SOUNDING ROCKET SYSTEM SPECIFICATION

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Table 1: Document Change History

Date	Rev	Description	Status
11/17/21	SSD-00	Initial Draft	Graded
02/07/22	SSD-01	Post Initial Grade Revision	Pre PDR
04/25/22	SSD-02	CDR Revisions	Final CDR

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1 Scope

This document serves as the Sounding Rocket Project System Specification. This System Specification describes and defines the specific “design-to” requirements for the Sounding Rocket as an entity. This includes system definitions for each off the functional areas of the rocket and the system requirements which speak to functional and performance requirements as well as allocation, the Technical Performance Measures (TPMs), and system trade-off studies.

2 Applicable Documents

Table 2: Applicable Documents

ID	Title
REQ-02	Requirements Sounding Rocket Matrix
CONOP-02	Sounding Rocket Concept of Operations (CONOPS)
MBSE-01	MBSE Model Overview Document

3 System Definition

3.1 General Description

The Sounding Rocket consist of a Rocket and Payload. The primary focus of the rocket is to launch a provided payload to a pre-determined altitude to collect video and telemetry with the ability to retrieve the data for post-flight feedback to the users. The Sounding Rocket is a Single Stage Class I Rocket divided into subsystems.

3.2 Functional Analysis and System Definitions

The functional analysis of the sounding rocket consisted of comparing multiple well established sounding rocket project that have been conducted and analyzing their different capabilities. Using this data, the functional areas of the rocket were determined to be the structure of the rocket, the propulsion system, the avionics, the payload, the recovery system, and the ground station. Each of the functional subsystems are required for the operation of the Class I Sounding Rocket.

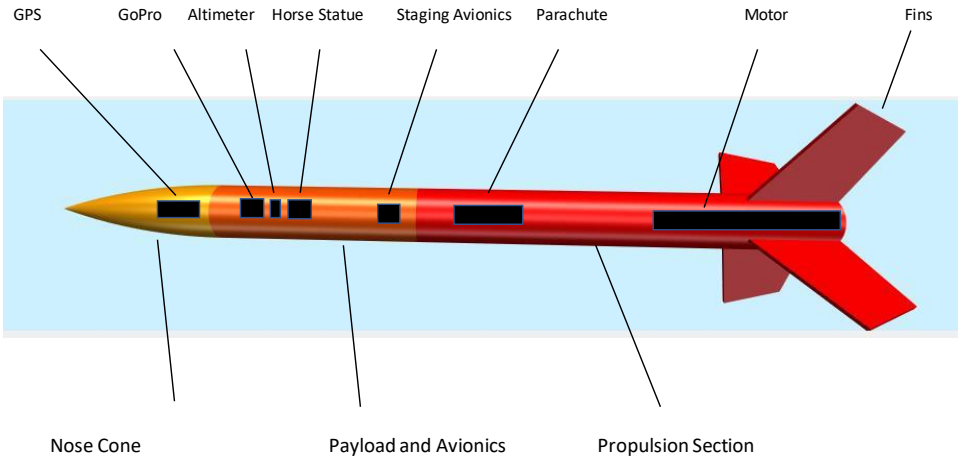

Figure 1: Sounding Rocket

3.3 System Characteristics

3.3.1 Performance Characteristics

The sounding rocket motor has the capability to produce thrust required to reach an altitude of 4,000 ft AGL. During the duration of flight, the sounding rocket will be collecting altitude data, recording video, and communicating GPS tracking data to the ground station. The sounding rocket recovery system provides the capability of a safe and secure landing of the rocket.

3.3.2 Physical Characteristics

The physical structure of the sounding rocket is a single stage rocket that will be within limits of 7.5ft in length, 4in in diameter, and weighing 76lbs. The rocket is a tubular rocket with a nose cone at the tip of the rocket, the mid sections consisting of the payload and avionics bays, the propulsion subsystem housing the recovery system and motor, and fins attached near the rear of the rocket. The structure is shown above and depicted further below in a block definition diagram:

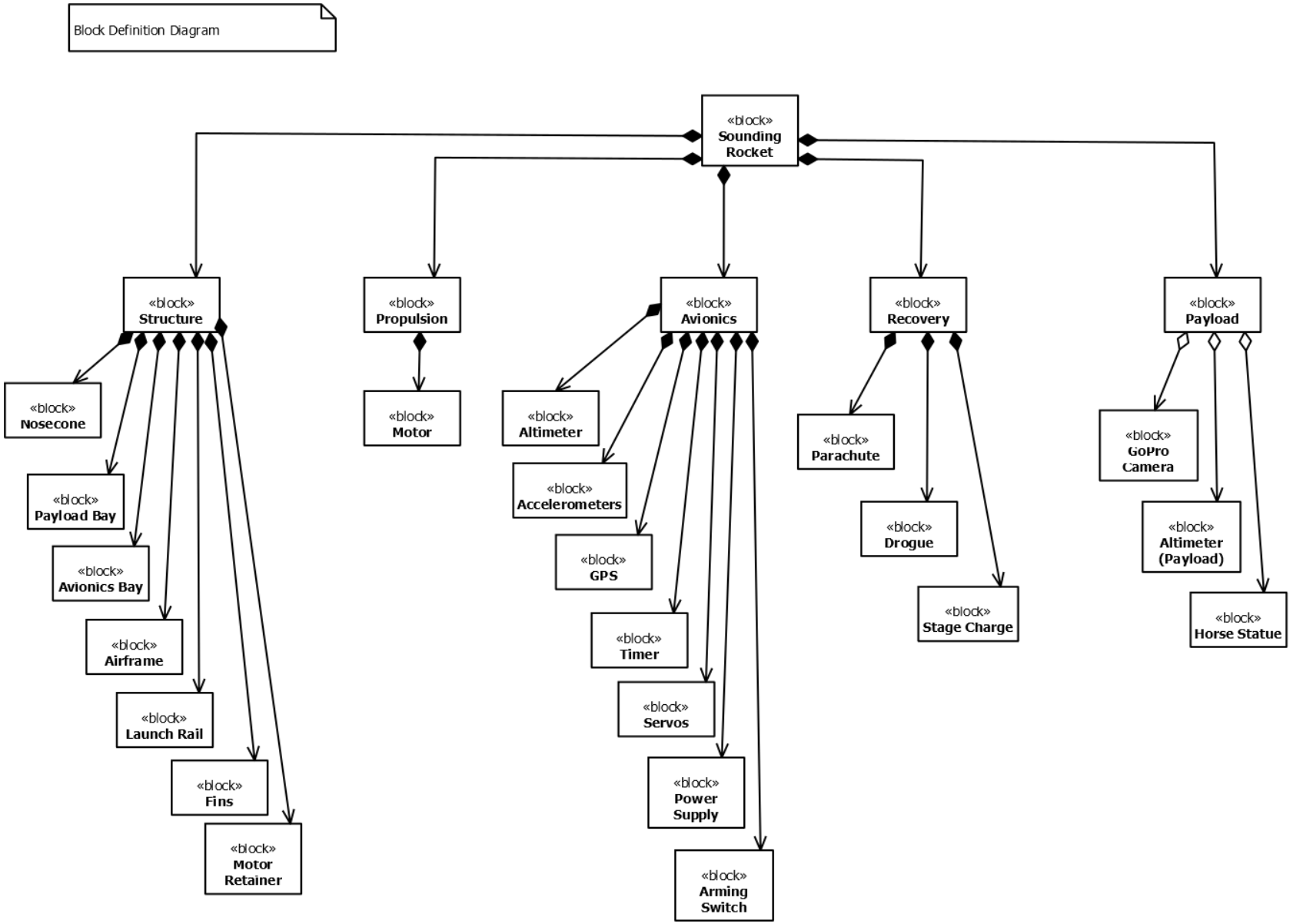

Figure 2: Block Definition Diagram

The sounding rocket body will also be painted to the desire of the stakeholder with the Kino Junior High Logo.

3.3.3 Trade Study Analysis with Rocksim

Rocksim provides the data needed for the sounding rocket design and configuration trade study analysis by providing COTS product options that meet the requirements of the sounding rocket. All of Configuration Items (CIs) for the functional areas of the rocket were decided on using the inherent trade study analysis within Rocksim. Rocksim allows you to view the specifications of COTS CI products and design a rocket to meet requirements. Each of the chosen COTS CIs for the sounding rocket utilized this technique of selecting the desired products, building the rocket, and then running simulations within Rocksim to confirm performance.

3.3.4 Structure – LOC Precision

The structure of the sounding rocket is comprised of LOC Precision COTS products to include the overall body tube of the rocket, the nose cone, the fins, and the division of each of the other subsystems. The structure of the rocket houses the other subsystems to include the payload bay, avionics bay, the propulsion bay, and the nose cone. The aerodynamic structure and fins provide a stable environment for the payload, avionics, and propulsion system to operate effectively.

Table 3: LOC Precision Structure Specification

Structure Specification	Measure
Temperature Resistance	$-20°C\ to\ 80°C$
Acceleration Endurance	$20\ g\ over\ 14\ sec.$
Overall Length	$60\ in.$
Inner Diameter	$3.9\ in.$
Overall Mass	$4\ lbs.$
Nose Cone Length	$12.8\ in.$
Payload Bay Inner Diameter	$3.9\ in.$
Payload Bay Length	$15\ in.$
Body Tube Inner Diameter	$3.9\ in.$
Body Tube Length	$29\ in.$
Fins Length	$7.25\ in.$
Fins Diameter	$18.25\ in.$

3.3.5 Propulsion - AEROTECH

The COTS propulsion system, AEROTECH 38MM PROPELLANT KIT - I284W-14A, provides the thrust necessary to launch the vehicle and sustain an acceleration and velocity required to reach the desired altitude. The propulsion system motor runs on a non-toxic propellent and is a single stage system. The motor fits appropriately within the propulsion section of the rocket and fits within the required mass requirements.

