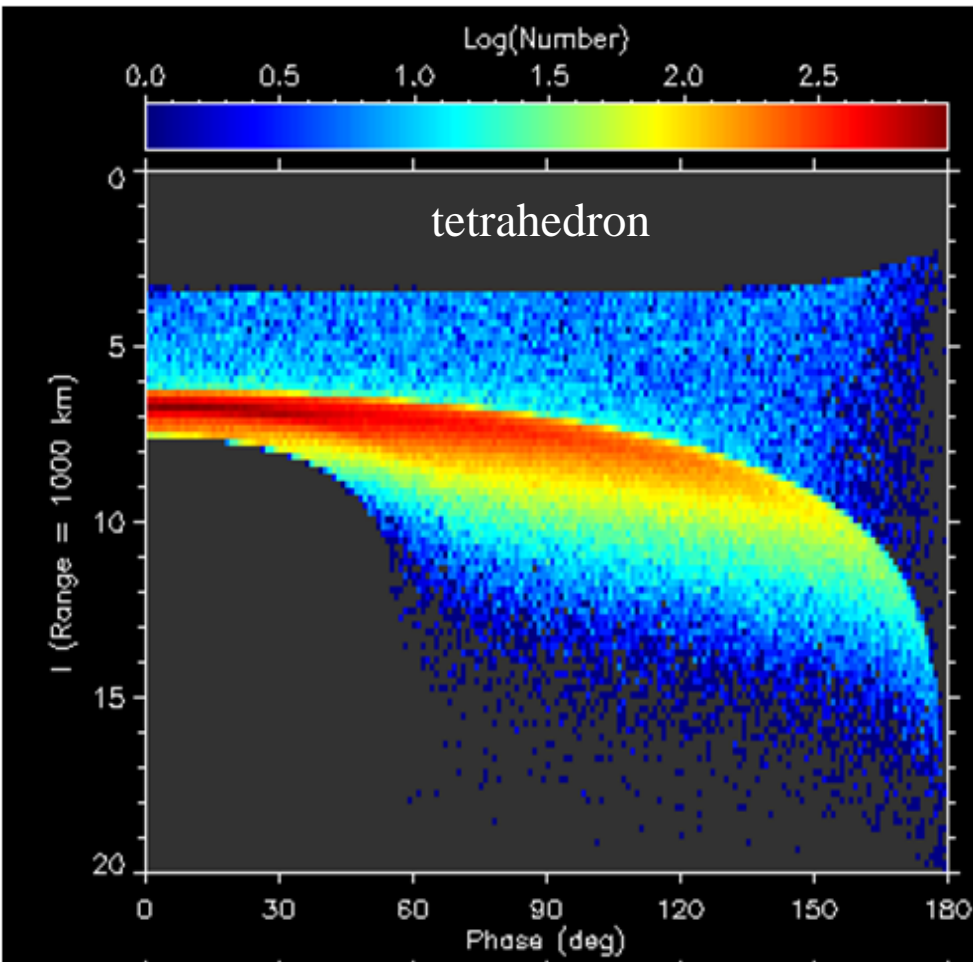
# Optical Shape Analysis



Courtesy – Doyle Hall



# Optical Shape Analysis



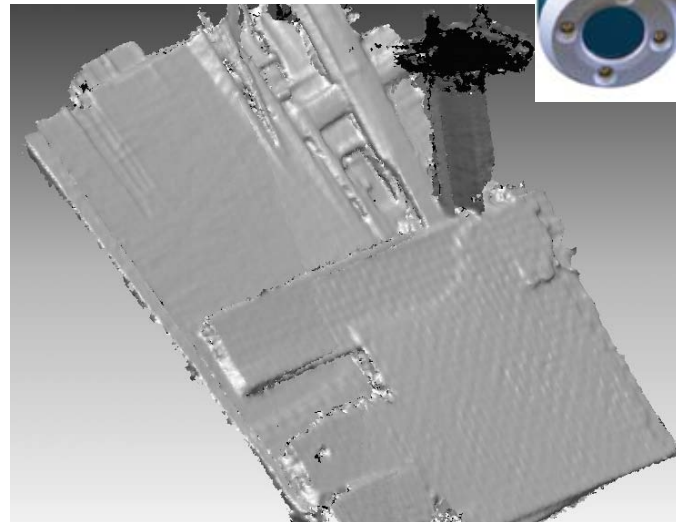
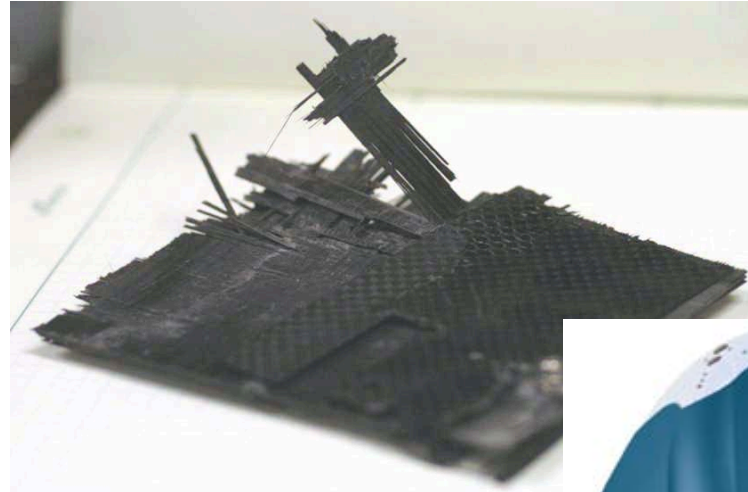
Courtesy – Doyle Hall





## Optical Size and Shape Determination

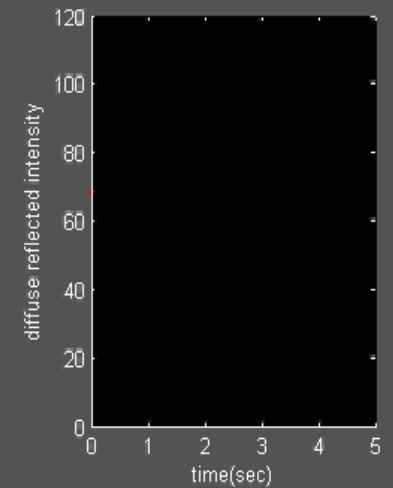
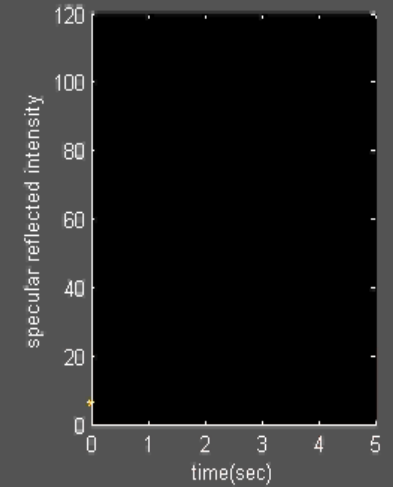
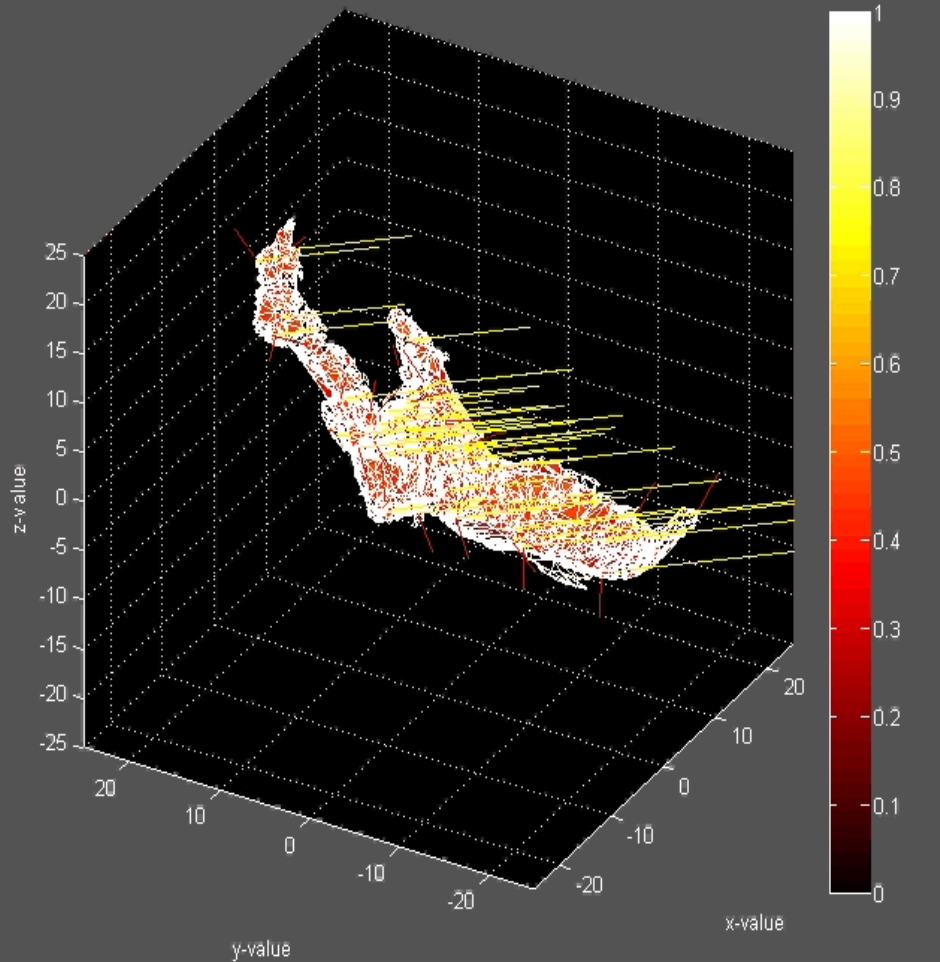
- **Debris objects will have much more complex shapes**
- **Using handheld 3-dimensional scanner to digitize realistic debris shapes from ground hypervelocity impact tests**
- **Once digitized, can be manipulated in four dimensions**
  - 2 dimensions to orient body
  - Sun direction
  - Observer direction
- **Calibrate brightness and phase function with laboratory measurements**





