Post-Launch Assessment Review

NASA University Student Post-Launch Assessment Review

Florida State University Panama City

4750 Collegiate Dr
Panama City, FL 32405

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Acronym & Nomenclature Bank

AGL - At groung level

CAD – Computer Aided Design

CAM – Computer Aided Manufacturing

CDR – Critical Design Review

CNC – Computer Numerical Control

EMI – Electromagnetic Interference

FAA – Federal Aviation Administration

FAMU – Florida Agricultural and Mechanical University

FRR – Flight Readiness Review

FSU – Florida State University

HAUS – Habitat for Agricultural Utilization Study

HPR – High Powered Rocketry

ICT – In-Circuit Testing

InSPIRE - Innovation, Sustainability, and Preeminent Research & Education

LRR – Launch Readiness Review

NAR – National Association of Rocketry

NASA – National Aeronautics and Space Administration

NFPA – National Fire Protection Association

OSHA – Occupational Safety and Health Administration

PC – Panama City

PCB – Printed Circuit Board

PDF – Payload Demonstration Flight

PDR – Preliminary Design Review

PhD – Doctor of Philosophy

PLA – Polylactic Acid

PDR – Preliminary Design Review

PLAR – Post-Launch Assessment Review

POC – Point of Contact

PPE – Personal Protective Equipment

RAM – Rocketry & Mechatronics

RSO – Registered Student Organization

SDS – Safety Data Sheet

SEARS – SouthEast Alabama Rocketry Society

STEM – Science Technology Engineering and Math

TRA– Tripoli Rocketry Association

UAS – Unmanned Aircraft System

USLI – University Student Launch Initiative

1 Summary of PLAR

1.1 Team Summary

The Terra Nova Project is a team composed of 4 Mechanical Engineering students, 1 Electrical Engineering student, and one Business Administration student, all of whom are seniors at Florida State University Panama City. We decided to undertake NASA's USLI program for our love for space, innovation, and chance to work with some of the greatest minds that this world has to offer. Our team of six has faced a diversity of problems and adversity, all of which requiring a collaborative effort to troubleshoot and address these issues with real world solutions. This both challenged our ability to solve complex problems while also doing it as a team. Through the duration of our project, our team has spent an estimated 1600 hours to bring this project to its fruition.

1.2 Launch Vehicle Summary

The launch vehicle as flown in competition was slightly modified as prescribed in the FRR Addendum. The final vehicle did not fly with a reef-style recovery system rather, a traditional two-stage deployment with drogue and main parachutes. In addition to this, the configuration of the drogue parashute on the shock cord was modified such that it was no longer directly attached to the HAUS section bulkhead, rather attached farther down the shock cord. This was to ensure that the HAUS section would not be above the main parashute when deployed at is prespecified altitude. The final launch vehicle had an overall length of 121" and utilized a transitional airframe, giving the rocket a OD of 6" -5" . The final mass of the launch-ready flight vehicle was 54.25 lb(868 oz). This weight was significantly lower than previously estimated due to the competition motor flown being lighter than anticipated. The motor utilized was an AeroTech L2200-G. The apogee reached by the Terra Nova as recorded by the chosen altimeter, the Altus Telemetrum, was 5089 ft with our targeted altitude of 4900 ft . Figure 1 shows the take off of the Terra Nova on the launch day thanks to Jim Wilkerson.

Figure 1: Flight Vehicle at Lift Off

2 Launch Vehicle

2.1 Competition Flight

2.1.1 Flight Data Analysis and Results

To conduct performance predictions, the weather conditions were measured at the competition siteand are tabulated in in Table 2.

Weather Conditions	
Parameter	**Value**
Wind Speed	13 mph or 19.1 ft/s
Atmospheric Pressure (measured by primary flight computer)	985.37 mBar
Ambient Temperature (measured by primary flight computer)	33.2°C or 91.76°F
Location	Bragg Farms, Toney, AL
Latitude (on launch pad)	34.89463°N
Longitude (on launch pad)	86.61657°W

Table 2: Weather Conditions

Using OpenRocket with the above weather condition and a 120” launch rail with a 7° tilt, the performance predictions were calculated. The results of this prediction are in Table 3.

Predicted Flight Timeline and Performance Metrics	
Parameter	**Value**
Total Flight Time	76.1s
Ascent Time	18.89s
Descent Time	57.21s
Drogue Descent Time	30.01s
Main Descent Time	27.2s
Apogee	4936 ft
Maximum Ascent Rate	575 ft/s(0.51 Mach)
Maximum Boost Acceleration	377 ft/s^2
Average Drogue Descent Rate	159.8 ft/s
Average Main Descent Rate	16.42 ft/s
Landing Velocity	17.4 ft/s

Drift	1300 ft

Table 3: Predicted Flight Timeline and Performance Metrics

The flight data shown was recorded from the launch using the primary flight computer, the Altus Telemetrum. This flight computer was located in the avionics bay and served as the primary device to stage deployment events and record data throughout the fullness of the flight. Key data points are listed in Table 4.

Actual Flight Timeline and Performance Metrics	
Parameter	**Value**
Total Flight Time	81.60s
Ascent Time	18.26s
Descent Time	63.34s
Drogue Descent Time	48.5s
Main Descent Time	15.2s
Apogee	5089 ft
Maximum Ascent Rate	621 ft/s(Mach 0.6)
Maximum Boost Acceleration	338 ft/s^2
Average Boost Acceleration	232 ft/s
Drogue Descent Rate	95 ft/s
Main Descent Rate	27 ft/s
Landing Velocity	11.3 ft/s
Latitude (landing)	34.893057°N
Longitude (landing)	86.6148564°W
Calculated Drift	0.15 mi or 792 ft

Table 4: Actual Flight Timeline and Performance Metrics

A variety of differences between the predicted and actual flight metrics can be observed with one significant difference to note is the apogee difference of 153 ft . This can be attributed to various random and systematic errors. During the design phase of the project, OpenRocket showed deployment forces and decent velocities that were extremely large and after further conversation with the technical team at NASA, it was made clear to the team that our rocket would not experience these decent rates specified by the software. While the software is not responsible for all of the discrepancies in flight data, it is a significant contributor.

