Art in Space: Using Art to interest K-12 students in aerospace design [STUDENT PAPER]

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Abstract

In the spring of 2019, the American rock band OK Go announced a competition inviting children (ages 11-18) from around the world to design an art experiment that could only be executed in space. Specifically, the art would be in a payload, in a rocket, and experience temporary microgravity. This competition was conducted in partnership with Blue Origin and the University of St. Thomas. After two winning designs were chosen, undergraduate research students from the Playful Learning Lab designed and built the payloads, collaborating with the students who proposed the ideas and with the OK Go band members. This project was both a major K-12 outreach project and also an intensive undergraduate research experience.

This paper will look at the following three elements of this project:

(1) The competition itself, including how it was promoted, the submission and judging process, and general contest logistics and information;
(2) The design and execution of the two winning ideas: Cosmic Song and Dark Origin;
(3) A reflection on the opportunities and challenges of running and participating in this project as an undergraduate research experience.

We will share lessons learned from this project in terms of promoting creative engineering opportunities for a K-12 audience and regarding empowering undergraduate students to play lead roles in aerospace engineering projects. Additionally, we will discuss detailed information, including schematics, of the two payloads.

Introduction

The title of this international contest was "Art in Space." It was inspired by the rock band OK Go's music video "Upside Down and Inside Out," which was filmed in microgravity on a Russian airliner with S7 Airlines. The official contest launch day was March 5th, 2019, and submissions were accepted until May 6th, 2019. The contest prompted student teams, under the guidance of one adult advisor, to submit their idea for an art project to launch on Blue Origin's New Shepard launch vehicle. The overall goal of the contest was to encourage students ages 11-18 to participate in artistic creativity within the realm of aerospace engineering design projects. The focus of the contest submission was on the formation of plans and ideas, not a fully engineered detailed project outline. The main sponsor for Art in Space was Cognizant, a leading company in encouraging continuous learning and preparing for the technology of the future. This

project was also made possible through sponsorship from Google and Morton Salt supporting OK Go Sandbox.

OK Go Sandbox is a free education resource that was developed based on OK Go's unique music videos. Concepts of math, engineering, art, science, and illusions are outlined in educator guides and tied to specific music videos. This resource was created through a partnership between OK Go and the Playful Learning Lab, an undergraduate research lab at the University of St. Thomas. The Playful Learning Lab, frequently abbreviated as "PLL" by its members, is an interdisciplinary group of over 30 St. Thomas students with majors in engineering, music, education, marketing, finance, computer science, and more.

To promote the contest, a team of undergraduate students within the Playful Learning Lab prepared a full marketing plan to attract as many applicants as possible within the two-month media campaign time frame from February 26th, 2019 to April 1st, 2019. The overall goal of the publications was to (1) engage students in creative art, science, and aerospace design along with independent learning, (2) bring attention to the contest as a whole and inspire student teams to submit entries, and (3) increase overall traffic and engagement on the OK Go Sandbox website. Over 40 posts were prepared and scheduled to be posted on specific dates on the OK Go Sandbox Twitter, Instagram, Facebook, and Pinterest pages. Some of the marketing posts correlated with specific national themes like Everything You Do is Right Day, National Scribble Day, National Library Week, and Astronomy Month. The publicity strategy included posts targeted specifically towards students or towards educators, and the content and language was altered for each audience. The team also leveraged the existing educator email base developed through the OK Go Sandbox website and sent direct promotional contest emails to engage long-term supporters of the free educational resource. Finally, an external communications company was hired to help identify and reach additional organizations and individuals who may be interested in the contest. All promotions contained a direct link to the Art in Space contest webpage and submission form.

Submissions and Judging

Submissions were collected using a Qualtrics form designed by the Playful Learning Lab marketing team and found on the OK Go Sandbox webpage. The first few questions consisted of basic contact and address information of the adult advisor and asked for the name and age of each team member because the contest required a minimum of three student team members. The final question requested a short essay of 500 words or less describing the art project, as well as any images or videos the team wanted to attach in order to help explain their concept. By the contest deadline on May 6th, we had successfully collected 48 eligible submissions. The design ideas received were from 12 different countries: Azerbaijan, India, Australia, France, Romania,

Philippines, England, Canada, Peru, Germany, South Korea, and 17 states within the United States.

