



# **ORSAT Modelling and Assessment**

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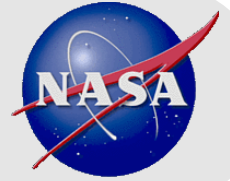
# Outline

- **ORSAT Models**
  - Aerodynamics
  - Aerothermodynamics
  - Trajectory
  - Heat transfer & conduction
  - Casualty Area
  - Risk calculation
- **ORSAT Assessment Workflow**
  - Fragment list
  - Input generation
  - Input visualization
  - Running ORSAT
  - Reconciling independent analyses
- **Conclusions and Future Work**



# ORSAT Overview

- ORSAT has six modules (trajectory, atmosphere, aerodynamics, aerothermodynamics, thermal, debris casualty area/risk)
- Basic method of input is to obtain trajectory data at entry interface and component data (dimensions, mass, & material) before starting analysis
- Central theme is that integrated heat load or absorbed heat is computed over time during entry; when this value exceeds material heat of ablation, object is considered to demise
- If object survives, ORSAT predicts debris casualty area and risk to humans on ground
- Parent body breakup altitude is assumed (normally 78 km - based on Aerospace observations) but can be varied



## ORSAT Overview (Cont'd.)

- **Aerothermal, ablation-only code**
- **Conventional material models**
  - Currently no charring, cracking, or pyrolysis modules



## ORSAT Overview (Cont'd.)

- Hierarchy of components is critical to input
- Components are modelled using a set of 10 shape primitives and 80+ aerospace materials
- Key output in ORSAT analysis is plot of demise altitude vs. downrange of all components
- Sample plot of sample spacecraft component demise altitudes shown in next slides
- For targeted entry, ORSAT can provide ground track of latitude vs. longitude



# Preprocessing

- Automatic generation of ORSAT input file from parts list
- Color coding by 'demise score'
- Non-standard materials easily incorporated

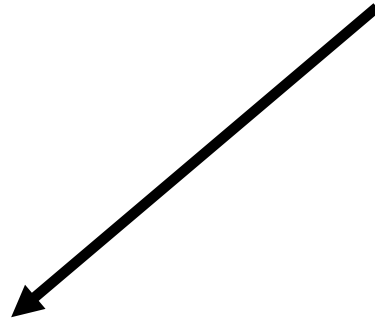
Microsoft Excel screenshot showing a parts list with columns for Name, Aero Mass, Material, Body Type, Thermal Mass, Diameter/Width, Length, Height, Thickness, Nodes, and Quantity. The data is color-coded by 'demise score' (Normal, Bad, Good, Neutral, Calculation, Check Cell, Explanatory..., Input, Linked Cell, Note).

1	Name	Aero Mass	Material	Body Type	Thermal Mass	Diameter/Width	Length	Height	Thickness	Nodes	Quantity	L	M	N	O	P	Q	R	S	T	U	V	W
2	Humphrey	11.976	Aluminum (generic)	Box	11.976	0.200	0.300	0.200	0.016	23	1												
3	Battery Box	0.500	Aluminum (generic)	Box	1.511	0.090	0.120	0.060	0.019	29	1												
4	Battery	0.048	Stainless Steel (generic)	Cylinder	0.048	0.019	0.065		0.002	2	15												
5	Telescope	1.000	Aluminum 7075-T6	Cylinder	1.000	0.080	0.150		0.011	16	2												
6	Lens	0.110	ULE Glass (Corning 7971)	Flat Plate	0.000	0.080	0.080			1	2												
7	Electronics radiator	0.043	Steel AISI 304	Box	0.043	0.050	0.050	0.002	0.001	1	1												
8	Motherboard	0.200	Fiberglass	Flat Plate	0.000	0.150	0.200			1	3												
9	Solar Cell 1	0.100	GaAs	Flat Plate	0.000	0.200	0.300			1	1												
10	Solar Cell 2	0.067	GaAs	Flat Plate	0.000	0.200	0.200			1	1												
11	Solar Cell 3	0.050	GaAs	Flat Plate	0.000	0.100	0.300			1	1												
12	Rxn Wheel	0.100	Lead Element	Cylinder	0.100	0.076	0.025		0.001	2	4												
13	Coolant Tank	0.080	Aluminum 6061-T6	Sphere	0.080	0.095			0.001	1	1												
14	Coolant	0.500	Water	Sphere	0.000	0.090				1	1												
15	Cold Gas Tank	0.600	Stainless Steel (generic)	Sphere	0.600	0.095			0.003	4	2												
16	Piping	0.068	Aluminum (generic)	Cylinder	0.068	0.020	0.100		0.006	8	4												
17																							