As mentioned earlier, the recovery system configuration consists of two separation events. The drogue deployment at +1s after apogee is reached. The main set to deploy at 550 ft AGL. Table 5 shows the actual timing of events performed by the Terra Nova.

Actual Recovery Event Timeline		
Event	**Description**	**Altitude**
Drogue Deployment	Drogue event occurred as intended, +1s from Apogee; separating the HAUS and Avionics	5065 ft
Main Deployment	Main event occurred as intended; separating the Avionics and Propulsion Sections	547.9 ft

Table 5: Actual Recovery Event Timeline

As can be observed, the recovery events occurred as they were programmed to.

In addition to the actual flight data, the kinetic energy of each section is calculated and tabulated in Table 6 using the landing velocity of 11.3 ft/s.

Actual Section Landing Energies and Weights			
Section	**Launch Weight**	**Landing Weight**	**Landing Kinetic Energy**
HAUS Section	16.125 lb(258 oz)	13.425 lb(214.8 oz)	31.97 lb-ft
Avionics Section	17.725 lb(283.6 oz)	13.425 lb(214.8 oz)	26.62 lb-ft
Propulsion Section	21.894 lb(350.3 oz)	16.781 lb(268.5 oz)	33.27 lb-ft

Table 6: Actual Section Landing Energies and Weights

The impact energies of the recovery design far exceeded the predicted performance projections due to the low landing velocity. The original design goal of remaining below 60 lb-ftwas easily met with the maximum resulting impact energy of 33.3 lb-ftfor the propulsion section.

The coefficient of drag for the rocket was estimated using Eq. 1.

$$C_D = \frac{2m_r(-a_r - g)}{\rho_{air} A V^2} \tag{1}$$

Where C_D is the launch vehicle's coefficient of drag (dimensionless), m_r is the mass of the rocket (kg), a_r is the acceleration of the rocket (kg/s^2), ρ_{air} is the density of air in (kg/m^3), g is earths gravitational constant (m/s^2), A is the cross-sectional area of the rocket (m^2), and V is the velocity of the rocket in (m/s). It must be noted that this equation is valid during the rockets coasting phase, between motor burnout and apogee.

Using the data recorded by the TeleMetrum, the coefficient of was estimated for all data points in the coasting stage of the rocket flight. The results of this calculation are displayed in Figure 2. Based on this, the C_D is estimated to be 0.322. This was assumed to be the coefficient of drag due to the lower scatter of data in the velocity range considered for the estimation of C_D, between 185 and 100 m/s. This is less than that estimated by OpenRocket $C_D = 0.367$. It is also significantly smaller than that estimated in the VDF and reported in the FRR Addendum $C_D = 0.347$. This estimation of the coefficient of drag may explain the higher resulting apogee than what was initially predicted.

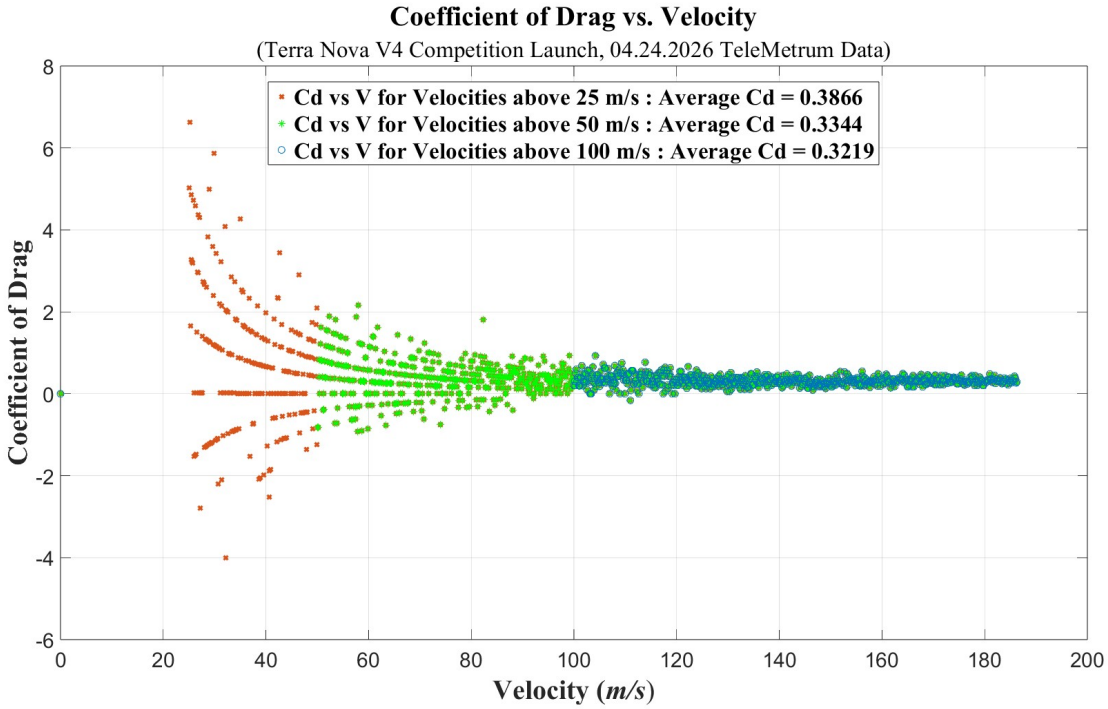

Figure 2: Coefficient of Drag vs. Velocity

2.2 Launch Vehicle Successes

On competition day, the launch vehicles had multiple successes. Once in the flight configuration on the launch pad, the vehicle successfully stayed armed for the duration of time up to launch. Once prompted by the ranger officer, the launch vehicle initiated take off with no delay. Observation of the ascent of the rocket shows an extremely straight and stable flight, being our straightest flight to date. This is likely due to the significantly higher velocity off the rail. All previous flights were using a weaker motor due to the unavailability of the specified primary motor. The apogee reached by the launch vehicle was 189 ft or 3.8% from our target goal of 4900 ft . It is important to note that the initially detected apogee of the Terra Nova was 5065 ft. The primary flight computed then initiated the drogue deployment 1̃s after. After the drogue deployment, the primary flight computer read the reported apogee of 5089 ft. The main was then deployed extremely close to the prescribed 550 ft AGL only 2.1 ft after. The launch vehicle experienced minimal drift even compared to the prediction landing only 792 ft away from the launch pad. Upon landing, the vehicle did not suffer any structural or electronic damage.

