FCC Experimental STA Application

Narrative Summary

Astranis Space Technologies Corp. ("Astranis") is a U.S.-based, space technology company headquartered in San Francisco, California. Astranis is developing a line of agile, frequency flexible and low-cost geostationary telecommunications satellites to open new and underserved markets, including those which do not otherwise support a costly traditional telecommunications satellite and those would benefit from a more incremental addition of satellite capacity.

To accomplish this mission, Astranis seeks to validate and demonstrate key technologies. Towards this end the Astranis Demosat-2 satellite, with its Software Defined Radio ("SDR") digital transponder payload, will allow Astranis to test and demonstrate components, software design, and operational concepts that are integral to the planned satellite product line.

The experimental tests and demonstrations planned by Astranis will be conducted intermittently over a six-month period commencing shortly after launch of the satellite. The TT&C and experimental payload communications frequencies, ground station location and operational constraints have been carefully identified to avoid the potential for interference to other spectrum users. In addition, this request is filed in accordance with the guidance and time frames established by the Commission for consideration of such experimental satellite applications.[1] Accordingly, grant of the requested experimental special temporary authorization ("STA") is fully consistent with Commission's guidance, policy and experimental licensing rules.[2]

Astranis notes that due to a launch slip, the expected launch date is now expected to be approximately September 1, 2017. Therefore, Astranis respectfully requests that the Commission consider and authorize the proposed experimental satellite operations (as appropriately conditioned) as soon as practicable, and in any event not later than approximately July 15, 2017, to ensure Astranis obtains such authority in time to support integration into the launcher as required by its launch provider.

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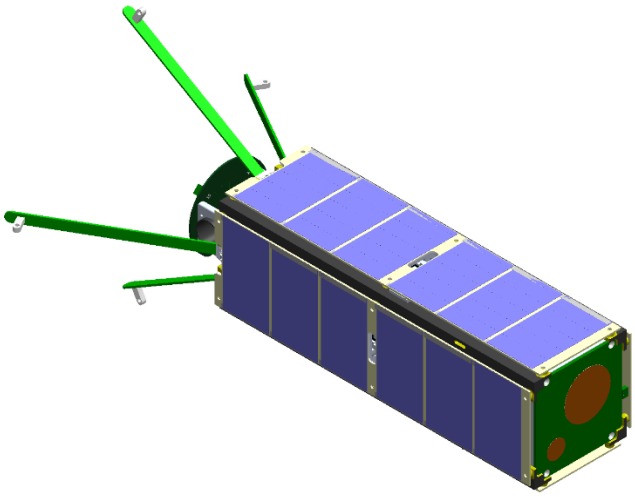
[1] *See* Guidance on Obtaining Licenses for Small Satellites, *Public Notice*, DA 13-445 (March 15, 2013) ("*Small Satellite Guidance*").

[2] *See* 47 C.F.R. Part 5; *see also* 47 C.F.R. §5.61 (Procedure for obtaining a special temporary authorization).

Experimental Satellite

The Astranis Demosat-2 satellite conforms to the form factor of a 3U cubesat (35 cm X 10 cm X 10 cm in size), with a total mass of approximately 5 kg. The maximum power generated by the solar panels is approximately 10 W, with a maximum transmitter output power of approximately 3 W. The communications payload uses patch antennas and the TT&C radio uses monopole antennas, as indicated in Figure 1.

Figure 1 – Demosat-2 Configuration



Orbit. The Astranis Demosat-2 satellite will be launched as a secondary payload aboard a Polar Satellite Launch Vehicle (PSLV) in September 2017. The satellite will be launched into a nominal circular, sun-synchronous orbit at 580 km apogee and 580 km perigee with an inclination from the equator of 97.71°. A potential lower drop-off deployment altitude of 550 km, also a circular sun-synchronous orbit, is being evaluated by the launch provider. If given this option we will deploy our spacecraft at the lower altitude. An orbital lifetime calculation for this orbit estimates that the satellite will remain on obit for approximately 16.6 years if deployed at 580 km altitude and 10.8 years if deployed at 550 km altitude, well within the limits set by internationally accepted guidelines.[3]

Communications Payload. The payload consists of an SDR-based digital transponder, including a low noise amplifier and a GaN solid state power amplifier with patch antennas for transmit and receive operations. Specific technical parameters include:

- 3 W spacecraft transmitter output power, 12.6 dBW EIRP
- TX in 2.390-2.400 GHz, RX in 5.950-5.960 GHz (10 MHz bandwidth)
- Circularly polarized, QPSK modulation

[3] *See* Orbital Debris Assessment Report (attached).

The communications payload will operate intermittently and on an as-needed basis to conduct experiments between one to six times per day while the satellites pass over dedicated earth stations located in Fairbanks, Alaska. Satellite communications will begin once the satellite has been deployed into its intended orbit (currently planned for mid-September 2017) and will cease six months thereafter. Accordingly, Astranis requests an STA period from September 1, 2017 to March 1, 2018.

Operation of the downlink payload will only take place during the brief periods (approximately 10 minutes) that the satellite is passing over the Fairbanks TT&C and communications earth station site. Satellite downlink (earth station receive) operations will be conducted in the 2.390-2.400 GHz band, which was chosen because it is consistent with Commission small satellite guidance.[4] In addition, based on NTIA spectrum use reports, Astranis understands there are no U.S. government operations in this band in Alaska,[5] and ULS reveals no licenses within Alaska that could be adversely affected by the proposed downlink operations.

TT&C. Tracking, telemetry and control of the Astranis Demosat-2 satellite will be conducted using a GomSpace AX100 UHF transceiver, with monopole antennas, for transmit and receive operations. TT&C downlink operations in the 401 MHz band will take place intermittently when the satellite is in view of the Fairbanks, Alaska earth station site. Astranis will coordinate its TT&C operations to ensure compatibility with any other co-frequency TT&C operations in the area. Particulars of the TT&C downlink operations include:

- 1 W spacecraft transmitter output power, 1.4 dBW EIRP
- Tx (downlink) at 401.600-401.750 MHz (150 kHz bandwidth)
- Linearly polarized, GMSK modulation

Communications Earth Stations

Earth station uplink and downlink operations will be conducted at a site in Fairbanks, Alaska. A General Dynamics Series 1244 2.4 m antenna will be located at an existing satellite earth station facility that serves other earth station antennas and provides associated support functionality (power, terrestrial connectivity, etc.). The earth station antennas will track the satellite as it passes over the site, and will transmit and receive intermittently and for brief periods (approximately 10 minutes) when the satellite is in view.