Each submission was reviewed and judged according to a rubric (Figure 1) created by the Playful Learning Lab educational team. To decide which entries would be selected as the winners, we hosted two judging sessions at the University of St. Thomas, inviting professors and advisors from multiple disciplines, as well as lab members, to participate as judges. Every application was printed in triplicate and judged by three different individuals using the judging rubric. Perspectives from the following disciplines were included when reviewing each team's ideas: Education, Music Education, Art History, Business, Civil Engineering, Computer Engineering, Computer Science, Economics, Electrical Engineering, English, Finance, Manufacturing Fabrication, Marketing, Mathematics, Mechanical Engineering, Ocean Engineering, Physics, and Studio Art. The submissions were critiqued based on six categories: Space Factor, Creativity, Feasibility, Technical Skills, Writing, and Overall Impact. The judges also considered whether or not the idea followed the safety requirements of the payload as defined by Blue Origin. Each category was weighted based on importance, and categories were given a score on a 2-1-0 scale. After the preliminary judging rounds, members of the Playful Learning Lab calculated and verified the point totals for all of the submissions.

Art In Space Payload Judging Rubric

Category	Exceeds (2)	Meets (1)	Below (0)
Space Factor 30%	Payload design would only fully succeed in a space environment	Payload design could fully succeed both in space and earth environments	Payload design would only fully succeed in an earth environment
Creativity 25%	Idea is very original, there are little to no submissions like it, and is not an idea that has been done before	Idea is somewhat original, there are many submissions like it, and is an idea that has been similarly done before	Idea is very unoriginal, there are a lot of submissions like it, and is an idea that has been done before
Feasibility 20%	Payload will work as designed and is possible	Payload can work with minimal alteration and is possible	Payload design is not possible
Technical Skills 15%	Exceptionally clear and neat presentation of all material (drawings, essay, timeline)	Fair presentation of all material (drawings, essay, timeline)	Disorganized and confusing presentation of all material (drawings, essay, timeline)
Writing 5%	Easy to read, clear and precise wording, little to no grammatical mistakes	Somewhat easy to read, some unclear wording, some grammatical mistakes	Difficult to read, ambiguous wording, many grammatical mistakes
Overall Impact 5%	A striking and memorable submission. Attracts and impresses, leaves a lasting impact	A satisfying submission. Holds attention, leaves a significant impact	A common and undistinguished submission. Not very impressive, leaves little to no impact
Submission Criteria			Does not meet safety and submission requirements, disqualified immediately
Total Points			

Figure 1: Weighted Art in Space contest judging rubric

The initial judging rounds were used to narrow down the applicant pool to the top five entries, based solely on points. The top submissions were then reviewed in open discussion. The participants of this discussion included the creative director of OK Go, an engineer from Blue Origin, the Art in Space undergraduate project lead, another undergraduate Playful Learning Lab member, and the faculty advisors of the lab. A lengthy conversation about the top five submissions focused on which ideas correlated best with the creative vision of OK Go, were objectively the most creative, and were the most impactful. At the end of the conversation, two submissions were tentatively chosen and sent to the OK Go band members for final approval. The band approved the winners, and the two winning teams were publicly announced on June 25th, 2019.

Announcement of the Winners

Figure 2: OK Go band members (left to right) Andy, Damian, and Tim congratulating two members of the Cosmic Song team

Members of OK Go joined impromptu video chat calls to congratulate the teams directly (Figure 2) prior to the announcement of the winning teams on media platforms. Recorded clips from these conversations were then used in an announcement video posted on OK Go's Youtube channel, as well as Facebook and the OK Go Sandbox website. The initial press release was launched exclusively through Fast Company. Additionally, other news sources picked up the story and also announced the Art in Space contest winners, including Yahoo News, Space.com, and Geekwire. Regardless of the fact that only two winners were selected, OK Go and the Playful Learning Lab wanted to extend a thank you to every team for their submissions and creative participation in the contest. To do this, the members of the lab packed and shipped

mailing tubes filled with Art in Space posters signed by the band, handwritten thank you notes, and other OK Go Sandbox merchandise, including a canvas bag and stickers.

Payload Details

Blue Origin Parameters

Blue Origin LLC provided us with numerous strict guidelines for the payload design--most notably, size (4”x4”x8” or 100mmx100mmx200mm), electrical power (4.5 watts at no more than 5V), and mass (1.1 lbm or 500 g). Further specifications for generated sound, vibration, magnetic field, liquid containment, and more were provided as they became relevant to the design stage.

Selected Teams: Cosmic Song

One of the winning teams proposed using the space flight opportunity to create audio and visual art made by space itself, and because of this their project was later titled “Cosmic Song.” A small, guitar-like instrument with electronic end effectors would be fitted inside the payload. Those end effectors would be triggered by a microcontroller in response to data gathered from a module detecting electromagnetic radiation abundant in the high atmosphere. The strings themselves would be coated in paint so that when struck the inside of the payload would itself become a canvas in parallel with the song.