2.3 Launch Vehicle Failures

The launch vehicle had no failures of its flight or recovery systems. The only exception was the payload retention system being physically fastened by screws to retain the payload and thus causing the payload to not be able to conduct its mission. This will be further discussed in the next section.

3 Payload

3.1 Payload Dimensions and Specifications

Upon the time of the competition launch, the payload utilized a variety of integrated mechanical systems, electronics, and sensors. The electronic devices were responsible for coupling with the mechanical design to provide the payload with usable power, control, and the means to perform the required soil test; a pH test. The various payload parameters, including overall dimensions and incorporated electronics have been tabulated in Table 7.

Terra Inquisitor Dimensions and Parameters		
Parameter	**Value/Description**	**Unit**
Width	4.92	in
Height	4.25	in
Length	13.5	in
Weight	5.7	lb
PH Sensor	AtlasScientific Mini Lab Grade pH Probe	N/A
Distance Sensor	Arduino Modulino Distance Sensor	N/A
Control System	Custom PCB	N/A
Automation System	Arduino Nano Every	N/A
DC Motors	Pololu 4741	N/A
Servo Motor	goBUILDA 2000 Series Dual Mode Servo	N/A
Battery	3s, 12v , 1300 mAh , 80c Lithium Polymer Batter	N/A

Table 7: Terra Inquisitor Dimensions and Parameters

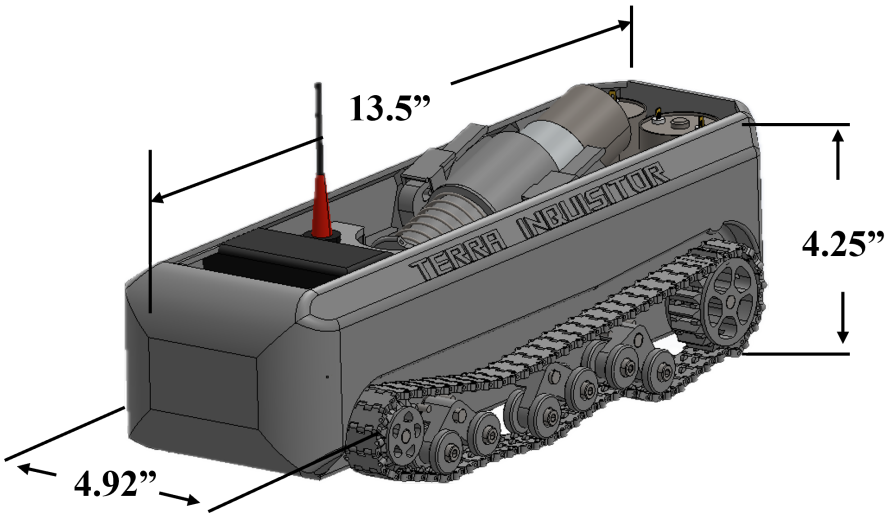

Figure 3: Terra Inquisitor Dimensions

The Terra Inquisitor implemented two primary mechanical systems and one primary electrical system. The mechanical systems include the propulsion and the drilling assemblies. The electrical system incorporates both the overall electronic control and sensory inputs for the decision making and operation of the mechanical systems. These three systems can be observed in Figure 4.

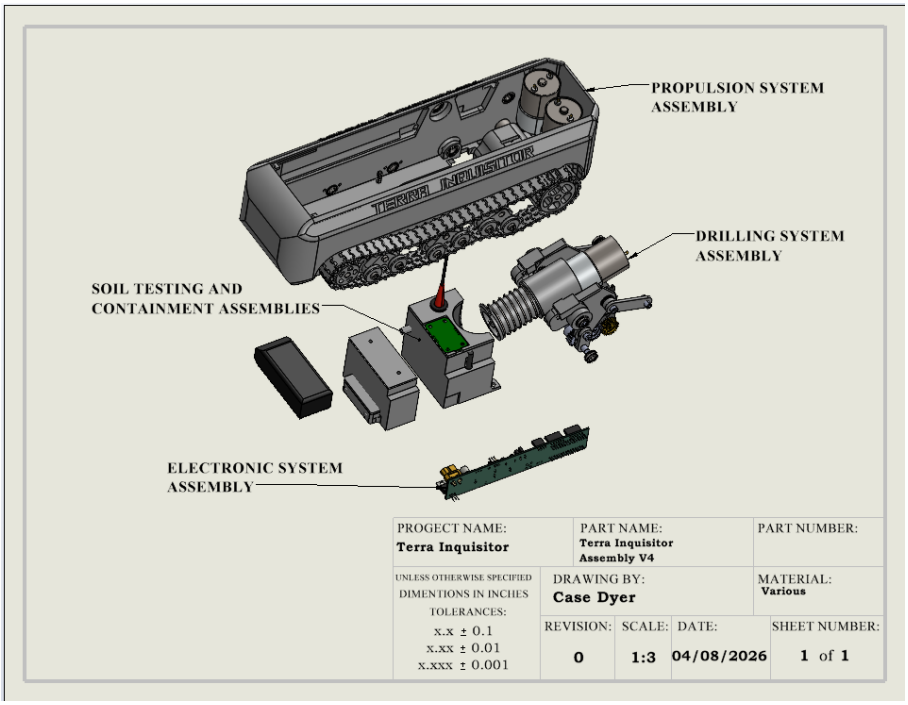

Figure 4: Terra Inquisitor Systems

This system was retained and deployed by a mechanical separation system that implemented two lead screws to hold, guide, and restrain the payload. The lead screws were connected to a plate epoxied into the nosecone of the airframe. This system was powered using a Pololu DC motor that drives a single shaft using a bevel gear system. On this shaft were two worm screws. The screws power their respective worm gears on a shaft coupled to the lead screws. The worm gear systems ensure the mechanical separation cannot separate unless the system is activated and powered by the DC motor. This design can be seen in Figure 5.

