October 2nd & 3rd, 2021

All Screwed Up!

Space Apps Challenge

Space Buds
BAILEY // CARROLL // CLARKE // CUSACK // SQUIRES // WILLIAMS

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List Of Acronyms

By order of appearance

Acronym -=-=-=-=-=-=-=-=-=-=- Expansion

MUN	Memorial University of Newfoundland
ECE	Electrical Computer Engineer
CAD	Computer Automated Design
CWSF	Canada Wide Science Fair
STEM	Science, Technology, Engineering, Mathematics
NASA	National Aeronautics and Space Administration
FEA	Finite Element Analysis
3D	Three-Dimension // Three-Dimensional
PCB	Printed Circuit Board
CAN	Controller Area Network
ASU	All Screwed Up!
RPM	Revolutions Per Minute
W	Watt(s)
mm	Millimeter(s)
A // Amp	Ampere(s)
V	Volt(s)
N-m	Newton-meter(s)
N	Newton(s)
IC	Integrated Circuit

1 – Meet the Team

The Space Buds team is composed of six Engineering students enrolled in Memorial University of Newfoundland. All members of the team are in their third year of the program, with an expected graduation in 2024. The team, composed of two Mechanical Engineering students, two Electrical Engineering students, and two Computer Engineering students – along with a wide variety of work experience and interests – is capable of handling a large variety of challenges of any sort.

Noah Bailey

Coming from a family full of engineers and scientists, Noah grew up eager to study and become an engineer just like those around him. A resident of Newfoundland his whole life, Noah is starting his third year of Electrical Engineering at MUN. Noah developed a love for all things computer and electrical at a young age, guiding him to inevitably study within the Electrical Computer Engineer (ECE) program provided at his local university.

He is interested in computing hardware, sound engineering and music production, physics, graphic design, and writing.

His skills include coding in various languages, mathematics, and Computer automated design.

Noah is competing in the Nasa SpaceApps challenge for his first time this year and is hoping to make a big impact along with his talented team members and classmates.

Ian Carroll

Ian is starting his third year of Computer Engineering at Memorial University. He is always eager to learn something new; over the last year, Ian has learned numerous programming languages and frameworks, taking a particular interest in electronics and embedded system development.

Ian's interests include choral singing, performing in plays and musicals, and playing basketball. This year is the first time Ian has competed in the Space Apps international hackathon. However, he is very excited to learn new things about hardware development and apply them to real-world problems.

Ian's already existing skills include C/C++ development for embedded systems, C# programming for cross-platform applications, and various applications of CAD development.

Aidan Clark

Aidan Clark is a third-year Mechanical Engineering student from a small town in Nova Scotia, currently studying at Memorial University of Newfoundland. Growing up, Aidan always had an interest in learning more about how things worked - which is why he decided to pursue a degree in engineering.

In his free time, he enjoys spending time outdoors, exploring the rugged Newfoundland coast, or playing volleyball.

This is Aidan's first Space Apps competition; however, he is excited to have the opportunity to further refine his engineering skills. Aidan's pre-existing skills include project management, computer-aided design, finite element analysis, Python, and public speaking.

Nick Cusack

Nick Cusack is a third year Electrical Engineering student at Memorial University of Newfoundland. Growing up in Saint John, New Brunswick, Nick enjoyed racing bikes, park skiing, and snowmobiling. From the age of eight years old he decided he wanted to become an Astronaut which is why he decided to participate in this challenge.

He's always had an engineer's mindset which can be seen from his bronze medal at the Canada Wide Science Fair (CWSF) in grade eight for building a prosthetic arm. Or competing again in the CWSF in grade nine for building a regenerative system for electric cars.

His latest project has been his company Cusack Innovations and their first product Folkins. Folkins is a distracted driving detection system named after the passing of his two friends the year Cusack Innovations was founded.

Madison Squires

Madison is currently a third year Mechanical Engineering student at Memorial University of Newfoundland. Madison was first exposed to Engineering in her junior high robotics team, and ever since then she was driven to pursue a STEM (Science, Technology, Engineering, Mathematics) career.

Madison is the President of her school's Engineering Society and has volunteered countless hours for the benefit of her fellow classmates.

Outside of school, she has many hobbies and interests that include playing guitar, hiking trails, and taking photographs. Madison's work experience ranges from oil and gas to healthcare, so her wide variety of skills were an excellent addition to the Space Buds team. She is thrilled to be a part of this year's NASA Space Apps Challenge.

Shane Williams

Shane is a third-year Computer engineering student at Memorial University of Newfoundland. Shane's exposure to engineering started in high school, when he competed internationally with an underwater robotics team and interned at a local tech company.

Shane has since worked in the space industry with Toronto's Kepler Communications, where he wrote ground station software and nanosatellite firmware. He currently works at NVIDIA where he is creating internal development PCBs and software for NVIDIA graphics developers.

Shane is also a member of Memorial University's Killick-1 Cubesat team, where he writes ground station software.

Shane's skills include PCB design and embedded software development, and he looks forward to applying these digital design skills to this year's Space Apps challenge.

2 – The Challenge

The purpose of this project was to compete in the tenth annual NASA-hosted Space Apps challenge, which took place on the second and third of October 2021. Within Space Apps, there are hundreds of thousands of students competing in various challenges, and the Challenge that was selected by the Space Buds team was "Let It Go (Without a Bang)".

What is Space Apps?

NASA's International Space Apps Challenge is a hackathon over two days that has engaged over 150,000 student programmers and engineers in over 150+ countries in previous years. This competition utilizes NASA's open-source data to allow participants to solve real-world problems and challenge their minds through technological developments, whether mobile application development, videogames, or hardware design. This year, there are over 25 challenges to choose from for each team formed with a maximum of six members. Additionally, to mark the 10th annual Space Apps Challenge, NASA has partnered with nine international space agencies, keeping the largest annual global hackathon ever-growing!

Let It Go – Without a Bang

As seen in the challenge's description, letting things go in Space is often a high-shock event. The Let It Go (Without a Bang) Challenge tasked the participants to design a device that can cut a parachute reefing line, a cable, or a bolt for an adapter ring, or instead, to design a mechanical separation device that can release two parts from one-another in space without the use of pyrotechnics – a commonly used technique in most current-day equipment.

Spacecraft require many different release devices for various components within the craft. Some examples are detaching from a rocket, releasing parachutes for landings, and enabling deployables to expand into space. As mentioned above, the current most common approach is to make use of pyrotechnics, however this is something that will ideally be moved away from in the near future and replaced with more eco-friendly and reusable options – once it goes boom, it can't go boom again! Pyrotechnic tools require extra safety precautions, as the large impact load – or shock – of the actuation of the device can be upwards of tens of Gs.

Design Constraints

The challenge was provided with numerous specifications and design objectives that must be met. For example, it is essential that the device should survive temperatures ranging from as cold as -50°C, and up to as hot as 80°C. It should be able to operate within a smaller range, of 0°C to 40°C. It is mentioned that heaters are permitted.

No debris should be released into space. All components must remain attached or must be captured by some mechanism so that they are not permitted to fly free. We do not want to create any more space junk!

The size constraints of the design are pretty tight. When working with Spacecraft, size is very important and thus having strict tolerances for components and mechanisms is essential. The device is required to be smaller than a cylinder with a length of fifteen centimeters and a diameter of two centimeters. It must weigh less than one kilogram in total.

The device requires a high reliability factor in order to be a viable option for use on a Spacecraft. Thus, it is said that the device should actuate without error upwards of 99.5% of the time. Also, the device has access to 20 watts (W) of power but may not draw more.

3 – The Idea

The Space Buds team devoted the first portion of time during the Hackathon to coming up with a viable idea for the design. Operating under the constraints of the challenge and attempting to make the most resourceful and useful design they could, the team began by considering all of their options and ideas for the challenge. The group discussion eventually led to a decision, and an action plan. The team divided the work to be done and began to bring their design to life.

Initial discussion

At the start of the day, the team began brainstorming different ways to cut a parachute reefing line without pyrotechnics. This thought transitioned into cutting a rope using a linear actuator, then using pneumatics, and lastly, using hydraulics. Given the conditions of outer space, all of these designs were deemed unusable and would provide an unsatisfiable solution to the problem.

