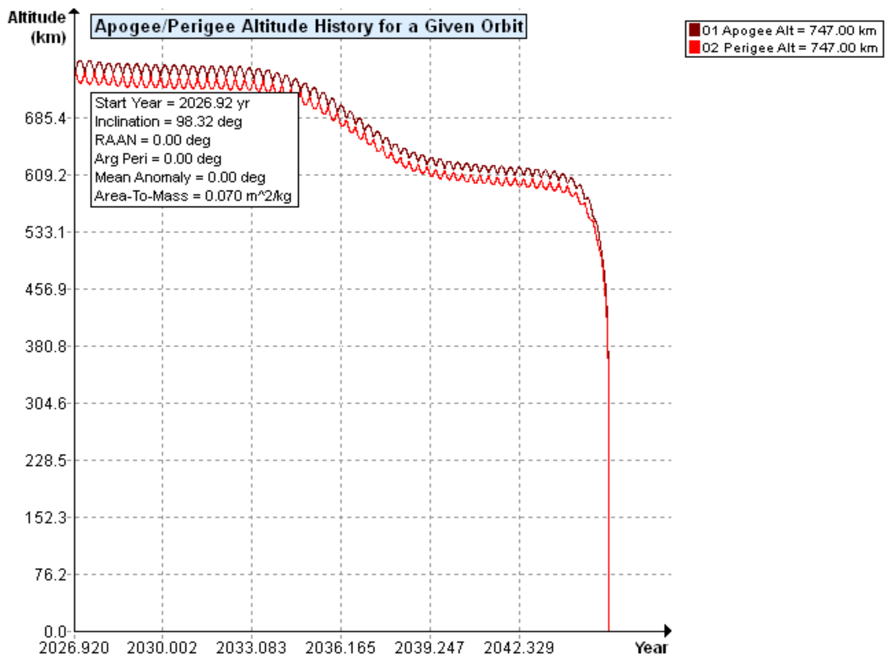
General Atomics Responses to FCC Questions Regarding OTB-3 Satellite ODAR

June 2, 2021

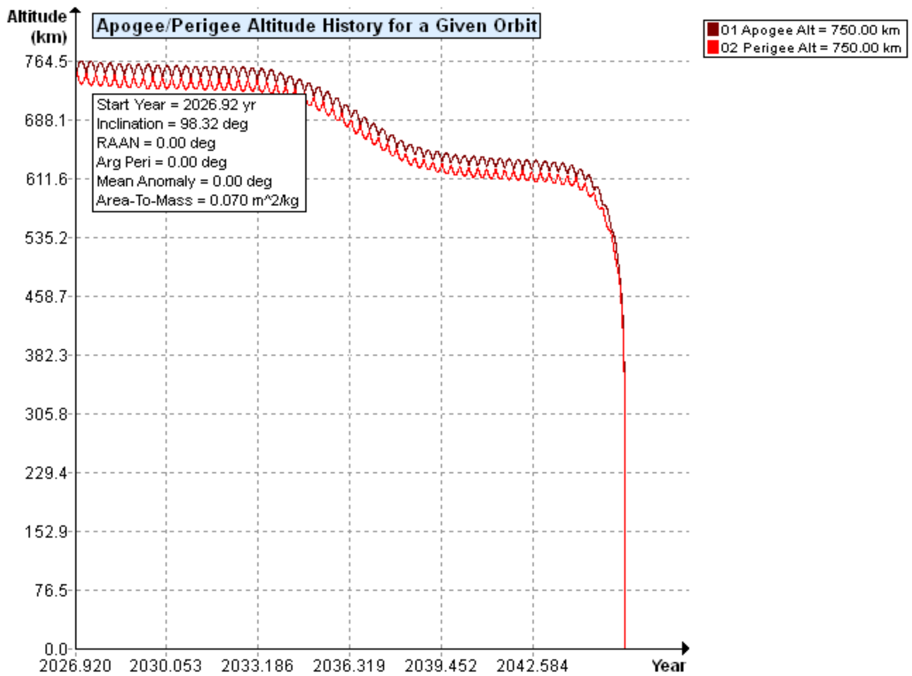
Provided below are responses to the FCC's email inquiries in the 1064-EX-CN-2020 application proceeding.[1] The FCC questions are specified below in bold.

