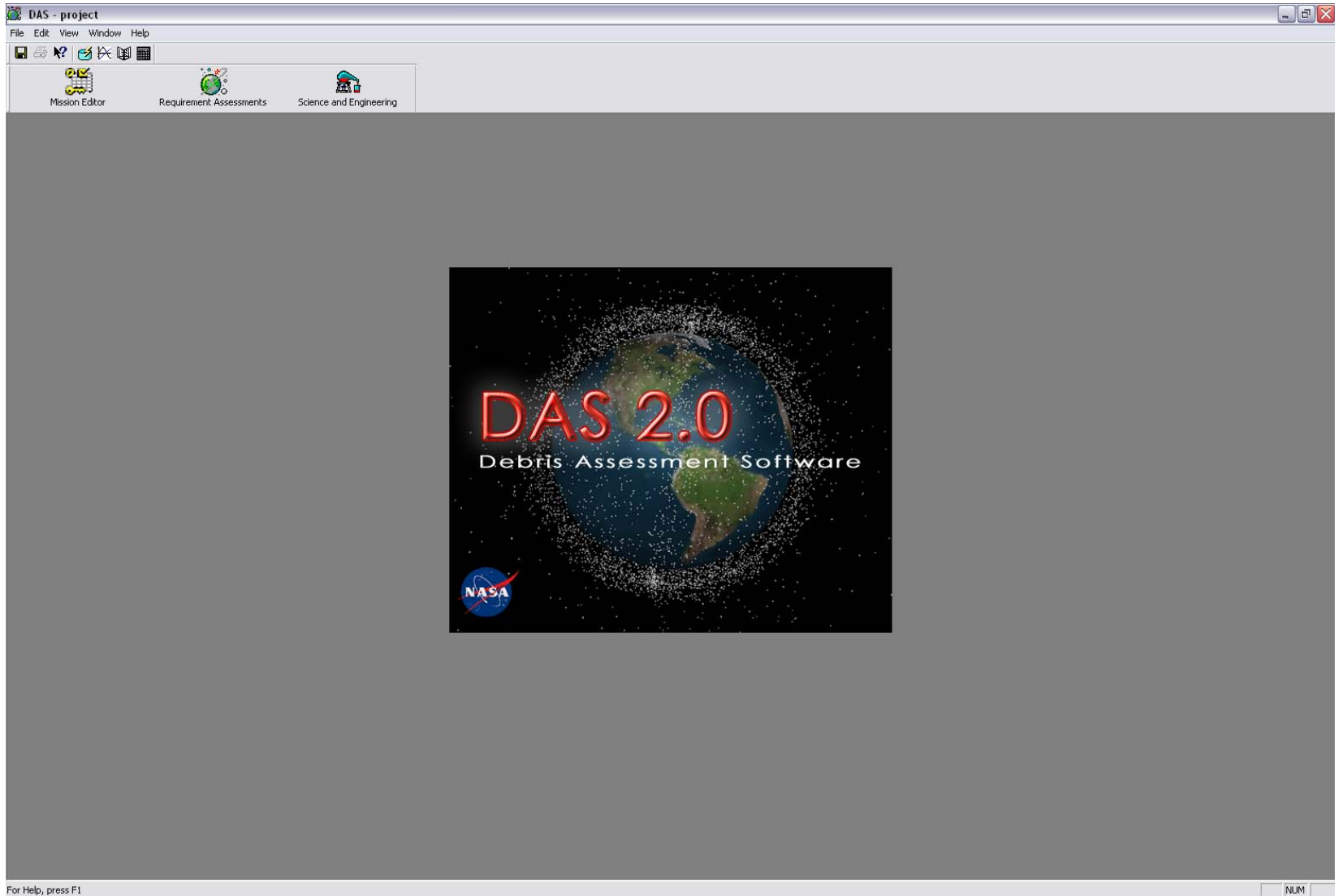




# DAS Reentry Survivability Analysis





# DAS Reentry Survivability Analysis

- **JSC Debris Assessment Software (DAS)**
  - Developed to assist NASA programs in performing orbital debris assessments
  - Able to evaluate compliance with many of the requirements in NSS 8719.14
- **Reentry Survivability Analysis in DAS can be accessed in 2 ways**
  1. As one item in an overall assessment of a project's compliance with NSS 8719.14
    - Provides Debris Casualty Area (DCA) and Risk
    - Inclination and Parent Objects flow down from Mission Editor
  2. As a separate routine under the Science and Engineering menu
    - Provides DCA only
    - Runs separate from Mission Editor
    - All data provided by user at run time
- **DAS can only assess the risk associated with uncontrolled reentry**
- **DAS's Reentry Survivability Tool is intended as "1<sup>st</sup> Cut" Assessment Tool**
  - Provides somewhat conservative results
    - Will classify all missions which clearly do not satisfy the requirement non-compliant
    - May also classify some mission which are borderline non-compliant