After this discussion, the team decided to give a solution to separating two spaceship components in zero-gravity. The previously stated methods were considered, although the group agreed on using a servo motor at the core of the design.

Essentially, the spacecraft portions that need to be detached would be bounded by a cylindrical casing protruding from each object. These encasings would engage in a handshake, where one encasing fit just over the lip of the other. When the cylinders are locked in a handshake, they would be locked internally via a screw, which would be detached via a servo motor rotating the screw away from one component and allowing for the spring to propel the objects away upon reaching the end of the threads.

The Objectives

Two main sub-sections needed to be considered for the team to create a functional device with the design mentioned above.

Firstly, there was the three-dimensional (3D) modelling of the entire device using SolidWorks software. SolidWorks is a CAD – Computer Automated Design – software which allowed the team to visualize the design, and perform a finite element analysis test, or simply a FEA test. The plan included creating a 3D model detailing the gearbox and motor attached, the motor mount attaching to the threaded rod, cylindrical encasing, and the threaded rod mounted to the shaft of the second object.

Secondly, there was the modelling of all circuitries aboard the device using KiCad. KiCad is a software similar to SolidWorks, although it is used for creating and rendering printed circuit boards, or PCBs. The KiCad model detailed the microcontroller providing logic to the device, the Motor Driver and Controller, the power regulator, and the CAN (Controller Area Network) communication bus.

Our plan of attack

Given the variety of disciplines that composed Space Buds, the team could naturally adapt to the required work for the design. The group's vast and diverse skill set allowed the Mechanical Engineering students to design and implement the physical 3D modelling of the device via SolidWorks, and the ECE members of the team to design and implement the hardware needed for the device. Throughout the two-day hackathon, Space Buds could prioritize, and complete, necessary tasks assigned appropriately across different skillsets on the team.

4 – The Design

The following section of the report will discuss in detail the design that was drafted and implemented throughout the two-day hackathon by the team. The specifications of the design, how it functions, and some of the challenges that were faced while implementing the design, will be explored in depth.

The Design – All Screwed Up!

The design that we decided to implement – dubbed the “All Screwed Up!” design – is an encasing device that can attach to entities together with enough strength for launch and travel but is also capable of releasing the two from one another without the use of any pyrotechnics. The design, hereafter referred to as ASU, is composed of two outer shell encasing shrouds, which house the connecting components on both sides – that being the main entity and the entity that we wish to detach.

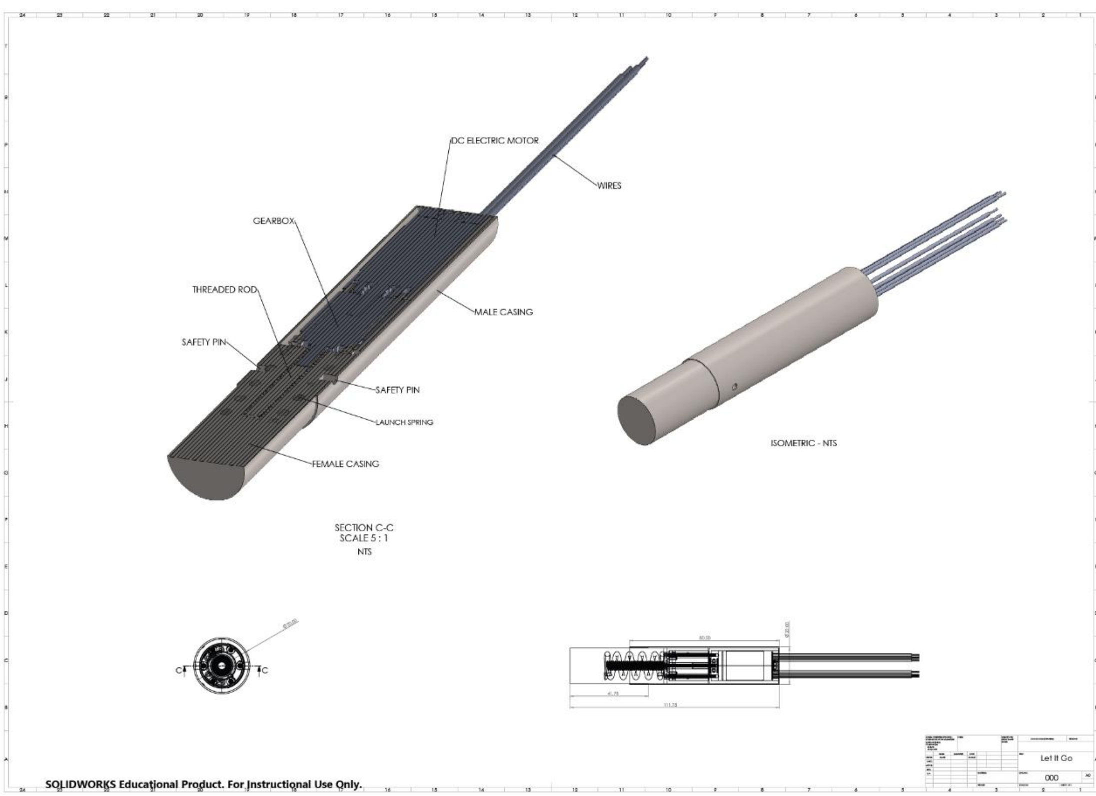


FIGURE 1 - THE DESIGN, ISOMETRIC VIEW

For the design of the ASU, we have realized a system that is reusable and releases no debris. The male component – a motor with a gearhead attached to a threaded rod, encased in Shroud A, will screw into the female end – a threaded hole encased in Shroud B.

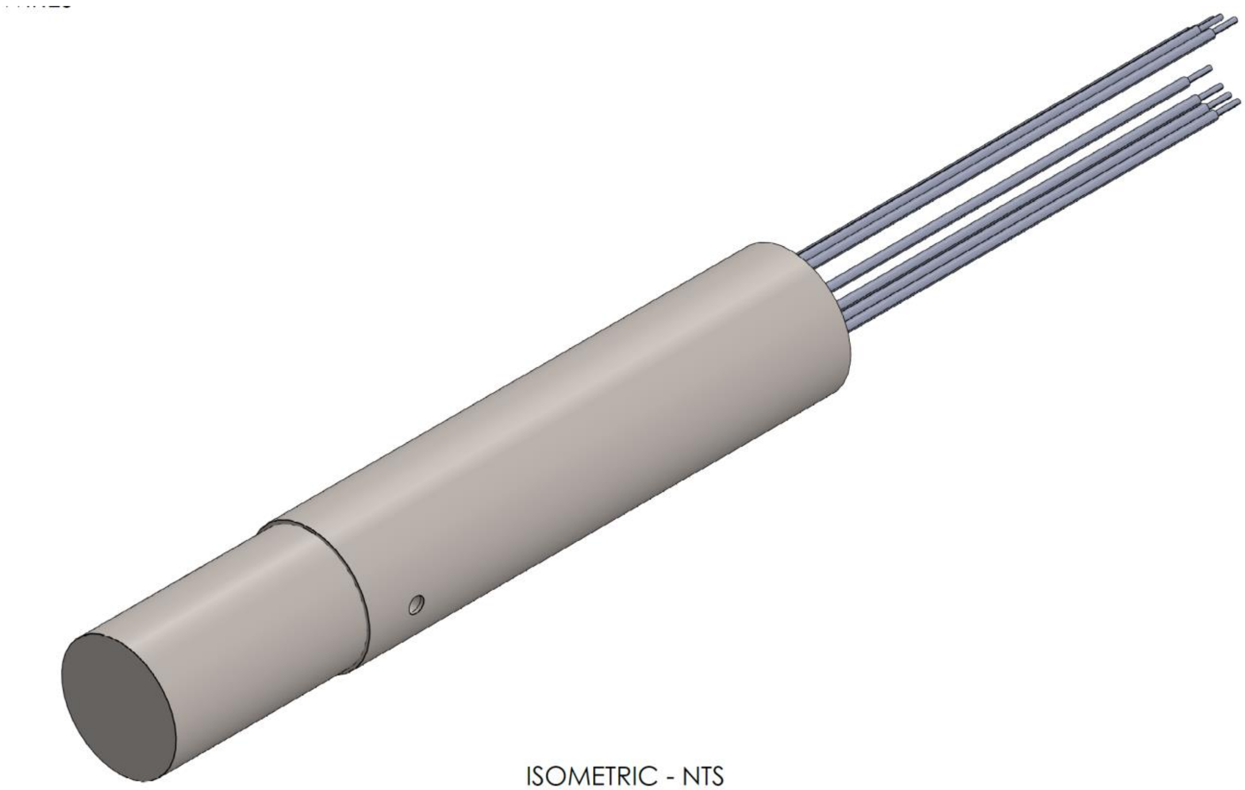


FIGURE 2 - THE ASU DEVICE

Another noteworthy feature of ASU is the spring. The spring will be compressed while the two entities are attached, and as the threaded bolt is unscrewed, the spring will decompress and force the two objects apart.

