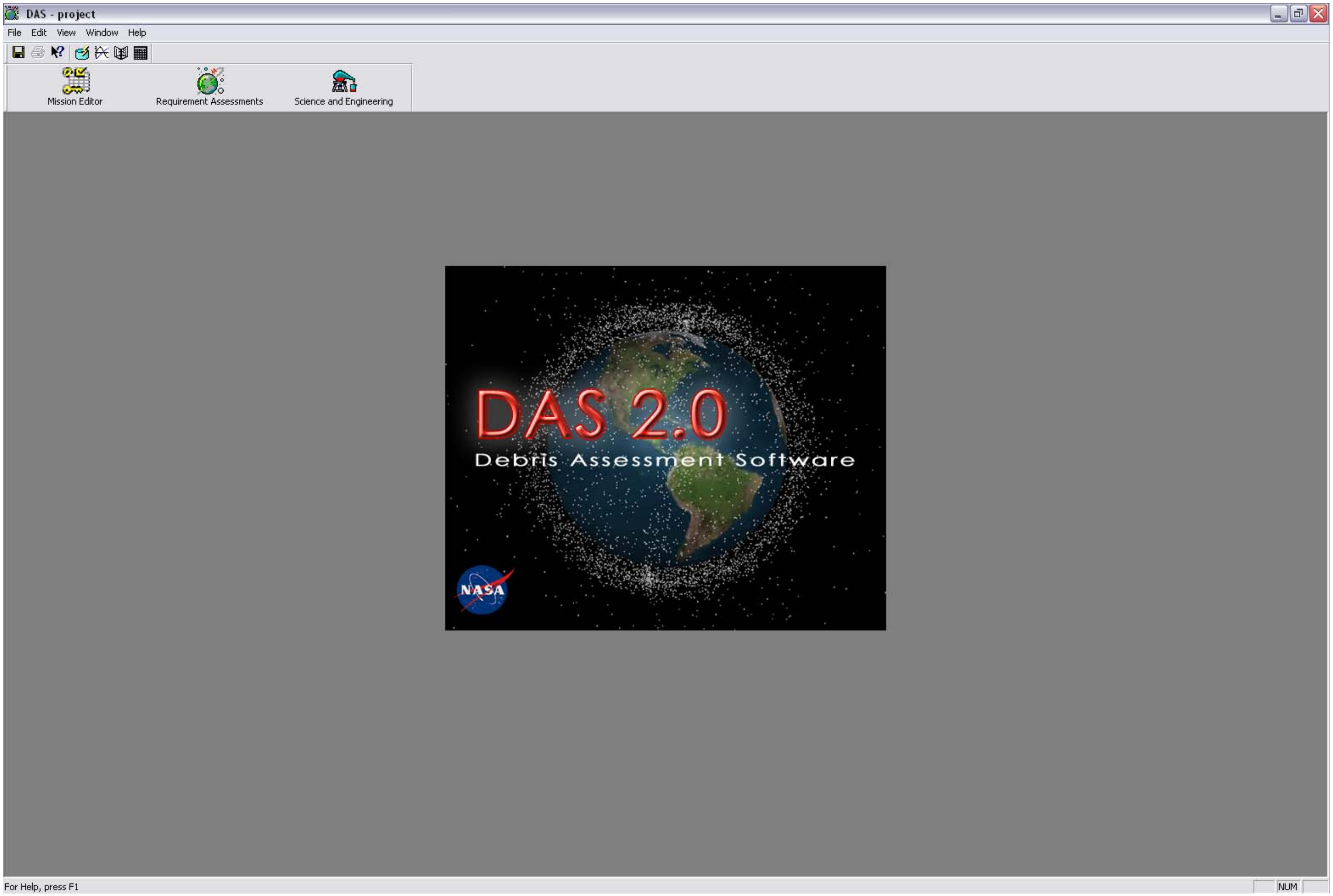
DAS Reentry Survivability Analysis



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 asses the risk associated with uncontrolled reentry**
- **DAS's Reentry Survivability Tool is intended as "1st 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 1st 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:

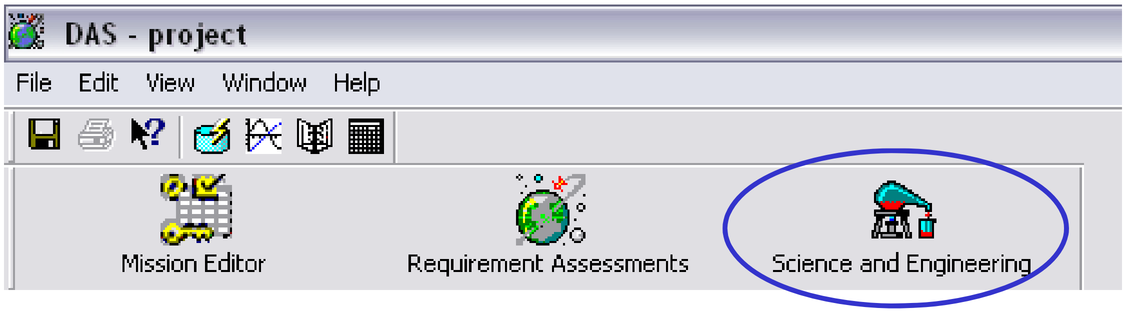
- $DCA = (0.6 + \sqrt{A})^2$
  - Additional area accounts for presence of person in proximity to reentering object
  - Area defined for each shape as:

    Spheres → $A = \pi * r^2$ Cylinders → $A = L*D$

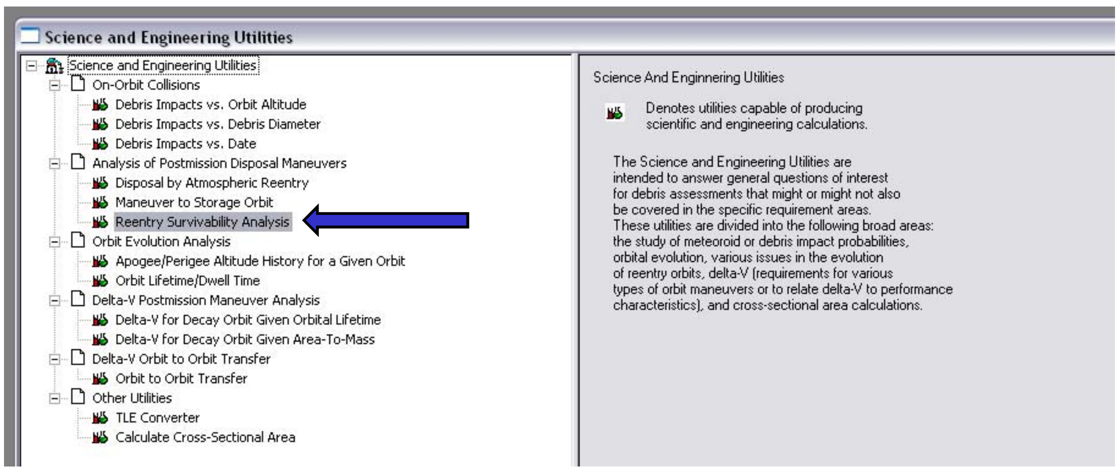
    Flat Plates → $A = L*W$ Boxes → $A = ½*(W*L+L*H)$