The uplink earth station will transmit with an EIRP of 49 dBW in the 5.950-5.960 GHz band. The earth station will be subject to operational constraints to prevent harmful interference to co-frequency terrestrial FS operations and C-band geostationary satellites. Astranis will operate at a minimum elevation angle of approximately 35° in southerly directions to maintain a 20°

[4] *See Small Satellite Guidance* at 2 ("What Frequencies Can Be Used?").

[5] *See* https://www.ntia.doc.gov/page/federal-government-spectrum-use-reports-225mhz-5ghz.

separation from the GSO arc and minimum elevation angles in more northerly directions that ensure there is no interference into any potentially affected terrestrial links.

The 20° minimum angular separation from the GSO arc will ensure compliance with the C-band equivalent power flux-density (EPFD↑) limit in the ITU Radio Regulations, with a substantial margin, to fully protect such operations from potential interference. Radio Regulation 22.5D provides that the EPFD↑ produced at any point in the GSO by emissions from NGSO earth stations shall not exceed the limits given in Table 22-2, establishes a limit of -183 dBW/m^2 per 4 kHz of spectrum for 100% of the time.

TABLE **22-2** (WRC-03)

Limits to the epfd↑ radiated by non-geostationary-satellite systems in the fixed-satellite service in certain frequency bands[15]

Frequency band	**epfd↑ (dB(W/m^2))**	**Percentage of time epfd↑ level may not be exceeded**	**Reference bandwidth (kHz)**	**Reference antenna beamwidth and reference radiation pattern**[16]
5 925-6 725 MHz	−183.0	100	4	1.5° Recommendation ITU-R S.672-4, *Ls* = −20

Using the §25.209-compliant General Dynamics Series 1244 2.4 m earth station antenna and a 20° angular separation from the GSO arc, Astranis' uplink operations in the 5.950-5.960 GHz band will produce an EPFD↑ value of -189.4 dBW/m^2/4 kHz, which satisfies the limit by more than 6 dB.

Geostationary Satellite Altitude	35786.0	km
Slant Range to Closest Possible GSO Satellite	39868.0	km
Main Lobe EIRP	49.0	dBW
Necessary Bandwidth	7.65	MHz
Sidelobe Isolation at 20 degrees	42.6	dB
Max EIRP toward GSO Arc	6.4	dBW
Max EIRP density toward GSO Arc	-62.4	dBW/Hz
Max EIRP density toward GSO Arc in 4 kHz band	-26.4	dBW/4 KHz
Spreading Loss	163.0	dB
EPFD up	-189.4	dBW/m^2/4 kHz
EPFD up - Margin	6.4	dB

Because compliance with the ITU EPFD↑ value is deemed to fully protect GSO operations, Astranis can conduct its intermittent, temporary uplink operations without causing interference to GSO satellite operations. Nonetheless, Astranis commits to adjust or suspend earth station operations in the 5.950-5.960 GHz band upon notification that such operations are causing harmful interference to GSO satellite operations.

In addition, Astranis has carefully examined co-frequency terrestrial microwave operations to ensure they are also not adversely affected by the proposed experimental operations. Employing a minimum elevation angle to preserve the 20° angular separation from the GSO arc will fully protect two terrestrial links in southerly directions from the Fairbanks, Alaska earth station site. In addition, Astranis will ensure that its minimum elevation angle in northerly directions protect the single FS link located in this region. Nonetheless, Astranis commits to adjust or suspend earth station uplink operations in the 5.950-5.960 GHz band upon notification that such operations are causing harmful interference to terrestrial operations.

TT&C Earth Station

Astranis will utilize a GomSpace GS100 radio and associated equipment, including an AS100 Yagi antenna, to conduct TT&C operations. The TT&C earth station will be collocated with the communications earth stations at the Fairbanks, Alaska facility. The TT&C earth station will transmit and receive in the 401.600-401.750 MHz band (150 kHz bandwidth). This band was selected because it is allocated to space operations and similar services, and can be used in both directions of transmission.[6]

TT&C uplink operations in the 401 MHz band will take place intermittently and for brief periods (approximately 10 minutes) when the satellite is in view of the Fairbanks, Alaska earth station site. Through coordination with any other co-frequency operations in the area, Astranis will ensure its TT&C operations will be fully compatibility with other spectrum users and are conducted on a strictly unprotected, non-interference basis only. Nonetheless, Astranis commits to adjust or suspend earth station uplink operations in the 401.600-401.750 MHz band upon notification that such operations are causing harmful interference to other spectrum users.

[6] The U.S. Table of Allocations includes Earth Exploration Satellite and Meteorological-Satellite operations in the Earth-to-space direction in the 401 MHz band, and such operations are similar to and compatible with intermittent, temporary TT&C operations. Astranis' proposed experimental TT&C uplink operations can be permitted in the band because they will be conducted on an unprotected, non-interference basis.

Orbital Debris Assessment

Astranis DemoSat-2

Revision 1

Overview

The Astranis DemoSat-2 test satellite is being launched to a sun-synchronous orbit, and will be deployed by a standard QuadPack satellite dispenser. The nominal starting altitude is 580 km. Optionally, if launch vehicle capacity allows, the satellite may be deployed at 550 km altitude. The satellite does not have propulsion, pressure vessels, detachable components, or any other similar potential sources of debris. The spacecraft conforms to the form factor of a 3U cubesat (35 cm X 10 cm X 10 cm in size), and spacecraft mass of 4.5 kg was used. All calculations were done using NASA's DAS (Debris Assessment Software) program, see the following pages for screenshots of the program outputs.