To control the motor for turning the screw head, we have designed our own printed circuit board, or PCB, which has been specifically designed to control the ASU device.

Additionally, the system is easily reusable, as the motor can operate both ways, meaning it is possible to attach to objects together – compressing the spring and screwing the bolt into the socket – as well as detach two objects – decompressing the spring as the threads are unwound.

The male thread of the ASU device may also be used for attaching to numerous different female entities, so long as the entity that we wish to attach has the appropriate female portion of the ASU mounted to it.

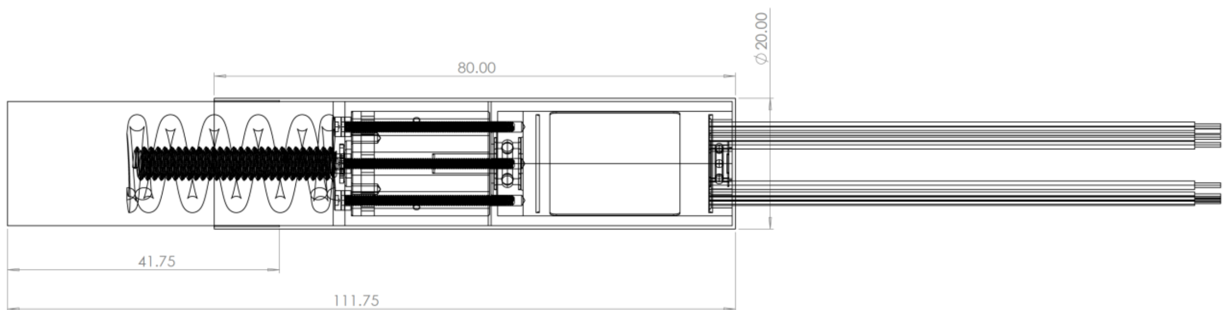


FIGURE 3 - ALTERNATE ASSEMBLY VIEW

How it Works

A custom designed PCB operates a motor. The motor travels through a gearhead, lowering the revolutions per min – RPM – and increasing the torque. The slow-spinning, high-torque shaft is friction-welded to a 10-24 threaded titanium alloy rod. Note - all titanium alloy used is Ti-6AI-4V Titanium alloy. When combined, the two encasings hold these elements, as well as a compressed spring, in place. The threaded rod screws into a port, holding the two entities together. As the motor activates and begins unscrewing the rod, the spring decompresses. Once the threads are fully separated, the spring fully decompresses, forcing the two entities apart.

Challenges Faced

Vacuum Compatibility

ASU was designed to be fully vacuum compatible. There are no airtight compartments to prevent pressurization as the part enters space.

Electrical components were also chosen with vacuum compatibility in mind. Electrolytic capacitors were avoided as they can become pressurized in space, and banks of parallel ceramic capacitors were used instead.

Thermal Design

All components chosen are rated for storage at the extreme temperatures of space, and are also rated to operate from 0 °C to 40 °C, as specified.

The casing, motor and gearbox also have a significant amount of mass and therefore thermal capacity, which can help cool the motor during operation. Overheating isn't of significant concern as the motor will only be run for seconds at a time, once per mission.

Cold Welding

Cold welding is of concern when similar metals make contact in space. This can be prevented by using materials and coatings that have been shown not to cold weld through significant flight heritage.

Choosing an Appropriate Motor

It proved to be quite the challenge to find an appropriate motor for the design of ASU. It is quite hard to find a small enough motor to fit the size constraints that is able to create the amount of torque required for connecting and separating the two entities. This led to the implementation of the gearhead, which allowed us to prioritize size and power constraints when it came to the motor – thus we could ignore the torque as it would be handled by the gear ratios.

Choosing Materials

Choosing materials that are space-worthy is a challenge. Not all materials are strong enough or have the properties required for space launch, or space travel. We ended up choosing to create any of our custom-designed components out of Ti-6AI-4V Titanium alloy. This material has been extensively researched and is frequently the material chosen for spacecraft and satellites in the current day. All of the sourced components of ASU have been checked to ensure that they operate within the desired temperature range and can withstand the pressures and forces they will experience throughout their use.

Computational Requirements

In order to run simulations, create renders, run calculations, and create CAD models, we require a massive number of computational resources. The Space Buds team, operating within a strict time constraint, had to be very resourceful as a whole in order to collect all of the desired data in time. This required great communication, planning, and time management as a unit.

5 – The Components

Each component of the ASU design has a specific and important function. Each piece individually must be able to work well with each other as a whole to perform the desired action safely, reliably, and consistently. When choosing the components of the ASU, every single detail had to be considered, no matter how minute. For example, the chosen materials needed to be resilient enough to survive launch, as well as strong enough to withstand space. They needed to be light and fit the size constraints. Power was a constant consideration, as the design may only consume 20W of power. Each component is accompanied by a specification drawing, detailing the materials and dimensions.

The Shrouds

The shrouds, or the casings, are two titanium alloy tubes that are keyed to lock within one another. The male shroud contains the components which are required to remain on the base module, being the motor, gearhead, spring, and threaded bolt. The female shroud protects the entity which will be detached from the base module and released into space. Within the female shroud is the hole in which the threaded bolt will be wound.

The shrouds protect all the components within from being damaged or destroyed throughout launch and flight. They are made from a sturdy and reliable metal alloy. As seen in the figure below, they are XXX millimetres (mm) long, and YYY mm wide.

The keying on the casings is an essential piece of the design. They are keyed to lock into one another once the two entities are connected. This prevents motion in the perpendicular plane, and also prevents rotation. Once attached, we do not want the two entities to shift side to side or to rotate out of the initial position, thus creating a need for a male and female key on the shrouds. With the shrouds, we are not worried about parallel motion, as this is stopped by the threaded bolt, as will be explained within the following sections.