DAS Reentry Survivability Analysis

- **Getting Started**



Select Science and Engineering

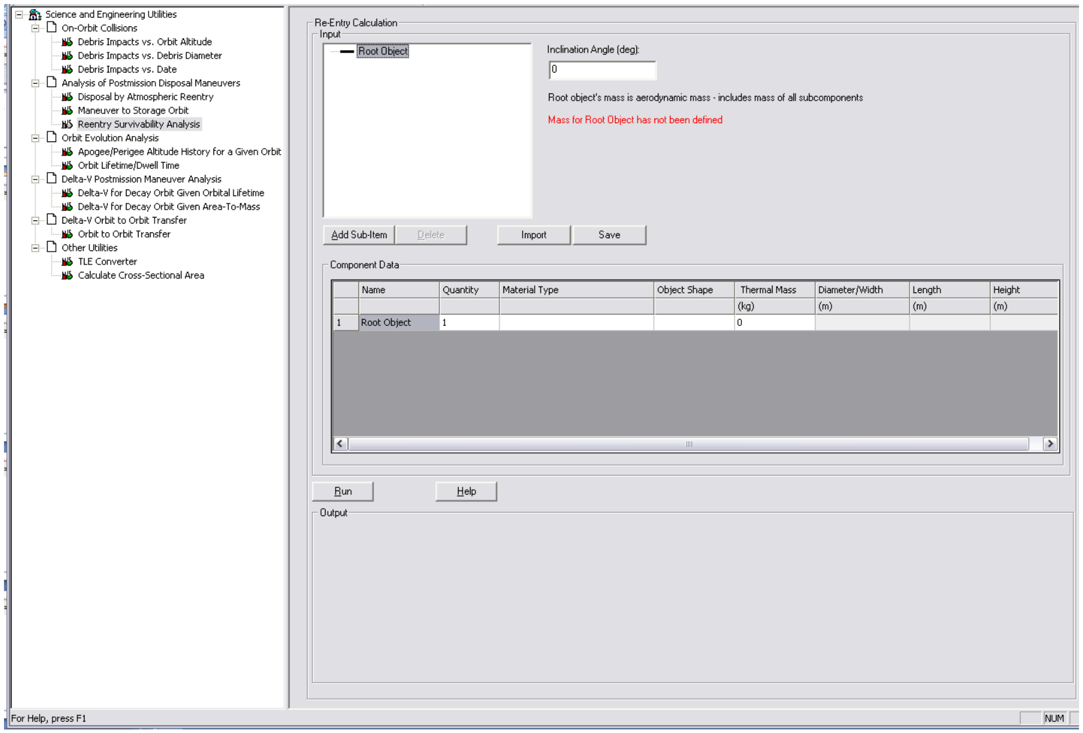


Select Reentry Survivability Analysis

- 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