Selected Teams: Dark Origin

The other team, self titled “Dark Origin” hoped to simulate the mechanism through which the planets were created. The current scientific model suggests that gravity steadily drew passing debris together, and over millions of years the debris was compressed into a single body. Given approximately 3.5 minutes of microgravity during flight, the force of gravity would be replaced with a magnet force, and the debris itself would be magnetized. When the microgravity flight state was reached, the debris would deploy into the payload, and fans would begin circulating that debris into “orbit” around magnetic cores suspended in the center.

Design Process

The goal of the Art in Space payload design project was to have the winning student teams work closely with the undergraduate engineering team from the Playful Learning Lab and the OK Go band to help create a payload that represented their core ideas while fulfilling Blue Origin’s payload constraints. This collaboration began with a kickoff call between the Playful

Learning Lab engineering team and a payload advisor at Blue Origin. This call outlined the details of the project as declared by Blue Origin. This included a timeline review, a discussion of some initial questions, and an introduction of the forms the Playful Learning Lab engineering team was required to submit. The main form, called the Payload Disclosure Packet (PDP), was an 18-page document that required a detailed description of all the aspects of the payload, how it would function, CAD models, and electronic schematics (Figures 6 and 11). Throughout the design process, the Playful Learning Lab team was required to submit ongoing drafts of the PDP. A complete bill of materials, detailing each component, its sourcing vendor, quantity, and Material Safety Data Sheet was also required. This was used to ensure each item in the payloads, down to the nuts and bolts used to secure and mount components, was safe to launch on Blue Origin's New Shepard rocket.

All project communications were managed by the Art in Space project lead and sent to the adult team advisors as a means of contacting the student teams. In mid-July an initial video chat was scheduled with each winning team to meet the PLL team and discuss their ideas. Most weeks, depending on the design progress, the Art in Space project lead sent emails to update the winning teams, the Playful Learning Lab undergraduate engineering team, and the OK Go band members. These email updates frequently included design sketches and 3D CAD models created by the PLL team, as well as questions for the student teams to provide input and critiques on their payload designs. Examples of the CAD models can be seen in Figure 4 and Figure 9. Starting in August, members of the Playful Learning Lab engaged in a monthly video chat check-in with the teams to talk about challenges or roadblocks that arose and ask for suggestions for how to proceed. The goal of these communication strategies was to maintain open collaboration with the students and the band and to make sure the payload designs remained aligned with the student teams' visions.

During late October of 2019, the project lead arranged video chats with both winning teams that included a few Playful Learning Lab members, a member from the OK Go band, OK Go's creative director, and an engineer working at Blue Origin. The purpose of these calls was to allow the student teams to talk directly with a professional engineer and receive some creative inspiration from the band to propel their ideas even further. This was a mid-design check-in, which allowed both the student teams and the band members to see the status of the payload and to make suggestions for alterations and future design decisions.

The process also included monthly calls between members of the Playful Learning Lab engineering team, the Art in Space project lead, and the Blue Origin payload advisor to answer questions and maintain the established timeline. Closer to the shipping date, these became bi-weekly calls, to confirm timely submission of the required forms and that the payloads would be completed in time for the launch. The final PDP was submitted on October 7th, 2019. To

provide Blue Origin with evidence of payload readiness, a prototype demonstration video was sent in on November 7th, 2019. Figures 3 and 4 are photos of the two payload prototypes. The construction of the prototypes was the first time the winning teams' ideas were fully actualized outside of digital modeling. During this building process, many electronic and physical challenges arose and had to be quickly solved in order to meet the deadline. The same pictures and videos sent to Blue Origin were sent to the student teams to share the updated status of each payload.