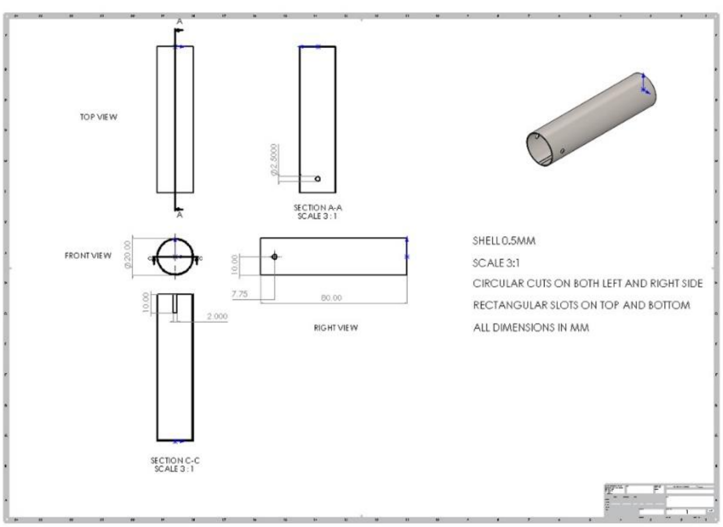


FIGURE 4 - THE MALE SHROUD

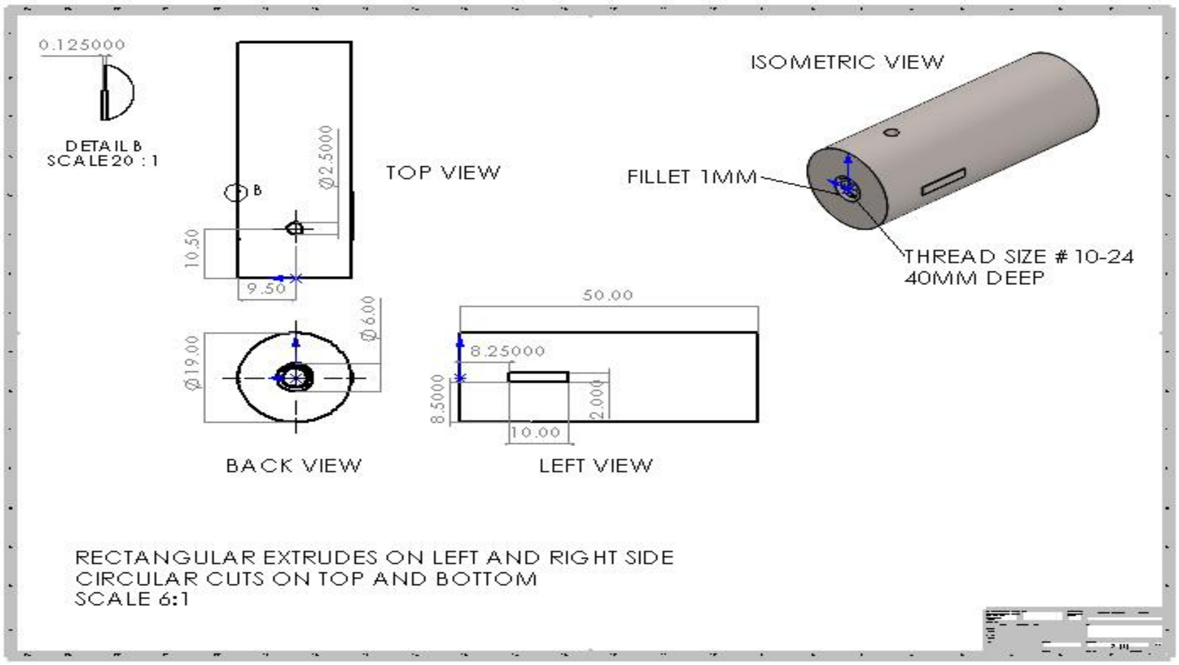


FIGURE 5 - THE FEMALE SHROUD

The Spring

One of the critical components required for the push-off during the detachment phase is the spring. This component is made from INSERT MAT, and it is X mm by Y mm by Z mm by WIDTH mm in size. The compressed spring was selected to perform optimally for the needs of the design. It does not cause any abrupt movements, smoothly letting the female shroud push off the male shroud with a small force – as not much force is required in zero gravity.

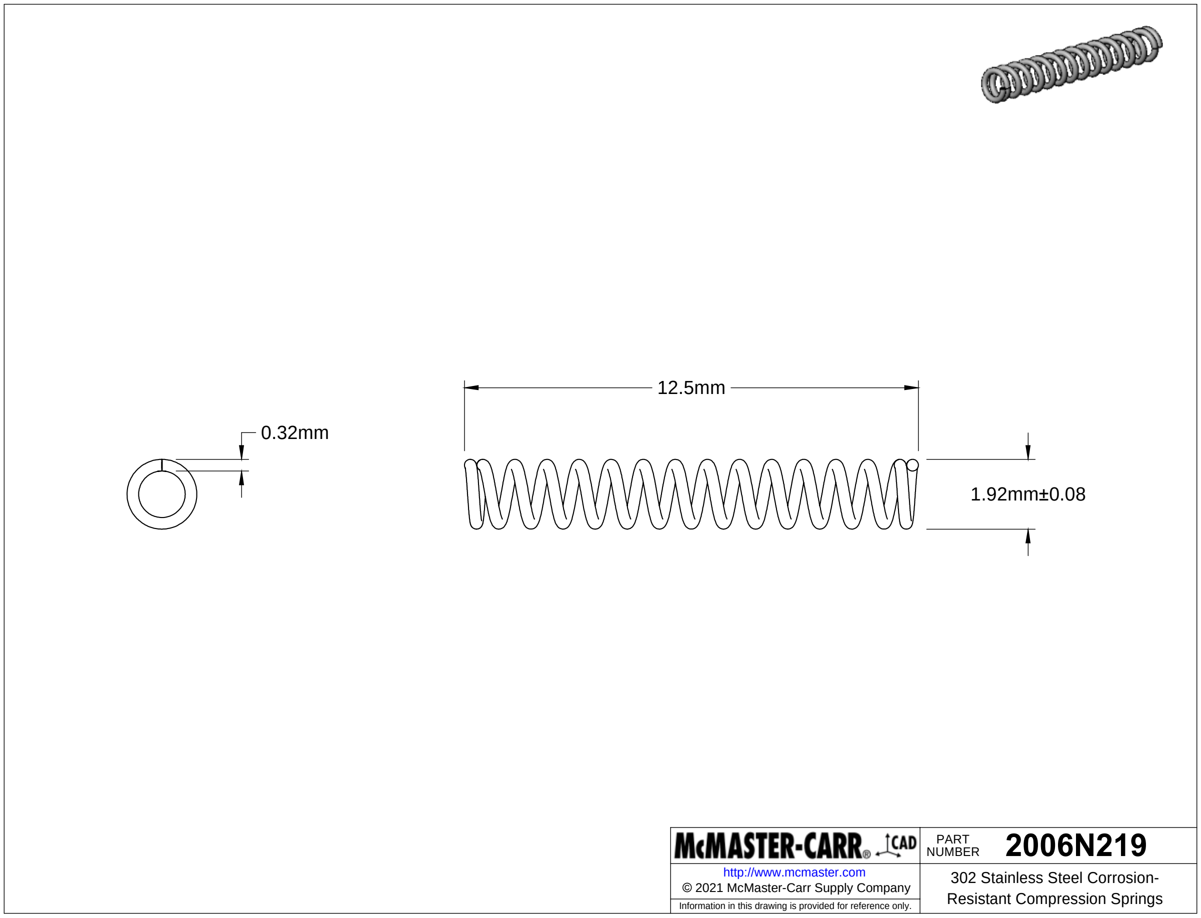


FIGURE 6 - THE SPRING

Choosing the spring was an interesting process, as the team required a spring with a specific spring coefficient. These are based on length, thickness, material, and diameter, as well as number of turns. All of these characteristics needed to be considered when choosing and designing the spring.

The Motor

Choosing an appropriate motor for the design proved to be one of the most challenging tasks of the entire design process. The motor used within the ASU is a brushless direct current (DC) motor. The motor selected by the space bud team is a Portescap motor, namely the 16ECP36 8B 380 .01 Ultra EC Slotless Brushless DC Motor.

This motor weighs 41 grams, and measures only 16mm in diameter, at 36mm in length with a shaft of 10mm. It is important to note that the 10mm shaft will be attached to the gearhead.

With a maximum continuous current of 0.3 amperes, or amps (A), operating at a voltage of 24 volts (V), the maximum power draw of the motor is 7.2W.

The motor sports a maximum RPM of 63,000, but this is much higher than the team required and will not be used. In fact, the gearhead attached to the motor will lower the revolutions per minute significantly and increase the torque.

The motor can function within a high temperature range, from -30°C to 100°C. It uses an odd wiring scheme, which was taken into account when creating our PCB, as will be seen in a later section.

The motor's data sheet and specification data can be seen in the following figures.