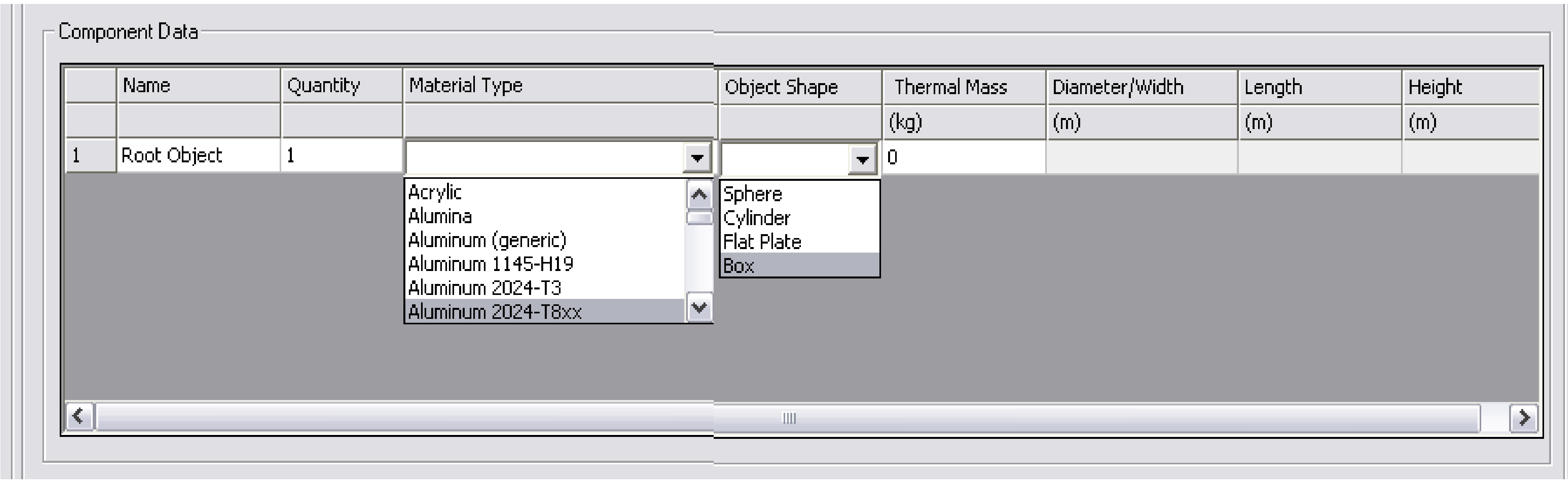
- **Object Modeling**



- 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

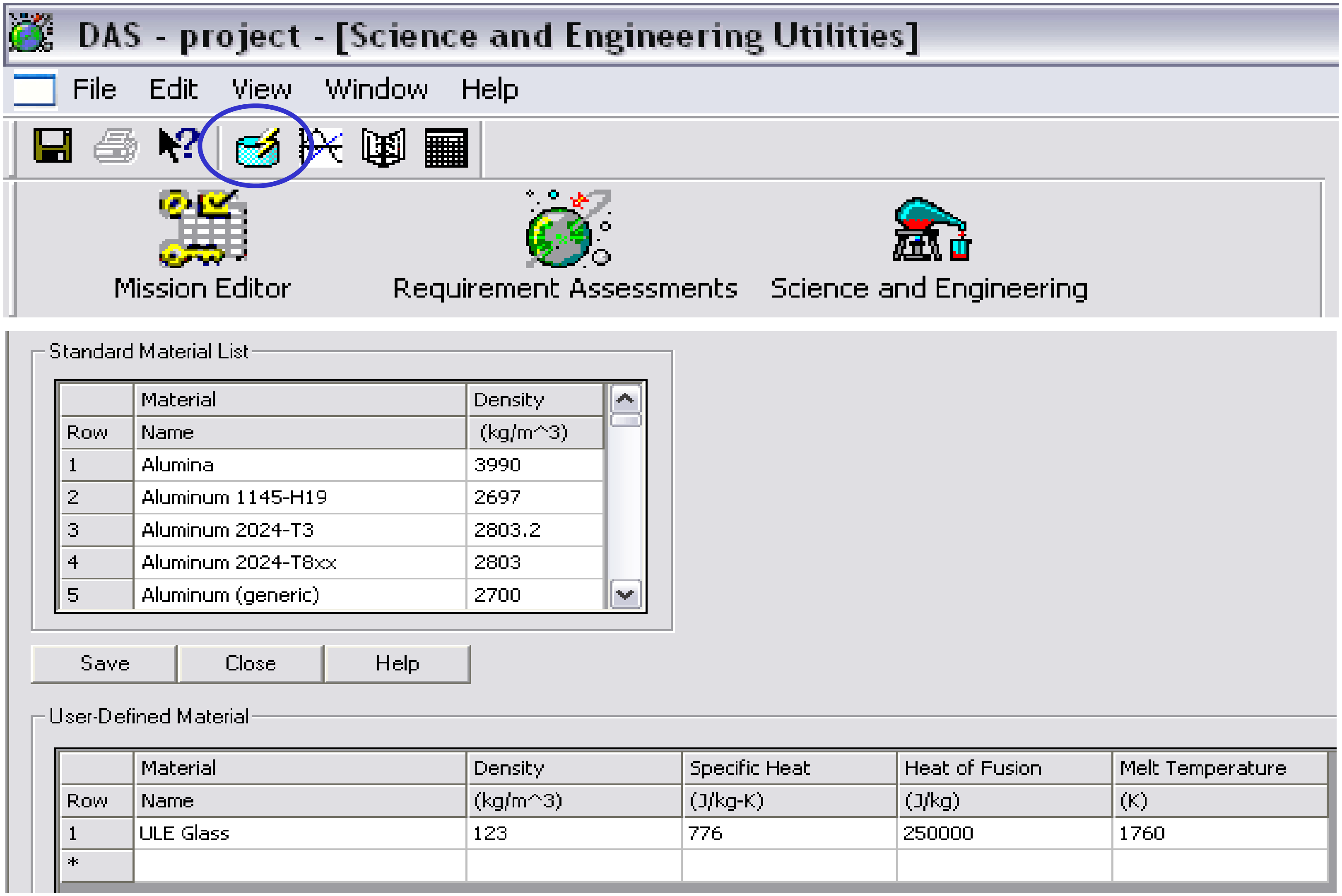
- **Object Modeling (cont.)**