Table 4: AEROTECH 38MM PROPELLANT KIT - I284W-14A Model 81351

Propulsion Specification	Measure
Burn Time	$1.9\ sec.$
Total Impulse	$607.3\ Newton-seconds$
Motor Length	$288\ mm$
Max Thrust	$570.6\ Newtons$
Total Mass	$568.0\ g$

3.3.6 Avionics

The avionics system consists of COTS components necessary to conduct, control, and execute the launch, flight control, and recovery of the rocket. These components meet the requirements to operate for Class I rockets and include a GPS (Featherweight GPS Tracker) and a flight computer (Eggtimer Quantum) that consists of an accelerometer, timer, servos, power supply, and arming switch.

3.3.6.1 GPS - Featherweight GPS Tracker

The GPS detects geographical location and altitude of the rocket and is used to provide the ground station telemetry data on the location of the rocket during flight and recovery operations.

3.3.6.2 Flight Computer - Eggtimer Quantum

The flight computer primary function is to monitor onboard flight status of the rocket by collecting and evaluating data from the timer, accelerometer, and GPS tracker in order to calculate when to deploy the recovery parachute and drogues after apogee is reached.

- **Accelerometer**

  The accelerometers are sensors that detect acceleration and help the flight computer to determine forward ascent air speed.

- **Timer**

  The timer is used by the flight computer in tandem with the altimeter and accelerometers to determine the best time to deploy the drogue and main parachutes for recovery.

- **Servo(s)**

  The servos are used for deployment of deployable payload items should any be chosen in the future for the rocket. For the sake of Kino Junior High (the sponsor), this is not needed but is reserved for future payloads needing to be deployed from the payload bay.

- **Power Supply**

The power supply provides power to all onboard avionics. It is battery operated and is capable of providing all voltage and current power to the onboard avionics.

3.3.6.3 Arming Switch – Eggtimer Wifi Switch

The arming switch provides power to the onboard power supply and is also used to arm the energetics used to deploy the parachute and drogues for recovery.

Table 5: Avionics Specification

Avionics Specification	Measure
Temperature Resistance	$-20°C\ to\ 80°C$
Acceleration Endurance	$20\ g\ over\ 14\ sec.$
Featherweight GPS Tracker	
GPS Board Size	$1.67\ in. x\ 0.8\ in.$
Total Length	$4.1\ in.$
Mass	$15\ g$
Advanced GPS	$10\ GPS\ Solutions\ per\ sec.$
Eggtimer Quantum Flight Computer Accelerometer, Timer, Servos, and Power Supply	
Size	$2.5\ in. x\ 0.9\ in.$
Mass	$15\ g$
Eggtimer Wifi Switch	
Size	$63.85\ mm\ x\ 23.85\ mm$
Range	$100\ ft.$

3.3.7 Payload

The sounding rocket will carry a payload that includes the GoPro camera for recording the flight, the customer provided altimeter that will collect altitude data, and the horse figurine provided by the customer.

3.3.7.1 GoPro

The GoPro Hero 9 with a GP2 Processer camera will record the rocket flight through a 2 in. x 2 in. opening in the payload bay so that the customer can view the recording after retrieving the camera post flight. This GoPro camera provides Hyper Smooth 4.0 video recording, Super View and Wide View options for field of view of recording, and a substantial amount of memory space to record the entire flight. The GoPro will be mounted using a custom designed Balsa Wood mount that will connect to the inside of the payload bay. This custom mount will hold the GoPro in place during the duration of the flight with the camera's field of view pointed out of the rectangular viewing hole measuring with a protective covering.

3.3.7.2 Customer Provided Altimeter - 002246 Estes Altimeter

The customer provided altimeter is an air-pressure sensor that detects the altitude through the change in air pressure as the rocket ascends. This is a separate altimeter than the one used by the flight computer and is purely for data collection for the customer to view after recovery.

3.3.7.3 Horse Figurine

The horse figurine provided by the customer is a representation of the school's mascot and is a fun way for the students to connect with the project. The horse figurine does not have any contributions to the sounding rocket system in a technical sense and will be secured by the payload bay insulation causing no issues concerning space and weight.

3.3.7.4 Payload Bay Insulation

The payload bay insulation serves as a securing and cushioning protection agent for the items within the payload bay. The insulation will fill the empty spaces as possible within the payload bay and will have an approximate mass of 0.5 oz not raising any concerns for weight restrictions.

Table 6: Payload Specification

Payload Specification	Measure
Temperature Resistance	$-20°C\ to\ 80°C$
Acceleration Endurance	$20\ g\ over\ 14\ sec.$
GoPro Hero 9	
Size	$2.4\ cm. x\ 1.3\ cm. x\ 1.8\ cm.$
Mass	$4.3\ oz.$
Mount Mass	$\leq 1\ oz.$
Viewing Hole Size	$2\ in. x\ 2\ in.$
002246 - Estes Altimeter	
Size	$2.1\ in. x\ 0.75\ in. x\ 0.5\ in.$
Mass	$0.415\ oz.$
Horse Figurine	
Size	$1.5\ in. x\ 1.5\ in. x\ 1.5\ in.$
Mass	$1\ oz.$

3.3.8 Recovery - LOC Precision Parachute

The recovery system is a LOC Precision Parachute COTS dual-event parachute that will land the sounding rocket safely in order for recovery.