1. **What is the expected altitude of the spacecraft after the 5-year mission completes, prior to deployment of the dragsail?**
   The expected orbital altitude of OTB-3 after completion of the five-year mission is roughly 747 km, assuming deployment of OTB-3 at the targeted 750 km orbital altitude.



Deorbit Plot from 747 km

[1] *See* Email from Doug Young, FCC, to Victor Gomez, General Atomics (May 6, 2021); Email from Doug Young, FCC, to Victor Gomez, General Atomics (May 13, 2021).



Deorbit Plot from 750 km

2. **Additionally, how would the change in timeframe affect collision risk and orbital lifetime during the end-of-life deorbit phase?**
   There are no material differences in terms of collision risk and orbital lifetime between de-orbiting at 750 km and 747 km.

3. **Is the deployment altitude of 750 km required by mission contract or would a lower initial altitude be sufficient?**
   Deployment of OTB-3 at the targeted 750 km altitude is required per mission contract.

4. **What, if any, design-for-demise considerations were taken into account during the design of the spacecraft?**
   General Atomics incorporated a combination of heritage and design-for-demise approaches when designing OTB-3. For example, the OTB-3 structure and materials were considered for design-for-demise:
   - General construction avoids the use of a singular "uni-body" design and metal plates of significant density so that the plating can separate upon re-entry impact, and properly combust. The OTB-3 spacecraft construction consists of light aluminum framing with exterior skins that will allow for this kind of destruction.
   - Materials with reasonable melting points were employed where possible to ensure combustion upon re-entry. Materials with high melting points were used only in small quantities or were not used at all.
   - Use of radioactive materials was avoided.

   Additional details are provided in the response to question 5 below.

5. **Please provide a detailed breakdown of the 6 unique surviving components of the spacecraft to include, at a minimum: all material types in the component, % of the component by material type, mass of the material type used in the component.**
   General Atomics revisited the DAS simulation and increased the fidelity of the models for the components that were previously shown to survive re-entry. The revised Table 7, identifying the major components of the spacecraft, is provided below. For the FCC's convenience, General Atomics has highlighted the cells containing revised or new data.

Updated Table 7:

No.	Name	Qty	Material	Body Type	Mass [kg]	Diameter or Width [m]	Length [m]	Height [m]	Demise Alt [km]	DCA [m^2]	KE [J]
1	**OTB-3**	1	Aluminum (generic)	Box	120	0.574	0.859	0.574		1.49	
2	**MLB**	1	Aluminum (generic)	Box	2.76	0.381	0.381	0.053	71.5		
3	**Avionics Bay**	1	Aluminum (generic)	Box	2.078	0.515	0.555	0.3	76.7		
4	Harness	1	Copper Alloy	Flat Plate	7.15	0.2	0.4		62.1		
5	Magnetorquers	3	Aluminum (generic)	Box	0.5	0.2	0.2	0.2	75.4		
6	10SP Reaction Wheel	3	Aluminum (generic)	Cylinder	1	0.104	0.102		69		
7	Battery	1	Aluminum (generic)	Box	4.4	0.159	0.221	0.068	61		
8	Avionics Bay Fasteners	1	Aluminum (generic)	Box	4	0.2	0.2	0.2	66.8		
9	**Avionics Stack**	**1**	**Aluminum (generic)**	**Box**	**2.4**	**0.515**	**0.547**	**0.288**	**75.1**		
10	PIU Tray	1	Aluminum (generic)	Box	0.6	0.294	0.322	0.033	73.6		
11	PIU Board	2	Fiberglass	Flat Plate	0.7	0.286	0.314		71.2		
12	AIM Tray	1	Aluminum (generic)	Box	0.6	0.294	0.322	0.033	73.6		
13	AIM Board	2	Fiberglass	Flat Plate	0.7	0.286	0.314		71.2		
14	ASM Tray	1	Aluminum (generic)	Box	0.6	0.294	0.322	0.033	73.6		
15	ASM Board	2	Fiberglass	Flat Plate	0.7	0.286	0.314		71.2		
16	S-Band Tx/Rx Tray	1	Aluminum (generic)	Box	0.6	0.294	0.322	0.033	73.6		
17	S-Band Tx/Rx Board	2	Fiberglass	Flat Plate	0.7	0.286	0.314		71.2		
18	OBC 750 Tray	1	Aluminum (generic)	Box	0.6	0.294	0.322	0.033	73.6		
19	OBC 750 Board	2	Fiberglass	Flat Plate	0.7	0.286	0.314		71.2		
20	PDM Tray	1	Aluminum (generic)	Box	0.6	0.294	0.322	0.033	73.5		

