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A Progress Report on the Pre-Phase A Design of HyperSat

Abstract:

The Georgia Tech Space Systems Design Laboratory is currently in the process of developing HyperSat. It is a 12U CubeSat designed to maneuver into a highly eccentric orbit with its periapsis inside the Earth's upper atmosphere. This will allow the CubeSat to perform its primary function of traveling through the Earth's upper atmosphere and collecting hypersonic CFD data. This paper details the design progress of the mission as of the end of the Summer 2024 academic semester, including a general overview of the spacecraft's budgets for mass, volume, and data generation. The communications architecture is laid out with design decisions for the onboard comms hardware, the ground station availability, and the available time to beam down scientific data. Lastly, some brief observations on how the design of the CubeSat may affect the post-launch spacecraft operations procedures are provided.

Section I: Introduction:

As of 2024, one of the primary competitive developments in the aerospace industry is the creation of robust hypersonic aircraft systems, where "hypersonic" is defined as any speed reaching Mach 5. Since the early 2000's, the United States Armed Forces has made the development of hypersonic systems a national priority as a strategic response to the concurrent hypersonic developments made by Russia and China, although funding has been limited [1]. As such, the necessity for a cost-efficient method for gathering data on hypersonic aerodynamics has soared in the last few years, and this is the primary motivation for the creation of HyperSat. This mission was envisioned by the Georgia Tech Research Institute as a CubeSat mission that has gradually grown in scale over the course of its initial design phase to its current iteration, continuing the current industry trend of using CubeSats as a cost-efficient mission structure. A CubeSat is a type of small satellite made of cubes with side length of 10 centimeters, and Georgia Tech has used this satellite structure heavily for its space missions over the last decade.

The basic principle of the HyperSat mission is to launch a CubeSat into a highly eccentric elliptical orbit around the Earth, with a perigee altitude of about 65 kilometers and an apogee height at about geosynchronous altitude. During the perigee pass, the CubeSat will deploy its Hypersonic Inflatable Aerodynamic Decelerator (HIAD) heat shield activate its payload to measure high speed flow properties used to validate CFD (computational fluid dynamics) models for the airflow, while the onboard shuttlecock heat shield keeps the satellite at a stable angle of attack. After this initial pass, the satellite will exit the atmosphere, where it will unload any excess angular momentum from the maneuver and transmit the CFD data down to Earth before its next low-altitude pass.

As the Pre-Phase A portion of this mission's design is wrapping up, this report lays out the current rendition of the mission concept, as well as some general information on its mass

properties, some cost estimates, and the volume budget for its subsystems. The paper proceeds with a top-down walkthrough of the different systems of the spacecraft. Section II covers the high-level mission operations and communications procedures for recording CFD data and beaming it down to Earth. This includes a brief summary of the ground station and the mission plans to contract for the data transfer. Section III gives a compact list of the components stored on the spacecraft, as well as their masses and volumes. There is also an overview of the systems' data generation and how this data flow can be managed between contacts. Finally, Section IV provides a low-level showcase of the spacecraft's general layout and the estimated mass properties of the spacecraft. Note that any data referenced that pertains to the projected orbital period and the required delta-V for maneuvers has already been compiled by other members of the Hypersat team and is out of the scope of this paper.

Section II: Mission Concepts

The process of maneuvering a spacecraft into the upper atmosphere of a planet to reduce its velocity is known as "aerobraking," a technique commonly used on deep space missions to dump momentum and lower the apoapsis of the spacecraft's orbit. For the HyperSat mission, dumping momentum in the atmosphere is a necessary consequence of gathering hypersonic data. During each pass through the upper atmosphere, the HyperSat will lose a bit more momentum and its apoapsis will decrease, eventually culminating in the spacecraft directly entering the Earth's atmosphere and burning up in re-entry. Although it is possible that the heat shield on board the spacecraft may allow the spacecraft to survive the initial descent, there are no parachutes located on board the satellite. Thus, this mission design proceeds on the assumption that recovering the spacecraft in the atmosphere is not a feasible strategy, and instead focuses on transmitting the data from the spacecraft to the ground while the spacecraft is not in atmosphere.