# DAS Reentry Survivability Analysis

- **Assumptions:**

Uses temperature dependent material properties for 77 common materials

- Allows user to define additional materials as needed

Includes aerodynamic and heating equations for 4 simple shapes

- Sphere
- Cylinder
- Flat Plate
- Box

Parent Object is assumed to break apart at 78 km, exposing 1<sup>st</sup> level of fragments

- DAS permits 3 levels of fragmentation after the 78 km Parent body break up

Fragments always begin with a temperature of 300 K

- Only inherits trajectory state vectors from the parents

Uses lumped mass thermal model

- No partial ablation means the DCA for an object is either 0 (demised) or the usual product of initial dimensions

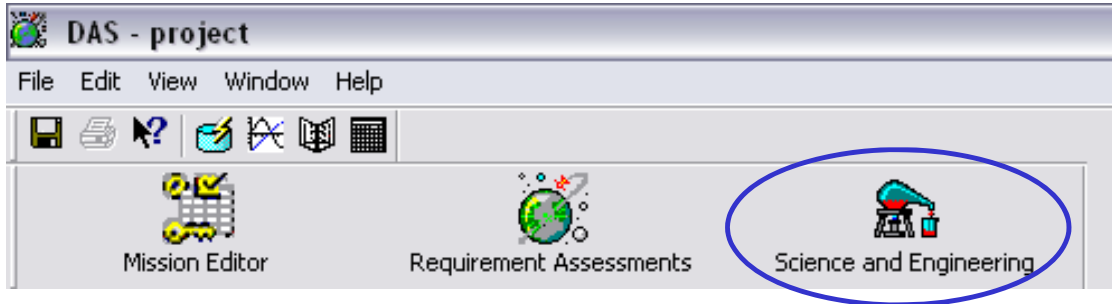
DCA for each object is calculated as follows:

- $DCA = (0.6 + \sqrt{A})^2$ 
  - Additional area accounts for presence of person in proximity to reentering object
  - Area defined for each shape as:
    - Spheres →  $A = \pi*r^2$     Cylinders →  $A = L*D$
    - Flat Plates →  $A = L*W$     Boxes →  $A = \frac{1}{2}*(W*L+L*H)$