- 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**

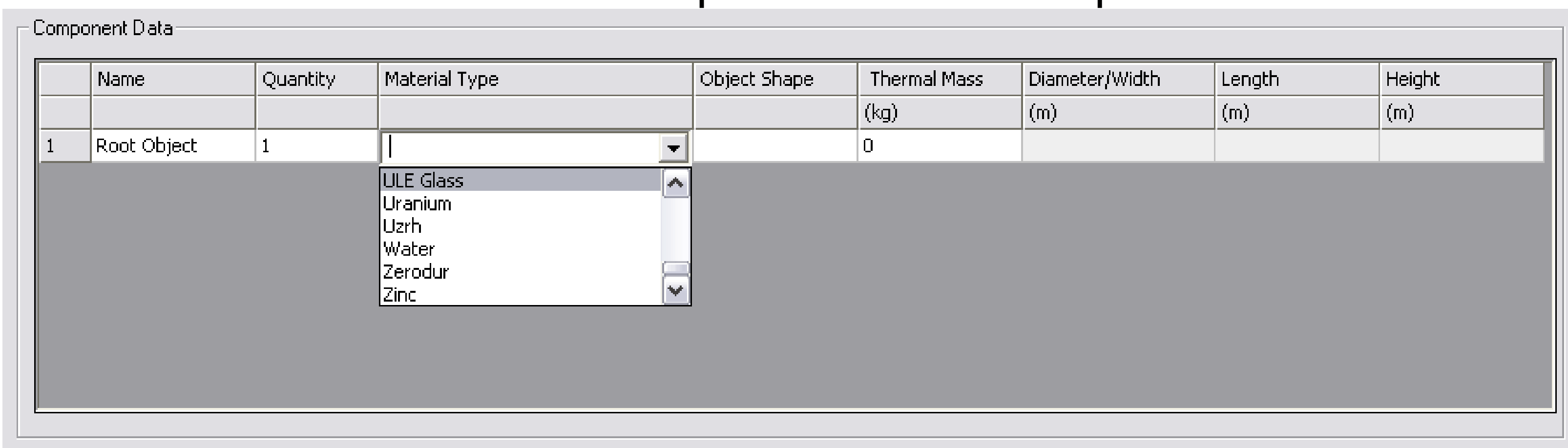


Row	Material Name	Density (kg/m^3)
1	Alumina	3990
2	Aluminum 1145-H19	2697
3	Aluminum 2024-T3	2803.2
4	Aluminum 2024-T8xx	2803
5	Aluminum (generic)	2700