The Terra Inquisitor used a single 3s Lithium Polymer Battery, with a a fully charged voltage of 12v , to power all mission operations. This battery included a capacity of 1300 mAh and a discharge rating of 80C. This main power rail fed into the main DC motors, as well as into a 7.5v switching converter. This allowed for a 7.5v power rail responsible for powering the servo motor. This 7.5v rail was then also fed into 5v linear regulators, allowing for a constant 5v power to the control devices and sensors.

3.2 Payload Successes

The final design of the Terra Inquisitor launch at the competition is as can be seen in Figure 6.

This final payload system was not able to succeed in its mission due to the retention system being physically fastened using screws. This was due to the mechanical separation

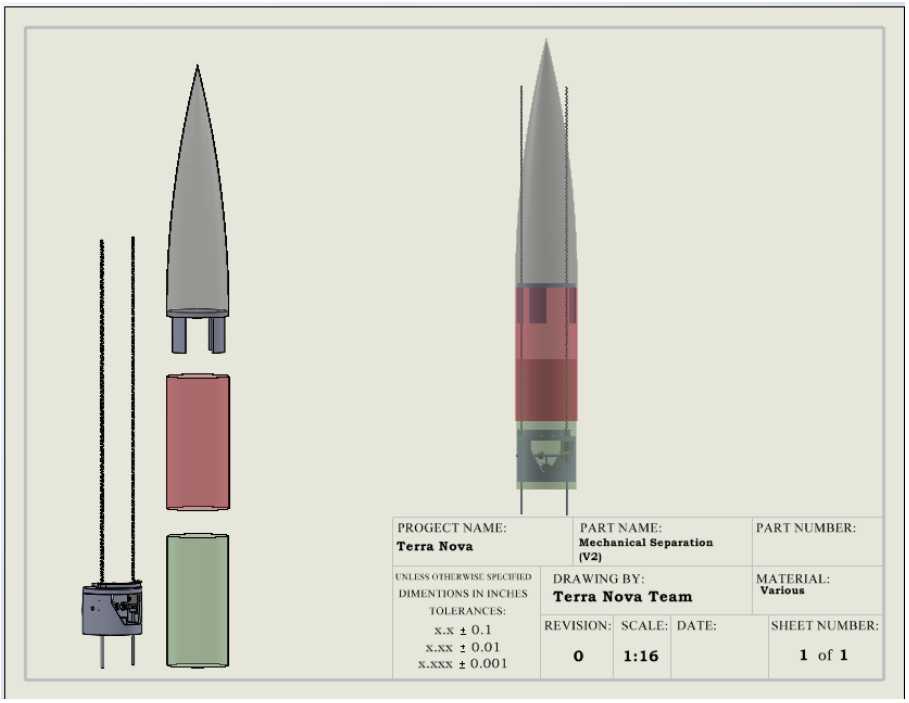

Figure 5: Mechanical Separation and Retention System

retention system not being fully proven in flight prior to the competition launch and thus not permitted to be flown as the primary means of retention.

The Terra Inquisitor system was operational. It was tested at the launch site and proved to be able to drive during its drilling phases and power the linkage system into all proper orientations for soil collection and containment.

3.3 Payload Failures

Although the Terra Inquisitor system was operational in its driving motion and linkage system, the drilling auger was not functioning properly at the launch site. The auger would only conduct the soil evacuation phase in which the system reverses the drilling direction to push the collected soil out of the drilling head assembly. However, during the drilling phase the auger motor would not move. The cause of this was uncertain at the launch site, however, upon further post analysis it suspected that the motor driver is the cause.

In addition to the payload system not being fully operational, the mechanical retention system was still not fully operational. The system burned out its motor driver and was not repaired in sufficient time for the competition launch. The batteries for the system were also undersized and thus unreliable due to the system needing to be operated to "lock" in the payload for flight, to last a possible 3 hour wait time, and then to separate the section upon landing.

4 Scientific Value

The Terra Nova team has dared many unique challenges and designs. Our team incorporated 3D printed aerospace grade metals, custom fabricated transitional airframes, boat-tailing, linkage system designing, and track system designing. Our team has con-

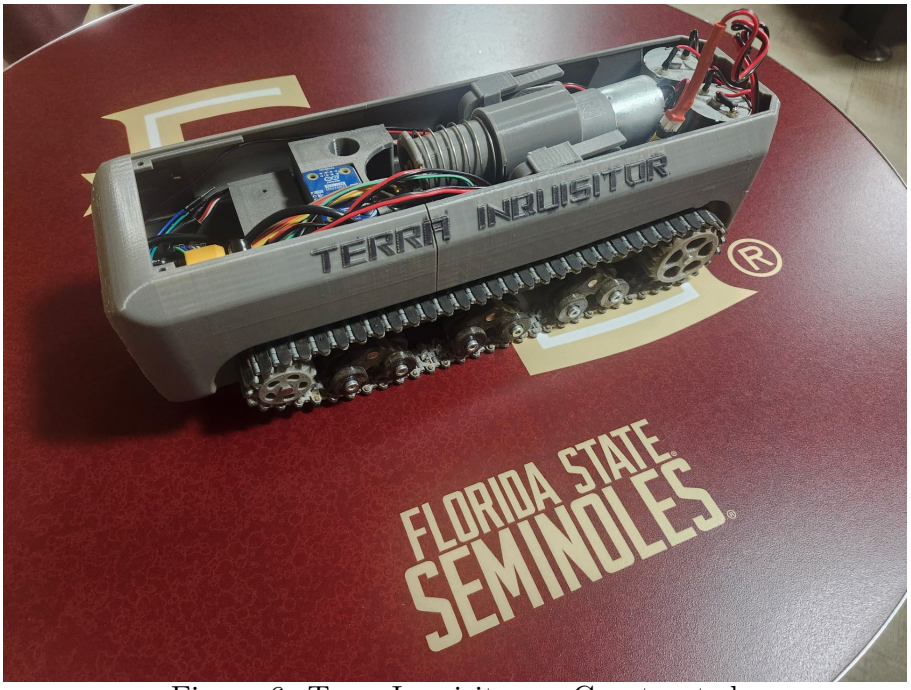

Figure 6: Terra Inquisitor as Constructed

ducted multiple tests on the implemented materials, the primary material being 3D printed Inconel 718 made using Laser-Powderbed Fusion. This material was tested in torsion due to the primary concern of failure of our bulkhead being in shear. This material was tested in a heat-treated and unheat-treated form to consider the effects of heat-treating on its mechanical properties. Some of the highlights from this testing can be seen below in Figures 7. - 9.