An orbital lifetime calculation for this orbit estimates that the satellite will remain on obit for approximately 16.6 years if deployed at 580 km altitude and 10.8 years if deployed at 550 km altitude. The satellite is assumed to be tumbling and the calculation was done with an average cross-sectional area with 20% factor applied for conservatism, per the ISO/ANSI draft standard 27852:2010(E).

Collision risk analysis was performed using the DAS software, which showed a collision probability of 0.00000 in both the 580 km and 550 km deployment scenarios. An atmospheric demise analysis was completed as well, showing a de minimis risk of human casualties.

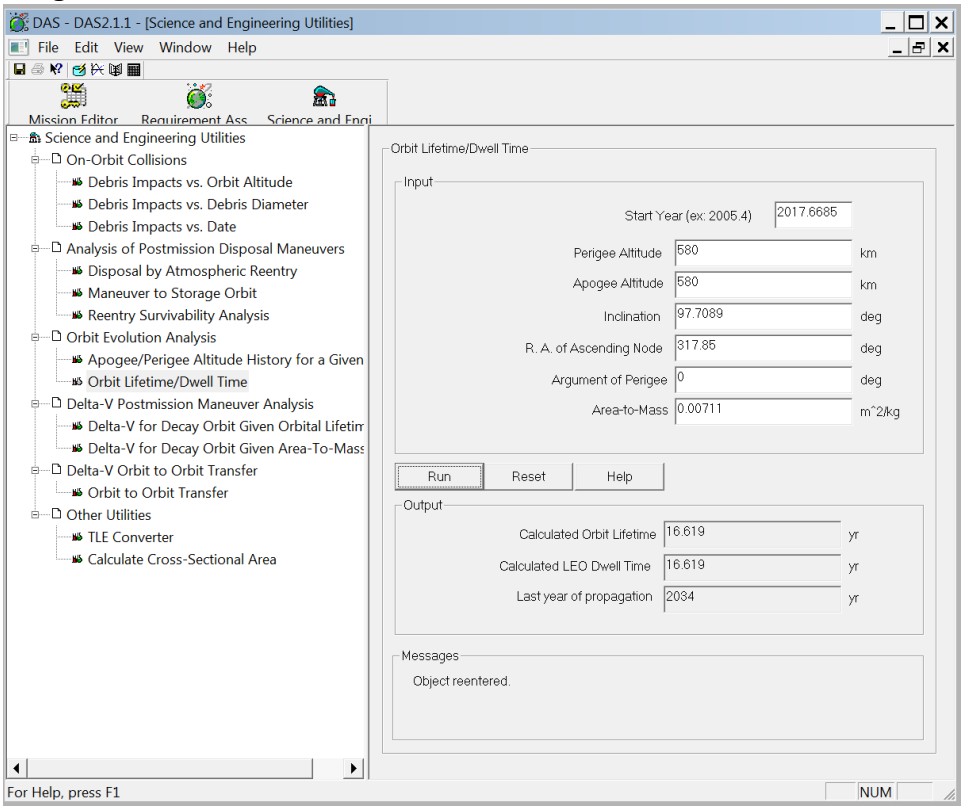
To support collision avoidance, Astranis will be in communication with JSpOC directly to provide orbital parameters and any other assistance necessary for the cataloging of the satellite. An Astranis employee will be assigned as the point of contact for communications with JSpOC regarding conjunction warnings. In this connection, it may be possible to alter the satellite cross-sectional presented along direction of travel to respond to possible conjunction events.

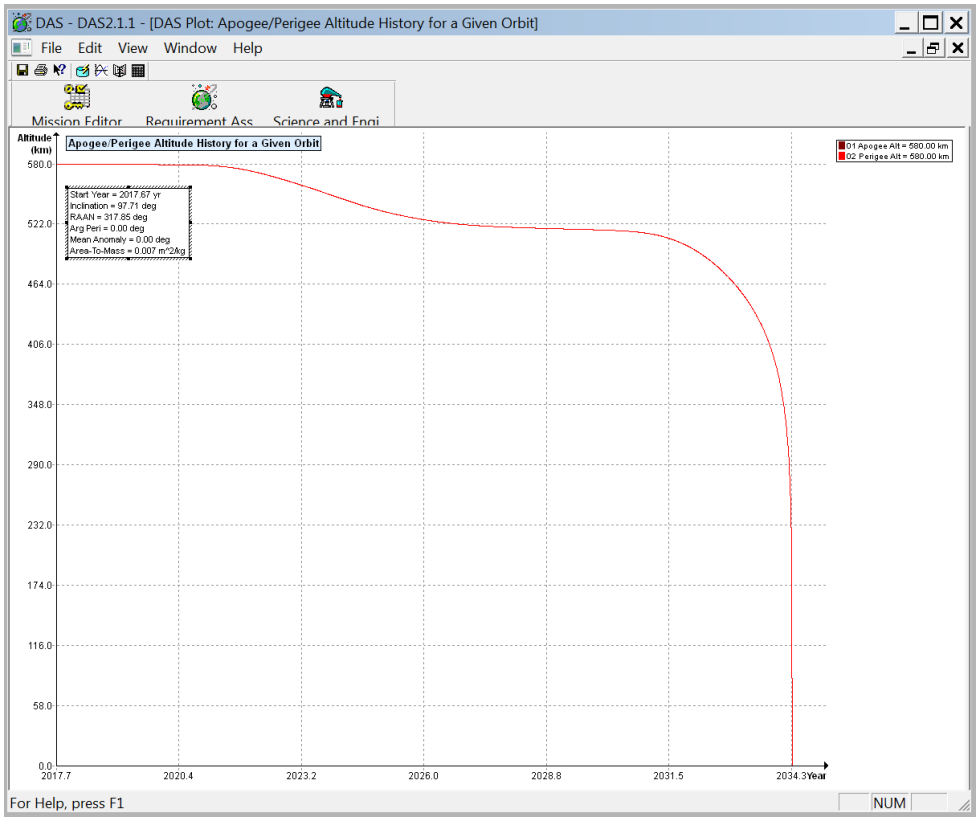
Orbital Lifetime Calculation

NASA DAS software was used to conduct an orbital lifetime analysis. The spacecraft was assumed to be tumbling and an average cross-sectional area was used. To determine the mean cross-sectional area of a tumbling rectangular parallelepiped, the approach in ISO/ANSI draft standard 27852:2010(E) was taken. The formula for the average cross-sectional area in that case is (S1+S2+S3)/2, with an additional factor of 20% applied for conservatism. This gave an area-to-mass ratio of 0.0071 m^2/kg.