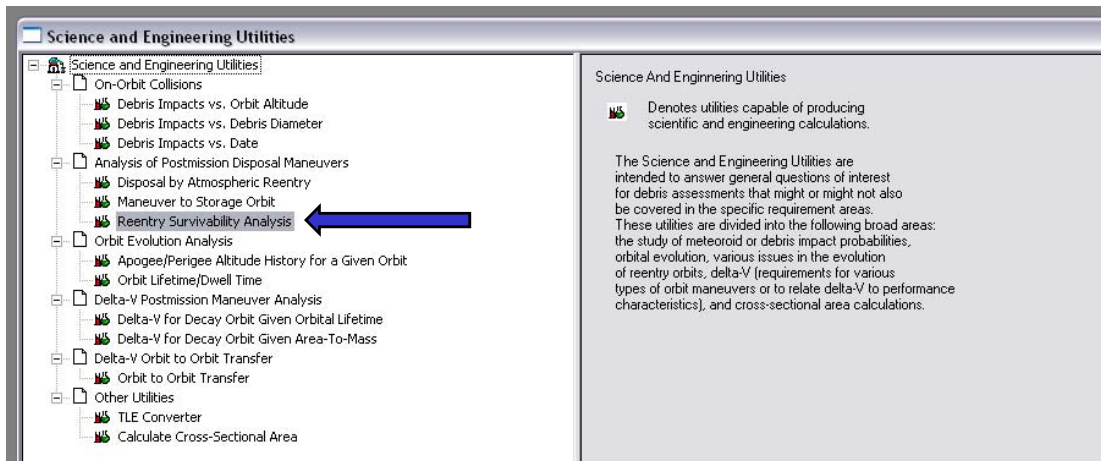


# DAS Reentry Survivability Analysis

- **Getting Started**



Select Science and Engineering



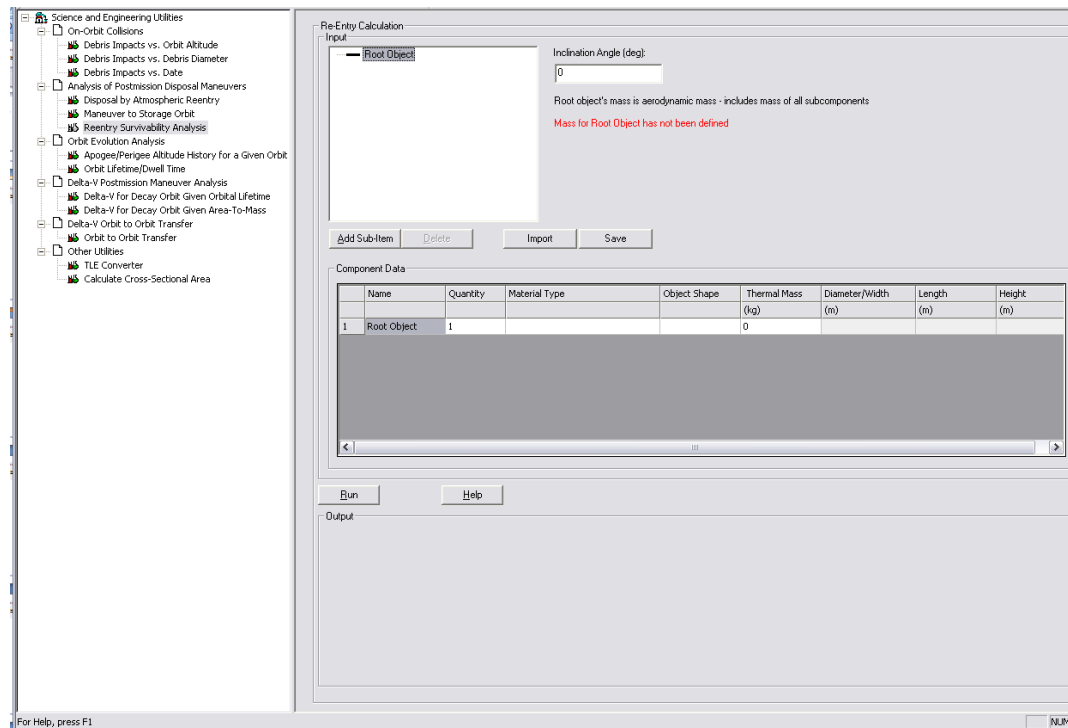
Select Reentry Survivability Analysis

- What is being illustrated in this tutorial is the use of the Science and Engineering menu
  - Any significant differences between it and the Requirements Assessment menu will be highlighted



# DAS Reentry Survivability Analysis

- **Object Modeling**



- The “Root Object” is the overall vehicle being analyzed
  - The mass of this object is the total mass of the entire vehicle
  - This object is used only to propagate the trajectory from 122 km to 78 km altitude
- Here the inclination is entered for the vehicle, under Requirements Assessment the inclination would have been populated using the Mission Editor value



# DAS Reentry Survivability Analysis

- **Object Modeling (cont.)**

Component Data

|   | Name        | Quantity | Material Type | Object Shape | Thermal Mass<br>(kg) | Diameter/Width<br>(m) | Length<br>(m) | Height<br>(m) |
|---|-------------|----------|---------------|--------------|----------------------|-----------------------|---------------|---------------|
| 1 | Root Object | 1        |               |              | 0                    |                       |               |               |

Material Type dropdown menu options: Acrylic, Alumina, Aluminum (generic), Aluminum 1145-H19, Aluminum 2024-T3, Aluminum 2024-T8xx

Object Shape dropdown menu options: Sphere, Cylinder, Flat Plate, Box

- Both the Material Type and Object Shape are drop down menus
  - Material Type includes all 77 built in materials representing some of the most commonly used materials
  - Object Shape lists the 4 object types used in DAS
- What if the proper material is not included?



# DAS Reentry Survivability Analysis

- Material Database

DAS - project - [Science and Engineering Utilities]

File Edit View Window Help

Mission Editor Requirement Assessments Science and Engineering

Standard Material List

| Row | Material Name      | Density (kg/m <sup>3</sup> ) |
|-----|--------------------|------------------------------|
| 1   | Alumina            | 3990                         |
| 2   | Aluminum 1145-H19  | 2697                         |
| 3   | Aluminum 2024-T3   | 2803.2                       |
| 4   | Aluminum 2024-T8xx | 2803                         |
| 5   | Aluminum (generic) | 2700                         |

Save Close Help

User-Defined Material

| Row | Material Name | Density (kg/m <sup>3</sup> ) | Specific Heat (J/kg-K) | Heat of Fusion (J/kg) | Melt Temperature (K) |
|-----|---------------|------------------------------|------------------------|-----------------------|----------------------|
| 1   | ULE Glass     | 123                          | 776                    | 250000                | 1760                 |
| *   |               |                              |                        |                       |                      |



# DAS Reentry Survivability Analysis

- **Material Database (cont.)**

- Allows the user to input additional materials not included in the standard list
- Requires non-temperature dependent values for material properties
- Saves materials to “matprops.csv” in the current working directory
- Adds custom material to the drop down menu in alphabetical order

