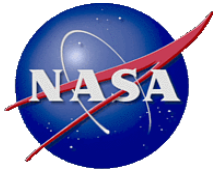
National Aeronautics and Space Administration




# Characterizing GEO Titan Transtage Fragmentations using Ground-based Measurements

H. Cowardin[1] and P. Anz-Meador[2]
[1]University of Texas-El Paso—Jacobs JETS Contract, NASA Johnson Space Center, Houston, TX 77058
[2]Jacobs, NASA Johnson Space Center, Houston, TX 77058

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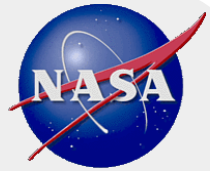
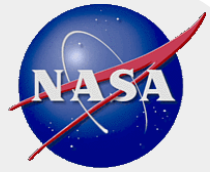
# Motivations



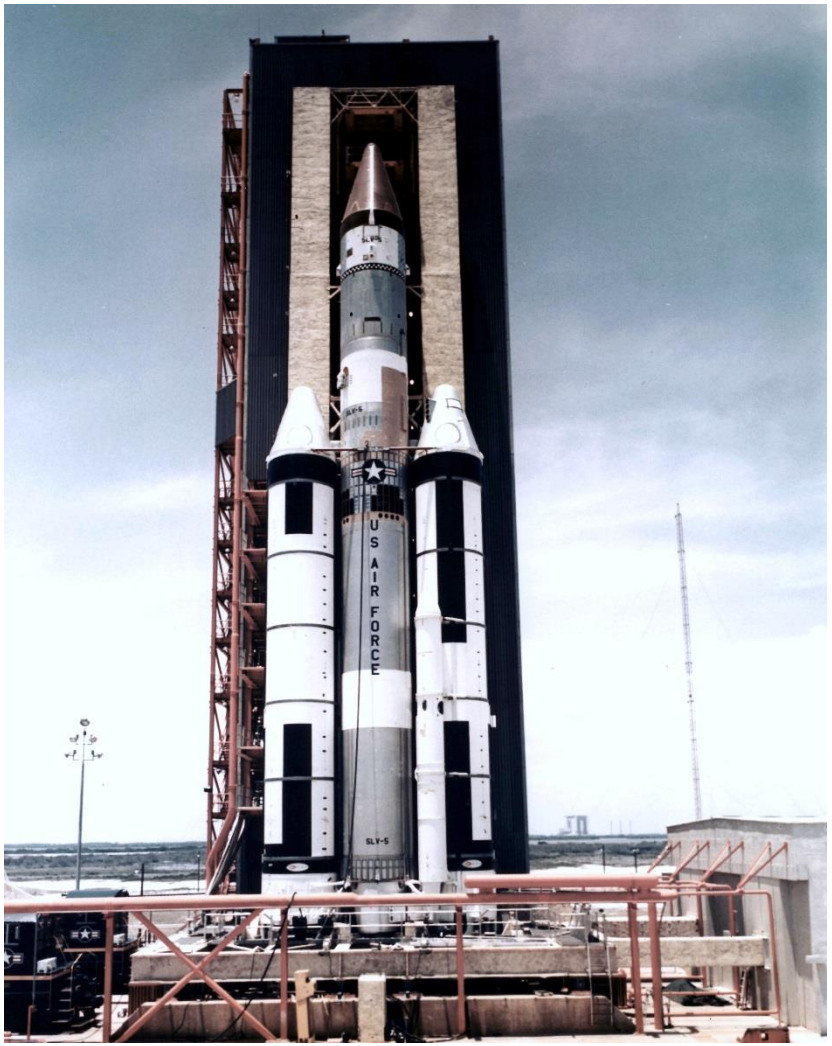

- **Titan IIIC Transtage upper stage has fragmented four times, to date**
  - 2/4 in Geosynchronous Earth Orbit (GEO)
  - 1 GEO Transfer Orbit (GTO)
  - 1 Low Earth Orbit (LEO)
- **Consequently, majority of known break-ups in GEO are from Titan IIIC Transtages**
- **Space community is interested in characterizing and understanding how these break-ups occur**
- **Titan Transtage test and display article, previously in custody, of the 309$^{th}$ Aerospace Maintenance and Regeneration Group (AMARG) in Tucson, AZ was found in "The Boneyard" during a 5K**
- **Initial inspection and material analysis demonstrated the test article was of sufficient fidelity**
- **Test article now in custody of the Orbital Debris Program Office at NASA\JSC to continue research, analysis, and historical documentation**