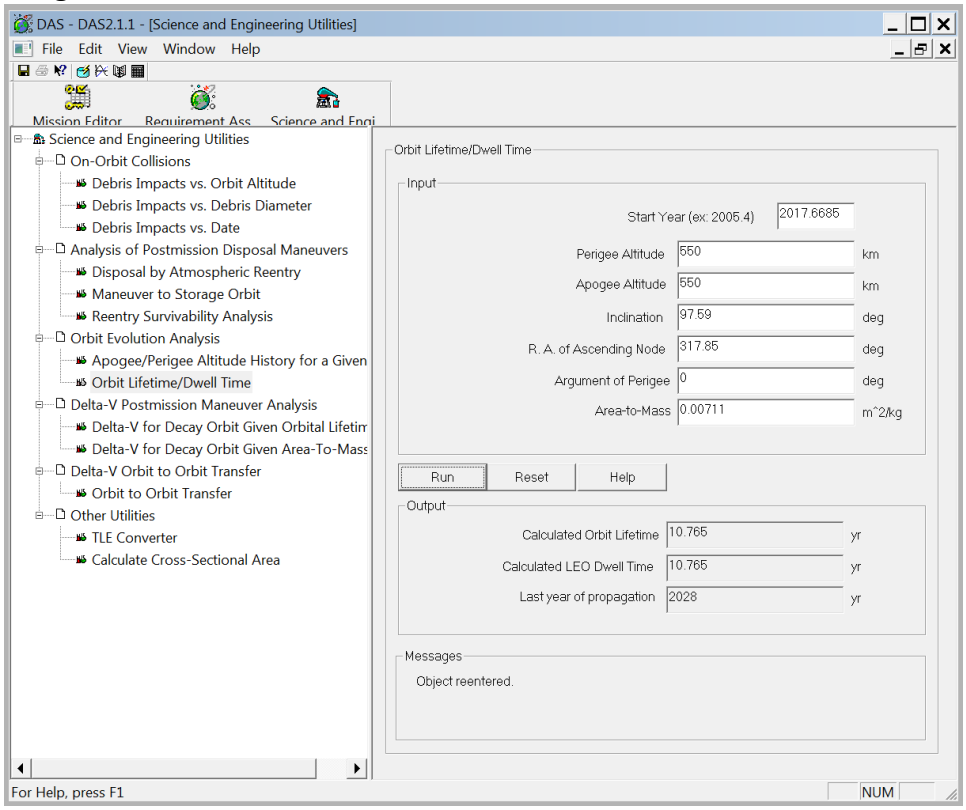
Spacecraft Dimensions and Mass	
Length	35 cm
Width	10 cm
Height	10 cm
Mass	4.5 kg
Calculated Parameters	
Nominal Area-to-Mass Ratio	0.0071 m^2/kg
Orbit Overview	
Altitude (Primary Payload)	580 km
Inclination (Primary Payload)	97.71 deg
Altitude (Potential Lower Secondary Deployment)	550 km
Inclination (Potential Lower Secondary Deployment)	97.59 deg
Orbit Lifetime	
580 km Deployment	16.62 years
550 km Deployment	10.77 years