# Computer Generated Light Curves from Scanned Fragments

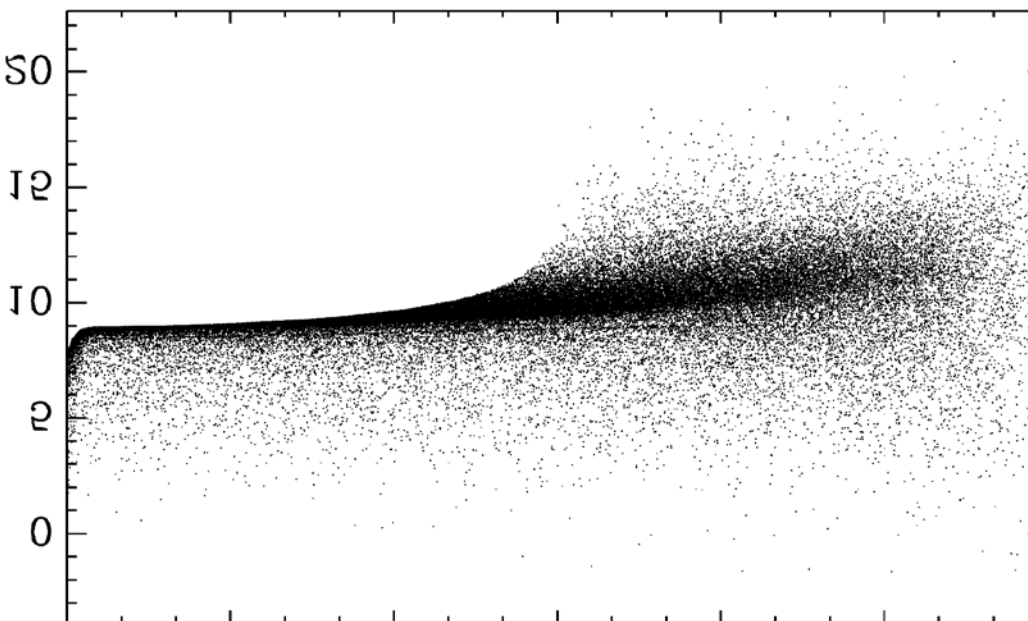
Fragment 30: phase angle=19.4539 degrees. nobs=(-0.75 -0.43301 0.5) nsun=(-0.5272 -0.68706 0.5)