# Input Visualization

- New visualization tool allows us to see what ORSAT thinks each object looks like (in piece-by-piece view):



```

Command Prompt - more inputin
0 IBATCH
0 IFAVRID
1 IATMOS
0 IENG
-----
62 NPRAG
Spacecraft structure
ITYPEF
3 NNODF
1 KROREF
1 NMAIF
3 INNF
8 0 0 0 IMATF
0.189 ROPF
0.186749476 RIF
1.14 DAEROF
1.14 DHERIF
0.802 LAEROF
0.802 LHERIF
0.378 HAEROF
0.378 HHERIF
26.61 MASSF
0 THMASSF
78000 ASTARIF
9999 ISTOPF
1 THM
1 IOS
1 IRR
0 IRAD
1 FACT
0.5 TAU
500 IINIT
-----
Spacecraft top deck
9 ITYPEF
1 NNODF
More (4%)
    
```

Component 1: A large circular structure with concentric rings of green, blue, yellow, and pink.

Component 2: A smaller circular structure with concentric rings of blue, green, and pink.

Component 3: A circular structure with a grey outer ring and a white center.

Component 4: A small black square.

Component 5: A grey cone.

Component 6: A vertical rectangular structure with three vertical stripes of green, red, and yellow.

Component 7: A horizontal rectangular structure with a black border and a light blue interior.

Component 1: Layers 1 : Collector/Scanner  
Layers 2 : Starboard apert 3  
Layers 3 : Solar Cells  
Resolution : 1

Component 2: Layers 1 : Starboard  
Layers 2 : Starboard apert 3  
Layers 3 : Starboard  
Resolution : 1

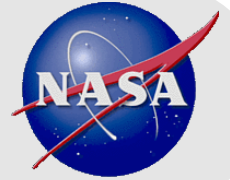
Component 3: Layers 1 : Antenna 1145-115  
Layers 2 : Antenna 1145-115  
Layers 3 : Antenna 1145-115  
Resolution : 1

Component 4: Layers 1 : Mast/Reflex  
Resolution : 1

Component 5: Layers 1 : Antenna 1145-115  
Resolution : 1

Component 6: Layers 1 : Starboard apert 1  
Layers 2 : Starboard apert 2  
Resolution : 1

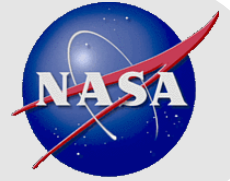
Component 7: Layers 1 : Mast/Reflex  
Layers 2 : Mast/Reflex  
Resolution : 1



# Running ORSAT

- **Standard initial conditions are used to begin simulation**
  - 0.1-deg. FPA at 122 km reentry interface
  - 78 km breakup altitude for parent objects
- **Objects propagated until demise or ground impact**
- **Fragments that show low-altitude demise, or high total thermal load typically re-run, varying initial conditions to determine most likely outcome**