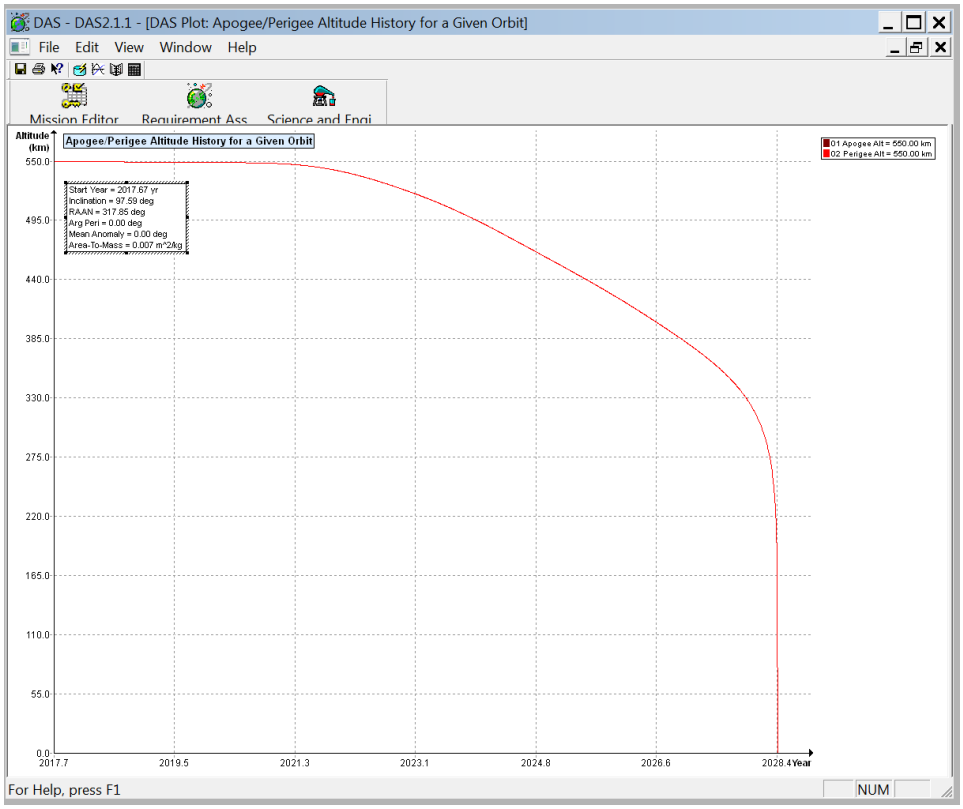
580 km Starting Altitude Case





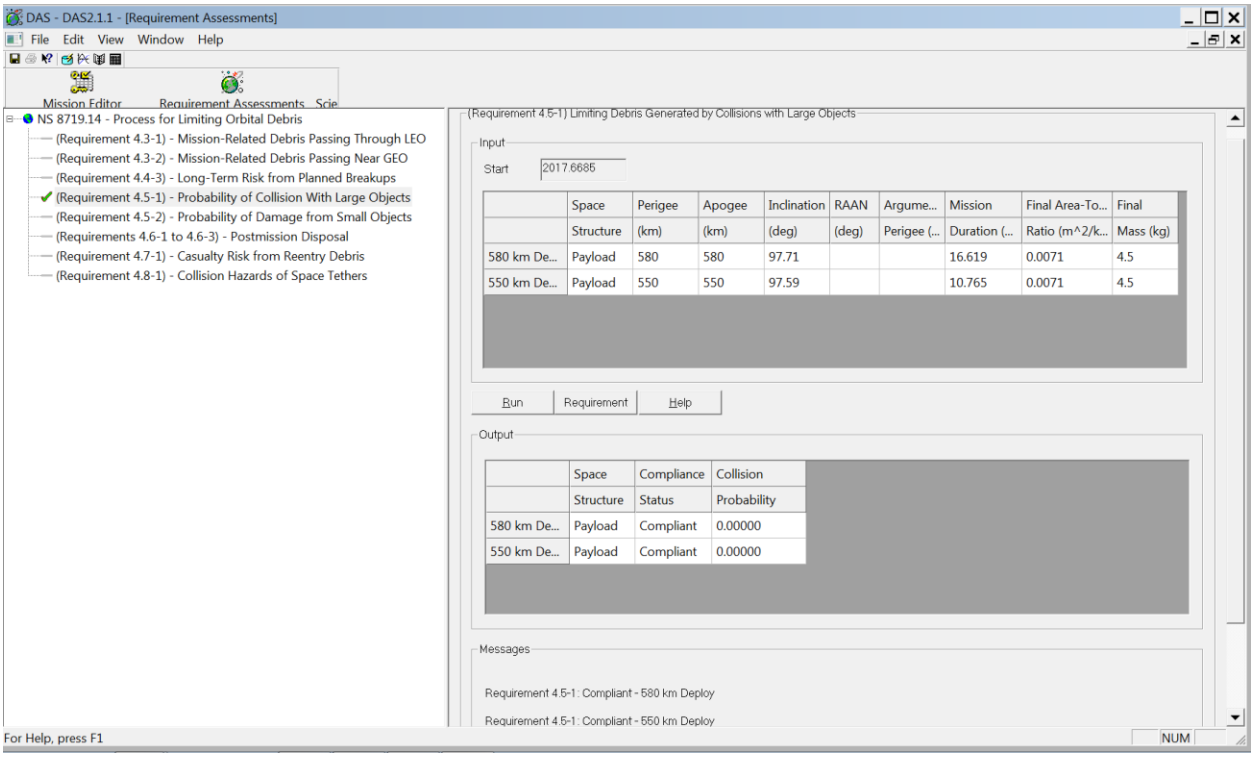
550 km Starting Altitude Case





Collision Risk Calculation

The DAS Software was used to calculate the probability of spacecraft collision with large objects. As before, two cases were analyzed—580 km deployment altitude and a 550 km deployment altitude. The DAS Software found the probability of a collision to be 0.00000 for both scenarios.