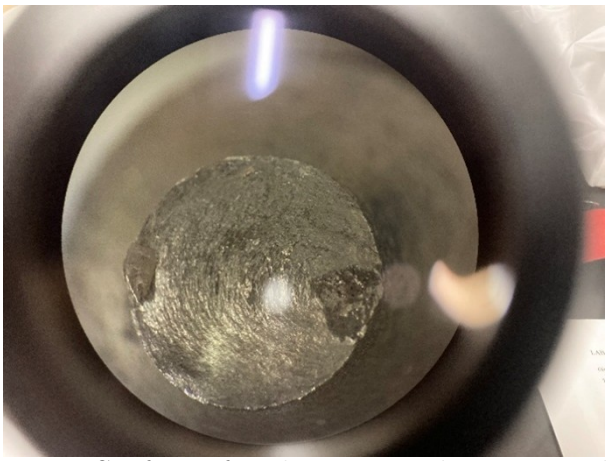
Figure 7: Fracture Surface of Unheat-treated 3D Printed Inconel 718

The Terra Nova team also experimented with custom transitional airframes to optimize the rocket design by reducing material weight and drag. The transitional airframe was made in house by the teams Payload Officer. The transitional airframe was made by 3D printing an inner mold (roughly the same diameter as a coupler) and then using #120-38 E-glass cloth and West Systems epoxy, the mold was slowly wrapped with the cloth and saturated with the epoxy until the sufficient thickness and outer diameter was achieved. The resulting airframe is as below in Figure 10 with the diameter transitioning from 6”-5”.

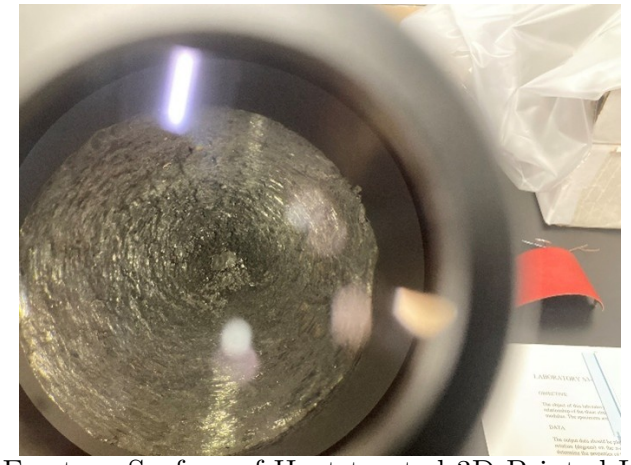

Figure 8: Fracture Surface of Heat-treated 3D Printed Inconel 718

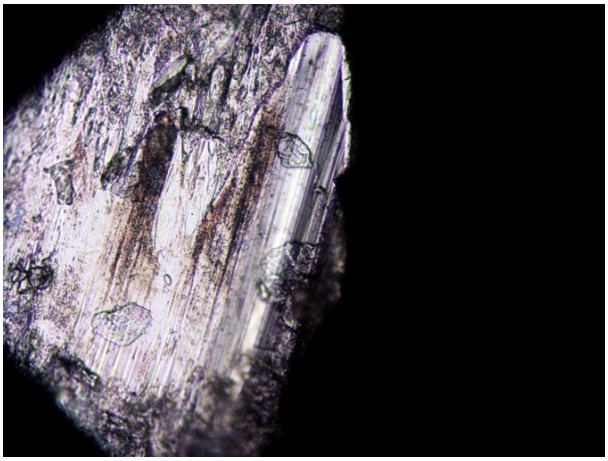

Figure 9: 20x Magnification of Heat-treated Inconel 718 Fracture Surface

Figure 10: Transitional Airframe with Inner Mold Removed

The Terra Inquisitor payload system also incorporated a unique linkage system that further the consideration and designing of linkage systems for complex motions. Our team

used this linkage to actuate and power the drilling assembly so that the auger head could be stored parallel to the airframe of the rocket and then rotate into a drilling position upon deployment. It also allows the complex motion to be powered by a single servo motor, thus reducing power consumption as well as control output. Control output is especially important as the Arduino Nano Every used by the team was completely used to control all the various electronic components. The linkage system was proven to be extremely reliable, in fact its operation was the most reliable system during the testing of the Terra Inquisitor. The system proved it provided significant mechanical advantage during its drilling phases as it was able to easily lift the front end of the Terra Inquisitor off the ground. Figure **??** shows the final design of the linkage system and its ability to be in both a stored and vertical drilling position.

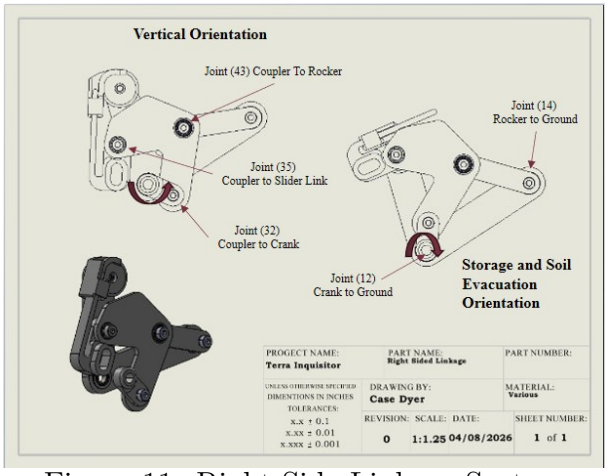

Figure 11: Right Side Linkage System

Through the implementation of these designs and testing all of our team has grown into better and more knowledgeable engineers. All of these systems can be further tested and improved on and hopefully by bringing them into view through all our STEM engagement and engagement with other USLI teams, we may have inspired some to further these ideas.