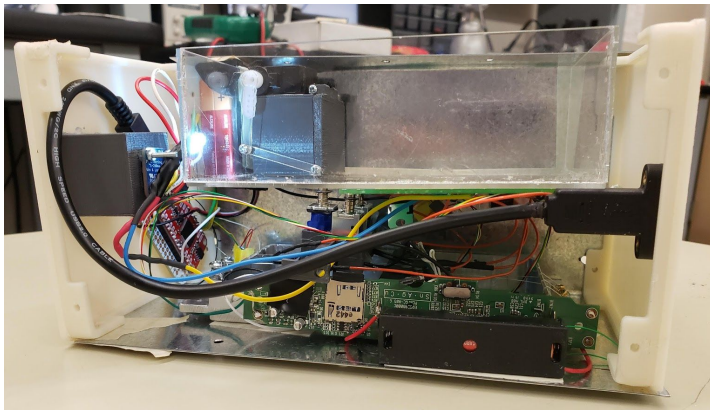

Figure 3: Prototype payload of Cosmic Song used for demonstration video

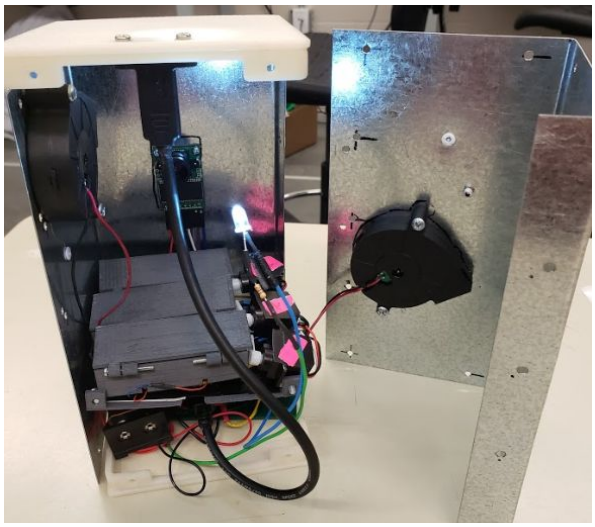

Figure 4: Prototype payload of Dark Origin used for demonstration video

Cosmic Song Payload Details

While designing the Cosmic Song payload, the Playful Learning Lab engineering team came across many challenges. One of the first design challenges was how to 'pluck' a guitar string remotely. The initial idea proposed by the students was akin to a small felt-covered piano

hammer. To maintain low physical volume and minimize the electronic components required to ‘pluck’ the strings, solenoids were used to act as a guitar pick. The final system included only three solenoids and three strings instead of the initially proposed five, primarily to reduce the overall weight of the payload. The original desired input to create the ‘cosmic song’ was using sensors to detect various types of space radiation. This was impossible because the crew capsule of the New Shepard is shielded against atmospheric electromagnetic radiation. Instead, in an effort to capture the “chaos” of spaceflight, we implemented a proximity sensor that measured the motion of small balls bouncing inside of a miniature plastic cube within the payload. The sensor data, along with real-time flight data of the altitude provided by Blue Origin, was used to trigger the solenoids.

Several methods and designs were tested to record the sound produced by the vibrating strings. The preliminary idea suggested by the students was to create an acoustic chamber to amplify the vibrations, using a microphone and SD card to record the sound produced. The volume required to create a useful acoustic chamber was too large relative to the payload size constraints. An electric guitar pickup was implemented to record an analog-to-digital signal output. This was accomplished with a signal amplifier and an Arduino microcontroller, but the computation required was too taxing for the microcontroller, considering the other systems it had to control. This is represented in a simplified electronic schematic in Figure 5. A lightly modified commercial guitar sound recording option was tested which recorded audio directly off of the guitar pickup. In the final iteration, the whole sound recording system was removed in order to meet the payload weight requirements and still create audio and visual art. Instead, the data from the proximity sensor was recorded, so the song that occurred from the movement in space could be recreated on earth in order to record it.