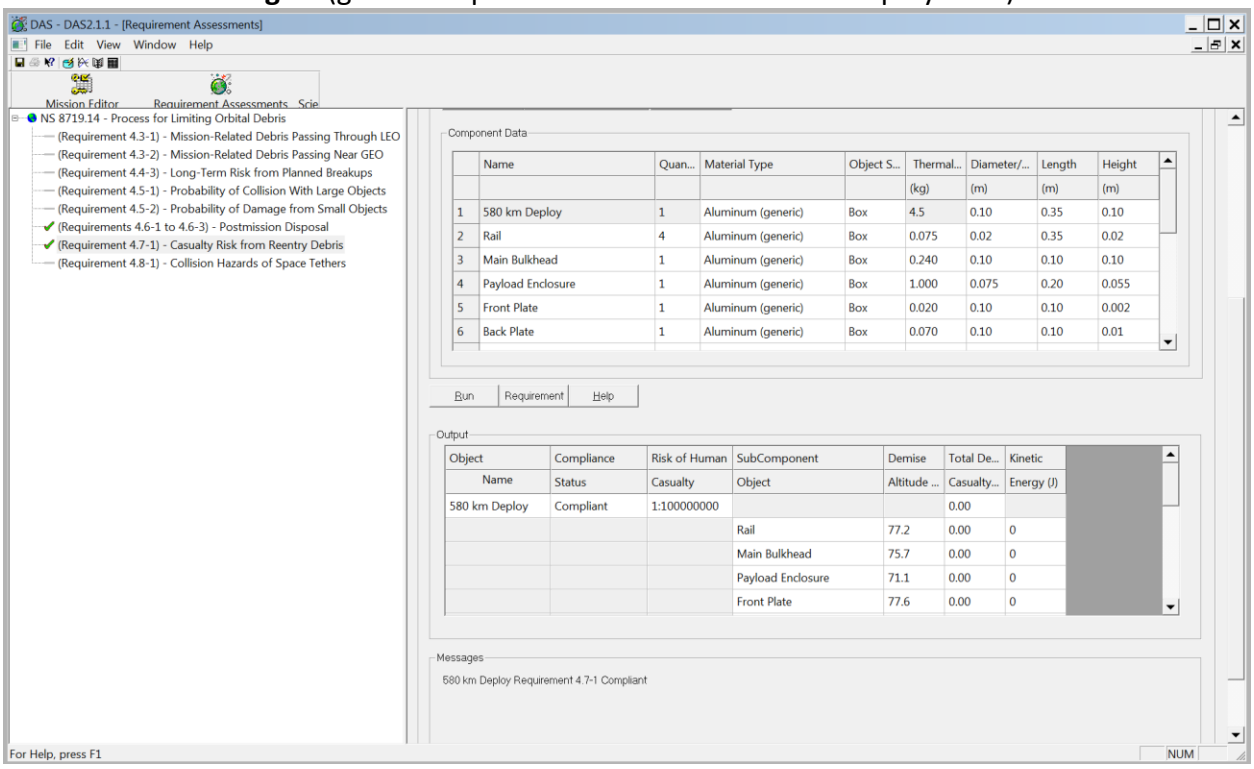
Ground Impact Risk Assessment

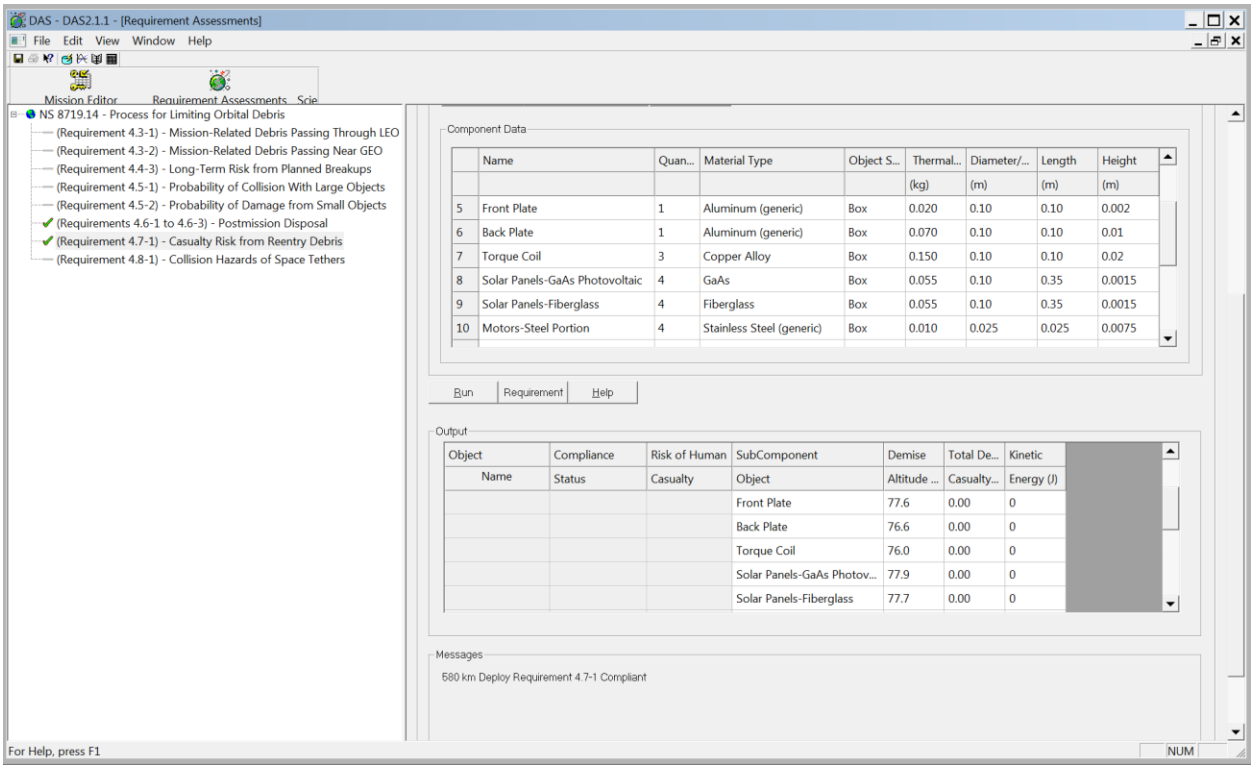
Given the spacecraft's small mass (4.5 kg) and the makeup of its constituent components (see table below), the spacecraft is expected to break up upon re-entry and for very little, if any, components to make it to ground.

The DAS analysis found the risk of human casualty to be de minimis. Only one component was found to make it to ground level with a kinetic energy of 2 Joules.