Table 7: LOC Precision Specification

Recovery Specification	Measure
Temperature Resistance	$-20°C\ to\ 80°C$
Acceleration Endurance	$20\ g\ over\ 14\ sec.$
Parachute	
Round Diameter	$35.9843\ in.$
Mass	$85\ g$
Shock Cord	
Shock Cord Mass	$51\ g$
Shock Cord Mount Mass	$7.1\ g$

3.3.9 Ground Station

The ground station is where the launch, flight, and monitoring of the rocket will be witnessed. The ground station provides monitoring capability using the Featherweight GPS Tracker mobile app facilitating the recovery of the rocket. The app provided real time updates as it communicates with the Featherweight GPS Tracker within the rocket.

3.4 Usability

3.4.1 Reliability

The sounding rocket utilizes COTS products that have been designed, tested, and used specifically for sounding rockets. The use of COTS products that have been tested and used on numerous sounding rocket projects with successful results directly contributes to a reliable sounding rocket for this project.

3.4.2 Human Factors

The human factors for the sounding rocket include assembly of the rocket, conducting launch pad setup, arming of the rocket, monitoring the GPS tracking data, and then recovering the rocket after landing. This is laid out and depicted within the use cases include in the MBSE-01 MBSE Model Overview Document. The operation specifics are described in detail within the CONOPS.

3.4.3 Transportability

The sounding rocket has the ability to be disassembled for transportation and then reassembled at the launch site for flight. The sounding rocket does not require special or unique transportation and can be transported using a standard vehicle.

3.4.4 Security / Safety

The COTS products utilized for this project have been thoroughly safety tested and have proven to be safe on other rocket projects. Specifically, the ignitor system utilizes a safety key that follows and adheres to standard Tripoli and NAR safety protocols. For security, the Tripoli and NAR launch

safety protocols are followed at the launch site with the guidance and supervision of a Range Safety Officer.

4 Requirements

4.1 Allocation of Requirements

The requirements are broken down into functional allocation categories aligning with the different subsystems of the rocket. The hierarchy of requirements is as follows:

- System Requirements
  - Functional Requirements
  - Performance Requirements
  - Configuration Item (CI) Requirements

4.2 System Requirements

The operational requirements for the Sounding Rocket start at the highest level with the customer or system requirements (SRs). The SRs are the overarching parent requirements for the project defining the overall purpose of the project and serve as the foundation for the rest of the requirements.

Table 8: System Requirements

Req ID	Description
SR-0001	The Sounding Rocket Project shall provide a solution for launching a Sounding Rocket with a recoverable payload.
SR-0002	The Sounding Rocket Project shall provide a solution for launching a Sounding Rocket that collects avionics data to include altitude and GPS tracking.
SR-0003	The Sounding Rocket Project shall provide a solution for launching a Sounding Rocket that records video during the duration of flight.

4.3 Functional, Performance, and Configuration Item Requirements

The functional requirements for the Sounding Rocket stem from the system requirements and are defined based on the functional areas of the sounding rocket. The performance requirements for the Sounding Rocket stem from the system requirements as well as the functional requirements and define the specific performance requirements for the functional areas of the sounding rocket. The configuration item (CI) requirements specify the requirements for the configuration aspects of the rocket. The requirements are also depicted within the MBSE-01 MBSE Model Overview Document.

4.3.1 General Requirements

The general requirements are requirements that pertain to the sounding rocket system as a whole. The general requirements are denoted with “GR” for the requirement identification. The general requirements do not have further detailed or CI requirements as they serve as requirements for the rocket as a system. The general requirements serve as parent requirements to the rest of the functional areas of the rocket in a way due to the relevance to the system as a whole.

Table 9: General Requirements

Req ID	Description	Type	Tolerance	Parent Req
GR-0001	The rocket shall carry a payload to the target apogee.	Functional	0	
GR-0002	The rocket during flight shall remain vertically stable and level to the launch point z-axis with implemented fixed aerodynamic surfaces.	Functional	0	
GR-0003	The rocket shall reach the apogee of 4000 ft.	Performance	+/- 200	
GR-0004	The rocket shall have an energetic device arming feature.	Functional	0	
GR-0005	The rocket will have an access location of all energetic device arming features to ensure security of personnel arming them.	Functional	0	
GR-0008	The rocket shall fit on the launch rails provided by Tripoli or NAR.	Functional	0	
GR-0009	The rocket assembly of the subsystems shall be in a horizontal orientation relative to the ground (launch point x-axis).	Functional	0	
GR-0013	All rocket subsystems and components shall have a thermal resistance temperature range of -20 to + 80 deg C.	Performance	0	

4.3.2 Structure Requirements

The structure requirements are requirements that pertain to the sounding rocket structure. The structure requirements are denoted with "ST" for the requirement identification. Structural CI requirements are designated with the "STCI" denotation.