No.	Name	Qty	Material	Body Type	Mass [kg]	Diameter or Width [m]	Length [m]	Height [m]	Demise Alt [km]	DCA [m^2]	KE [J]
21	PDM Board	1	Fiberglass	Flat Plate	1.2	0.286	0.314		69.1		
22	BCM Tray	1	Aluminum (generic)	Box	0.6	0.294	0.322	0.033	73.6		
23	BCM Board	1	Fiberglass	Flat Plate	1.7	0.286	0.314		67.9		
24	Tie Rods	8	Titanium (6 Al-4 V)	Cylinder	0.066	0.008	0.3		71.4		
25	**Lower Payload Bay**	1	Aluminum (generic)	Box	8.489	0.547	0.547	0.4	73		
26	Argos RPU	1	Aluminum (generic)	Box	14.37	0.304	0.305	0.2	0	0.77	21958
27	HDRM	2	Aluminum (generic)	Cylinder	0.66	0.12	0.093		67.7		
28	Magnetometers	2	Aluminum (generic)	Box	0.215	0.061	0.099	0.05	70.4		
29	Lower Payload Bay Fasteners	1	Aluminum (generic)	Box	2	0.1	0.1	0.1	57.3		
30	**Upper Payload Bay**	1	Aluminum (generic)	Box	8.153	0.547	0.58	0.2	71.9		
31	L-Band Transmitter	2	Aluminum (generic)	Cylinder	1.9	0.06	0.25		60.7		
32	Filter	1	Aluminum (generic)	Box	0.4	0.068	0.1	0.063	67.6		
33	Switch	1	Aluminum (generic)	Box	0.1	0.068	0.1	0.063	70.9		
34	Diplexer	1	Aluminum (generic)	Box	0.985	0.127	0.1524	0.0508	63.8		
35	Argos TXU	1	Aluminum (generic)	Box	8.8	0.284	0.31	0.121	0	0.72	11299
36	Upper Payload Bay Fasteners	1	Aluminum (generic)	Box	2	0.1	0.1	0.1	55.6		
37	**Argos UHF Antenna**	1	Aluminum (generic)	Cylinder	2.8	0.136	0.681		73.7		
38	**S-Band Patch Antennas**	6	Aluminum (generic)	Box	0.08	0.082	0.082	0.067	77.1		
39	**Monopole antenna**	4	Aluminum (generic)	Cylinder	0.06	0.06	0.15		77.4		
40	**Argos L-Band Antenna**	1	Aluminum (generic)	Cylinder	0.29	0.057	0.263		76.1		
41	**Radiator Panels**	2	Aluminum (generic)	Flat Plate	1.9	0.58	0.7		75.2		
42	**Deployed Solar Panel**	2	Aluminum (generic)	Flat Plate	2.9	0.58	0.934		74.6		
43	**Body Solar Panel**	2	Aluminum (generic)	Flat Plate	2.02	0.55	0.55		74.1		
44	**Deorbit Sail**	1	Polyamide	Flat Plate	2.8	0.45	2.8		77.7		
45	**Sun Sensors**	2	Aluminum (generic)	Box	0.35	0.15	0.15	0.15	76.6		