# Titan IIIC Transtage Break-ups

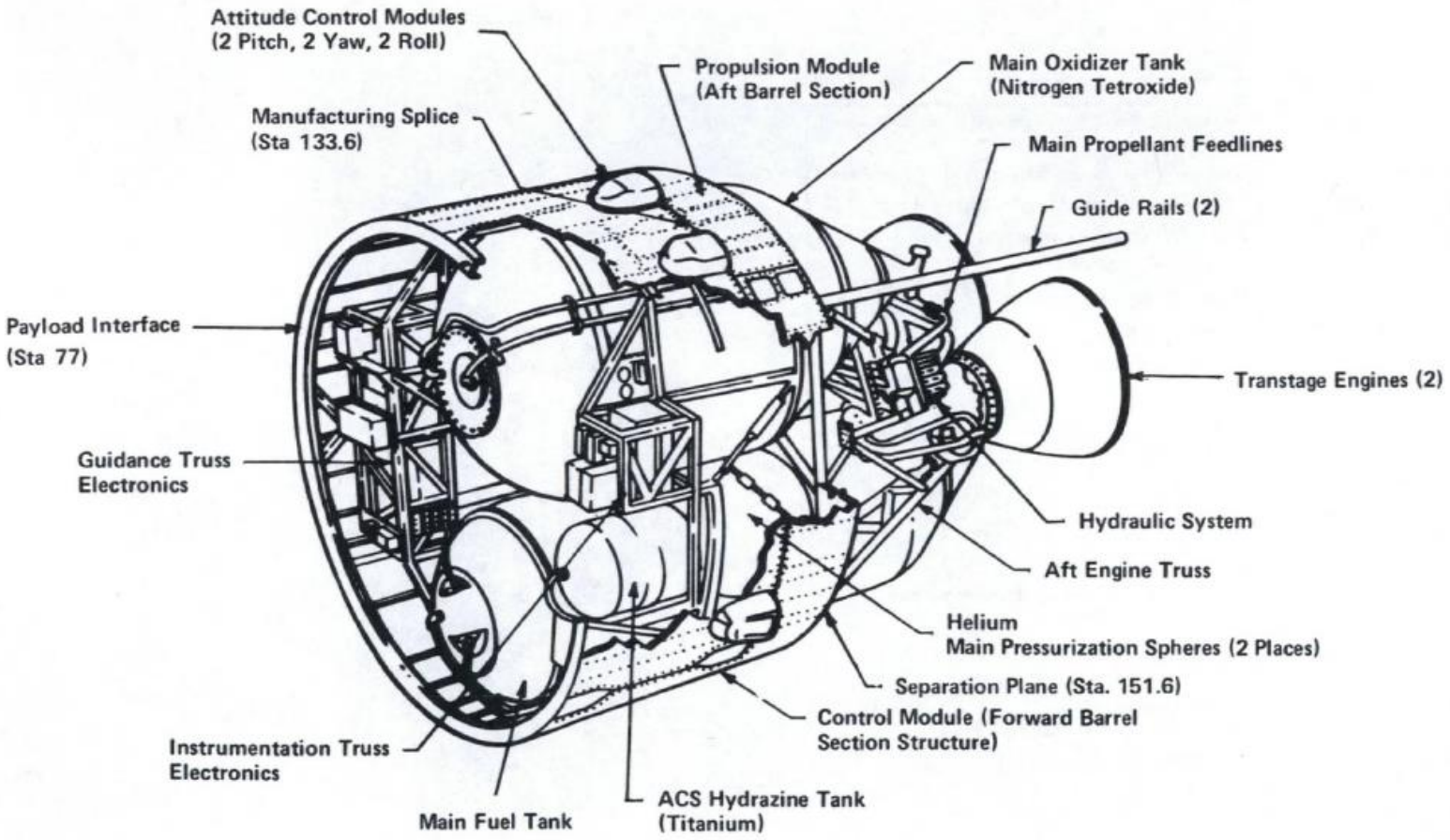



- **GEO Transtage 3C-5 (1968-081E) on 21 February 1992 (23.4 yr on orbit)**
  - Parent body SSN# 3432
  - Associated fragments: 29 cataloged/29 on-orbit as of 4 January 2016
  - Cause: unknown, but possibly residual propellants or collision with smaller fragment
- **GEO Transtage 3C-17 (1969-013B) on 4 June 2014 (45.3 yr)**
  - Parent body SSN# 3692
  - Associated fragments: 1/1
  - Cause: unknown, but possibly residual propellants or collision with smaller fragment
- **GTO Transtage 3C-8 (1965-108A) on 21 December 1965 (launch)**
  - Parent body SSN# 1863
  - Associated fragments: 108/101
  - Cause: propulsion
- **LEO Transtage 3C-4 (1965-082DM) on 15 October 1965 (launch)**
  - Parent body SSN# 1822
  - Associated fragments: 473/33
  - Cause: propulsion