Table 10: Structure Requirements

Req ID	Description	Type	Tolerance	Parent Req
ST-0001	The rocket structure shall ensure accessibility to the inside by ground operations personnel.	Functional	0	
ST-0002	The rocket structure will have adaptive casing for holding subsystems to prevent free movement of subsystems.	Functional	0	
ST-0003	The rocket structure shall have a maximum mass of 4 lbs.	Performance	max	
ST-0004	The rocket structure shall have an inner diameter maximum of 3.9 in.	Performance	0	
ST-0005	The rocket structure shall have a maximum length of 60 in.	Performance	+/- 5 in.	
ST-0006	The rocket structure shall prevent unintended internal pressure to develop during flight by means of adaptive venting.	Functional	0	
ST-0007	The rocket structure shall withstand the operating stresses, such as thrust force and environmental factors, and retain structural integrity under conditions encountered during flight.	Functional	0	
ST-0008	The rocket structure shall provide external access to the arming device.	Functional	0	
ST-0009	The rocket structure shall have sand and dust resistant seals at interfaces to maintain subsystem functionality.	Functional	0	
ST-0010	The rocket structure shall be able to be disassembled for transportation and reassembled for flight.	Functional	0	
STCI-1001	The nose cone shall have a maximum length of 12.8 in.	CI	0.25	ST-0005
STCI-1002	The nose cone shall have a maximum diameter of 4 in.	CI	0.25	
STCI-1003	The nose cone shall have a maximum wall thickness of 0.125 in.	CI	0.1	

STCI-1004	The body insert shall have a maximum diameter of 3.88 in.	CI	0.25	
STCI-1005	The body insert shall have a maximum length of 3.75 in.	CI	0.25	
STCI-1006	The fins shall have a maximum length of 7.25 in.	CI	0.25	ST-0005
STCI-1007	The fins shall have a maximum diameter of 18.25 in.	CI	0.25	ST-0004
STCI-1008	The fins shall have a maximum mass of 440 g.	CI	10	
STCI-1009	The fins shall have pre air foiled fins to increase efficiency when assembling the rocket.	CI	0	

4.3.3 Propulsion Requirements

The propulsion requirements are requirements that pertain to the sounding rocket propulsion. The propulsion requirements are denoted with “PR” for the requirement identification. Propulsion CI requirements are designated with the “PRCI” denotation.

Table 11: Propulsion Requirements

Req ID	Description	Type	Tolerance	Parent Req
PR-0001	The rocket propulsion system when ignited shall provide thrust.	Functional	0	
PR-0002	The rocket shall have a departure velocity minimum of 480 mph to ensure the LV will follow a predictable flight path.	Performance	+/- 10	GR-0003
PR-0003	The rocket shall be able to sustain a minimum acceleration of 20 g over 14 seconds of time during ascent.	Performance	min	GR-0003
PR-0008	The rocket propulsion system shall use a non-toxic propellant type.	Functional	0	
PR-0009	The rocket propulsion system shall be a Commercial off the Shelf Motors (COTS) that has been certified by both the Tripoli and NAR associations.	Functional	0	
PRCI-1001	The rocket motor mass shall be no more that 570 g.	CI	+/- 10	ST-0003
PRCI-1002	The rocket motor length shall be no more than 455 mm.	CI	+/- 5	ST-0005
PRCI-1003	The rocket motor outer diameter shall be no more than 305 mm.	CI	+/- 5	ST-0004

PRCI-1004	The propulsion bay shall have a length of no more than 15 in.	CI	0	ST-0005
PRCI-1005	The propulsion bay shall have an outer diameter no more than 3.9 in.	CI	0	ST-0004

4.3.4 Avionic Requirements

The avionic requirements are requirements that pertain to the sounding rocket avionics. The avionic requirements are denoted with "AV" for the requirement identification. Avionic CI requirements are designated with the "AVCI" denotation.

Table 12: Avionic Requirements

Req ID	Description	Type	Tolerance	Parent Req
AV-0001	The rocket avionics will include an altimeter that tracks altitude for flight events.	Functional	0	
AV-0002	The rocket avionics will include a GPS tracker that reports GPS location of the rocket to the ground station.	Functional	0	
AV-0003	The rocket avionics will include an arming switch that enables the rocket to be powered on.	Functional	0	
AV-0004	The rocket avionics will include sensors/flight computers that will determine flight altitude and staging events.	Functional	0	
AV-0005	The rocket avionics shall include a power supply that can be turned on/off.	Functional	0	
AV-0006	The rocket avionics shall include energetics to deploy parachutes when designated by flight computer.	Functional	0	
AV-0007	The rocket avionics shall include electric initiators that initiate avionics subsystems.	Functional	0	
AV-0008	The rocket avionics shall include an accelerometer that is used to determine force of flight as well as detect apogee.	Functional	0	
AV-0009	The rocket avionics shall include a timer used by the flight computers to determine when to deploy recovery parachutes.	Functional	0	
AV-0010	The rocket avionics computer shall make decisions based on essential flight events such as accent, apogee, decent, and parachute deployment.	Functional	0	
AV-0011	The rocket avionics shall command recovery system to initiate at specified altitude.	Functional	0	
AV-0012	The rocket avionics shall determine when apogee occurs.	Functional	0	