The screenshot shows a window titled "Component Data" containing a table with the following columns: Name, Quantity, Material Type, Object Shape, Thermal Mass, Diameter/Width, Length, and Height. The units for Thermal Mass, Diameter/Width, Length, and Height are (kg), (m), (m), and (m) respectively. The first row shows a "Root Object" with a quantity of 1 and a thermal mass of 0. The "Material Type" column has a dropdown menu open, showing a list of materials: ULE Glass, Uranium, Uzrh, Water, Zerodur, and Zinc.

|   | Name        | Quantity | Material Type | Object Shape | Thermal Mass<br>(kg) | Diameter/Width<br>(m) | Length<br>(m) | Height<br>(m) |
|---|-------------|----------|---------------|--------------|----------------------|-----------------------|---------------|---------------|
| 1 | Root Object | 1        |               |              | 0                    |                       |               |               |

- It is important to note that the composite materials built into DAS (i.e. Graphite Epoxy) are sometimes best defined using the Material Database, as the properties of these materials can vary significantly depending on the manufacturer





# DAS Reentry Survivability Analysis

- **Object Nesting**
  - Each fragment of the vehicle can have up to 3 layers of internal fragments

Re-Entry Calculation Input

Inclination Angle (deg):

Object Nesting Diagram:

```

graph TD
    Root[Root Object] --> Battery[Battery Box]
    Root --> Frame[Frame Structure]
    Root --> Tank[Tank]
    Battery --> Cell[Battery Cell]
    Cell --> Anode[Anode]
    Cell --> Structure[Cell Inner Structure]
  
```

Buttons: Add Sub-Item, Delete, Import, Save

Component Data Table:

|   | Name                | Quantity | Material Type           | Object Shape | Thermal Mass (kg) | Diameter/Width (m) | Length (m) | Height (m) |
|---|---------------------|----------|-------------------------|--------------|-------------------|--------------------|------------|------------|
| 1 | Root Object         | 1        | Aluminum 2024-T3        | Box          | 600               | 2.0                | 3          | 1          |
| 2 | Battery Box         | 1        | Aluminum 2024-T3        | Box          | 0.85              | 0.1                | 0.1        | 0.05       |
| 3 | Battery Cell        | 6        | Stainless Steel 17-4 ph | Cylinder     | 0.035             | 0.0125             | 0.085      |            |
| 4 | Cell Inner Struc... | 6        | Copper Alloy            | Cylinder     | 0.015             | 0.012              | 0.08       |            |
| 5 | Anode               | 6        | Platinum                | Cylinder     | 0.01              | 0.01               | 0.02       |            |
| 6 | Frame Structure     | 1        | Aluminum 2024-T3        | Box          | 0.001             | 0.95               | 0.95       | 0.001      |
| 7 | Tank                | 1        | Titanium (6 Al-4 V)     | Sphere       | 85                | 1                  |            |            |

- Fragment masses should be thermal masses which do not account for the mass of any contents



# DAS Reentry Survivability Analysis

- **After entering in all component information hit “Run” to get results**
  - At this point DAS will verify the following:
    - All required fields are filled for each object
    - The entered mass does not exceed a limit defined by an object's dimensions and its material density
      - For flat plates the computed density is based on an assumed height of 1/10 the width
      - Plates that do not pass input validation or are thicker, should be modeled as boxes
    - For boxes, the values must be entered such that  $\text{Length} \geq \text{Width} \geq \text{Height}$
    - A cylinder must have a length of at least 30% of its diameter
      - If its length is less than 10% of its diameter then model it as a flat square plate of equivalent area
      - If its length is between 10% and 30% of its area then it should be modeled as a box of equivalent area
  - If any of the data is not valid, the assessment ceases and the data must be corrected before continuing



# DAS Reentry Survivability Analysis

## • Results

| Object      | SubComponent       | Demise        | Total Debris      | Kinetic    |
|-------------|--------------------|---------------|-------------------|------------|
| Name        | Object             | Altitude (km) | Casualty Area ... | Energy (J) |
| Root Object |                    |               | 2.21              |            |
|             | Battery Box        | 71.1          | 0.00              | 0          |
|             | Battery Cell       | 67.8          | 0.00              | 0          |
|             | Cell Inner Stru... | 67.1          | 0.00              | 0          |
|             | Annode             | 0.0           | 2.26              | 5          |
|             | Frame Structure    | 71.1          | 0.00              | 0          |
|             | Tank               | 0.0           | 2.21              | 170181     |

### Results from Science and Engineering Routine

- Gives DCA and impact Kinetic Energy for each object
- Gives total DCA of all objects which impact with a Kinetic Energy greater than 15 J