# Titan IIIC

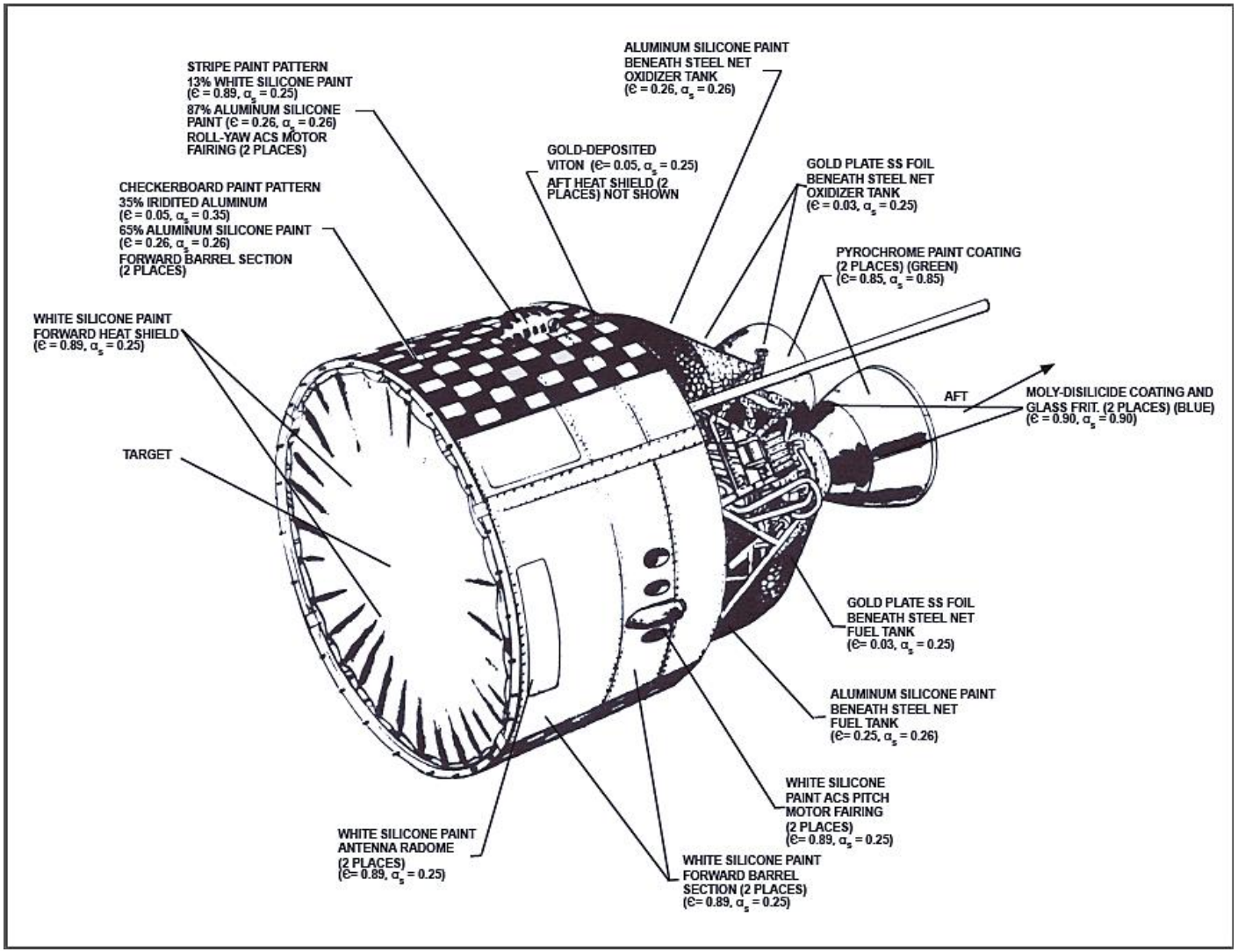


# Titan Transtage Schematic




*Transtage*

# Titan IIIC Transtage Material Properties



# Picture of Transtage at AMARG

# NASA Inspection


# Transport Pictures


1) The Titan Transtage is lifted onto a tractor-trailer for transport to NASA JSC. (Image courtesy of Rob Raine, U.S. Air Force 309th Aerospace Maintenance and Regeneration Group).
2) The Titan Transtage arrives at JSC after a road journey shared with curious drivers. The 18-wheeler was detained going through Houston by a curious sheriff who said “You aren’t doing anything wrong. I just wanted to see what this thing was.” (Image credit: NASA/David DeHoyos).
3) NASA JSC team members maneuver the Titan Transtage into a holding cradle in B9S. (Image credit: NASA/David DeHoyos).