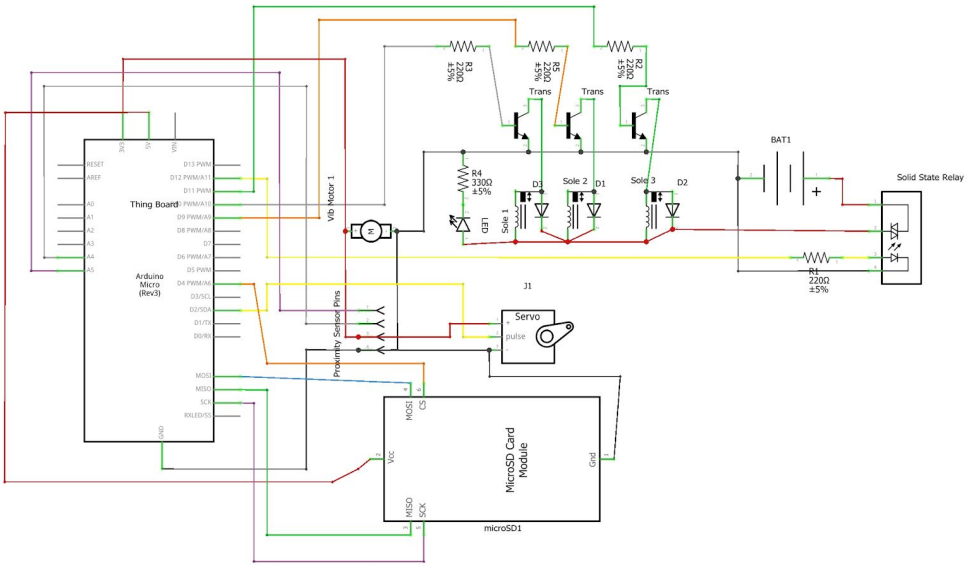

Figure 5: Simplified schematic for Cosmic Song electrical system

One of the biggest challenges involved in designing the Cosmic Song payload was creating the visual art component. The team originally proposed covering each string in liquid paint, releasing paint onto the inner walls of the payload as each string was plucked. Due to liquid containment requirements, we needed to create an entirely separate section of the payload for the paint, isolated from all of the electronics. Liquid paint was not used due to its mass and the complexity required to release liquid or prevent it from drying during payload shipment. The final decision was powder paint, of the same colors as the palette chosen by the student team. It was contained in a box opened by a cam system, all within a lightweight container made of clear tape, and lined with double-sided adhesive to capture the powder as it landed. Figure 6 depicts the final design of the Cosmic Song payload.

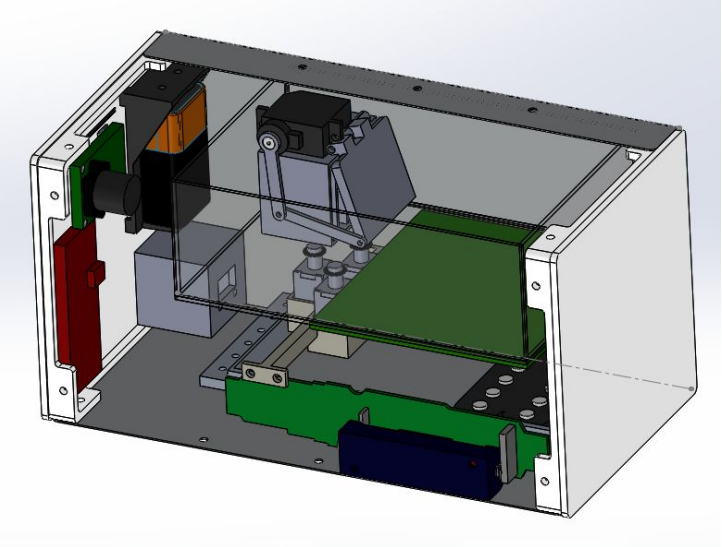

Figure 6: Final Solidworks CAD model of the Cosmic Song payload

Dark Origin Payload Details

The design of the Dark Origin payload brought up a completely different set of challenges. The first step was deciding what the magnetized debris would consist of, and there were several iterations and ideas. In their contest submission, the students proposed using “dust and chips of iron, nickel, gold, and platinum, small lightweight rocks made with dryer lint, silver, and iridescent glitter, metal stars, wire pieces, crystals, wood, metal, plastic, paper, and textile fragments.” The initial suggestions were narrowed down because the materials that are non-magnetic were not used. Then decisions were made based on size, weight, and physical consistency. The student team took it upon themselves to create some prototypes of lightweight rocks, but the rocks were too large to be used as a collective set of debris. Iron filings, as well as small metal balls, were considered, but not used in the final payload because they were too small, and the filings could have caused unsafe interactions with the electronic systems within the

payload. The final choice of debris was small styrofoam balls covered in bright paint filled with magnetic iron filings and covered in glitter. The student team assisted with hands-on creation of the debris that was sent up in the completed payload.