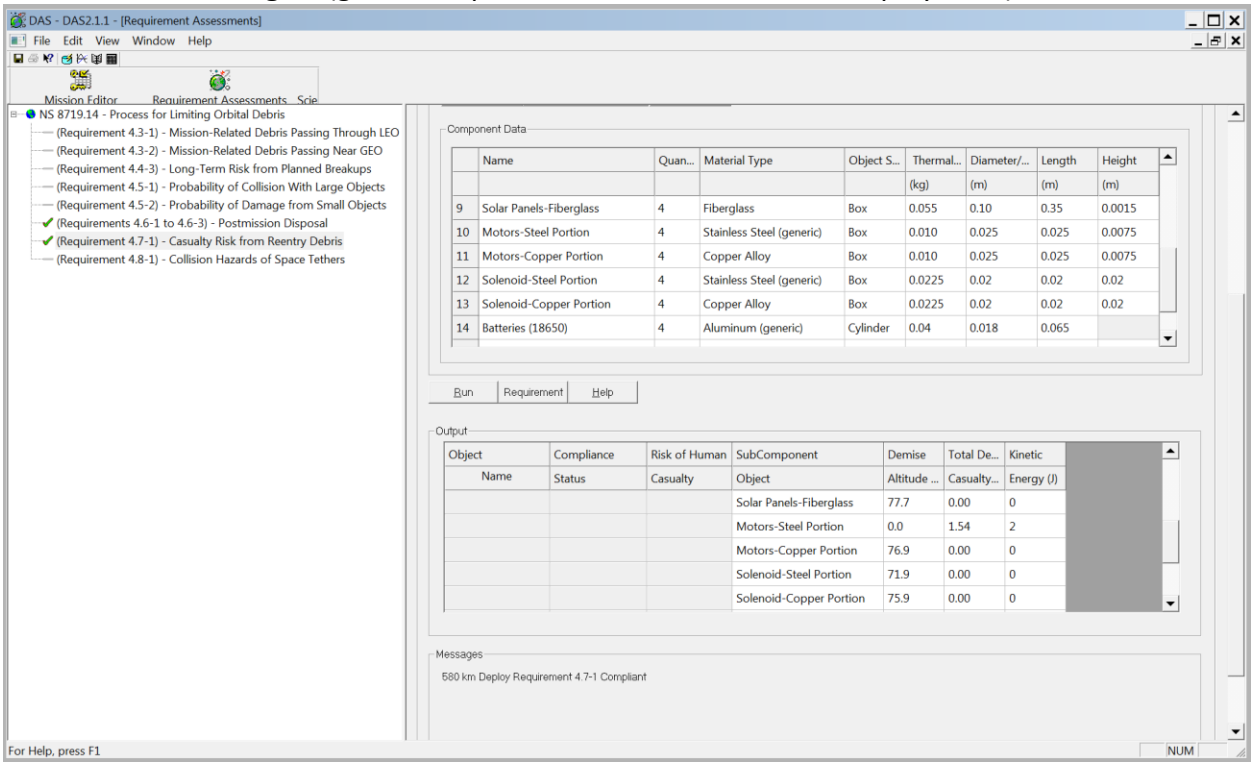
Name	Qty	Material	Dimensions (m)	Mass per	Mass total
Rails	4	Al	0.02 x 0.35 x 0.02	0.075	0.300
Main bulkhead	1	Al	0.10 x 0.10 x 0.10	0.240	0.240
Payload enclosure	1	Al	0.20 x 0.075 x 0.055	1.000	1.000
Front plate	1	Al	0.10 x 0.10 x 0.002	0.020	0.020
Back plate	1	Al	0.10 x 0.10 x 0.01	0.070	0.070
Torque Coil	3	Copper	0.10 x 0.10 x 0.02	0.150	0.450
Solar Panels-GaAs Photovoltaic	4	GaAs	0.35 x 0.10 x 0.0015	0.055	0.220
Solar Panels-Fiberglass Cover	4	Fiberglass	0.35 x 0.10 x 0.0015	0.055	0.220
Motors-Steel Portion	4	Steel	0.025 x 0.025 x 0.0075	0.010	0.040
Motors-Copper Portion	4	Copper	0.025 x 0.025 x 0.0075	0.010	0.040
Solenoid-Steel Portion	4	Steel	0.02 x 0.02 x 0.02	0.0225	0.090
Solenoid-Copper Portion	4	Copper	0.02 x 0.02 x 0.02	0.0225	0.090
Batteries (18650)	4	Al	(18650 cell) Cylinder, Dia=0.018, Ht=0.065	0.040	0.160
Brackets	20	Al 6061	Default based on density: 0.03x0.03x0.03	0.050	1.000
PCBAs	8	Fiberglass	0.10 x 0.10 x 0.01	0.050	0.400
Total mass					**4.34 kg**

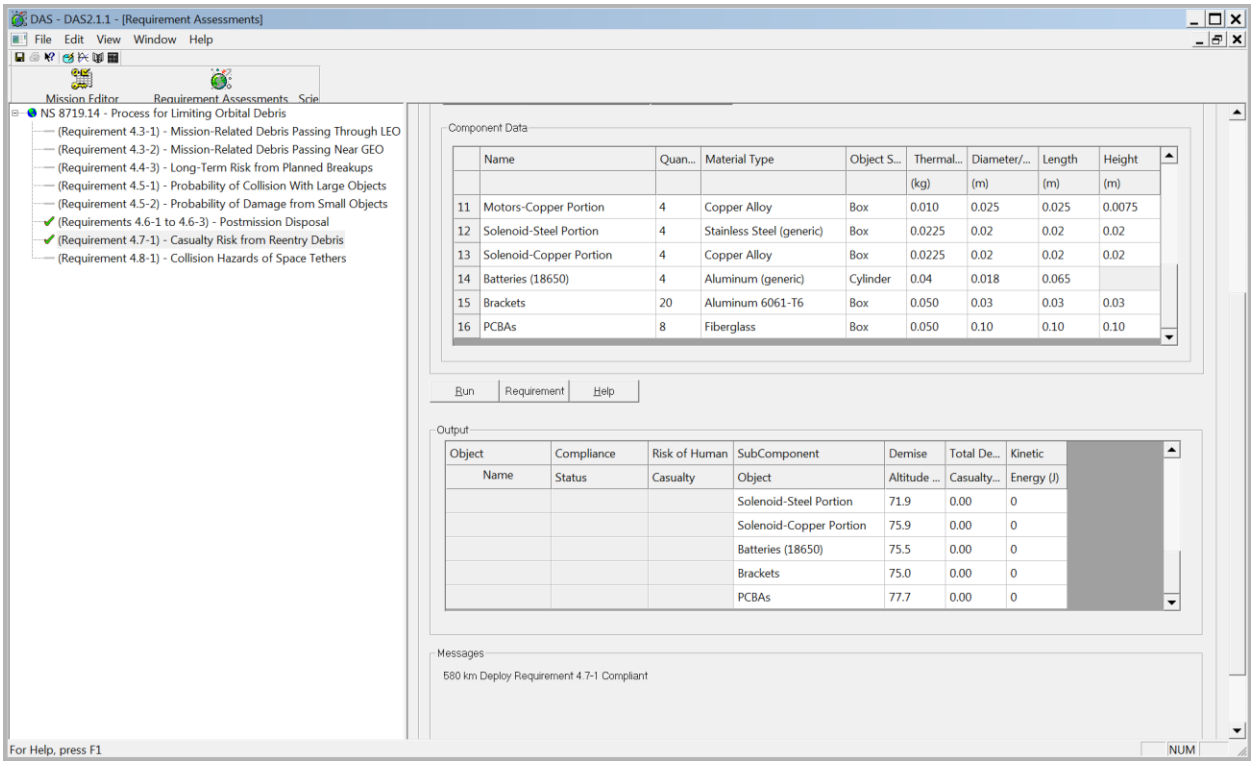
DAS Screenshots Page 1 (ground impact risk assessment 580 km deployment)