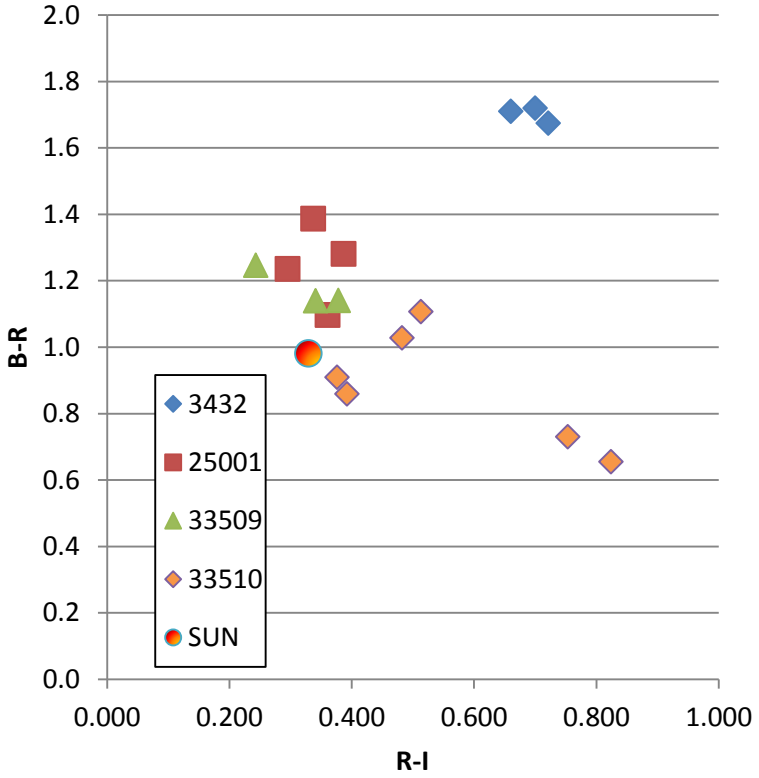
**ODQN 20-3*

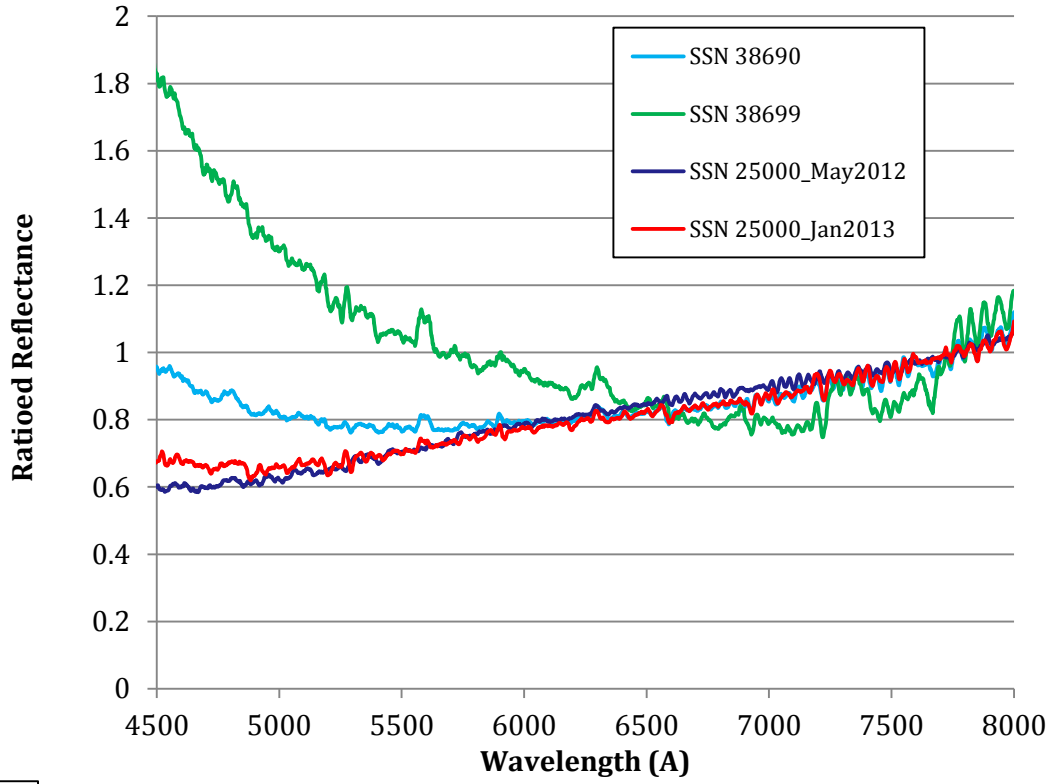
# Material Characterization

- **Process:**
  - Removed several samples for test article at Arizona for initial analysis, Summer 2015
  - Performed spectral measurements on 28 material samples, Summer 2015
  - Test article moved to NASA\JSC for further inspection 26 May 2016
  - Spectral measurements will be conducted in Fall 2016 on intact Transtage (including the interior which was previously not available for inspection)
  - Compare laboratory data with previously collected telescopic data

# Previous Titan Transtage Data characterization

- **Cowardin, H., et al, Observations of Titan IIIC Transtage Fragmentation Debris, AMOS 2013.**

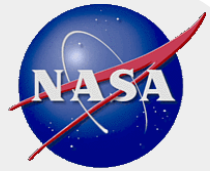



- Data acquired using the CTIO 0.9-m telescope in Chile using Johnson/Kron-Cousins B, V, R, and I filters (Five exposures in each filter)
- Calibrated R magnitude data and color index data with respective photometric 1-sigma errors