Section II.1: Spacecraft modes

While in flight, the spacecraft can have its internal power and data parameters modified to both conserve power and time for the mission operators. These sets of parameters categorize the satellite's mission phases, where each piece of the mission's CONOPS corresponds to a different setting, or "mode," for the spacecraft's bus in terms of its power consumption and its data recording rate. For the HyperSat mission, six primary modes have been defined, with each mode having a different purpose, duration, and position in the mission.

Table 1: Spacecraft Mode Definition

Mode Name	Mode Description	Duration Per Orbit
Standby	Idle behavior in between contacts and passes	4 hours
Safe	Fault protection mode for emergencies. Temporarily loses position lock on Earth while cycling between transmitting and receiving commands Battery charging may also occur.	Indefinite

Charge	Solar panels point at the Sun, minimal power consumption.	4 hours
Science	Spacecraft mode used during atmospheric passes. High power use and data generation.	20-40 minutes
Communications	Mode used during contacts. Either the transmitter or the receiver is active, though likely both.	2 hours
Maneuver	Mode used during propulsion burns or momentum dumps. Elevated temperatures and power usage.	10 minutes maximum

Section II.2: Communications Concepts

There are a multitude of aspects for downlinking data from a spacecraft, all of which must be considered for HyperSat. Although the data downlinking process can be made automatic, a human operator should be present during all contacts to carry out the following procedure for robustness. First, the data is generated onboard the spacecraft via the payload. Due to the modular design of HyperSat, the payload will be fitted with its own computer that can write scientific data in real time, and then send that data to the central processor in the spacecraft bus after the low-altitude pass. The specific actions of the payload are not the focus of this paper, but once this data is written to the central processor, the data can then be sent to Earth via a command sequence uploaded by the operator on Earth. Both command sequences and the data must pass through a powerful antenna on the ground known as a "ground station." While the Georgia Tech SSDL does possess its own ground station, the extremely high altitudes reached by HyperSat during its apoapsis pose an issue that this ground station may not be able to generate enough signal power to close the spacecraft communication link budget. Additionally, there is a high chance that the spacecraft will not be in view of Atlanta during its apoapsis. Therefore, the HyperSat team has decided to contract out to a third-party commercial ground station array such as KSAT, for example. This ground station network is both powerful enough and has enough stations around the world to facilitate this program, and the HyperSat team plans to rent timeslots for the mission launch and operations in order to contact the spacecraft. This time can be rented either directly through KSAT, or by using the NASA SCaN office as a medium. Other options for rental ground stations include TDRSS, a satellite relay network orbiting the Earth at geostationary altitudes, or a Space Force-owned relay network, which would only be available by agreement with the Space Force.

In addition to the payload data, the HyperSat is constantly generating miscellaneous flight data unrelated to its primary science objective. These data packets consist of key telemetry about the spacecraft's internal temperature, its momentum state, its position around the Earth, and fault ID data if anything is amiss aboard the spacecraft. These data packets are generated by the flight software on board the spacecraft's central processor and are a key part of any satellite operations mission. Thus, during a contact, the operators must downlink the data from the satellite bus as well as the payload data in order to ensure the wellbeing of the spacecraft. Since

any single ground station rented by the HyperSat team will have a set maximum bandwidth, the amount of data that is generated by the spacecraft per pass around the apoapsis needs to be estimated.

As of June 2024, the size of each payload experiment data packet generated during an atmospheric pass has yet to be rigorously calculated, nor have any rigorous tests of the amount of data generated by the flight software been conducted.

The following numbers for the satellite data traffic going forward are based on the Lunar Flashlight (LFL) mission, another CubeSat mission designed and operated by the GT Space Systems Design Lab. For analysis of the data, the order of magnitude of the payload data will be estimated to be the same as LFL, at one megabit per second. Thus, for an atmospheric pass lasting 30 minutes, there will be 1,800 megabits of science data to send at the end of an atmospheric pass, all of which needs to be written from the payload computer to the central processor before it can be sent down to Earth.