5 Community STEM Engagement

Given the small size of the team and the high technical demands of the project, the team has developed a focused STEM engagement strategy centered on high-impact local outreach events rather than school-based programs hosted independently by schools. Rather than trying to spread resources across many small events, the team focused on participating in existing university and regional STEM outreach opportunities that allowed them to engage a larger audience while still supporting project development activities.

The team participated in several university-sponsored STEM outreach events on campus, including "Tech Days" and "Discovery Days." On these occasions, team members showcased the launch vehicle and explained the engineering principles of high-power rocketry and payload system integration. The team used demo hardware such as previous competition rockets, airframe diagrams of the launch vehicle, and 3D printed linkage systems to help students visualize the complex mechanical motion used in the deployment

mechanism of the payload's auger. Students got hands-on with the engineering hardware and asked questions about rocket stability, recovery systems, payload mechanisms, avionics and additive manufacturing.

In addition to on-campus outreach, the team participated in the Thunderbirds Air Show in Panama City Beach for two days. This event gave us the opportunity to reach a much larger audience of students, families and members of the surrounding community. The team showcased the completed launch vehicle and payload system and discussed the goals of NASA Student Launch and the engineering challenges of the project. To increase student engagement, the team ran 3D printers during the event and produced small printed aircraft models, including F-35 and F-16 aircraft, that helped to facilitate conversations around aerospace engineering, manufacturing, and STEM careers.

Overall, the team met and exceeded its initial outreach engagement goal of 200 students. The university "Tech Days" and "Discovery Days" events averaged just over 50 student participants per event, for a total of four such events, resulting in over 200 direct student interactions from university outreach activities alone. We had a ton of foot traffic with the Thunderbirds Air Show with over a thousand student attendees throughout the two-day event. Through these activities, the team met and exceeded its STEM engagement goals while promoting aerospace engineering, NASA Student Launch and hands-on STEM education to the local community.

Figure 12: Thunder Birds Air Show

6 Final Budget

Terra Nova Project Budget								
Item	**Description**	**Quantity**	**Estimate Shipping & Handling**	**Price ea.**	**Total**	**Link**	**Vendor**	**Status**
Full Scale Airframe and Motors								
Motor Tubing/ MMTHD-300x34	75mm Motor tube, Redundancy	1	$10.00	$23.18	$33.18	Click Here	locprecision	Purchased

Terra Nova Project Budget (continued)								
Item	**Description**	**Quantity**	**Estimate Shipping & Handling**	**Price ea.**	**Total**	**Link**	**Vendor**	**Status**
L1395 CTI Blue	Motor Propelent	1	$70.00	$428.65	$498.65	Click Here	wildmanrocketry	Purchased
75MM Forwarded Closure	75MM FORWARD CLOSURE Aerotech 75 mm forward closure	1	$0.00	$98.99	$98.99	Click Here	wildmanrocketry	Purchased
Fiberglass Nose Cone	6 inch, 4:1 Ogive	1	$0.00	$190.98	$190.98	Click Here	locprecision	Purchased
Motor Tubing/ MMTHD-300x34	75mm Motor Tube, Length 34”	1	$0.00	$23.18	$23.18	Click Here	locprecision	Purchased
5 inch fiberglass airframe	Length: 60”	1	$0.00	$259.35	$259.35	Click Here	wildmanrocketry	Purchased
5 inch fiberglass couplers	Length: 12”	2	$0.00	$62.57	$125.14	Click Here	wildmanrocketry	Purchased
Fiberglass Sheet	1/4” thick, 1ft x 1ft,	2	$0.00	$46.00	$92.00	Click Here	wildmanrocketry	Purchased
L1395 CTI Blue	Motor Propelent	2	$0.00	$428.65	$857.30	Click Here	wildmanrocketry	Purchased
L2200G Mojive Green	Motor Propellant	1	$0.00	$376.99	$376.99	Click Here	wildmanrocketry	Purchased
Motor Retainer	75mm motor RMS motor retainer	1	$5.00	$55.00	$60.00	Click Here	Chris’ Rocketry	Purchased
54mm X 17in Motor Mount		1		$9.14	$9.14	Click Here	Chris’ Rocketry	Purchased
54mm X 14in Motor Mount		1		$6.18	$6.18	Click Here	locprecision	Purchased
Fiberglass Cloth	#120-38-E-Glass (Quantity in yards)	20	$28.00	$10.50	$238.00	Click Here	aircraftspruce	Purchased
					Total:			$2,869.08
Sub-Scale Airframe and Motors								
Rail Button	1515 rail	1		$2.50	$2.50	Click Here	Chris’ Rocketry	Purchased
Aerotech J540R-14A Redline Rocket Motor	Purchased for first launch	1	$70.00	$135.99	$205.99	Click Here	Chris’ Rocketry	Purchased
Aerotech J540R-14A Redline Rocket Motor	Purchase for 2nd and 3rd launch	2	$70.00	$135.99	$341.98	Click Here	Chris’ Rocketry	Purchased
RMS	AeroTech RMS-54/1280 Complete Motor	1		$232.99	$232.99	Click Here	Aerotech	Purchased
Possible Forward Bulkhead		1	$0.00	$4.44	$4.44	Click Here	locprecision	Purchased
Possible Aft Bulkhead		3	$0.00	$5.06	$15.18	Click Here	locprecision	Purchased
Lower Couplers		2	$0.00	$5.31	$10.62	Click Here	locprecision	Purchased
Nose Cone (3.9” - $30)		1	$0.00	$29.16	$29.16	Click Here	locprecision	Purchased
Upper Body Tube		1	$0.00	$17.77	$17.77	Click Here	wildmanrocketry	Purchased
Aft Body Tube		2	$0.00	$14.16	$28.32	Click Here	wildmanrocketry	Purchased
Upper Coupler		1	$0.00	$7.14	$7.14	Click Here	wildmanrocketry	Purchased
Tail cone Assembly ($53)		1	$0.00	$53.00	$53.00	Click Here	wildmanrocketry	Purchased
G12CT-3	12 in	1	$0.00	$33.48	$33.48	Click Here	wildmanrocketry	Purchased
G12CT-4	8 in	1	$0.00	$25.12	$25.12	Click Here	wildmanrocketry	Purchased
G12-4.0 - 30”		1	$0.00	$71.39	$71.39	Click Here	wildmanrocketry	Purchased
G12-3.0 - 30”		2	$0.00	$62.92	$125.84	Click Here	wildmanrocketry	Purchased
					Total:			$1,204.92
Recovery Systems								
MAKO Line Cutters (1 Pair - $180)	Pair	1	$0.00	$180.00	$180.00	Click Here	Tinder Rocketry	Purchased