- Data acquired using Las Campanas 6.5-m Clay Magellan Telescope in Chile, using Low Dispersion Survey Spectrograph (Version 3) covers 4000-8000 Angstroms (Å)
- Normalized to one using an average value from 7500-8000 Å

# Previous Titan Transtage Data characterization Continued…

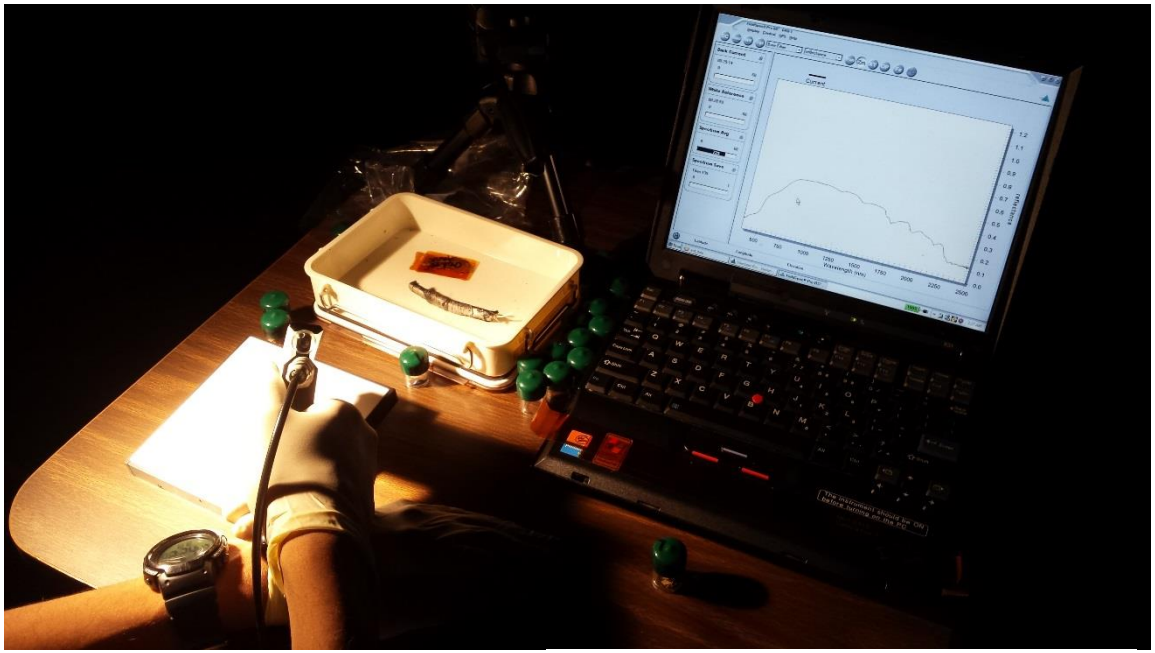


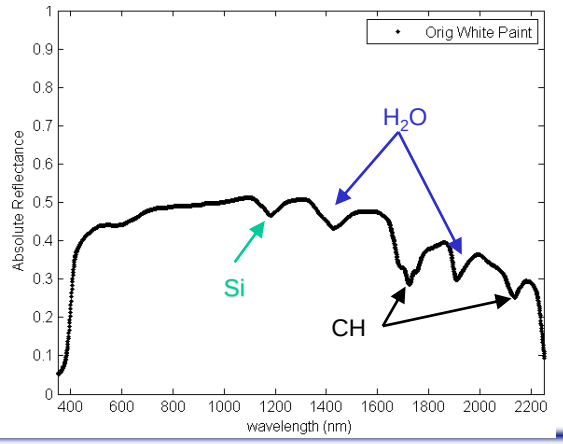

- **Cowardin, H., et al, Observations of Titan IIIC Transtage Fragmentation Debris, AMOS 2013.**
  - Titan IIIC-5 Transtage (1968-081E) fragmentation pieces were observed using broad R filter with MODEST, Johnson/Bessell filter photometry with CTIO 0.9-m, and a visible regime spectrograph with 6.5-m Clay Magellan Telescope
  - Photometry data were compared with laboratory photometry data to best correlate materials (3432, 25001, 33509, 33510)
  - Spectral data were compared with laboratory spectral data on known materials associated with Titan Transtage (25000 – two observing periods, 38690, 38699) based on shape characteristics and slope factors