Next, an estimate for the flight software data generated per pass needs to be made. One important aspect of satellite data management is that while the flight software is constantly measuring state data in real time, the rate at which this data is recorded into packets can be changed. When fewer packets of data are being recorded per second, there is less data that needs to be downlinked per contact. This packet rate can be determined either automatically depending on what mode the spacecraft's flight software is in, or it could be determined manually by an operator. Reference data from Lunar Flashlight documents show that the primary difference in data generation takes place in either the standby, science, or maneuver modes, and these numbers are referenced below as estimates for the HyperSat data generation. The standby, safe, charge, and communications modes all generate approximately 1200 bits per second passively without any alterations by the operator. The maneuver mode generates about 6400 bits per second, as propulsion data and the spacecraft's linear and angular momentum states must be carefully recorded to properly navigate. Finally, the science mode generates approximately the same amount of data per second as the standby and adjacent modes, but with the addition of the payload data being written to the central computer. In total, with an initial orbit period of 10.47 hours, assuming no maneuver is necessary during the orbit, approximately 43.79 megabits of data will be generated over the course of one orbit, which is almost negligible compared to the science data load. Therefore, most of the time during a contact will be spent downlinking science data after flight software data has finished downlinking.

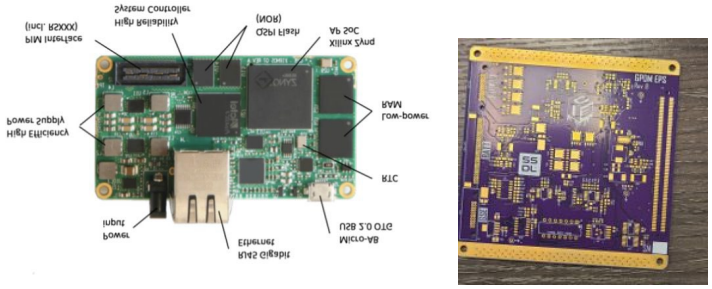
Section III: Mass and Volume Budgets

Last year, the HyperSat team in the SSDL conducted a variety of trade studies to determine options for each subsystem onboard the spacecraft bus. As of June 2024, the team has made a preliminary decision on which parts can be chosen for each subsystem. Over the last year, the Georgia Tech SSDL has tried to centralize the bus design between all projects, resulting in many similarities between the design of HyperSat and the NASA GPDM project. The two

missions therefore have similar mass and volume distributions and specific parts for each subsystem, each of which is listed below.

Section III.1: System Descriptions

As mentioned, the HyperSat bus contains a central computer meant to direct power and manage data across all of the different systems of the satellite. The central computer inside the CubeSat consists of three primary circuit boards: a flight computer, an electronic interface board, and an EPS board to manage the power flow between components. The flight computer will consist of a Xiphos Q7S, an FPGA chip used on the GPDM mission that is programmable by the engineers at the SSDL. The flight software mentioned before will be loaded onto the central FPGA, and it will be responsible for storing all of the data written from the payload, as well as managing commands from the operator. The FPGA will be connected to the interface board and EPS board. The SSDL has devised original designs for these two circuits boards which are manufactured in-house for a lower total cost on electronics. Images of both the flight computer and the interface board are both shown below.



(Image credits: Satsearch (left) and Robert Lammens (right))

Figure 1: Xiphos Q7S as flight computer (left) and SSDL-made Interface Board (right)