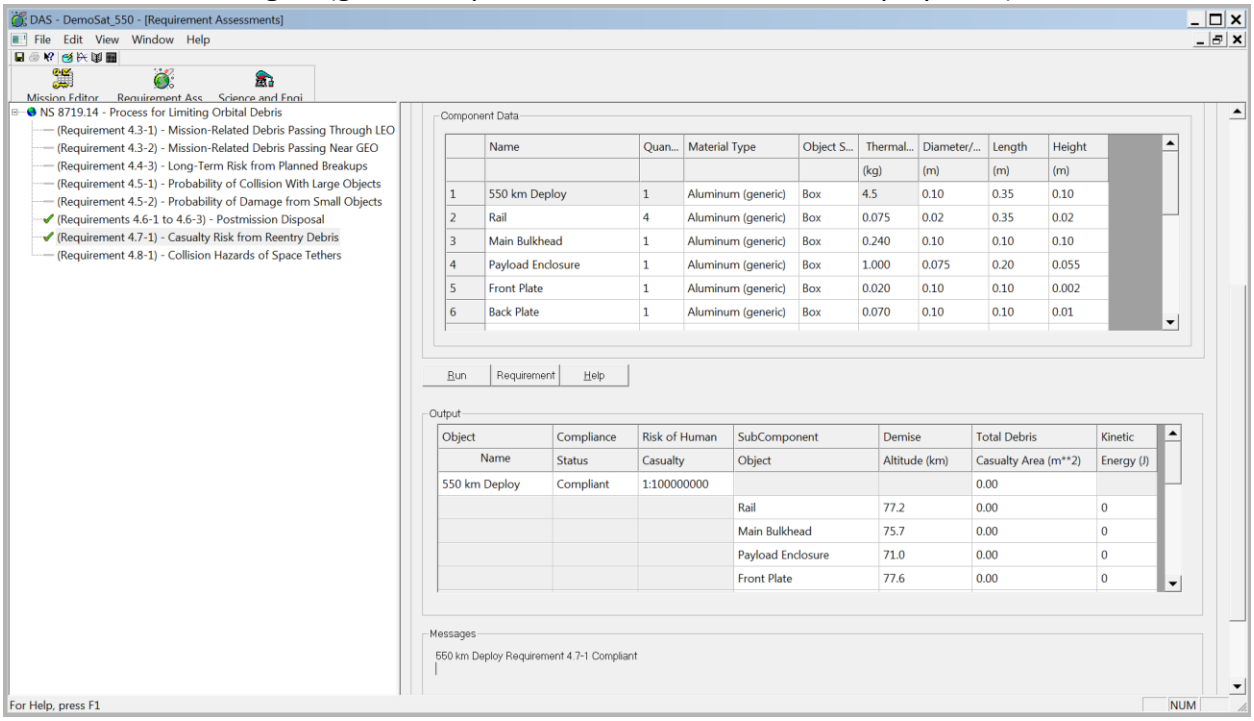


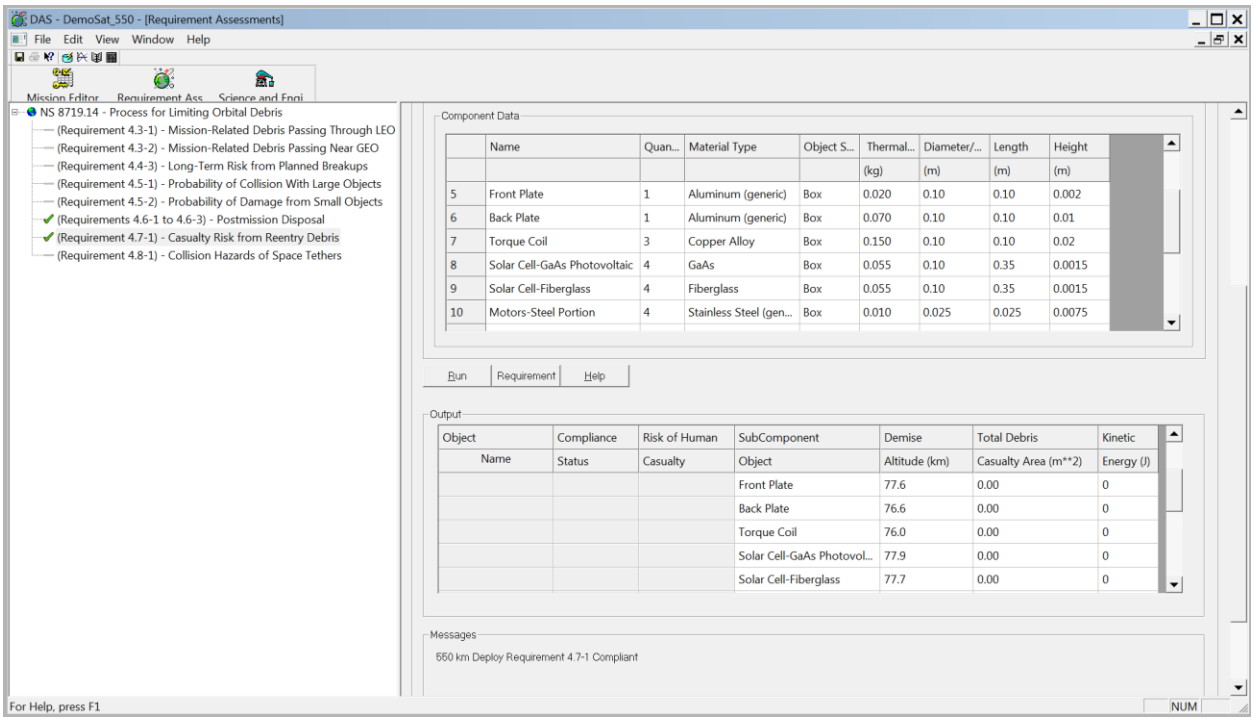
DAS Screenshots Page 2 (ground impact risk assessment 580 km deployment)





DAS Screenshots Page 3 (ground impact risk assessment 550 km deployment)





DAS Screenshots Page 4 (ground impact risk assessment 550 km deployment)