AV-0013	The rocket avionics shall include a system status indicator for a system check.	Functional	0	
AV-0014	The rocket avionics altimeter shall detect launch in order to start gathering altitude measurements.	Functional	0	
AV-0015	The rocket avionics system shall save data with the ability to retrieve data collected during flight.	Functional	0	
AV-0016	All avionics components shall have an overall mass limit of 0.1 lbs.	Performance	max	
AVCI-1001	The altimeter shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	GR-0013
AVCI-1002	The altimeter shall track altitude and be used for flight events such as staging and recovery.	CI	0	AV-0001
AVCI-1003	The altimeter shall be able to endure acceleration of 20 g over 14 seconds of time during ascent.	CI	0	PR-0003
AVCI-1004	The Altimeter shall have an overall mass limit of < 0.1 lbs.	CI	max	AV-0016
AVCI-1005	The GPS shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	GR-0013
AVCI-1006	The GPS tracker shall provide GPS location and tracking information to ground station.	CI	0	SR-0002 AV-0002 GR-0001
AVCI-1007	The GPS tracker shall be able to endure acceleration of 20 g over 14 seconds of time during ascent.	CI	0	PR-0003
AVCI-1008	GPS tracker shall have an overall mass limit of < 0.1 lbs.	CI	max	AV-0016
AVCI-1009	The Arming Switch shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	GR-0013
AVCI-1010	The arming switch shall be used to supply power to the avionics and all energetic components.	CI	0	AV-0003
AVCI-1011	The arming switch shall be able to endure acceleration of 20 g over 14 seconds of time during ascent.	CI	0	PR-0003

AVCI-1012	GPS tracker shall have an overall mass limit of < 0.1 lbs.	CI	max	AV-0016
AVCI-1013	The timer shall provide data to the flight computer which will be saved for flight tracking	CI		SR-0002
AVCI-1014	The timer shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	GR-0013
AVCI-1015	The timer shall be used for denoting staging events in the flight computer	CI	0	AV-0004
AVCI-1016	The timer shall be able to endure acceleration of 20 g over 14 seconds of time during ascent.	CI	0	PR-0003
AVCI-1017	Timer shall have an overall mass limit of < 0.1 lbs.	CI	max	AV-0016
AVCI-1018	The accelerometer shall provide data to the flight computer which will be saved for flight tracking	CI	0	SR-0002
AVCI-1019	The accelerometer shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	GR-0013
AVCI-1020	The accelerometer shall be used for calculating speed and reaching apogee for staging events	CI	0	AV-0004
AVCI-1021	The accelerometer shall be able to endure acceleration of 20 g over 14 seconds of time during ascent.	CI	0	PR-0003
AVCI-1022	Accelerometer shall have an overall mass limit of < 0.1 lbs.	CI	max	AV-0016
AVCI-1023	The flight computer shall collect avionics data to include timing, altitude, and GPS tracking data	CI	0	SR-0002
AVCI-1024	The flight computer shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	GR-0013
AVCI-1025	The flight computer shall use inputs from the timer and accelerometer to make flight staging decisions	CI	0	AV-0004
AVCI-1026	The flight computer shall be able to endure acceleration of 20 g over 14 seconds of time during ascent.	CI	0	PR-0003

AVCI-1027	The flight computer shall be a maximum of 3 in. x .1 in in size.	CI	0.25	
AVCI-1028	Flight Computer shall have an overall mass limit of < 0.1 lbs.	CI	max	AV-0016
AVCI-1029	The power supply shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	GR-0013
AVCI-1030	The power supply shall provide power to all onboard avionics.	CI	0	AV-0005
AVCI-1031	The power supply shall be able to endure acceleration of 20 g over 14 seconds of time during ascent.	CI	0	PR-0003
AVCI-1032	Power Supply shall have an overall mass limit of < 0.1 lbs.	CI	max	AV-0016
AVCI-1033	The stage charge shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	GR-0013
AVCI-1034	The stage charge shall include energetics to deploy nose cone, drogue, and parachute recovery.	CI	0	AV-0006
AVCI-1035	The servos shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	GR-0013
AVCI-1036	The servos shall be actuators that are used for payload operations and recovery operations.	CI	0	AV-0007
AVCI-1037	The servos shall be able to endure acceleration of 20 g over 14 seconds of time during ascent.	CI	0	PR-0003
AVCI-1038	Servos shall have an overall mass limit of < 0.1 lbs.	CI	max	AV-0016

4.3.5 Payload Requirements

The payload requirements are requirements that pertain to the sounding rocket payload. The payload requirements are denoted with "PL" for the requirement identification. Payload CI requirements are designated with the "PLCI" denotation.

