Alpha CubeSat Structures Chapter

Dimensions and Mass Properties of ACS Structure

The structural layout is defined to be a 1Ux1Ux3U center stack with tandem 0.5Ux1Ux3U volumes on either side. This configuration is to position the main propulsive system thrust through the center of gravity of the spacecraft. Deployable trifold solar panels will be attached to the 2Ux3U sides of the spacecraft. Our size is constrained by the SLS Payload User's Guide (SLS-SPIE-HDBK-005) as defined in table 5-1 on page 22, our maximum stowed dimensions cannot exceed:
Width: 239.00mm
Length: 366.00mm
Depth: 113.00mm
Mass: 14 kg.
The outer chassis will bear a significant portion of the design loads and will be modeled in a finite element analysis to prove structural integrity.
The Alpha CubeSat chassis outer mold line dimensions and mass follow the SLS Payload constraints.

<u>Alpha CubeSat chassis outer dimensions and mass properties:</u>
Width: 239.00mm
Length: 366.00mm
Depth: 98.00mm
Maximum Mass: 1 kg
Internal Volume: 6,302 cubic centimeters

The internal volume was calculated assuming similar chassis thickness (approximately 17 mm) as Pumpkin CubeSat products. For example, the Pumpkin 6U CubeSat (SUPERNOVA-Rev00_20140925.doc) states outer length of their spacecraft as 365 mm and inner dimension as 329.2 mm bringing the internal volume to 7000 cc. ACS internal volume is 9.2% smaller due to less depth as a result of folded solar panels.

<u>ACS Inner dimensions:</u>
Width: 206 mm
Length: 329 mm
Depth: 93 mm

These body outer and inner mold line dimensions do not include deployables in their stowed configuration such as the solar panels (each panel is 2.5mm thick per ClydeSpace information) and antenna. The plan is to use three 6U sized panels from ClydeSpace per solar panel array totaling six panels total. With trifold panels, the solar panels in their stowed configuration are expected to be 7.5mm thick in a triple stack and will be faced against the two 2Ux3U faces of the 6U body.

The Alpha CubeSat outer stowed dimensions including all deployables vary from the chassis outer dimensions by 15 mm (symbolizing the 7.5mm thick folded solar panels on either side of the spacecraft) in the depth dimension bringing the Depth to 113.00 mm total. The solar panel mass will not exceed 2.346 kg taking into account a 15% structural mass reserve.

The center of mass envelope is defined in the table below from the CubeQuest Challenge requirements:

Parameters	Units	6U	
		Min.	Max.
Center of Mass, X	in. (mm)	-1.57 (-40)	+1.57 (+40)
Center of Mass Y	in. (mm)	+0.39 (+10)	+2.76 (+70)
Center of Mass Z	in. (mm)	+5.24 (+133)	+9.17 (+233)

Construction

Two options exist for the construction of the outer chassis of the ACS. It is most economical to obtain materials as off-the-shelf, space ready cubesat pieces from Pumpkin and custom machine the pieces to fit our configuration. The materials used for the chassis will be primarily AL7071 and Al6065.

It is also possible we will find a vendor motivated by demonstrating their machining technology that will 3-D print our primary structure using identical aluminum alloys as are commonly used in cubesat construction.

The chassis of the ACS spacecraft will undergo optimization iterations to acquire the lowest mass possible. For the structural analysis, the factors of safety planned to be used are 1.1 for Yield Strength and 1.5 for Ultimate strength as taken from NASA Payload Flight Equipment Requirements and Guidelines for Safety–Critical Structures (SSP 52005 Rev D) Table 5.1.2-1 Minimum Safety Factors For Payload Flight Structures Mounted to Primary and Secondary Structure.

The critical deployable mechanisms on ACS are the two solar panel arrays. Attachment points for the solar panels are constructed as follows. Each wing panel of the trifold are attached to the central panel by leaf-springs from tape measure strips to provide attachment and a mechanism to spring them open. The central panel is attached to the forward face (opposite of the engine exhaust) by a wire coil spring that allows the folded trifold 90 degrees of articulation to fold the stowed panel against the cubesat's 6U body faces. It also provides a mechanism to spring the arrays into their fully-deployed position and a mast attachment point from the array to the satellite body that can be articulated by rotation around the mast's axis to point the array towards the sun

The following section describes the design loads applicable to structure design.

DESIGN LOADS

Launch Loads

The maximum structural loads on the ACS spacecraft will occur during launch.
Launch vibrations have been summarized as x, y, z directional loads in g's as seen in the table below. A finite element analysis is planned for the chassis design and the launch loads will be applied as forces on the satellite located at the contact points of the deployment mechanism and moments around the center of gravity.

ACS will be designed to structural standards as defined in the DESIGN LOADS section of the NASA SECONDARY PAYLOAD INTERFACE DEFINITION AND REQUIREMENTS DOCUMENT (SLS-SPIE-RQMT-018).
Table 3-7 Secondary Payload Component Loads Due to Random Vibration from the Secondary Payload IDRD states:

Configuration 1a – 41lb Payload		
Axial	**Lateral**	**Radial**
±28.2g	±15.6g	±18.0g
Configuration 1b – 60lb Payload		
Axial	**Lateral**	**Radial**
±18.0	±14.3	±18.0
Configuration 2 – Sequencer		
Axial	**Lateral**	**Radial**
±28.2g	±15.6g	±18.0g

The above loads are the maximum load case scenario to be experienced by ACS and correspond to attaining the SLS EM-1 launch.
These loads will be applied to a finite element model of the ACS chassis to prove the design will have sufficient structural integrity.

Temperature Loads

It is also stated in the Secondary Payload IDRD (SLS-SPIE-RQMT-018) that the thermal environment range for spacecrafts is -143 degrees F to +200 degrees F. A finite element model of the ACS structure will undergo a transient thermal analysis to simulate rapid temperature change characteristic of the extreme space environment.

Propulsion Loads

The propulsion loads are planned to not exceed an acceleration higher than 1g. This will be accomplished by designing the HTSD propulsion system to have the appropriate limited thrust. At current, at the fully-loaded mass of 14kg, the thrust maximum can be 137.2N. This maximum thrust will have to be reduced as the vehicle expends mass in propellants and deployed payloads over the mission.
At this time, COTS solutions for cubesat propulsion have demonstrated thrust that is below this maximum. The exception is the N_2O-40% Aluminized Paraffin Hybrid Motor that will exert 10.204gs at 14kg.

However, it is expected that with a proper redesign of the propulsion system to have a throttle, an adjusted chamber pressure, throat area and engine bell expansion ratio, the thrust maximum limit can be achieved.

For more details on propellant amounts, including the total mass of propellant for the GT-2 baselined combination HTSD & LTLD propulsion system that respectively uses a N_2O-40% Aluminized Paraffin Hybrid Motor and 4 Busek BIT-1 electric ion thrusters fueled by Iodine, see the Propulsion Chapter of this document. The propellant masses were developed using the original DeltaVs of the GT-1-level trajectory and propulsion system analysis that were required to complete the ACS mission and meet the vehicle mass and volume requirements.

The maximum loads produced by propulsion on the ACS will be applied to the flight configuration (with solar panels deployed) to assure structural integrity of the solar panel deployment mechanism. A finite element model will be created of the ACS and deployed solar panels to test the attachment points specifically and prove they will withstand propulsion loads.