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

DAS Reentry Survivability Analysis

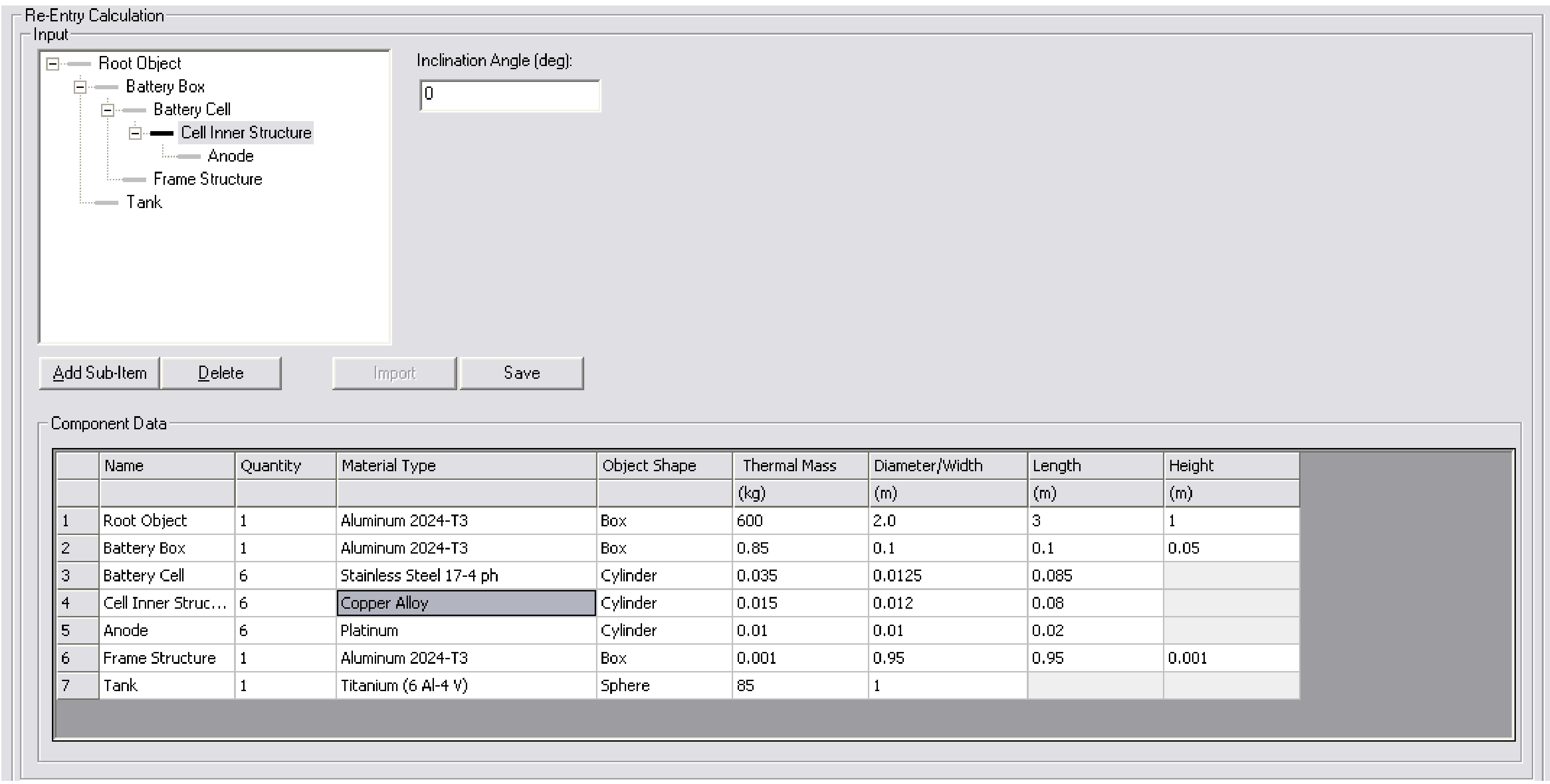
- **Material Database (cont.)**
  - Allows the user to input additional materials not included in the standard list
  - Requires non-temperature dependent values for material properties
  - Saves materials to “matprops.csv” in the current working directory
  - Adds custom material to the drop down menu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



  - 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



	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 and 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 Length ≥ Width ≥ 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 than 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**

Output

Object Name	SubComponent Object	Demise Altitude (km)	Total Debris Casualty Area ...	Kinetic 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

Output

Object Name	Compliance Status	Risk of Human Casualty	SubComponent Object	Demise Altitude (km)	Total Debris Casualty Area ...	Kinetic 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

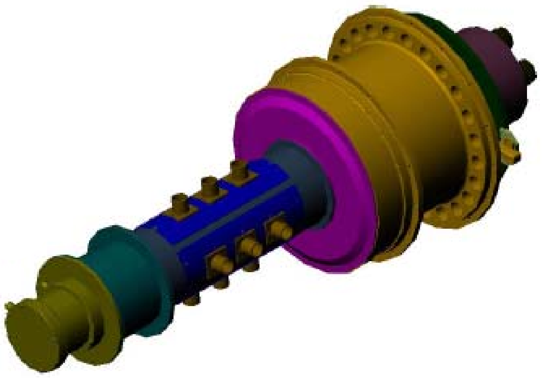
- **Saving**
  - Modeling data and results are saved to .csv files able to be opened by Excel
  - Clicking Save in the Science and Engineering Routine allows the user to define file name and save location
  - The Requirements Assessment Routine saves the data and results to “reentry.csv” in the project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