Table 13: Payload Requirements

Req ID	Description	Type	Tolerance	Parent Req
PL-0001	The rocket payload shall include a GoPro for capturing video of the rocket flight for a minimum of 1 hour.	Functional	0	
PL-0002	The rocket payload shall include a GoPro mount for securely attaching the GoPro within the payload bay.	Functional	0	
PL-0003	The rocket payload components shall have an overall mass no more than 0.5 lb.	Performance	0	
PL-0004	The rocket payload bay shall have a length of no more than 15 in.	Performance	0	
PL-0005	The rocket payload bay shall have an outer diameter no more than 3.9 in	Performance	0	
PL-0006	The rocket payload bay shall carry a horse figurine provided by the customer.	Functional	max 4^3 in	
PL-0007	The rocket payload shall include a horse figurine mount for securely holding the figurine.	Functional	0	
PL-0008	The rocket payload bay shall carry an altimeter provided by the customer.	Functional	0	
PLCI-1001	The GoPro shall have a mass no greater than 4.3 oz.	CI	+/- 0.25	ST-0003 PL-0003
PLCI-1002	The GoPro shall have a length no greater than 2.4 cm.	CI	+/- 0.25	PL-0004 PL-0005
PLCI-1003	The GoPro shall have a width no greater than 1.3 cm.	CI	+/- 0.25	PL-0004 PL-0005
PLCI-1004	The GoPro shall have a depth no greater than 1.8 cm.	CI	+/- 0.25	PL-0004 PL-0005
PLCI-1005	The GoPro mount shall have a mass no greater than 1 oz.	CI	+/- 0.25	ST-0003 PL-0003

PLCI-1006	The GoPro mount shall have a length no greater than 15 in.	CI	+ 0	PL-0004 PL-0005
PLCI-1007	The GoPro mount shall have a width no greater than 3.5 in.	CI	+ 0	PL-0004 PL-0005
PLCI-1008	The GoPro mount shall have a depth no greater than 2 in.	CI	+ 0	PL-0004 PL-0005
PLCI-1009	The GoPro shall be able to sustain a minimum acceleration of 20 g over 14 seconds of time during ascent.	CI	min	GR-0013
PLCI-1010	The GoPro shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	GR-0013
PLCI-1011	The payload bay shall have a rectangular hole for the GoPro to record out of that is 2 in. x 2 in.	CI	0	PL-0004 PL-0005
PLCI-1012	The payload bay GoPro viewing hole shall have a clear protective covering that is 2 in. x 2 in.	CI	0	PL-0004 PL-0005
PLCI-1013	The payload bay GoPro viewing hole clear protective covering shall have a mass no greater than 1 g.	CI	0	ST-0003 PL-0003
PLCI-1014	The horse figurine shall have a mass no greater than 1 oz.	CI	+/- 0.25	ST-0003 PL-0003
PLCI-1015	The horse figurine shall have a length no greater than 1.5 in.	CI	+/- 0.25	PL-0004 PL-0005
PLCI-1016	The horse figurine shall have a width no greater than 1.5 in.	CI	+/- 0.25	PL-0004 PL-0005
PLCI-1017	The horse figurine shall have a depth no greater than 1.5 in.	CI	+/- 0.25	PL-0004 PL-0005
PLCI-1018	The horse figurine shall be able to sustain a minimum acceleration of 20 g over 14 seconds of time during ascent.	CI	min	GR-0013
PLCI-1019	The horse figurine shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	GR-0013

PLCI-1020	The altimeter shall have a mass no greater than 0.5 oz.	CI	+/- 0.25	ST-0003 PL-0003
PLCI-1021	The altimeter shall have a length no greater than 2 in.	CI	0	PL-0004 PL-0005
PLCI-1022	The altimeter shall have a width no greater than 1 in.	CI	0	PL-0004 PL-0005
PLCI-1023	The altimeter shall have a depth no greater than 1 in.	CI	0	PL-0004 PL-0005
PLCI-1024	The altimeter shall be able to sustain a minimum acceleration of 20 g over 14 seconds of time during ascent.	CI	min	GR-0013
PLCI-1025	The altimeter shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	GR-0013
PLCI-1026	The payload bay insulation shall have a mass no greater than 0.5 oz.	CI	+/- 0.25	ST-0003 PL-0003

4.3.6 Recovery Requirements

The recovery functional requirements are functional requirements that pertain to the sounding rocket recovery. The recovery requirements are denoted with “RC” for the requirement identification. Recovery CI requirements are designated with the “RCCI” denotation.