The power supply consists of 2 body-mounted solar panels by DHV Technologies, each one placed on opposing ends of the satellite. These lightweight solar panels will generate a small amount of power over the course of the mission, enough to fuel the power demands of the satellite for the mission duration. However, the solar panels are only there to top off the onboard battery system, also developed in-house by the SSDL. The battery system is able to directly deliver up to 10.4 volts, though the interface board contains transformers to adjust that voltage when power is being transferred to a specific system. Analysis of electrical properties for each system inside the satellite reveals the maximum voltage drop across all systems of the satellite bus to be 57.9 volts, so a total of 6 battery systems will be needed to validate this requirement. However, it should be noted that both the communications system and the propulsion system, both of which draw up to 12 volts at a time, will never be fully turned on at the same time to the spacecraft mode restrictions, meaning the actual maximum voltage drop during the mission will be well below 57.9 volts. Due to the short duration of the HyperSat mission, these battery systems should provide power through the entire mission with minimal recharging required, though further analysis on the robustness of these arrays is required. The reliance on stored power in battery systems as opposed to solar panels is due to the mass constraint of the mission,

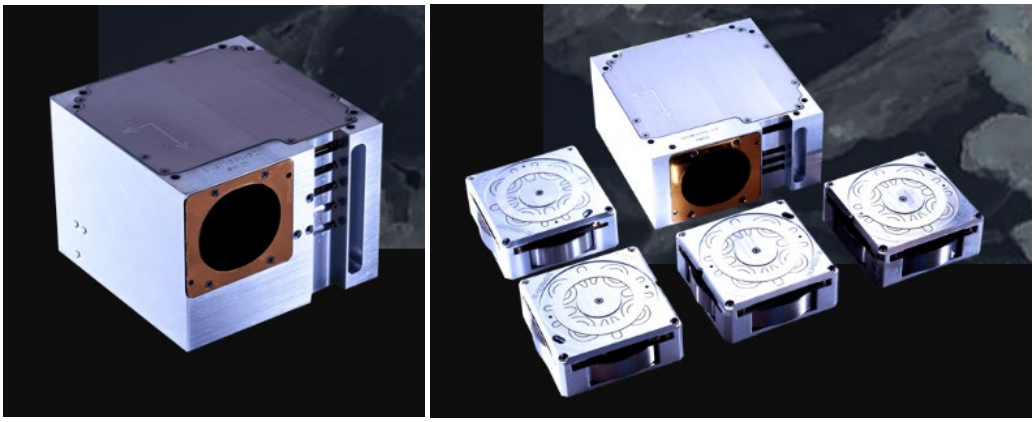
as the satellite cannot accommodate enough body-mounted solar panels on board to provide ample power to the spacecraft systems and also fit inside the 24 kg mass limit. An array of deployable solar panels that all point in the same direction is also out of consideration, as the deployment mechanisms would be too fragile to mount on a satellite moving through the atmosphere at hypersonic speeds.

The centralized SSDL CubeSat design adopts the Quasonix TIMTER and RDMS as the radio modules, being a transmitter and a receiver respectively[2][3]. This is in contrast to previous SSDL CubeSat missions, where radios such as the IRIS that were onboard the Lunar Flashlight were equipped with both transmitting and receiving capabilities. However, by the time that HyperSat launches, the SSDL will have launched the NASA GPDM mission, which is also being designed with the Quasonix receiver and transmitter. The other reason for this choice is that the Quasonix modules have a much higher uplink and downlink speed than any of the available radios that the SSDL has used in previous missions, boasting a downlink rate of 28 megabits per second and uplink rate of 5 megabits per second, though whether this number is rated for low Earth orbit or geosynchronous orbit is yet to be determined. Even if the downlink speed is only 10% effective at geosynchronous altitudes near the apoapsis when the contact takes place, the 2.8 Mbps available downlink speed will be able to downlink the 43.79 megabits of flight software data in only 16 seconds and downlink the estimated 1,800 megabits of science data in 642 seconds, or just under 11 minutes. With a 2-hour contact, this leaves plenty of time for the operators of HyperSat to downlink all necessary data and perform checkups on the spacecraft's health in the allotted time. The downside is the obvious loss in volume allowance with the two modules being separate, but the increase in downlink speed is likely to make up for this deficit.