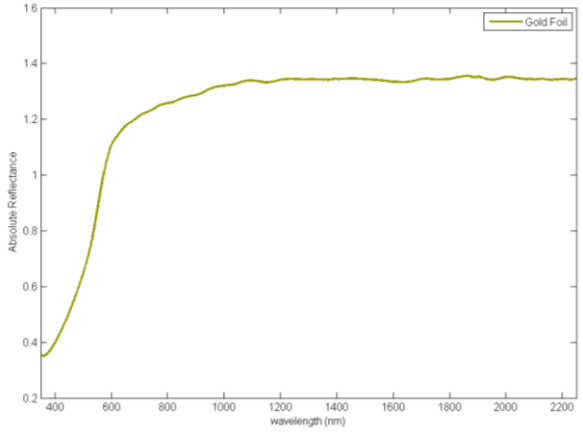
| *SSN* | *Material* | *Likely Candidate Materials* |
|---|---|---|
| **3432** | Dielectric | composite |
| **25000** | Dielectric | white paint |
| **25001** | Dielectric | composite/electronic circuit board |
| **33509** | Metal | aluminum |
| **33510** | Metal | aluminum |
| **38690** | Dielectric/Metal | black paint/aluminum covered with particulates |
| **38699** | Dielectric | blue/green paint |

# Spectral Data Analysis from Material Samples Collected from AMARG

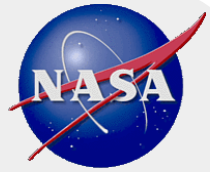
| | |
|---|---|
| 001 | Wire Retention Netting |
| 002 | Silver Foil |
| 003 | Green Paint Right |
| 004 | Yellow Paint Right |
| 005 | Gold Foil |
| 006 | "L" SLV-5 Paint |
| 007 | Insulating Tape R |
| 008 | Fuel Tank Wire |
| 009 | White Paint Checkerboard from Sandpaper |
| 010 | Silver Paint Checkerboard from Sandpaper |
| 011 | Fiber Matt |
| 012 | Fiber Matt |
| 013 | Blue Paint |
| 014 | Yellow Paint |
| 015 | Metal Tag |
| 016 | Aluminum Metal |
| 017 | Rubber |
| 018 | Attitude Control |
| 019 | Painted Screw |
| 020 | Right Primer |
| 021 | Left Green Paint |
| 022 | Left Yellow Paint |
| 023 | Orig White Paint |
| 024 | Exterior Red Paint |
| 025 | Left Blue Paint |
| 026 | Plastic Container - Control |
| 027 | Oxidizer Tank |
| 028 | Copper Wire |





# Plans Forward



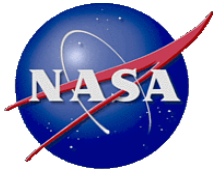

- **Compare lab-based spectra with telescopic photometric and spectroscopic data, better define observed materials**
  - Available data from MODEST, CTIO 0.9 m, Magellan & Baade 6.5 m telescopes, UKIRT, and MCAT.

- **Forensic analysis to better characterize what materials have been observed and if there is a potential link to understanding what is causing these known break-ups**

- **Create 3D scan of Transtage to be scaled for use in NASA's Optical Measurement Center for photometric analysis and lightcurve studies**

- **Potential future development with active debris removal using a complicated, realistic Transtage**


Thank
you




# BACK-UP CHARTS