### Results from Requirements Assessment Routine

- Reports total risk for the calculated reentry year
- States whether or not compliant

| Object      | Compliance | Risk of Human | SubComponent       | Demise        | Total Debris      | Kinetic    |
|-------------|------------|---------------|--------------------|---------------|-------------------|------------|
| Name        | Status     | Casualty      | Object             | Altitude (km) | Casualty Area ... | Energy (J) |
| Root Object | Compliant  | 1:50800       |                    |               | 2.21              |            |
|             |            |               | Battery Box        | 67.5          | 0.00              | 0          |
|             |            |               | Battery Cell       | 63.7          | 0.00              | 0          |
|             |            |               | Cell Inner Stru... | 62.8          | 0.00              | 0          |
|             |            |               | Annode             | 0.0           | 2.26              | 5          |
|             |            |               | Frame Structure    | 67.5          | 0.00              | 0          |
|             |            |               | Tank               | 0.0           | 2.21              | 170182     |

Messages  
Root Object Requirement 4.7-1 Compliant



# DAS Reentry Survivability Analysis

- **Saving**
  - Modeling data and results are saved to .csv files able to be opened by Excel
  - Clicking Save in the Science and Engineering Routine allows the user to define file name and save location
  - The Requirements Assessment Routine saves the data and results to “reentry.csv” in the project directory
- **Importing**
  - Data can be entered into a .csv file and imported into DAS using Excel using the following format

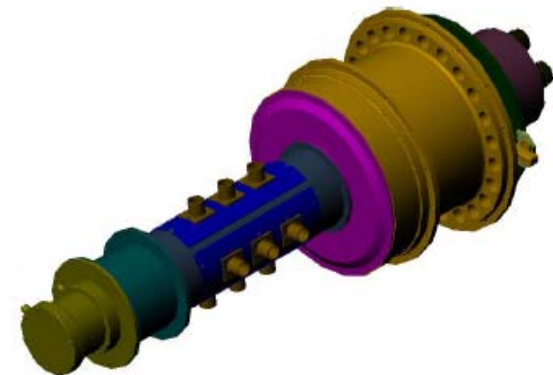
| Row Num | Name                 | Parent | Qty | Material                | Body Type | Thermal Mass | Diameter/Width | Length | Height |
|---------|----------------------|--------|-----|-------------------------|-----------|--------------|----------------|--------|--------|
| 1       | Root Object          | 0      | 1   | Aluminum 2024-T3        | Box       | 600          | 2              | 3      | 1      |
| 2       | Battery Box          | 1      | 1   | Aluminum 2024-T3        | Box       | 0.85         | 0.1            | 0.1    | 0.05   |
| 3       | Battery Cell         | 2      | 6   | Stainless Steel 17-4 ph | Cylinder  | 0.035        | 0.0125         | 0.085  |        |
| 4       | Cell Inner Structure | 3      | 6   | Copper Alloy            | Cylinder  | 0.015        | 0.012          | 0.08   |        |
| 5       | Anode                | 4      | 6   | Platinum                | Cylinder  | 0.01         | 0.011          | 0.02   |        |
| 6       | Frame Structure      | 2      | 1   | Aluminum 2024-T3        | Box       | 0.001        | 0.95           | 0.95   | 0.001  |
| 7       | Tank                 | 1      | 1   | Titanium (6 Al-4 V)     | Sphere    | 85           | 1              |        |        |