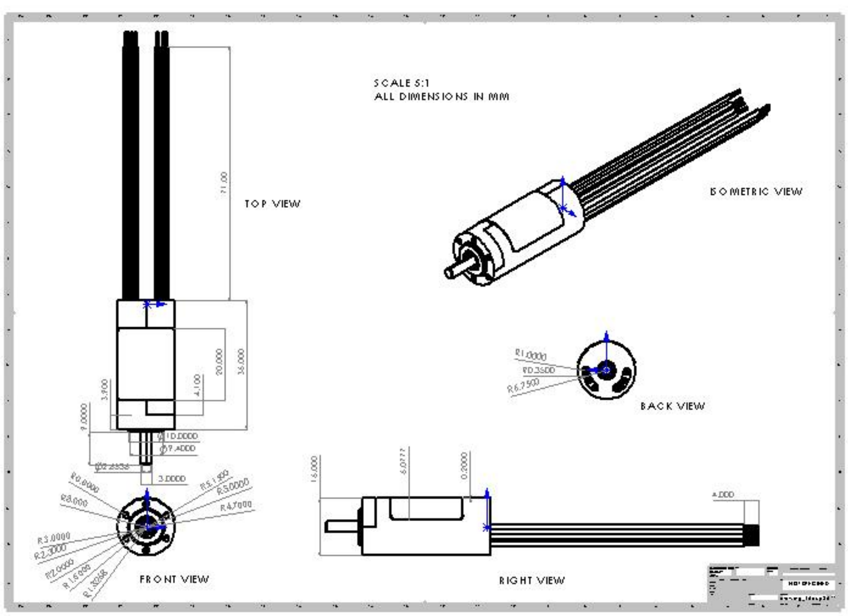
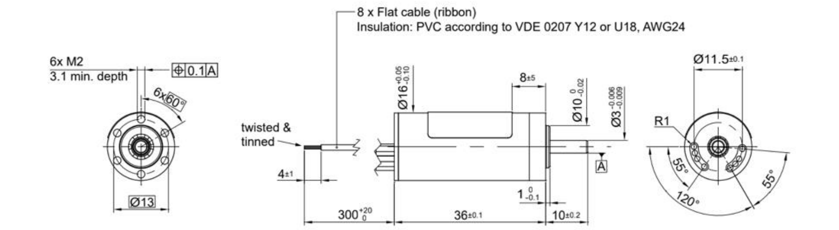


FIGURE 7 - R16ECP36 MOTOR

Brushless DC Slotless Motors **Portescap**

16ECP36 Ultra EC™ Ø 16 mm • 2-pole • 27 W



Dimensions in mm.

Electrical Data	Symbol	16ECP36-8B-xxx.01 380	245	108	49	Unit
1 Nominal Voltage	U_N	24	24	24	12	Volt
2 Optimization Direction	-	Symmetrical	Symmetrical	Symmetrical	Symmetrical	-
3 No Load Speed	n_0	8,100	12,420	29,000	31,550	rpm
4 Typical No Load Current	I_0	20	35	85	160	mA
5 Max Continuous Mechanical Power (@25°C)	P_{max}	27.5	27.5	27.5	27.5	W
6 Max Continuous Current	$I_{e\,max}$	0.3	0.4	0.9	2.1	A
7 Max Continuous Torque	$M_{e\,max}$	7.0 (1)	7.2 (1.02)	7.1 (1.01)	7.5 (1.07)	mNm (oz-in)
8 Back EMF Constant	k_E	2.82	1.84	0.80	0.37	V/1000 rpm
9 Torque Constant	k_M	26.9	17.6	7.7	3.5	mNm/A
10 Motor Regulation	R/k^2	71.8	67.9	69.2	62.4	10^3/Nms
11 Motor Regulation	$k/R^{½}$	3.7 (0.53)	3.8 (0.54)	3.8 (0.54)	4 (0.57)	mNm/$W^{½}$ (oz-in/$W^{½}$)
12 Internal Resistance - phase to phase	R_I	52.00	21.00	4.05	0.78	ohms
13 Line to Line Resistance at Connectors	R_L	52.10	21.10	4.13	0.82	ohms
14 Inductance Phase to Phase	L	3.93	1.63	0.32	0.07	mH
15 Mechanical Time Constant	τ_m	3.9	3.7	3.8	3.4	ms
16 Electrical Time Constant	τ_e	0.08	0.08	0.08	0.08	ms

General Data	Symbol	Value	Unit
17 Maximum Motor Speed	n_{max}	63,000	rpm
18 Ambient Working Temperature Range	-	-30 to + 100 (-22 to + 212)	°C (°F)
19 Ambient Storage Temperature Range	-	-40 to + 100 (-40 to + 212)	°C (°F)
20 Ball Bearings Preload	-	5.3	N
21 Axial Static Force w/o Shaft Support (max)	-	34	N
22 Maximum Winding Temperature	-	125 (257)	°C (°F)
23 Thermal Resistance	R_{th}	3.5 / 17	°C/W
24 Thermal Time Constant	τ_w	580	s
25 Weight	-	41 (1.45)	g (oz)
26 Rotor Inertia	J	0.60	g-cm²
27 Hall Sensor Electrical Phasing*	-	120	Electrical °

*Available without hall sensor

Figure 8 - Motor Data Sheet

The Gearhead

The part responsible for providing enough torque to rotate and push the screw away is the gearhead. Given the previously mentioned specifications of the brushless DC motor, the gearhead was able to attach to the head of the motor with a conversion ratio of 915, allowing for a significant increase of torque ability.

The chosen gearhead is a Portescap gearhead specifically designed to pair with the chosen Portescap motor, the R16-0-915 Sleeve Bearing Mini Motor Gearhead. It can operate within a temperature range of -30°C to 85°C, which is ideal for the ASU application. It weighs only 19 grams, and is highly efficient, with four gear stages, and a static torque of one Newton-meter (N-m).

Lastly, two notable details of the gearhead: firstly, the size of the gearhead is 28.3 mm long by 16 mm diameter, which fits inside the constraints of the cylindrical shrouds, and secondly, it can rotate in either direction – a key feature to ensure the reusability of the ASU device.

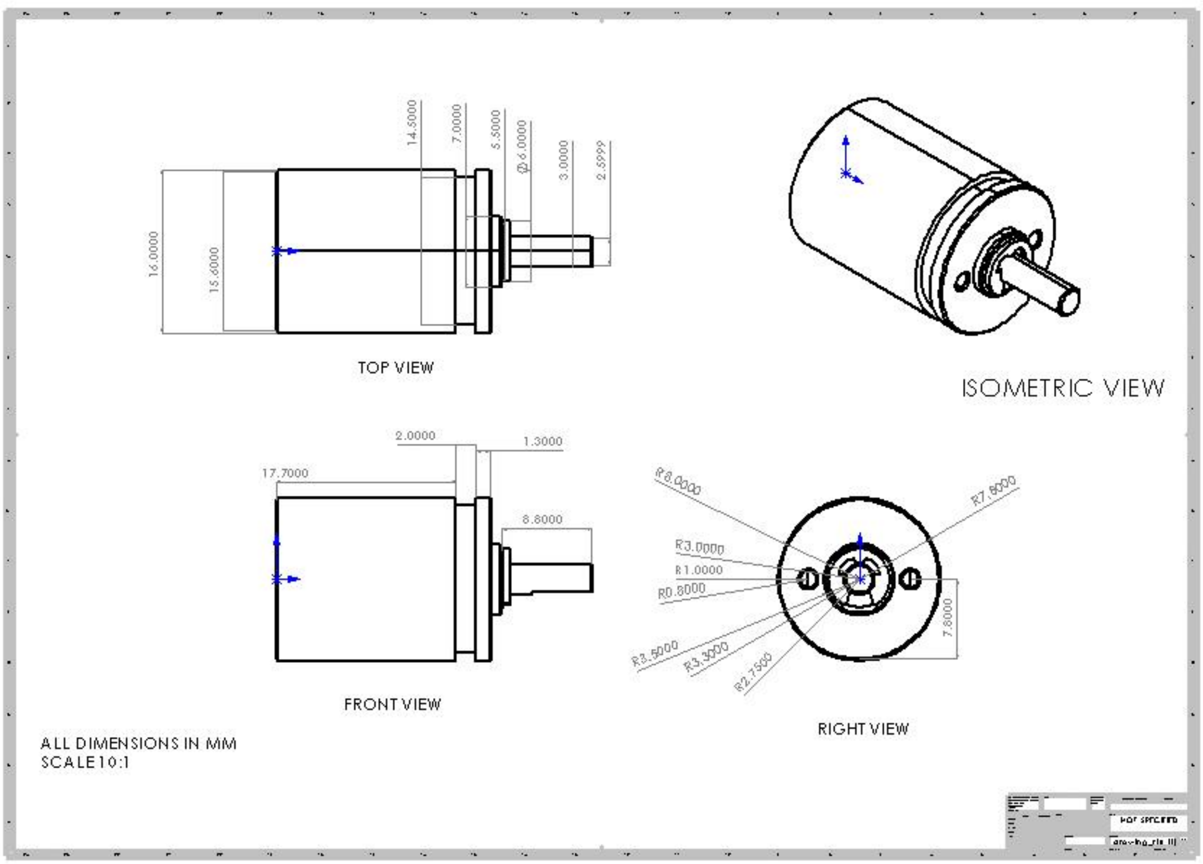
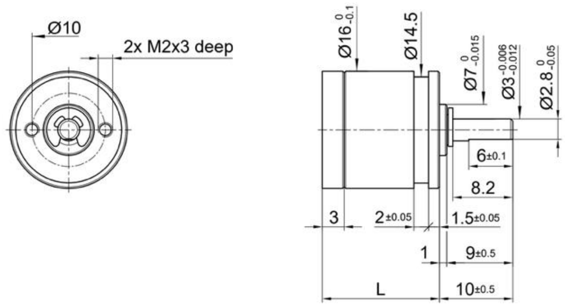


FIGURE 9 - R16 SLEEVE BEARING GEARHEAD

Gearheads **Portescap**

R16 Ø 16 mm • Planetary Gearbox • 0.3 Nm



Dimensions in mm.