Reentry Data									
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		

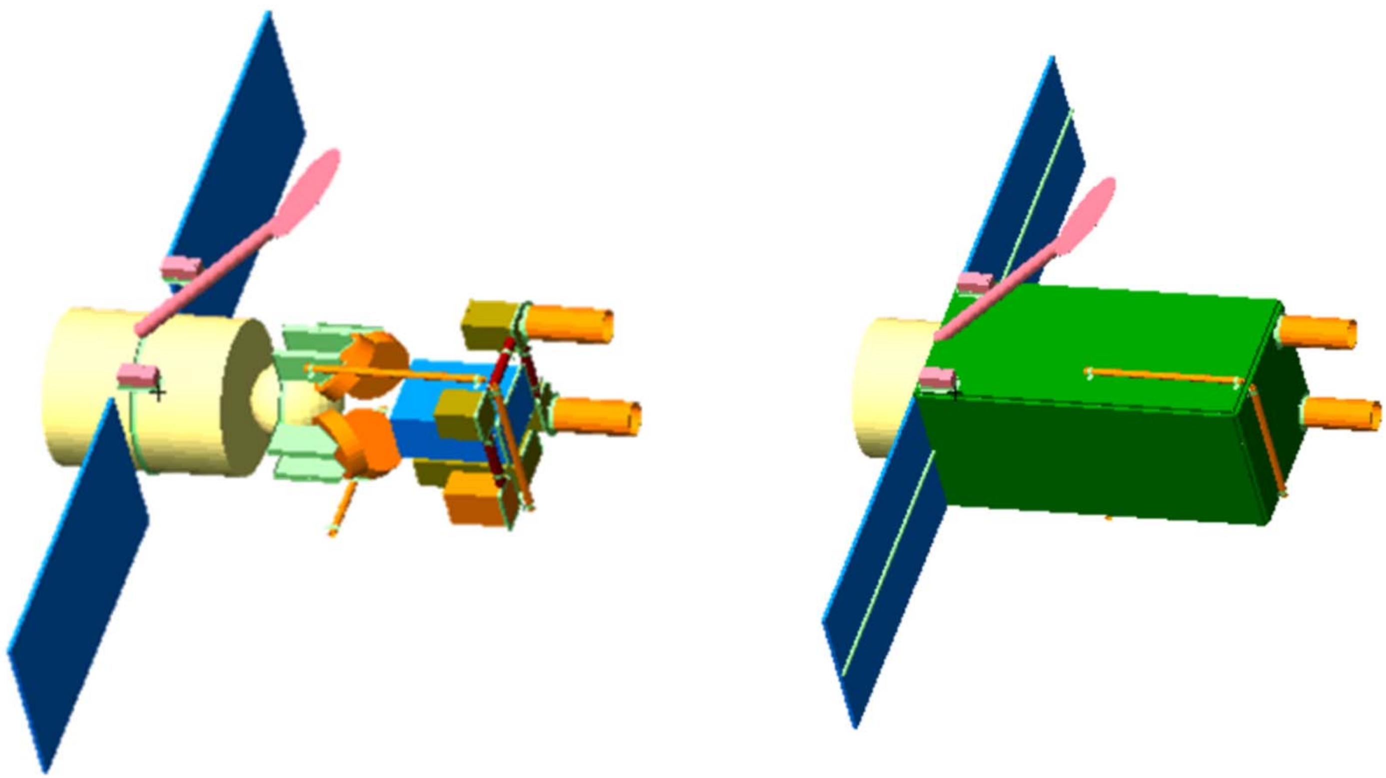
  - Note if importing into the Requirements Assessment Routine, omit the first row