- Note if importing into the Requirements Assessment Routine, omit the first row



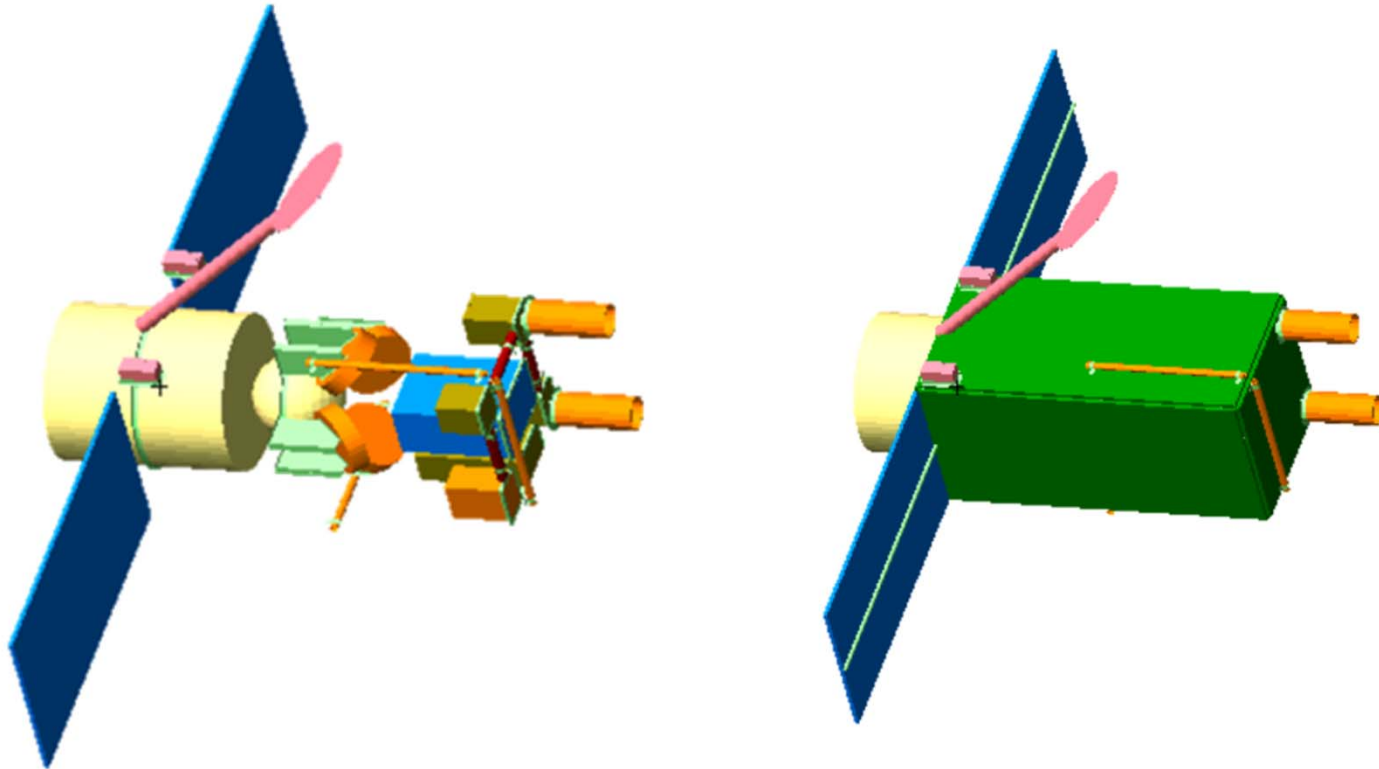
# DAS Reentry Survivability Analysis

- **Known Limitations**
  - Honeycomb Panels
    - Typically these panels consist of a layer of aluminum honeycomb sandwiched between two aluminum or composite face sheets
    - Due to the limitation of the thermal model these objects often survive a DAS reentry analysis and require higher-fidelity analysis
  - Objects with complex shapes
    - Items in this category constructed of a single material can be modeled using equivalent area simplified shapes
    - Items constructed of multiple materials are more complex and typically require higher-fidelity analysis





# Reentry Example 1 - GenSat



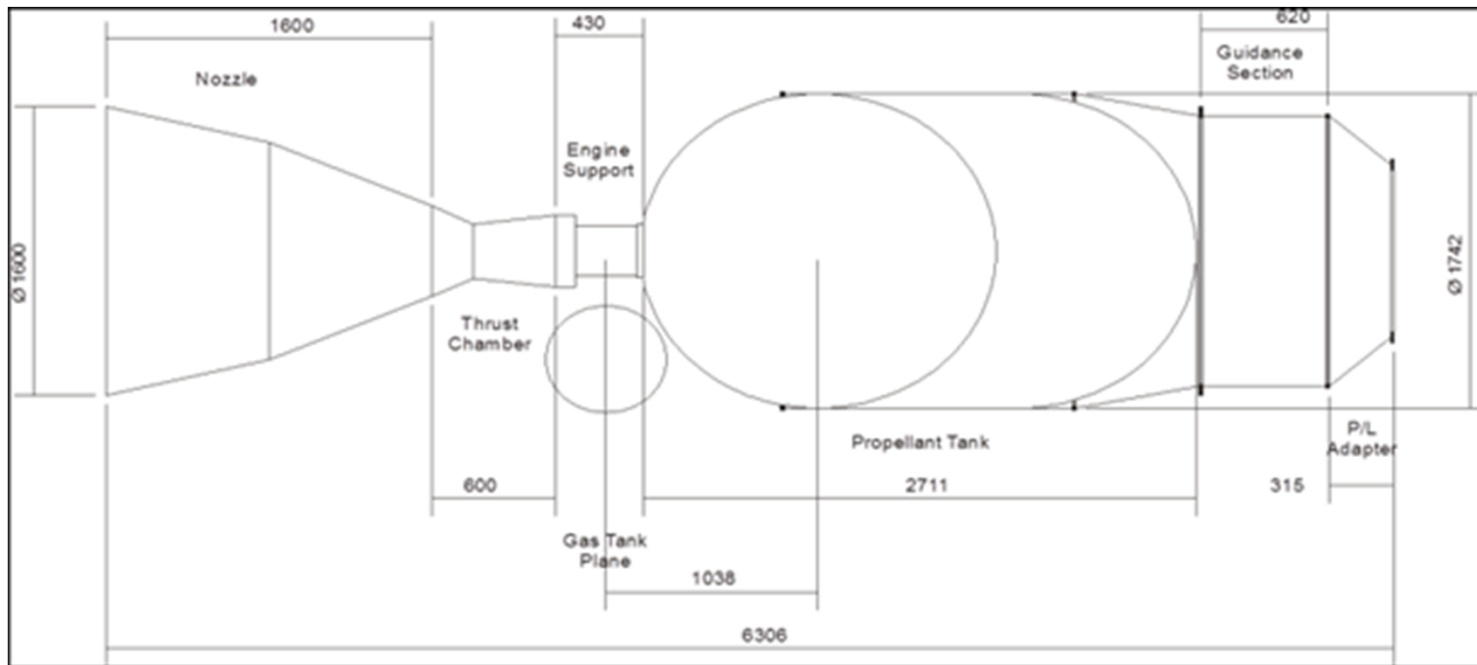
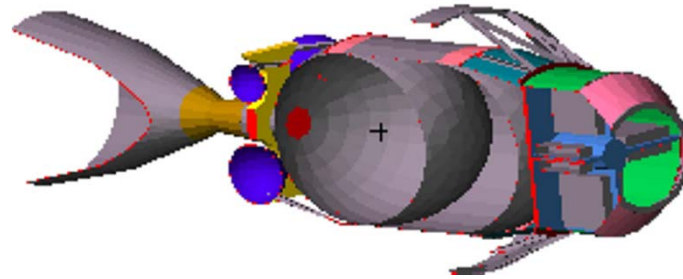