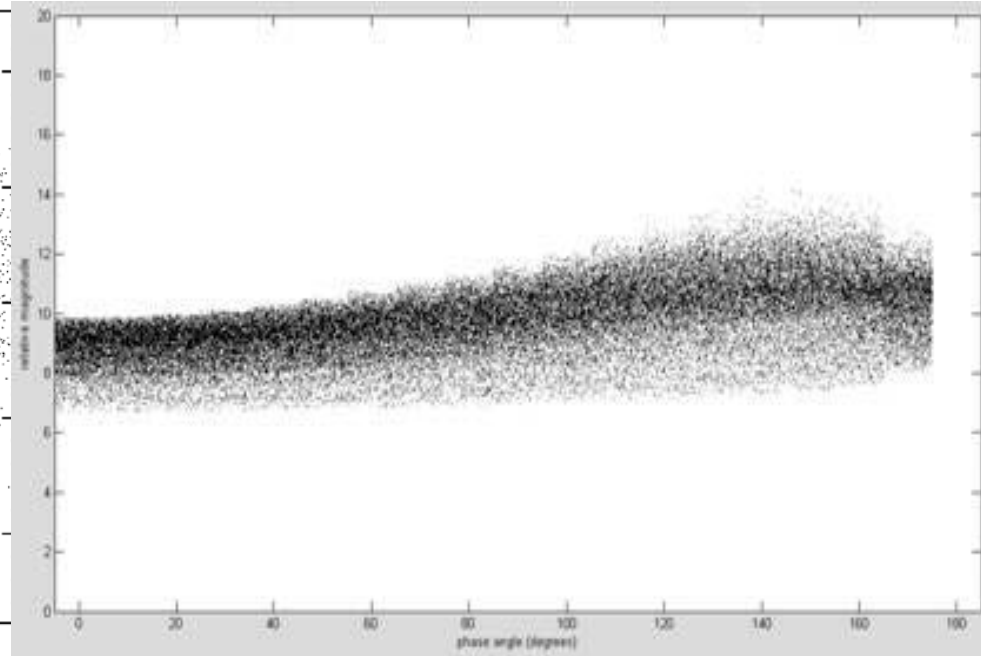


# Optical Shape Analysis

**Cube**



**Flake**



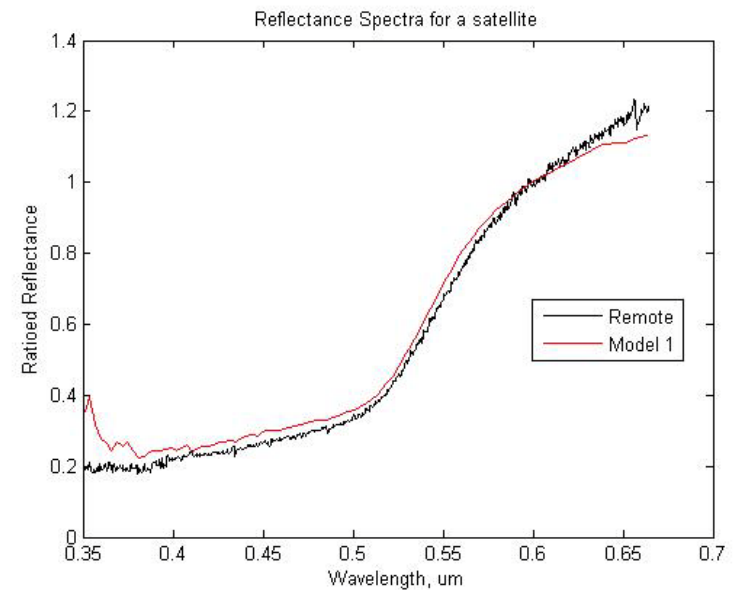
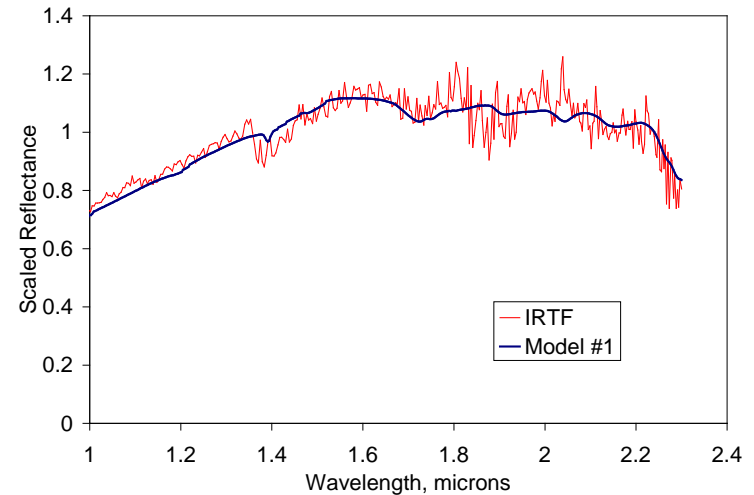
Left image courtesy – Doyle Hall





# Spectral Studies

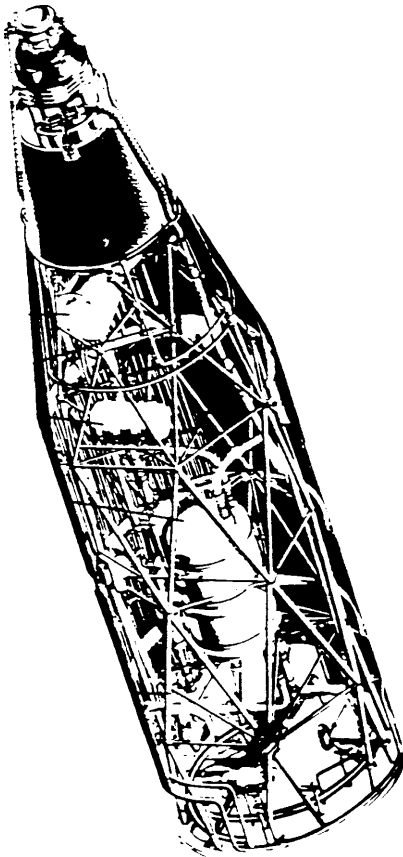
- **Use reflectance spectroscopy in the visible and near-infrared to determine the surface material of space objects**
  - Database of ground measurements using common spacecraft materials
- **Each material has specific absorption features that make it unique**
  - Using those features, as well as slope, creates a model for materials that best fits the spectrum taken of the object in space
- **Space weathering**
  - Measured pristine spacecraft prior to launch and looked at space weathering of materials
  - Many objects show a reddening on-orbit





## Putting it all together - RORSAT Debris

### Bouk Reactor



- **Peak @ 850-1000 km altitude is most dominant feature in the Haystack data**
- **Not seen by other sensors**
  - Few pieces larger than 3-5 cm - too small for SSN
  - No returned materials from these altitudes
- **Altitude distribution wrong for explosion/collision**
- **Sodium-Potassium (NaK) liquid metal coolant from Bouk reactors on Radar Ocean Reconnaissance SATellites (RORSATs) hypothesized**
- **Radar signature & polarization consistent with conducting spheres**
- **Optical signatures compatible with metallic spheres**
- **Optical albedo consistent with NaK**
- **Area-to-mass consistent with NaK**
- **Number consistent with available material**



## Summary

- **Space Situational Awareness for debris – knowing all there is to know**
- **No single sensor or technique gives a complete picture**
  - Can borrow from DoD ‘Data Fusion’ concepts
- **Some success stories**
- **Just beginning to use advance techniques to better understand physical characteristics of debris**