For the propulsion system, it was determined by the HyperSat team that a 12U system weighing 20 kg would require a delta-V of 40 m/s to make all of the required maneuvers over the mission. Since then, the planned weight of the CubeSat has increased to 24 kg, which would require more velocity than the previous prediction. Due to this planned increase in required thrust over the mission, the SSDL plans to use a Rubicon-based monopropellant thruster for HyperSat as opposed to a cold gas thruster. The SSDL has experience with integrating and operating monopropellant thrusters, and they provide a higher specific impulse and thrust per unit weight than the previously planned cold gas thrusters [4]. The specific mass distribution of all of the thruster parts is Rubicon proprietary information, but the entire thruster system has a wet mass of approximately 2.37 kg per thruster with a 10% margin of error, not including an integrated SSDL propellant management chip that weighs an extra 17 grams. In total, the propellant system, assuming no higher degree of power is required, would weigh 2.387 kg, and produce enough thrust to conduct all of the maneuvers over the mission.

Next for the attitude determination and control (ADCS) system, the SSDL bus design includes the XACT system by Blue Canyon Technologies. The XACT is a system that can both determine the spacecraft's attitude via a star tracker and control the attitude using a series of 3 reaction wheels. For the HyperSat mission, the SSDL is considering the use of both the lighter

XACT-50 and the heavier XACT-100. Both systems are almost identical with the exception of their mass and volume distribution. The XACT-50, as its name suggests, can store up to 50 millinewton-meter-seconds (mNms) of angular momentum until saturation, at which point the thruster needs to be fired to dump some of the momentum. It weighs 1.23 kg and takes up a total of 0.754 units of CubeSat space, where the "units" refers to a 10x10x10 centimeter cube, or 1 liter of volume. The XACT-100 can store up to 100 mNms of momentum, and also comes with reaction wheels detached from the central star tracker, allowing for freer positioning inside the CubeSat. The central star tracker only weighs 0.433 kg, but the detachable reaction wheel systems weigh a total of 1.38 kg, bringing the total weight of the XACT-100 up to 1.813 kg. [5] Both systems are shown below to give context as to their relative sizes.



(Image credit to Blue Canyon Technologies)

Figure 2: XACT-50 (left) and XACT-100 (right)

The primary purpose of the XACT during the HyperSat mission is not to stabilize the spacecraft while it is passing through the atmosphere, but rather to stabilize the spacecraft immediately after the CubeSat exits the atmosphere. The extreme turbulence that the satellite will face while aerobraking will be too much for even the heavier XACT-100 to handle, with the predicted torques on the satellite in atmosphere being on the order of several newton-meters. The shuttlecock design of the spacecraft's HIAD will mitigate this initial in-atmosphere torque using air resistance, but when the spacecraft exits the atmosphere, there will be no air to stabilize the craft anymore, resulting in some leftover momentum on the spacecraft. This leftover momentum is what the XACT will store over several passes, and each time the thruster will be fired to dump this momentum to allow the XACT to repeat the process again. The magnitude of this leftover momentum post-atmosphere is unknown, and the SSDL is currently planning to use the XACT-100 as a safety precaution, giving the spacecraft the widest possible margin of error to unload the momentum. However, should new calculations emerge later in the design process that proves the leftover momentum will be significantly less than 50 mNms, the XACT-50 will be installed in the CubeSat instead in order to save on mass and volume costs.

In total, the mass and volume costs for all of the spacecraft's known systems in the bus needs to fit in a 12U CubeSat structure, which is a series of 12 steel cube frames, each 10 centimeters in length. Additionally, rideshare facilities will only offer space for a CubeSat under

a certain weight, hence the 24 kg mass limit on the satellite. Therefore, a budget has been constructed for the mass and volume of all the systems in the satellite. The table below shows all of the systems discussed previously in addition to patch heaters and radiators that need to be scattered about the internal systems of the satellite, providing heating and cooling when necessary so none of the parts malfunction.