	Ratio		5.5	22	30.2	88	121	166	352	484	665.5	915
1	Number of Gear Stages		1	2	2	3	3	3	4	4	4	4
2	Direction of Rotation		=	=	=	=	=	=	=	=	=	=
3	Efficiency		0.85	0.75	0.75	0.65	0.65	0.65	0.55	0.55	0.55	0.55
4	L (mm)		16	20.1	20.1	24.2	24.2	24.2	28.3	28.3	28.3	28.3
5	Weight	g	10	13	13	16	16	16	19	19	19	19
		(oz)	(0.352)	(0.458)	(0.458)	(0.564)	(0.564)	(0.564)	(0.670)	(0.670)	(0.670)	(0.670)

6	Available with Motor – L2 - Length with motor (mm)										
	16C18	31.7	35.8	35.8	39.9	39.9	39.9	44	44	44	44
	16N78	44	48.1	48.1	52.2	52.2	52.2	56.3	56.3	56.3	56.3
	16G88	44	48.1	48.1	52.2	52.2	52.2	56.3	56.3	56.3	56.3
	17S78	34.7	38.8	38.8	42.9	42.9	42.9	47	47	47	47
	17N78	41.9	46	46	50.1	50.1	50.1	54.2	54.2	54.2	54.2
	P110	35	39.1	39.1	43.2	43.2	43.2	47.3	47.3	47.3	47.3
	16DCP/16DCT/17DCT CB	42	46.1	46.1	50.2	50.2	50.2	54.3	54.3	54.3	54.3
	16DCP/16DCT/17DCT PM	41.5	45.6	45.6	49.7	49.7	49.7	53.8	53.8	53.8	53.8
	16ECP36	50.5	54.6	54.6	58.7	58.7	58.7	62.8	62.8	62.8	62.8
	16ECP52	66.5	70.6	70.6	74.7	74.7	74.7	78.8	78.8	78.8	78.8
	32BF	27.2	31.3	31.3	35.4	35.4	35.4	39.5	39.5	39.5	39.5

	Characteristics	Unit	R16 • 0 • ····	R16 2R • 0 • ····
7	Shaft Bearings		Sleeve	Ball Bearing
8	Maximum Static Torque	Nm (oz-in)	1 (141)	1 (141)
9	Maximum Radial Force			
	@ 8mm from mounting face	N (lb)	5 (1.12)	20 (4.5)
10	Maximum Axial Force	N (lb)	8 (1.8)	10 (2.2)
11	Maximum Press Fit Force	N (lb)	100 (23)	100 (23)
12	Average Backlash @ no-load		1.25°	1.25°
13	Average Backlash @ 0.3 Nm		2°	2°
	Shaft Play:			
14	-radial	µm	≤ 20	≤ 10
15	-axial	µm	50-150	≤ 50
16	Maximum Recommended Input Speed	rpm	7,500	7,500
17	Operating Temperature Range:	°C (°F)	-30 to +65 (-22 to +150)	

Figure 10 - Gearhead Data Sheet

The Threaded Bolt

The threaded bolt is mounted to the drive shaft of the gearhead via friction welding, a process which is able to weld one object inside of another. The threaded bolt is bored out wide enough to insert the shaft from the gearhead, which is when the two undergo friction welding to secure them together indefinitely. This process was decided upon as it is much stronger and more reliable than any other method of attaching the two, such as a pin mechanism.

The threaded bolt is used to screw the male module into the female module. It is made out of titanium alloy and is YYY mm long. It has 10-24 thread, perfect for the strength needed to securely hold the two entities together during launch and travel. The manual pins of the ASU travel on either side of the threaded bolt.

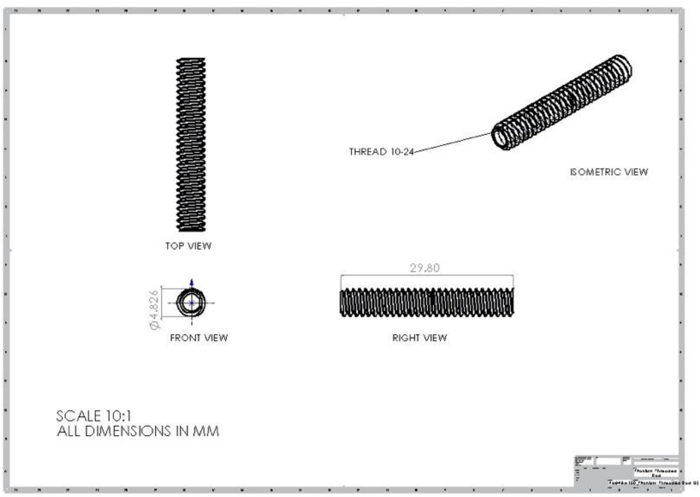


FIGURE 11 - THREADED ROD

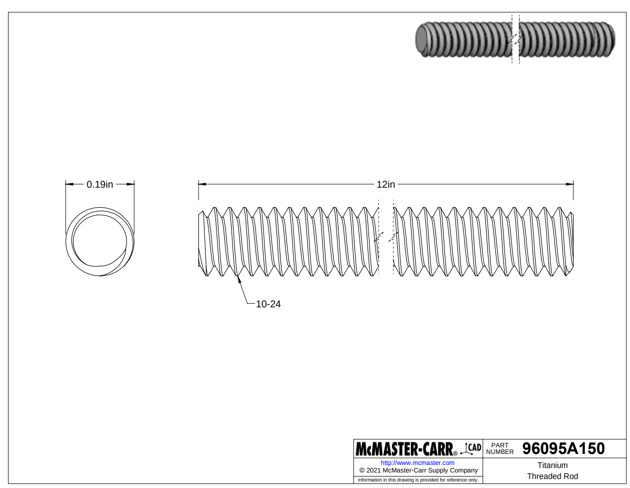


FIGURE 12 - THREADED ROD ALTERNATE DRAWING

The Manual Release Pins

The manual release pins were implemented into the design of the device as a safety precaution. When the safety pins are left in before launch, it ensures that the device will not release before intended but must be removed before the device is launched into space.

The safety pins that we designed are X mm by Y mm by Z mm and are made of titanium alloy metal.

The manual safety pins are simply an extra precaution to ensure the device does not accidentally fire before it is wanted. Typical manual safety pins in modern technology are labelled with a large tag that say "Remove Before Flight" on a large red ribbon. This is a feature that may be implemented onto the manual pins of the ASU.

The Printed Circuit Board

For the ASU design, the Space Buds team took it upon themselves to fully design a custom PCB in order to drive and control the motor, which is the center piece of the design. If the motor were the heart of the design, the PCB would be the brain.

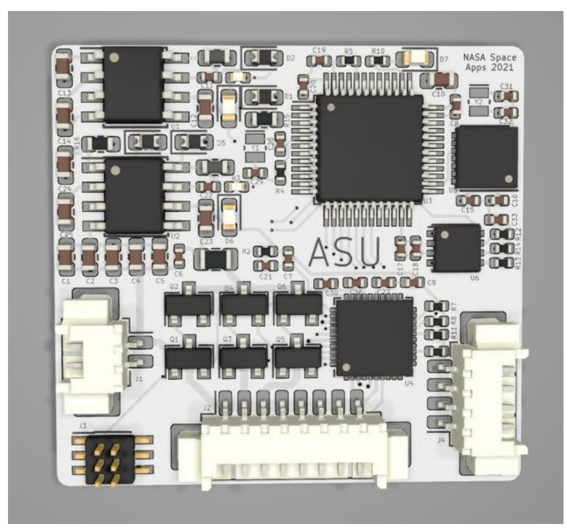


FIGURE 13 - PCB FRONT VIEW

The board designed featured numerous Integrated Circuit elements, or IC elements. These chips will be described in detail within the following subsections, as well as how they all interact with one another to achieve the desired result.