# Reentry Example 1 - GenSat

| Row Num | Name                                    | Parent | Qty | Material                  | Body Type  | Thermal Mass | Diameter/Width | Length    | Height   |            |
|---------|---|--------|-----|---------------------------|------------|--------------|----------------|-----------|----------|------------|
| 1       | GenSat                                  | 0      | 1   | Aluminum (generic)        | Box        | 391.641      | 1              | 2         | 1        |            |
| 2       | Side Panels                             | 1      | 3   | Aluminum (generic)        | Flat Plate | 14.239       | 1              | 2         | 0.0254   | Honey Comb |
| 3       | Side Panels (with cutout )              | 1      | 1   | Aluminum (generic)        | Flat Plate | 12.814       | 1              | 2         | 0.0254   | Honey Comb |
| 4       | Top Panel                               | 1      | 1   | Aluminum (generic)        | Flat Plate | 7.1196       | 1              | 1         | 0.0254   | Honey Comb |
| 5       | Mid Panel (with cutout for LH2 tank)    | 1      | 1   | Aluminum (generic)        | Flat Plate | 5.7004       | 1              | 1         | 0.0254   | Honey Comb |
| 6       | Bottom Panel (with cutout for LO2 tank) | 1      | 1   | Aluminum (generic)        | Flat Plate | 2.6134       | 1              | 1         | 0.0254   | Honey Comb |
| 7       | Solar Array Boom                        | 1      | 2   | Aluminum (generic)        | Cylinder   | 0.71859      | 0.0254         | 2.0254    | 0        |            |
| 8       | Battery Box (outer box)                 | 1      | 1   | Aluminum (generic)        | Box        | 28.655       | 0.4668         | 0.6168    | 0.3168   |            |
| 9       | Battery Box (inner frame, part 1)       | 8      | 2   | Aluminum (generic)        | Flat Plate | 3.11         | 0.295788       | 0.449984  | 0.008408 |            |
| 10      | Battery Box (inner frame, part 2)       | 8      | 1   | Aluminum (generic)        | Flat Plate | 3.154        | 0.299984       | 0.449984  | 0.008408 |            |
| 11      | Mounting Profiles (Battery Box, part 1) | 1      | 2   | Aluminum (generic)        | Flat Plate | 0.045        | 0.0254         | 0.3168    | 0.0254   |            |
| 12      | Mounting Profiles (Battery Box, part 2) | 1      | 2   | Aluminum (generic)        | Flat Plate | 0.066        | 0.0254         | 0.4668    | 0.0254   |            |
| 13      | Batteries                               | 8      | 12  | Nickel                    | Cylinder   | 1.912        | 0.145788       | 0.295788  | 0        |            |
| 14      | Solar Panels                            | 1      | 2   | Aluminum (generic)        | Flat Plate | 14.239       | 1              | 2         | 0.0254   |            |
| 15      | LH2 Tank                                | 1      | 1   | Titanium (generic)        | Sphere     | 10           | 0.5            | 0         | 0        |            |
| 16      | LO2 Tank                                | 1      | 1   | Aluminum (generic)        | Cylinder   | 38.9         | 0.8984         | 1         | 0        |            |
| 17      | Magnetic Torquer Rod                    | 1      | 3   | Iron                      | Cylinder   | 3.3336       | 0.045          | 1         | 0        |            |
| 18      | Star Tracker                            | 1      | 2   | Aluminum (generic)        | Cylinder   | 6.5009       | 0.2            | 0.45      | 0        |            |
| 19      | Reaction Wheel Assy Housing             | 1      | 4   | Aluminum (generic)        | Cylinder   | 4.36         | 0.4            | 0.1       | 0        |            |
| 20      | Reaction Wheel Flywheel                 | 19     | 4   | Titanium (generic)        | Disk       | 3.1363       | 0.3            | 0         | 0.01     |            |
| 21      | Reaction Wheel Assy Shaft               | 19     | 4   | Stainless Steel (generic) | Cylinder   | 0.22734      | 0.02           | 0.0910812 | 0        |            |
| 22      | Gyroscopes                              | 1      | 1   | Aluminum (generic)        | Box        | 9.9036       | 0.246          | 0.3295    | 0.176    |            |
| 23      | X-Band Antenna                          | 1      | 1   | Aluminum (generic)        | Disk       | 1.9813       | 0.6            | 0         | 0.0025   |            |
| 24      | X-Band Boom                             | 1      | 1   | Graphite Epoxy 1          | Cylinder   | 3.1928       | 0.09           | 1.7       | 0        |            |
| 25      | S-Band Transponder                      | 1      | 2   | Aluminum (generic)        | Box        | 3.2711       | 0.1            | 0.2       | 0.1      |            |
| 26      | Computer                                | 1      | 1   | Aluminum (generic)        | Box        | 2.0058       | 0.3            | 0.6       | 0.2      |            |
| 27      | Data Storage                            | 1      | 1   | Aluminum (generic)        | Box        | 16.989       | 0.2            | 0.25      | 0.2      |            |
| 28      | Command                                 | 1      | 1   | Aluminum (generic)        | Box        | 24.867       | 0.25           | 0.4       | 0.15     |            |
| 29      | Telemetry                               | 1      | 1   | Aluminum (generic)        | Box        | 10.383       | 0.2            | 0.3       | 0.2      |            |
| 30      | Louvers (Blades)                        | 1      | 6   | Aluminum (generic)        | Flat Plate | 0.070075     | 0.05           | 0.5       | 0.001    |            |
| 31      | Louvers (Shafts)                        | 1      | 6   | Aluminum (generic)        | Cylinder   | 0.019021     | 0.005          | 0.54      | 0        |            |
| 32      | Louvers (Frame, part 1)                 | 1      | 2   | Aluminum (generic)        | Flat Plate | 0.057181     | 0.02           | 0.34      | 0.003    |            |
| 33      | Louvers (Frame, part 2)                 | 1      | 2   | Aluminum (generic)        | Flat Plate | 0.08409      | 0.02           | 0.5       | 0.003    |            |
| 34      | Cold Plate                              | 1      | 1   | Aluminum (generic)        | Flat Plate | 13.072       | 0.34           | 0.54      | 0.0254   |            |
| 35      | Space Radiator                          | 1      | 1   | Aluminum (generic)        | Flat Plate | 4.2045       | 0.3            | 0.5       | 0.01     |            |
| 36      | Cable                                   | 1      | 3   | Copper Alloy              | Cylinder   | 10.937       | 0.06           | 0.5       | 0        |            |