Terra Nova Project Budget (continued)								
Item	**Description**	**Quantity**	**Estimate Shipping & Handling**	**Price ea.**	**Total**	**Link**	**Vendor**	**Status**
Super Epoxy Pack	For both sub scale and full scale	1	$0.00	$196.98	$196.98	Click Here	Amazon	Purchased
PARAMAX Shock Cord (100 ft - $35)	We need 2, 100 foot sections	2	$0.00	$34.75	$69.50	Click Here	theparacordstore	Purchased
Paracord Reef (100ft - $11)	We need 2, 100 foot sections	2	$0.00	$10.75	$21.50	Click Here	theparacordstore	Purchased
12” Fruity Chutes		1	$0.00	$87.51	$87.51	Click Here	Fruity Chutes	Purchased
72” Parachute CD:2.2		1	$0.00	$175.00	$175.00	Click Here	RocketMan	Purchased
12in Topflight Chute		1	$0.00	$6.50	$6.50	Click Here	Chris’ Rocketry	Purchased
24in Parachute		1	$0.00	$50.00	$50.00	Click Here	RocketMan	Purchased
48in Parachute		1	$0.00	$120.00	$120.00	Click Here	RocketMan	Purchased
45 gm CO2 ctg	Recovery Testing	2	$0.00	$23.00	$46.00	Click Here	Tinder Rocketry	Purchased
E-match O-rings	Recovery Testing/Launch	2	$8.50	$3.00	$14.50	Click Here	Tinder Rocketry	Purchased
Eye bolts	3/8-16 in. Forged Steel Machinery Eye Bolt in Shoulder Pattern (1-Pack)	4	$0.00	$11.24	$44.96	Click Here	Home Depot	Purchased
25gm CO2 Cartridge		6	$0.00	$14.00	$84.00	Click Here	Tinder Rocketry	Purchased
Eagle Replacement O-rings		2	$0.00	$3.00	$6.00	Click Here	Tinder Rocketry	Purchased
45gm CO2 Cartridge		2	$0.00	$23.00	$46.00	Click Here	Tinder Rocketry	Purchased
PDW CO2 38g Threaded Cartridges		4	$0.00	$15.00	$60.00	Click Here	Planet Cyclery	Purchased
CO2 38 Gram	Only 4 available, purchase as many as possible	4	$0.00	$8.25	$33.00	Click Here	Chris’ Rocketry	Purchased
Firewire Electric Match Bundle of 20		3	$0.00	$16.00	$48.00	Click Here	Chris’ Rocketry	Purchased
15” Parachute	Drogue Parachute	1	$0.00	$88.20	$88.20	Click Here	Fruity Chutes	Purchased
Paracord 550	Reefing Supplies (Quantity in 100 ft)	1	$0.00	$10.75	$10.75	Click Here	theparacordstore	Purchased
120” Parachute	Main Parachute	1	$0.00	$325.00	$325.00	Click Here	RocketMan	Purchased
1/2” Brass Grommets 24 pack	Reefing Supplies	0	$0.00	$0.00	$8.99	Click Here	ACE	Purchased
25g CO2 Cartridge	Supplier: Evo	4	$0.00	$5.00	$20.00	Click Here	EVO	Purchased
38G CO2 Cartridge	Separation CO2 Cartridge	4	$0.00	$15.00	$60.00	Click Here	ridepdw	Purchased
48g CO2 Cartridge	Redundancy Separation CO2 Cartridge	3	$0.00	$13.39	$40.17	Click Here	bulkreefsupply	Purchased
E-Match O-Rings		3	$0.00	$3.00	$9.00	Click Here	bellhelmets	Purchased
TR Lube		3	$0.00	$3.00	$9.00	Click Here	Tinder Rocketry	Purchased
Eagle Return Spring		4	$0.00	$3.00	$12.00	Click Here	Tinder Rocketry	Purchased
Eagle O-Rings		3	$0.00	$3.00	$9.00	Click Here	Tinder Rocketry	Purchased
					Total:			$1,881.56
Payload System								