This PCB features a low-power microcontroller, a CAN subsystem for communication to a central controller, two power regulators for creating 3.3 V and 5 V digital power rails and a motor controller/driver with driver transistors.

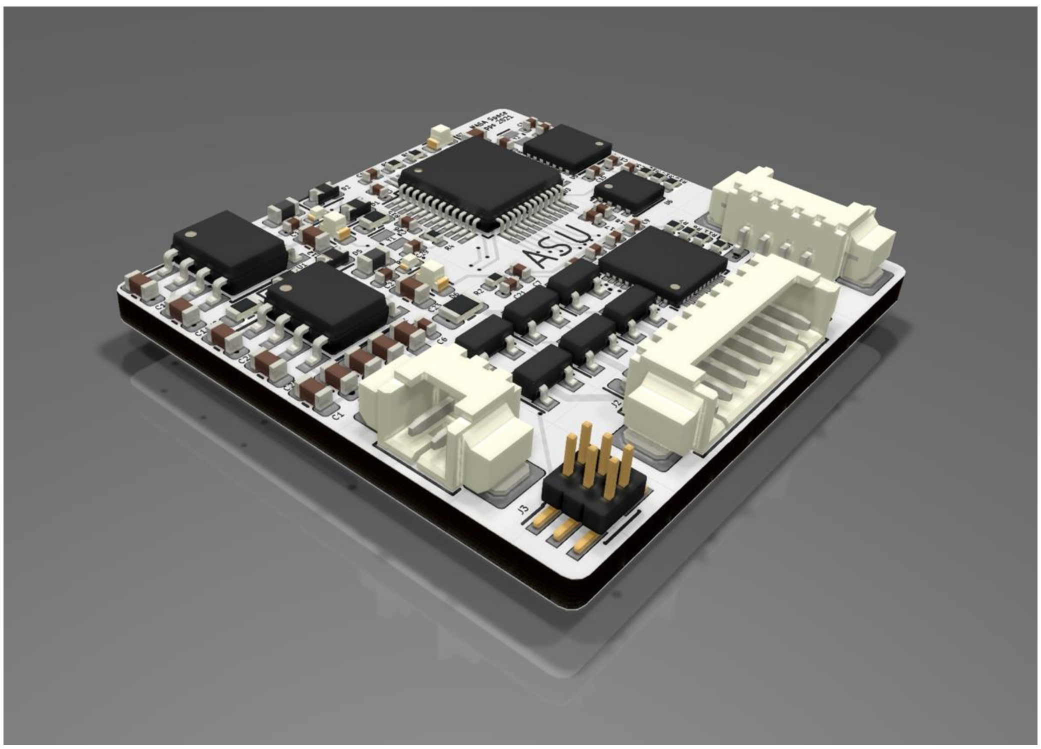


FIGURE 14 - PCB ANGULAR VIEW

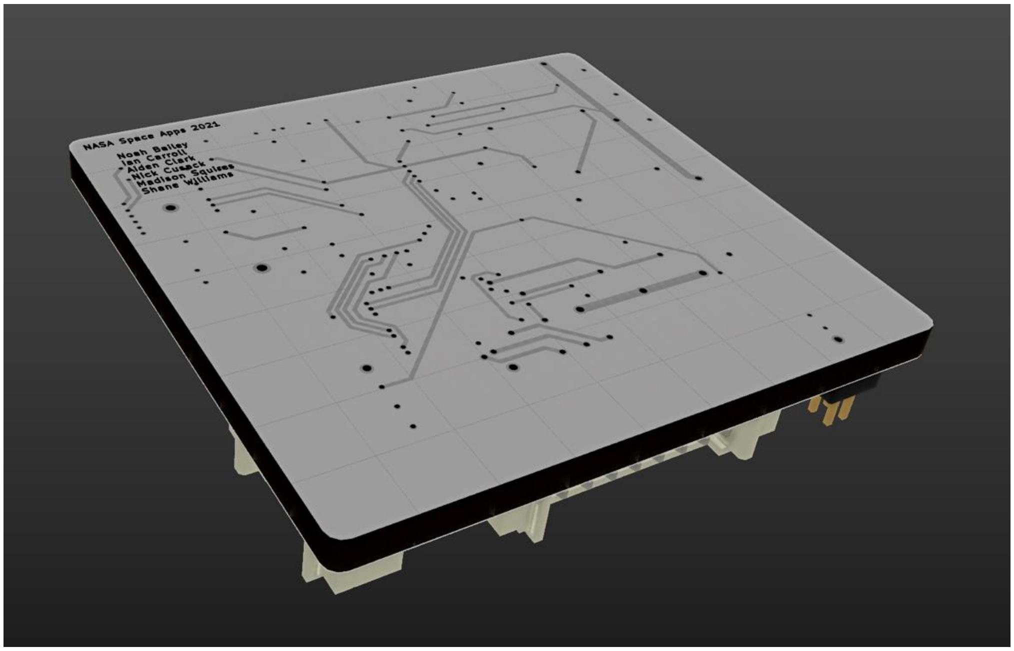


Figure 15 - PCB Back View

Microcontroller

The microcontroller interfaces with both the CAN controller and the motor driver. This allows for CAN control of the device, as well as fault management.

The chosen microcontroller was an STM32L031C6. This microcontroller was chosen because it met our requirements for number of pins, processor speed and peripherals, namely SPI and PWM. Other benefits of this chip include its low power consumption, integrated temperature sensor and significant software support.