# Reentry Example 2 – Generic Upper Stage







## Reentry Example 2 – Generic Upper Stage

| Row Num | Name                 | Parent | Qty | Material              | Body Type | Thermal Mass | Diameter/Width | Length | Height |
|---------|----------------------|--------|-----|-----------------------|-----------|--------------|----------------|--------|--------|
| 1       | Parent               | 0      | 1   | Aluminum (generic)    | Cylinder  | 924.343      | 6.3            | 1.8    | 0      |
| 2       | Propellant Tank      | 1      | 1   | Stainless Steel (gene | Cylinder  | 267.675      | 2.7            | 1.7    | 0      |
| 3       | Thrust Chamber       | 1      | 1   | Inconel               | Cylinder  | 45.8         | 0.6            | 0.44   | 0      |
| 4       | Gas Tank 1           | 1      | 2   | Titanium (generic)    | Sphere    | 10.056       | 0              | 0.41   | 0      |
| 5       | Gas Tank 2           | 1      | 2   | Titanium (generic)    | Sphere    | 30.548       | 0              | 0.59   | 0      |
| 6       | Nozzle               | 1      | 1   | Graphite Epoxy 1      | Cylinder  | 99.594       | 1.6            | 1      | 0      |
| 7       | Engine Support       | 1      | 1   | Aluminum (generic)    | Cylinder  | 52.175       | 0.43           | 0.3    | 0      |
| 8       | Guidance Electronics | 1      | 8   | Aluminum (generic)    | Box       | 10.337       | 0.45           | 0.5    | 0.1    |