Terra Nova Project Budget (continued)								
Item	**Description**	**Quantity**	**Estimate Shipping & Handling**	**Price ea.**	**Total**	**Link**	**Vendor**	**Status**
4mm Non-Flanged Ball Bearings	SKU: 1600-0410-0004	6	$0.00	$3.39	$20.34	Click Here	GoBilda	Purchased
6mm Flanged Ball Bearings	SKU: 1601-0412-0006	4	$0.00	$2.88	$11.52	Click Here	GoBilda	Purchased
Submersible Water Pump	Soil Testing	1	$0.00	$2.95	$2.95	Click Here	DigiKey	Purchased
TB6612FNG	Motor Controllers	6	$0.00	$1.82	$10.92	Click Here	DigiKey	Purchased
HX711	Amplifier	2	$0.00	$11.50	$23.00	Click Here	DigiKey	Purchased
LM1117T-5.0/NOPB	Voltage Regulator	2	$0.00	$1.37	$2.74	Click Here	DigiKey	Purchased
Micro_SD	SD Card	1	$0.00	$15.39	$15.39	Click Here	DigiKey	Purchased
Female SMA Connector	Soil Testing	1	$0.00	$2.80	$2.80	Click Here	DigiKey	Purchased
Pololu 37D 4741	DC Motors	3	$15.00	$44.95	$149.85	Click Here	Pololu	Purchased
Pololu 6V D24V22F6	Buck Converter	1	$5.00	$19.95	$24.95	Click Here	Pololu	Purchased
Mini Lab Grade pH Probe		1	$0.00	$89.99	$89.99	Click Here	atlas-scientific	Purchased
EZO pH Circuit		1	$20.00	$45.99	$65.99	Click Here	atlas-scientific	Purchased
Crossed Helical Gears	Part #: 3598N291	4	$0.00	$17.99	$71.96	Click Here	McMaster-CARR	Purchased
Carbon Steel Acme Lead Screw	Right Hand, 1/4"-16 Thread Size, 6 Feet Long	1	$0.00	$29.28	$29.28	Click Here	McMaster-CARR	Purchased
Carbon Steel Acme Hex Nut	Right Hand, 1/4"-16 Thread Size	6	$0.00	$3.51	$21.06	Click Here	McMaster-CARR	Purchased
Metal Worm Gear	Bronze, 1 Module, 10:1 Speed Ratio	2	$0.00	$29.06	$58.12	Click Here	McMaster-CARR	Purchased
Steel Worm	1 Module, 6 mm Shaft Diameter, 2 Starts	2	$0.00	$15.63	$31.26	Click Here	McMaster-CARR	Purchased
Button Loadcell	FS1901-0000-0500-G	1	$15.00	$40.06	$55.06	Click Here	DigiKey	Purchased
M3 Screws, 6mm Length	SKU: 2800-0003-0006	2	$0.00	$2.99	$5.98	Click Here	GoBilda	Purchased
M3 Screws, 12mm Length	SKU: 2800-0003-0012	3	$0.00	$3.29	$9.87	Click Here	GoBilda	Purchased
4002 Series Flexible Clamping Shaft Coupler	6mm Round Bore to 0.250" Round Bore	2	$15.00	$6.99	$28.98	Click Here	GoBilda	Purchased
Steel Miter Gear (6mm round Bore, 24 Tooth)	SKU: 2317-0006-0024	2	$0.00	$10.19	$20.38	Click Here	GoBilda	Purchased
PTFE Cable-Guide Tubing	SKU: 2926-0204-1000	1	$0.00	$5.99	$5.99	Click Here	GoBilda	Purchased
Springs	Extension Spring, Spring Steel Const, Nickel-Plated Finish, .047 GA x 7/16 in. x 1-7/8 in., Closed Single Loop, (2-Pack)	2	$0.00	$2.65	$5.30	Click Here	Home Depot	Purchased
Battery	Common Sense RC Lectron Pro 1350mAh 80C LiPo Battery with XT60 Connector for FPV Racers (3-Cell, 11.1V)	1	$0.00	$25.74	$25.74	Click Here	bhphotovideo	Purchased
Lower cover spring #1	11908CS	1	$15.00	$10.43	$25.43	Click Here	centuryspring	Purchased

Terra Nova Project Budget (continued)								
Item	**Description**	**Quantity**	**Estimate Shipping & Handling**	**Price ea.**	**Total**	**Link**	**Vendor**	**Status**
Lower cover spring #2	S-151CS	1	$0.00	$12.08	$12.08	Click Here	centuryspring	Purchased
6mm Flanged Bearings		6	$0.00	$3.39	$20.34	Click Here	GoBilda	Purchased
Carbon Steel Acme Lead Screw	Left Hand, 1/4”-16 Thread Size, 3 Feet Long	1	$0.00	$36.62	$36.62	Click Here	McMaster-CARR	Purchased
Carbon Steel Acme Hex Nut	Left Hand, 1/4”-16 Thread Size, 15/64”	1	$0.00	$3.64	$3.64	Click Here	McMaster-CARR	Purchased
					Total:			$887.53
Safety								
Eye Protection	3M SecureFit 200 Safety Eyewear SF200P1-DC: Premium eyewear with anti-fog lens and flexible fit; also, from Home Depot.	4	$0.00	$6.98	$27.92	Click Here	Home Depot	Purchased
Eye Protection (Over-the-glasses)	3M Over-the-Glass Safety Eyewear (47110-WV24)	2	$0.00	$1.22	$2.44	Click Here	Home Depot	Purchased
Lung Protection	3M Disposable Particulate Respirator, N95, 20/Pack (8200)	1	$15.00	$28.19	$43.19	Click Here	Staples	Purchased
Gloves	Gloveworks GWON Nitrile Gloves, Large, Orange, 100/Box	1	$0.00	$24.69	$24.69	Click Here	Staples	Purchased
Ear Protection	3M E-A-Rsoft Uncorded Earplugs, 33 dB, Neon Yellow, 200/Pack	1	$0.00	$45.49	$45.49	Click Here	Staples	Purchased
Heavy Duty Gloves	ProFlex 812 Standard Utility Glove	3	$0.00	$21.99	$65.97	Click Here	Staples	Purchased
					Total:			$209.70
Transportation, Lodging, Community Outreach, & Misc.								
Campus Vehicle	Provided by Florida State University - Panama City	1	Not Applicable	$0.00	$0.00	Not Applicable		—
Gas	Estimate For all Travel both community events and launches	1	Not Applicable	$400.00	$400.00	(Estimate)		—
Air B&B	Housing for the 22nd to the 26th of April	1	Not Applicable	$2,000.00	$2,000.00	Click Here	Air B&B	Purchased
Shirts	Custom designs incorporating University branding, team logo, and team sponsors		Not Applicable		In-Kind Donation	Not Applicable		Purchased
Food	Food for students for occasions like launch days and the Hudson Trip	1	Not applicable	$600.00	$600.00	(Estimates)		—
PETG Creality Printing Filament	1 kg rolls	4	$0.00	$29.76	$119.04	Click Here	Grainger	Purchased
PETG Sunlu Printing Filament	4kg, 1kg per spool	2	$0.00	$39.99	$79.98	Click Here	Sunlu	Purchased

Terra Nova Project Budget (continued)							
Item	**Description**	**Quantity**	**Estimate Shipping & Handling**	**Price ea.**	**Total**	**Link**	**Vendor**	**Status**
					Total:			$3,199.02
Fundraised								
Company	Description				Given Funds	Contact		
Florida State University Panama City	Funding through the Deans Office to participate in the NASA USLI Competition				$10,000.00			
Jim & Sandy Defoe					$500.00			
							Total:	$10,251.81
							Fundraised:	$10,500.00
							Remaining Funds:	$248.19