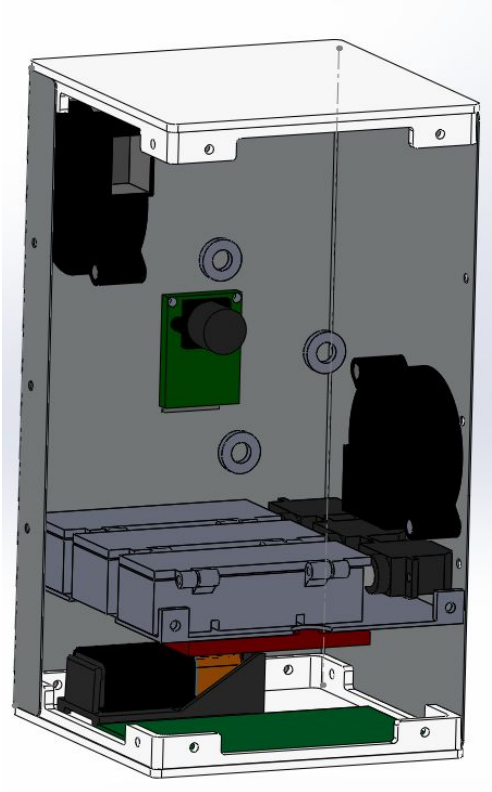

Figure 7: Intermediate design of the Dark Origin payload

Another challenge the PLL team had to figure out was how to release the debris. The students initially suggested having a pile of the debris in a corner of the payload, but together it was decided that the debris would need to be contained somehow and then released to ensure that the 'formation' process of the debris around the center magnets only occurred during the microgravity portion of the flight. We went through many iterations of a box release system--with rotary mechanisms and linear spring motion--but decided on a simple rectangular box to be opened by a cam on a servo attached to a slot on the box, actuated by a microcontroller. Vibration motors placed underneath each box were included to further assist in ejecting the debris from the containers. The students proposed using a fan to assist in the movement of the debris, which developed into using two small squirrel cage fans oriented oppositely on either side of the payload. The intermediate design of this payload system can be seen in Figure 8. The Playful Learning Lab engineering team also encountered roadblocks in powering all the electronics required in the system of two servo motors, four vibration motors, two fans, and a camera. An additional power source of a 9V battery was added to power the

components within the payload. The electrical schematic for this payload can be found in Figure 8.

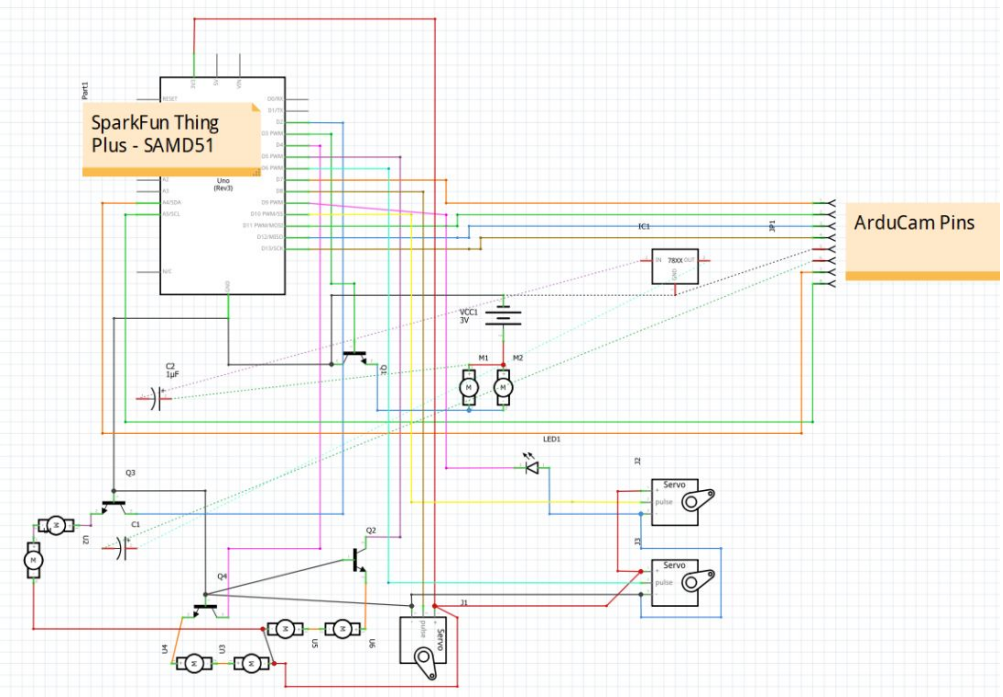

Figure 8: Simplified schematic of Dark Origin electrical systems

The main focus of the student team's design idea was to create a suspended artistic sculpture, formed using magnetism and microgravity. Initial plans were to suspend the magnets using nylon wire secured with rivets to the walls of the payload. Tested commercial nylon products could not stand up to the simulated rigors of spaceflight. Instead, the magnets were supported by machined, delrin posts anchored to the walls of the payload. The final payload, post flight, can be seen in Figure 10. The differences in design (including only using 2 debris containers, the cams for opening containers, and the posts used to replace the wire for suspending magnets) can be seen by comparing Figure 10 and Figure 7.