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



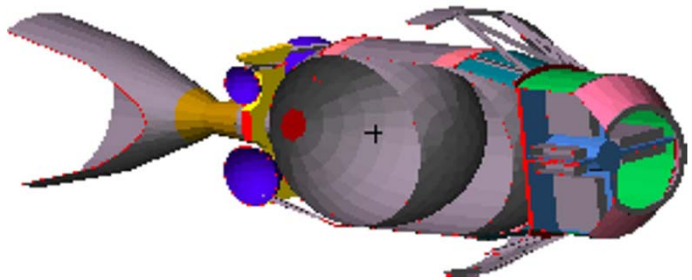
Reentry Example 1 - GenSat

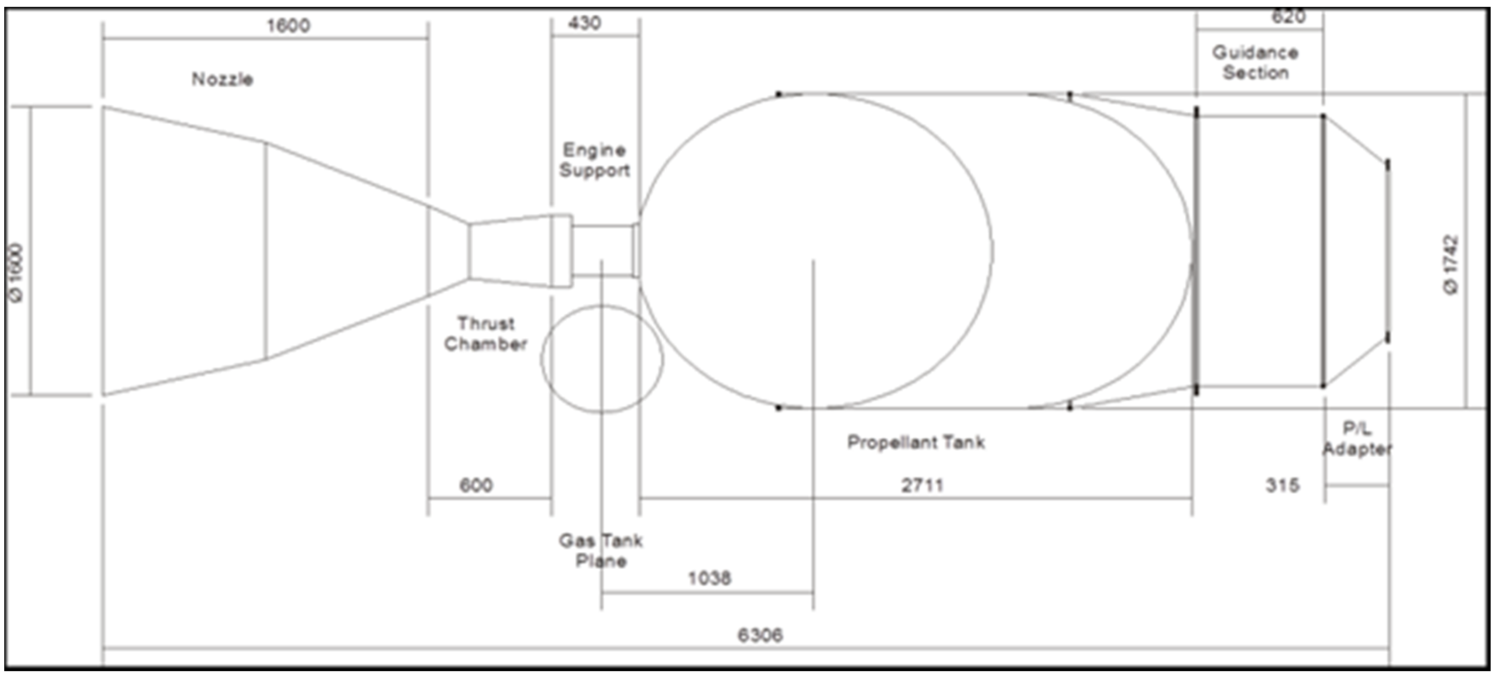


Reentry Example 1 - GenSat

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