Table 14: Recovery Requirements

Req ID	Description	Type	Tolerance	Parent Req
RC-0001	The rocket recovery system shall utilize a Dual-Event Parachute method.	Functional	0	
RC-0002	The rocket recovery system shall reduce the descent velocity to less than 30 ft/s (9 m/s) before it descends through an altitude of 1,500 ft AGL.	Performance	+/- 2	
RC-0003	The rocket shall be capable of being recovered safely.	Functional	0	
RCCI-1001	The drogue shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	RC-0002
RCCI-1002	The drogue shall work to reduce descent velocity to less than 30 ft/s before it descends through an altitude of 1500 ft AGL.	CI	0	RC-0002
RCCI-1003	The drogue shall be able to endure acceleration of 20 g over 14 seconds of time during ascent.	CI	0	PR-0003
RCCI-1004	Drogue shall have an overall mass limit of < 0.1 lbs.	CI	max	
RCCI-1005	The parachute shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	RC-0002
RCCI-1006	The parachute shall reduce descent velocity to less than 30 ft/s before it descends through an altitude of 1500 ft AGL.	CI	0	RC-0002
RCCI-1007	The parachute shall be able to endure acceleration of 20 g over 14 seconds of time during ascent.	CI	0	PR-0003
RCCI-1008	Parachute shall have an overall mass limit of < 0.1 lbs.	CI	max	
RCCI-1009	The stage charge shall have a thermal resistance temperature range of -20 to + 80 deg C.	CI	0	RC-0002
RCCI-1010	The stage charge shall reduce descent velocity to less than 30 ft/s before it descends through an altitude of 1500 ft AGL.	CI	0	RC-0002

RCCI-1011	The stage charge shall be able to endure acceleration of 20 g over 14 seconds of time during ascent.	CI	0	PR-0003
RCCI-1012	Stage charge shall have an overall mass limit of < 0.1 lbs.	CI	max	

4.3.7 Ground Station Requirements

The ground station functional requirements are functional requirements that pertain to the sounding rocket ground station. The Ground Station requirements are denoted with “GS” for the requirement identification. Ground Station CI requirements are designated with the “GSCI” denotation.

Table 15: Ground Station Requirements

Req ID	Description	Type	Tolerance	Parent Req
GS-0001	The ground station system shall provide the capability to monitor the GPS tracking of the rocket.	Functional	0	
GSCI-1001	The ground station shall allow monitoring of GPS tracking without directional antennas.	CI	0	GS-001
GSCI-1002	The ground station tracking system shall run for up to 5 hours.	CI	0	
GSCI-1003	The ground station system shall provide real time updates of GPS data to the user during flight.	CI	0	GS-001
GSCI-1004	The ground tracking system shall provide mobility to the user.	CI	0	

4.3.8 TPMs

The below trade study results were the foundation for our sounding rocket project. The trade studies produced TPMs that served as the basis for our further research of our functional areas. The numbers have since been refined and are shown in our requirements.

4.3.8.1 Launch Vehicle Configuration

The single stage sounding rocket configuration was decided upon using trade study analysis (full trade study of TPMs documented within the CONOPS) and is desirable given its low complexity compared to other types of sounding rockets. The single stage sounding rocket configuration is a lightweight configuration with the capability to launch the desired payload size capacity needed to fly the payloads required by our sponsor. The launch vehicle configuration is capable of a maximum 32-mile altitude, however, the altitude of Arizona (e.g.) flight locations is between 4500 ft AGL or 48,000 ft AGL, thus a smaller motor will be utilized. Below are the maximum TPMs for the sounding rocket launch vehicle and serve as a ceiling:

Table 16: Launch Vehicle TPMs

	Metric	Unit
Payload Mass	9.9	lbs.
Altitude	32	miles
Stages	1	stage
Thrust	336	lbf
Mass	76	lbs.
P/M Ratio	0.130	P/M Ratio
T/W Ratio	4.4	T/W Ratio
Length	7.5	ft
Diameter	4	in
Reusability	0	times

4.3.8.2 Camera

The sounding rocket GoPro Hero 9 with a GP2 processer camera gives the user the ability to record the rocket flight and view after retrieving the camera post flight. This specific GoPro was decided on based on trade study analysis. The TPMs for the camera are listed below:

Table 17: Camera TPMs

GoPro Hero 9	Description
Photo	20MP + Super Photo with HDR
Video	5.3K60
100Mbps Bit Rate	5.3K / 4K / 2.7K
Video Stabilization	Hyper Smooth 4.0
Horizon Leveling	In-Camera
Digital Lenses / FOV	Super View, Wide, Linear, Linear + Horizon-Leveling, Narrow
Front Screen	1.4" Color LCD with Live Preview and Status
Mods	Media Mod (HERO10 Black)
Time Warp Video	Time Warp 3.0

Slow-Mo	8x (2.7K, 1080p)
Hindsight	Yes
Scheduled Capture	Yes
Duration Capture	Yes
Wake on Voice	—
Compatible Housing	Protective Housing (HERO10 Black)
Processor	GP2

4.3.9 Functional Interfaces and Criteria

The functional interfaces and criteria are defined within our MBSE-01 document which includes block diagrams depicting the interfaces between subsystems and components.