Launch Day and Beyond

The original launch date for Blue Origin's New Shepard rocket mission 12 (NS-12) was December 3rd 2019, but it was postponed due to the time needed to finish up a previous flight on the same launch pad and prepare for the next one. The next scheduled date was a week later, on December 10th, but it got postponed by one day due to weather concerns. So the two payloads went up into microgravity flight on December 11th, and the launch was televised on Blue Origin's website. The student team members, their adult advisors, members of the Playful Learning Lab, faculty, parents, and math classes gathered to watch the live streaming of the

rocket launch. The whole flight took about fifteen minutes, and the post-launch payloads arrived at the University of St. Thomas just a week later.

There was no clear expectation of what the payloads were going to look like after their space flight experience. A video call was set up with each team so the students could watch a live unboxing of each payload. For the Cosmic Song payload, the powder paint visual art ended up mixing well enough to create a muddled gray color, so it was difficult to distinguish the original choice of colors. The ‘cosmic song’ itself created by space-triggered string plucking was replicated using the data collected and saved in a file successfully. The post-launch payload can be seen in Figure 9. In the Dark Origin payload, the debris boxes had opened, and the ‘planets’ were formed. The art seemed to have remained fairly intact through shipping, although there was extra debris inside the payload that escaped the magnetic fields. The post-launch payload can be seen in Figure 10.

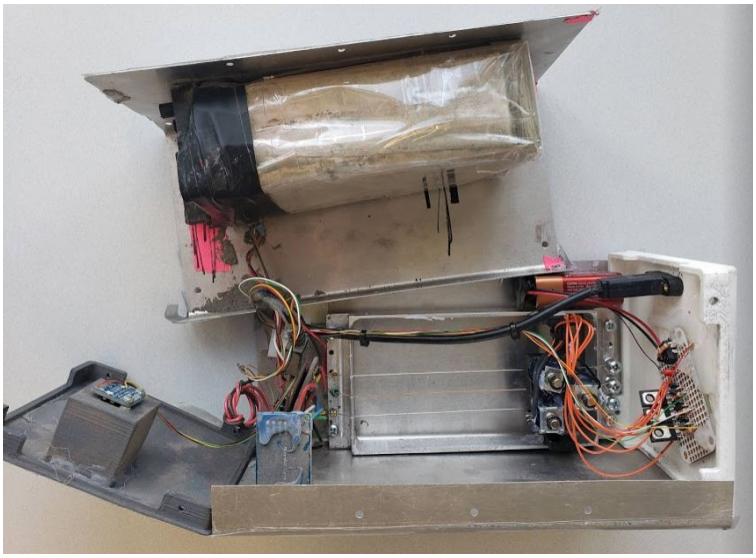

Figure 9: Post-flight Cosmic Song payload

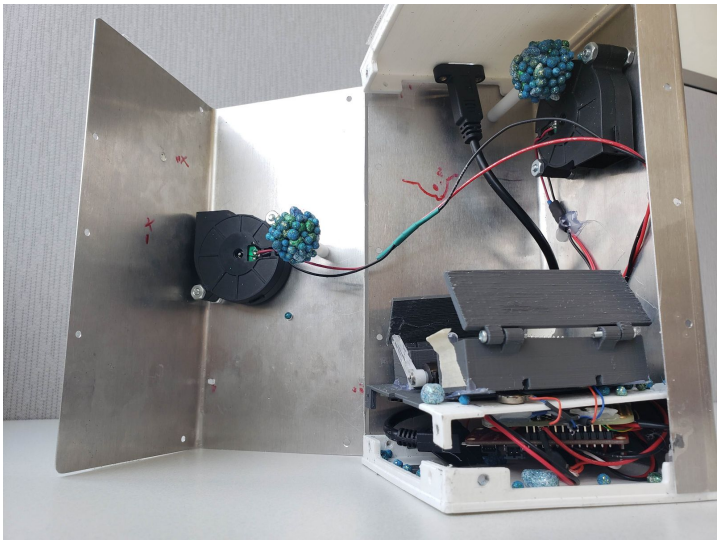

Figure 10: Post-flight Dark Origin payload

To wrap up the project experience for the students, the Art in Space project lead put together a full design binder for each team that included every single sketch, every 3D CAD model, electronic schematic and design plans from the start to the finish of the payload creation. Before the launch, pictures of each team were put inside the payloads, so a surprise memento of the students 'in space' could be sent to them as well. Additionally, gifts from Blue Origin of pins, patches, and t-shirts for the NS-12 launch were shipped to the students along with their payloads. The cosmic song music file, along with all digital files produced by the Playful Learning Lab, were shared with the teams over email. Well wishes and congratulations were shared, and the project was concluded.