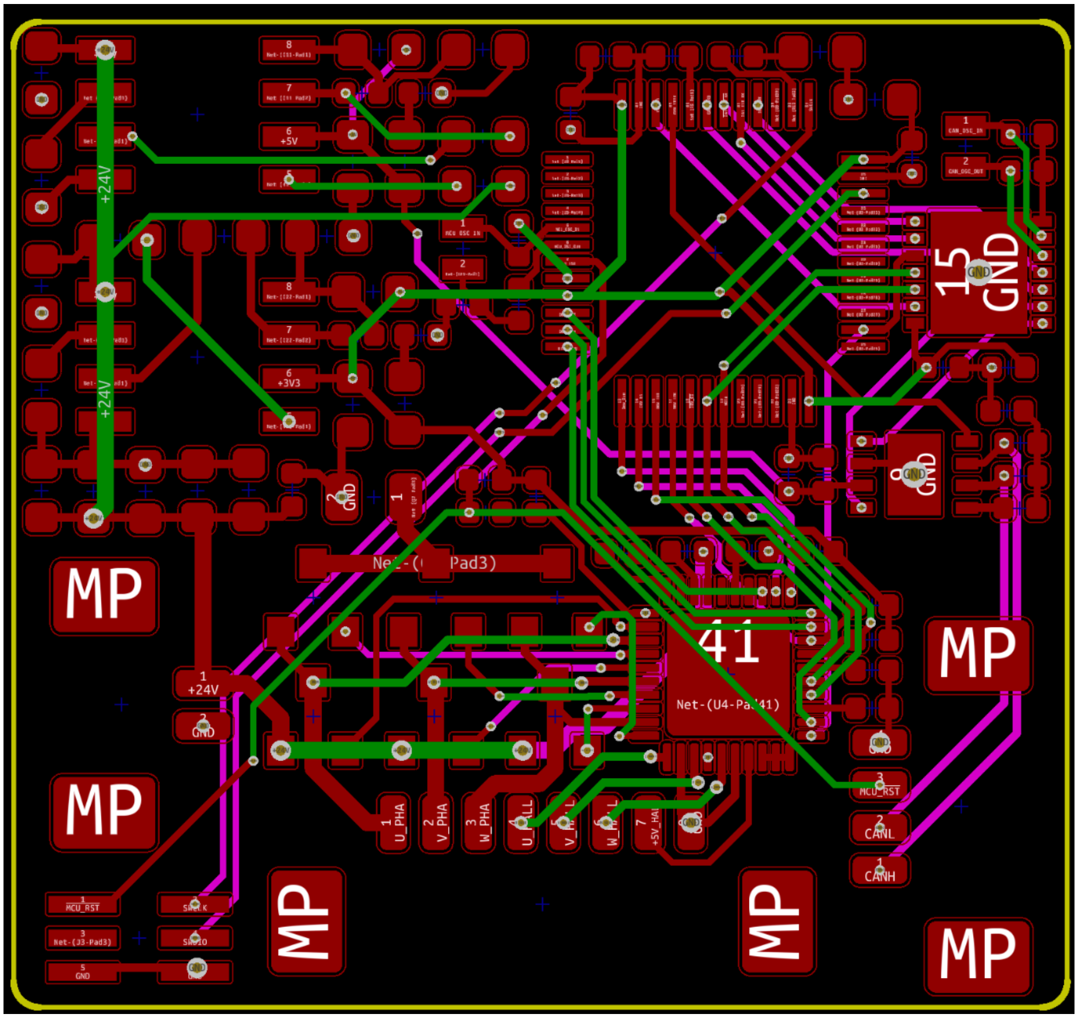


FIGURE 16 - PCB LAYOUT

Motor Driver / Controller

A Texas Instruments DRV8308 brushless DC motor controller/driver IC was used to control the motor. This IC uses a closed-loop control technique which relies on the motor's integrated hall sensors and drives 6 Metal Oxide Semiconductor Field Effect Transistors (MOSFET).

We chose this driver because of its SPI connectivity, PWM control and because it met our voltage and power requirements.

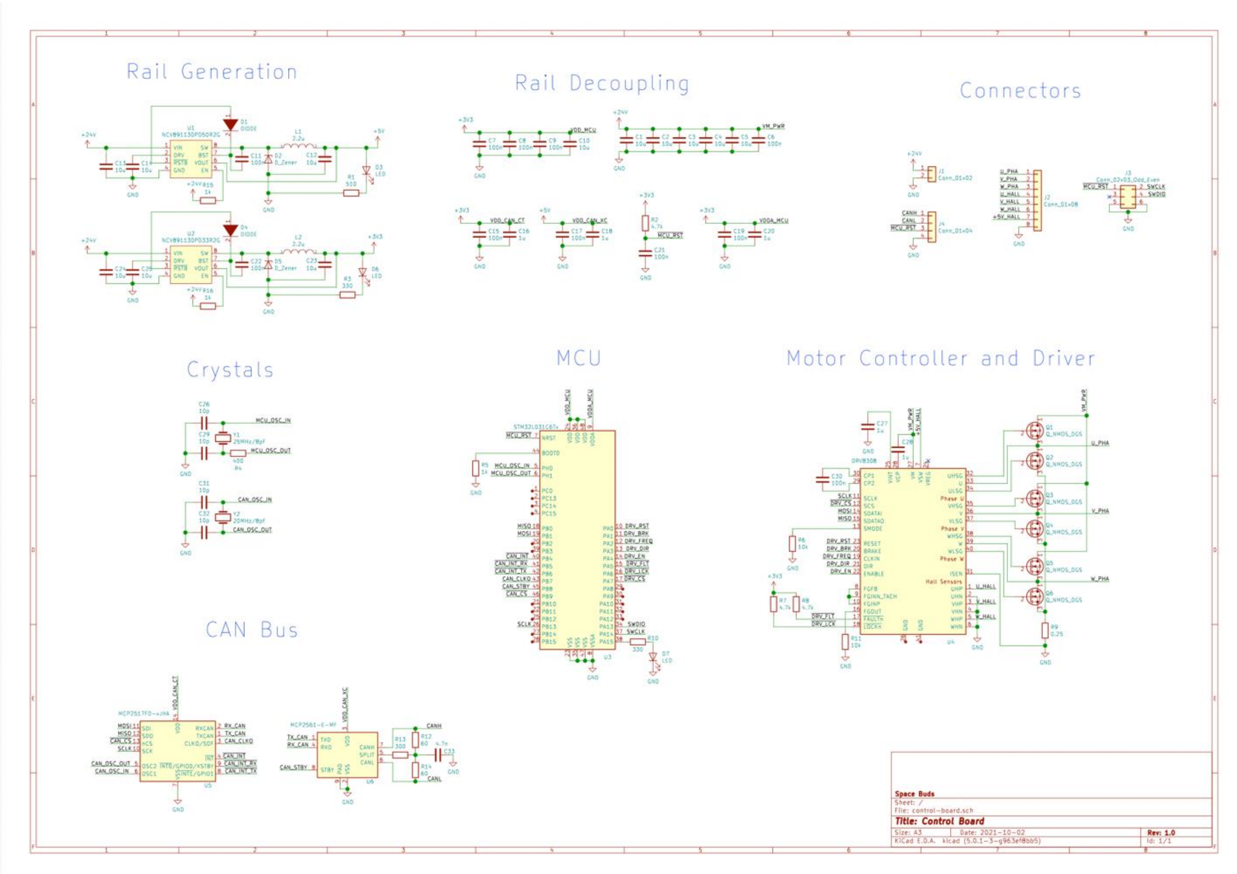


FIGURE 17 - PCB SCHEMATIC DESIGN

Power Regulator

We used 2 hybrid low-dropout/switching regulators to convert the 24 VDC input into 3.3 VDC and 5 VDC rails for digital devices on the PCB, namely the microcontroller, CAN controller and CAN transceiver. The NCV891130 power regulator was used.

CAN Bus

A MCP2517FD SPI CAN controller was used in combination with a MCP2561-2 CAN transceiver to enable CAN control of the motor.

Reliability & Safety

To ensure that the device is reliable, various tests were run in order to validify the 3D model and hardware of the design. These simulations were the first step in testing the design, before a prototype could be created and tested in real life.

One test to confirm the validity of the 3D model was using Finite Element Analysis (FEA), where the analysis ensured that the device could withstand 4000 newtons (N) as specified in the challenge details. This test was handled by the mechanical team and produced some interesting results. It allowed the team to test the design quickly in a simulation environment, and to make any necessary changes based off of obstacles encountered throughout the scientific process.

Secondly, design rule checking was used in KiCad software to verify that the PCB maintained all connections. The design rule checking simulations were handled by the ECE team, and the circuit board was tested in depth and any optimizations were made as seen fit.

The next step to testing reliability of the device would be to fabricate actual prototypes and see how they function under different situations. By adjusting control and independent variables, more specific and before unseen optimizations can be made. This may include modifying the physical design, the PCB design, or the code used to run the electrical elements of the ASU.

When it comes to engineering of any sort, it is always of paramount importance to consider safety. A safe design is extremely important, as a design that is dangerous not only reflects poorly on the team that created it, but often puts others in dangerous situations.

The Space Buds makes no exceptions – safety is the number one priority. While designing the ASU, it was always important to evaluate the risks associated with any features or components. We asked ourselves, "Is this safe? How can it go wrong? What damage could it cause?" Followed by “How can we make this more reliable? What safety features can we implement? Is there a better way to implement this?”

The ASU is made of reliable and well-researched materials, and has safety mechanisms in place to ensure no assets are damaged or lost, and no people can be harmed by the device.

7 – Conclusion

Over the course of the tenth annual Space Apps challenge, the Space Buds team dedicated their time and effort into designing a brand-new product, which was titled “All Screwed Up!” The design was created to separate two entities from one another within space, after having survived a launch.

Through hours of research and development, design, calculations, simulations, and discussion, the team produced a design that they were happy with.

Overall, the Space Apps challenge was a fun experience for the whole team, and we look forward to participating again in the future. The ASU design process was a remarkable learning experience for us all, and allowed us to perfect our skills as well as learn some new skills from each other.

The ASU design has passed all of the specifications as noted in the challenge description and has even gone above and beyond what we thought may be possible. It is lightweight, durable, draws little power, and is even quite scalable. The majority of components were designed and created in-house, and the others were chosen carefully from reputable sources and companies, who were able to provide specification data and resources to aid us in the design and implementation.

The final design was tested under various conditions through various software simulations and met all of our expectations and completed all of the objectives. It makes use of a slotted brushless DC motor, a gearhead, two shrouds, a threaded bolt, a spring, and a custom designed PCB, as well as some extra safety precautions such as manual safety release pins.

The time constraint for the challenge was to complete the design within two days, which put quite the strain on the Space Buds team, but through great communication and teamwork, the challenge was completed.

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