No.	Name	Qty	Material	Body Type	Mass [kg]	Diameter or Width [m]	Length [m]	Height [m]	Demise Alt [km]	DCA [m^2]	KE [J]
46	**Sun Sensor Bracket**	1	Aluminum (generic)	Box	0.28	0.15	0.15	0.15	76.9		
47	**External Fasteners**	1	Aluminum (generic)	Box	6	0.2	0.2	0.2	64.1		

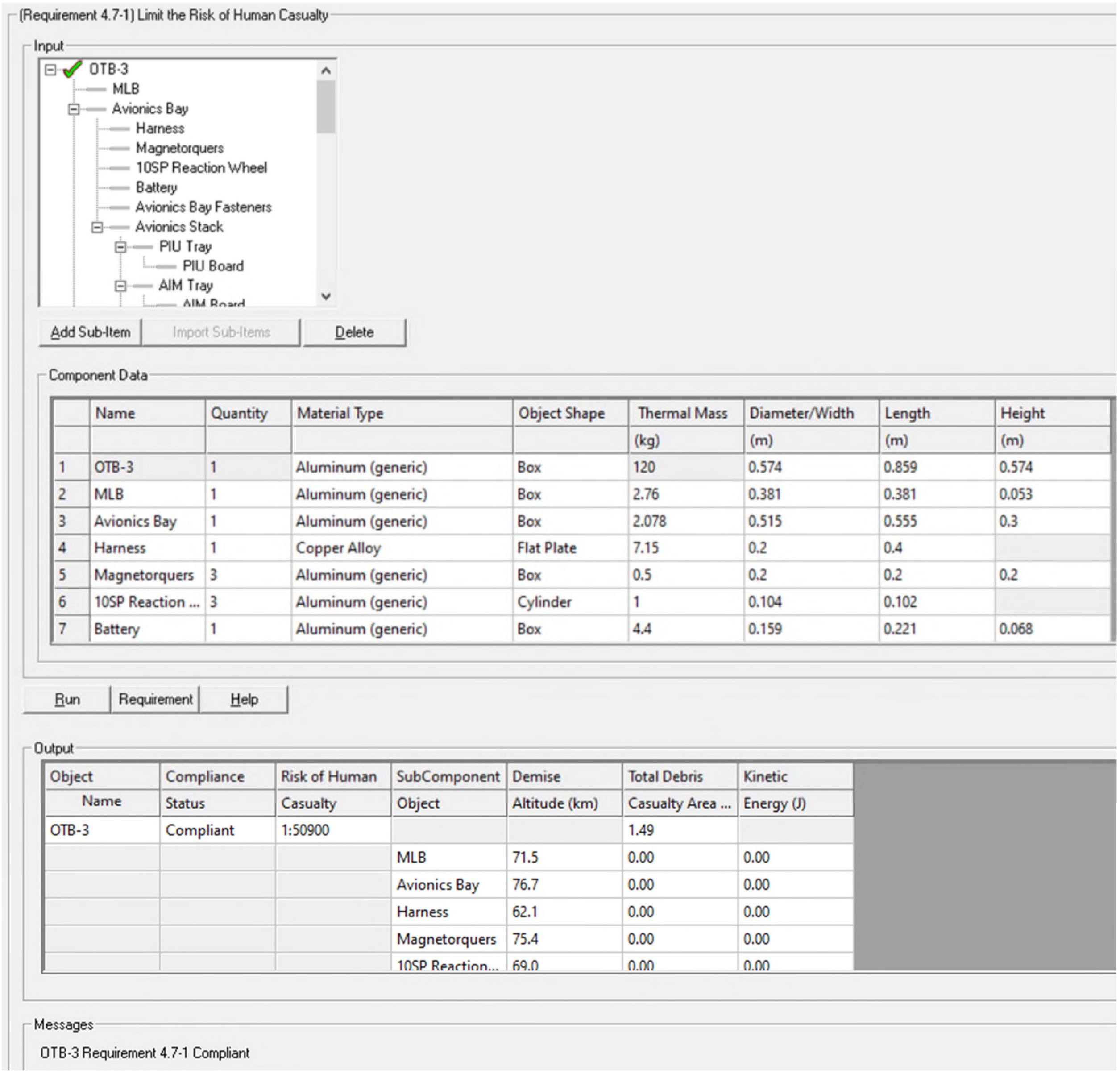
The updates that were made to the DAS simulation are as follows:

- The tie rods were modeled with the specific titanium alloy (Ti-6Al-4V) in use, instead of the generic 100% titanium used in the prior model.
- The components in the avionics stack were modeled with higher fidelity. The prior model listed the AIM, ASM, PIU, PDM, and OBC as 100% fiberglass bricks. The revised DAS model shows these items as aluminum trays with standard FR4 circuit cards.
- The separation system and spacecraft harness were each updated to reflect more precise mass parameters.

As modeled with greater fidelity, only two components are now expected to survive re-entry, the NOAA-furnished payloads. The table below identifies the two components, the material types of the components, the percentage of the components by material type, and the mass of the material types used in each component:

Object Name	Quantity	Material	% Material	Mass (kg)	Debris Area (m^2)	Kinetic Energy (J)
Argos RPU	1	aluminum	100%	14.37	0.77	21957.61
Argos TXU	1	aluminum	100%	8.8	0.72	11299

The Argos RPU (Table 7, Item No. 26) and Argos TXU (Table 7, Item No. 35) are two separate 7075 machined aluminum chassis that house customer-provided transmit and receive electronics. The components are a mission requirement by NOAA and cannot be altered by General Atomics. The revised probability for human collision is 1:50,900, as specified in the DAS output screen below. This probability is less than 1:10,000 and, accordingly, is compliant with NASA and FCC requirements.



(Requirement 4.7-1) Limit the Risk of Human Casualty

Input

OTB-3
MLB
Avionics Bay
Harness
Magnetorquers
10SP Reaction Wheel
Battery
Avionics Bay Fasteners
Avionics Stack
PIU Tray
PIU Board
AIM Tray
AIM Board

Add Sub-Item | Import Sub-Items | Delete

Component Data

	Name	Quantity	Material Type	Object Shape	Thermal Mass (kg)	Diameter/Width (m)	Length (m)	Height (m)
1	OTB-3	1	Aluminum (generic)	Box	120	0.574	0.859	0.574
2	MLB	1	Aluminum (generic)	Box	2.76	0.381	0.381	0.053
3	Avionics Bay	1	Aluminum (generic)	Box	2.078	0.515	0.555	0.3
4	Harness	1	Copper Alloy	Flat Plate	7.15	0.2	0.4	
5	Magnetorquers	3	Aluminum (generic)	Box	0.5	0.2	0.2	0.2
6	10SP Reaction ...	3	Aluminum (generic)	Cylinder	1	0.104	0.102	
7	Battery	1	Aluminum (generic)	Box	4.4	0.159	0.221	0.068

Run | Requirement | Help

Output

Object Name	Compliance Status	Risk of Human Casualty	SubComponent Object	Demise Altitude (km)	Total Debris Casualty Area ...	Kinetic Energy (J)
OTB-3	Compliant	1:50900			1.49	
			MLB	71.5	0.00	0.00
			Avionics Bay	76.7	0.00	0.00
			Harness	62.1	0.00	0.00
			Magnetorquers	75.4	0.00	0.00
			10SP Reaction...	69.0	0.00	0.00

Messages

OTB-3 Requirement 4.7-1 Compliant

DAS Output Screen

6. Is there any heritage data on the DragNET system as a whole, or is the heritage information focused on the individual components?

Section 6 of the ODAR provides heritage information and other details on the MMA Design LLC dragNET system. As explained in the submitted ODAR, the system was used to successfully de-orbit the ORS-3 Minotaur I Upper Stage. Additionally, the same dragNet system is on board the STPSAT-3, a small-satellite mission of the U.S. Air Force, and is awaiting mission completion to activate. *See also* https://mmadesignllc.com/product/dragnet-de-orbit-system/.