Undergraduate Engagement

The contest and payload design project was a tremendous growing experience not only for the Cosmic Song and Dark Origin student teams but also for the Playful Learning Lab undergraduates. There were a multitude of questions that did not have direct answers because the two payload ideas required creating something that had never been done before. One of the most useful resources for the undergraduates during this process was expert advice. Because the engineering work was located on a college campus, many professors became project advisors, helping the team find solutions and stay within the payload restraints. The Playful Learning Lab ended up hiring outside engineering consultants as we were approaching the shipping deadlines (Figure 11). This created an opportunity for the undergraduates to work on an engineering project with professionals and learn how to approach roadblocks more creatively within a collective team. Playful Learning Lab alumni also pitched in to act as advisors because they had experience with the lab's work style, and they helped to encourage the personal and professional

development of current lab members. “Because of the environment at the University of St. Thomas, we have almost unlimited access to field experts from every branch of engineering, and it was exciting tapping into that knowledge to make it all happen and modify it how we saw fit,” said a senior engineering student from the Playful Learning Lab.

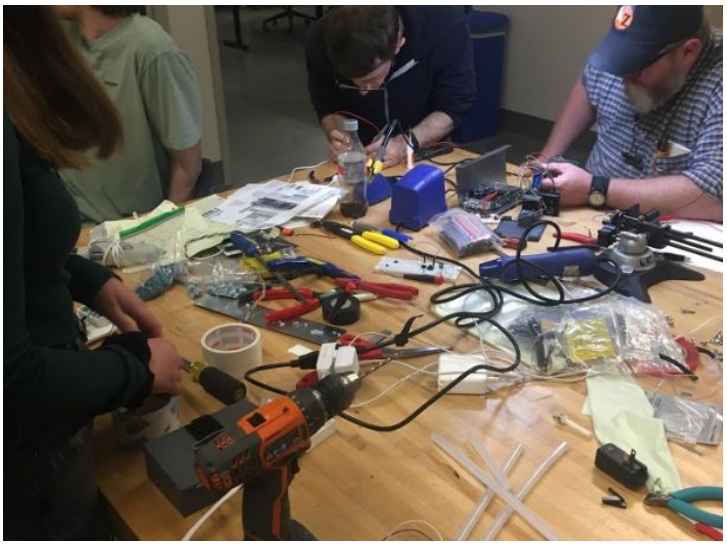

Figure 11: The Playful Learning Lab team and engineering consultants collaborating

The majority of the lab’s undergraduate engineering team were not seniors, so they had no experience with the University of St. Thomas Engineering Senior Design capstone prior to working on the Art in Space project. This contest provided real-life effective preparation and practice for future professional engineering work. It was difficult for many of the team members to balance lab work, social life, and academic life, but it was possible. With the challenging design process and deadlines, the Playful Learning Lab members developed and reinforced vital time management skills. Many of the Art in Space project members were concurrently working on other lab projects, were traveling, or became unavailable during some periods of time during the year-long project. This posed a challenge in the overall development of the payloads but was manageable.

This contest was also a powerful learning experience for the undergraduate Art in Space project lead. The role included frequent communication between team members, workplace superiors, consultants, the student teams, and OK Go. It was necessary that everyone working on this project had updated information on the design progress in order to effectively move forward. Productive and timely meetings were vital to the projects’ progression. It involved scheduling across time zones, which was an unfamiliar experience for the project lead. This project challenged the third-year undergraduate engineering student to be in a management role leading professionals and other undergraduates who had much more knowledge and experience. This led

to an active management style of friendly and constant feedback, the project lead communicating from a position of humility, and actively adapting based on feedback from the team. Managing a complex long-term and public design process helped the undergraduate to gain more confidence in team leadership skills and what her role as an engineer could look like post-graduation.

Summary

The Art in Space contest launched by the band OK Go was the catalyst for an engineering project that spanned over a year and involved intense collaboration by more than 45 people. Planning and discussions started in mid-2018, and in January 2020 the final shipment was mailed to send the post-flight payloads to the winning teams. The process was strongly interdisciplinary, requiring contributions from a variety of fields. It was an enormous problem-solving challenge for undergraduate students in the Playful Learning Lab at the University of St. Thomas. Every party involved experienced learning during this long-term project, whether it technical skills or collaboration skills, everyone gained some amount of aerospace engineering knowledge. Overall, the main goal of this contest was to encourage K-12 youth to be more involved in and inspired by aerospace engineering and design, and that goal was achieved.