Table 2: Mass and Volume Budget of all Major CubeSat Systems

SUMMARY TABLE:	*Mass (kg)*	*Volume (CubeSat units)*	*Margin of Error*
Propulsion	4.758	4.092	20%
Navigation/Control	2.005	0.55	10%
C&DH	0.840	1	40%
Communications	1.382	3.001	10%
Power	3.660	0.24	40%
Structure	3.900	N/A	30%
Thermal Control	0.065	0.056	40%
Payload	7.390	3.061	
Total=	24 kg	12 U	

Note: The numbers shown above include the margin of error

The table above uses mass and volume estimates for 2 monopropellant thrusters and the XACT-100, as well as both the Quasonix TIMTER and RDMS. All parts included in the budget have their properties measured, including a margin of error, depending on how much information on each part is publicly available. With all of the parts described above included, this leaves an 8.1 kg mass margin and 3.06 U volume margin for all payload parts to be included in the spacecraft, including the HIAD heat shield, the wind tunnel, and the test airfoils for any hypersonic wind tests. As of June 2024, other members of the HyperSat team are currently modeling the payload design to fit inside this limit and will continue to do so into the next fiscal year.

With all of these systems laid out, the next logical question is how much would assembling all of this cost? Everything described in the previous section is available online at various satellite piece retailer websites or are directly available from the manufacturer website. Surface level part acquisition estimates place each system cost in the range of between $10,000 and $300,000. The following is a rundown of the costs for all of the systems based on estimates carried out by the GT SSDL HyperSat team.

Table 3: HyperSat System Acquisition Cost Estimates

System Name	Subsystems	Estimated Cost (USD)
Propulsion	Rubicon Monopropellant Thrusters	300,000
Attitude Control	XACT-100	300,000
C&DH	Xiphos Q7S, SSDL Interface and EPS Boards	50,000 (including manufacturing costs)

RF Communications	Quasonix RDMS, TIMTER	150,000
Power Supply	DHV Solar Panels, SSDL Battery Arrays	40,000
Internal Thermal Systems	PTCA-20 Heaters	10,000
Structural Material	12U CubeSat Superstructure	50,000
Ground Systems	TDRS / KSAT Contact Time	100,000
Payload	Thermistors, Pressure Sensors, Internal Computers, Test Foils, etc.	240,000

The total cost for the part acquisition for the CubeSat bus and payload comes out to 1.24 million dollars, however, this will only be a small portion of the total cost of the entire mission. Additional costs for the mission will include paying for a rideshare rocket for the satellite to achieve orbit, alongside any R&D costs for developing the payload itself. While every other major part of the spacecraft can be sourced from outside vendors or within the SSDL, the HyperSat payload is still in development, being tested and designed by the GT Research Institute. The full cost of this R&D in order to achieve the desired technology readiness is beyond the scope of this paper.

Section IV: Operational Considerations

All of these design decisions for both the communications and the spacecraft bus will eventually affect the way that the spacecraft is operated. On June 18th, the HyperSat team attended a meeting with the Test Resource Management Center in Tennessee, who believe that figuring out the operations of the satellite in the early phases of design are important to consider. For the spacecraft operations, there are two phases of the mission that must be considered. First are the early launch operations, where the spacecraft is stabilized in space and prepared for long-term standby through various command sequence uplinks. The second phase to be considered is the contact made with the spacecraft during normal operations: where the spacecraft passes through the atmosphere to gather data and transmit it to a ground station or relay satellite.

One of the main talking points for the HyperSat operations design is how the data from the satellite is going to be handled after it is generated during the atmospheric pass. For security reasons, any customers who fund the mission are going to want the data transferred from the satellite both quickly and securely. Immediately before the atmospheric pass, the satellite will enter the previously mentioned Science mode, where the spacecraft will be prepared to record and store scientific data to the payload. This is normally done by an operator uploading a command sequence to the satellite that forces the satellite to start an experiment with a set duration. When the timecode for the experiment passes, the satellite is normally left unperturbed for the duration of the experiment, and then is commanded to write the data to the central spacecraft bus when safe to do so. However, there is nothing specifically preventing the spacecraft from receiving commands during the experiment phase. The spacecraft's Science

Mode is a simple change in the spacecraft's software whose only real purpose is to allow for the activation of the payload's internal hardware. Therefore, it is theoretically possible to write and downlink the data from the spacecraft during the atmospheric pass in a live data stream. However, there are two problems with this approach that limit the usefulness of this strategy.