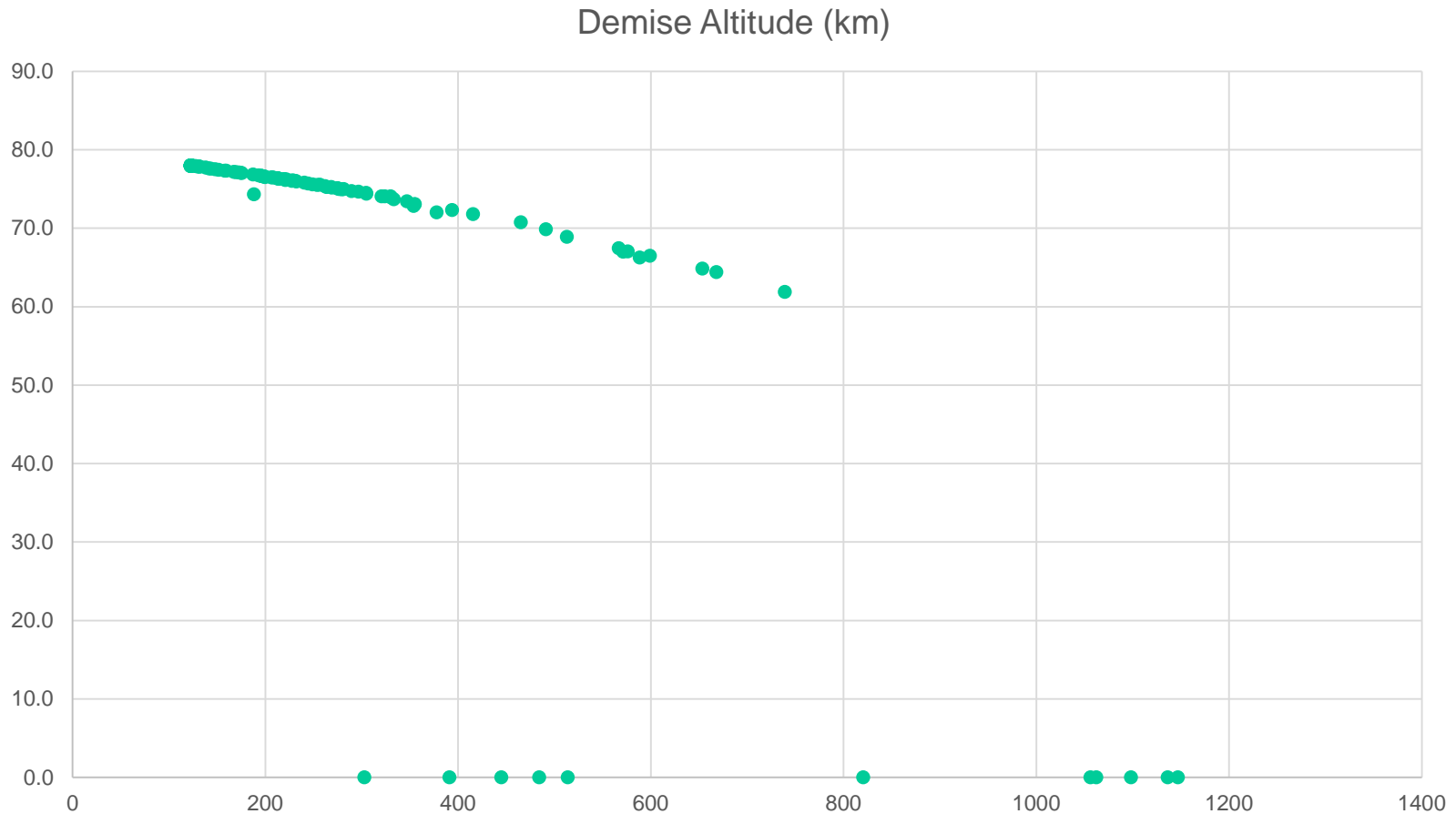


# Independent Analyses

- **Each ORSAT project is assessed by two analysts**
  - End-to-end independent analysis to ensure most accurate outcome
  
- **Results are compared, differences reconciled, and finalized**
  - Modelling assumptions challenged and defended
  - Analyzed geometry examined for similarity to as-built components
  - Any differences and rationale are archived for future review and reference



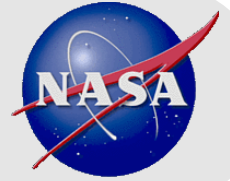
# Demise Altitude vs. Downrange for Example Spacecraft





## Future Work

- **ORSAT and DAS updates**
  - Updated NS 8719.14, Process for Limiting Orbital Debris
    - **Currently under revision by NASA**
  - Increased automation of ORSAT process
    - **Develop database of sample object reentries to estimate likelihood of survival prior to any analysis**
  - Probabilistic risk assessment and Parametric Studies



## Future Work (Cont'd.)

- **Adding new aerospace materials to database**
- **Continue Latitude Bias research**
  - Distribution of FPA at entry interface
- **New CFRP and GFRP model development**
  - Supported by plasma and arcjet testing in 2018
- **Characterizing high-altitude pyrolysis effects**