The first problem is the time in which it takes for the data to be processed onboard the satellite before it can be beamed down. As mentioned before, the data needs to be written from the payload computer to the central processor, which takes time to complete. The current plan for operations states that all of the data from the previous pass needs to be downlinked before the next pass through the atmosphere, so the writing of the data to the central processor can be performed with the upload of a bridge sequence to the satellite. For the current plan of downlinking the data while the satellite is near its apoapsis, this sequence can autonomously execute commands at specific times even while the spacecraft is not in contact with a ground station. The bridge sequence commands the spacecraft to write the data before a contact with the ground station, leaving the operator enough time during the satellite's apoapsis pass to command the satellite to downlink its flight software data and the science data from the payload. However, if the satellite is going to transmit the data to the surface during an atmospheric pass, this time delay of writing the data is going to place a massive latency on the data stream, as the writing of data takes several minutes even without other commands being processed during the data transfer. If the data is to be streamed live, then it is highly likely that any data generated during the pass will have a latency of several minutes before arriving at the ground station. With the current data handling architecture, a much more powerful processor is needed than what has been acquired previously on SSDL CubeSat missions. Further testing is required to know if the Xiphos flight computer mentioned above is capable of such a fast read-write process.

The second problem faced by a data livestream is the interference that the satellite will encounter from the atmosphere itself. When a satellite enters the atmosphere, the surrounding air is compressed until the air heats up and ionizes, creating a plasma shield around the satellite. As plasma is, by nature, highly electrically charged, this will create interference for the signal passing through the atmosphere on its way down to Earth. Antenna noise in decibels (dB) is directly proportional to temperature added to the Boltzmann constant $k = -228.6\ dB/K$ [6]. Past satellites on atmospheric reentry have experienced temperatures of approximately 3,200 K [7`], so it is safe to assume similar temperatures will be experienced by HyperSat during each atmospheric fly-through. Such massive amounts of heat will inevitably transfer to the space surrounding the antenna, creating a large amount extra noise for the signal. Any link budget for a radio signal must maintain a certain signal-to-noise ratio for the signal to be readable upon its reception. This massive heat-generated noise will require an inordinately strong signal just to punch through this noise, and it is unclear if the Quasonix TIMTER is capable of such a signal. The GT Space System Design Laboratory will continue to research the plausibility of this data livestream in future months, but this heat problem remains a roadblock to this capability for the near future.

Section V: Conclusion

The Pre-Phase A design of the HyperSat spacecraft has culminated in a vision for a 12U spacecraft capable of gathering CFD data from hypersonic flow. However, there is still a lot more information to process before the spacecraft can be manufactured, some of which are outside the scope of this paper and the capabilities of the SSDL, while some are problems that have yet to be solved by the HyperSat team. One unsolved problem within the SSDL's capabilities is the 3D modeling of the spacecraft to find a good estimate of its mass and inertial properties. At the time of this paper's writing, two models exist that have been created by the team, but neither as of yet provides an accurate rendition of the HyperSat spacecraft. These mass measurements are necessary for other members of the team to adequately model a shuttlecock nose design that will aerodynamically stabilize the spacecraft during an atmospheric pass, along with making a suitable mass and volume allocation for the payload designers in more detail than the numbers provided in Table 2. Additionally, security concerns over the clearances that will be required by the ground operators have been brought up by the HyperSat team, citing issues with the current structure of export-control certified spacecraft operators currently at Georgia Tech. Many defense contractors such as TRMC do not believe that student operators have the necessary requirements to conduct strict security procedures for transmitting sensitive data from the satellite to the customers. These issues still need to be worked out before early design can be considered complete.

Once the early design of the spacecraft is complete, a comprehensive set of requirements for the spacecraft will need to be laid out and validated against the parts considered in this paper to ensure the viability of each system's design. This is what future endeavors of the SSDL team will be focused on in the coming years until the launch of the HyperSat spacecraft.

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