# The History of SDSU Rocket Project

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**The Aerospace Industry has evolved rapidly in the past half century and has been a constant attraction to many young aspiring engineers. Students graduating college for the last two decades have grown up watching the Space Shuttle program and are now inspired by the exciting new push to make rockets reusable and economical. The allure of building rockets has only increased as the industry becomes more mature and the technology that fuels it becomes more inexpensive and accessible. Liquid collegiate rocketry programs that were previously unthinkable were now feasible at the turn of the 21st century. Many new collegiate rocketry programs began to form and establish themselves at universities across the nation, with San Diego State University (SDSU) being one of the first. In 2003, a group of 5 students founded SDSU Rocket Project with the goal of building bi-propellant liquid fueled rockets. The club has since impacted over 500 SDSU students and has grown to an operating body of over 70 active members. Although well established, SDSU Rocket Project has had no shortage of failures and setbacks, sometimes resulting in long periods of time with little to no development. Regardless, Rocket Project continues to be a successful club with a thriving student body, a testament to the hard work that countless students have dedicated to Rocket Project for almost 20 years. We are writing this to both commemorate the many individuals who have supported SDSU Rocket Project and provide lessons learned to future rocketry enthusiasts at SDSU and other Universities.**

**Figure 1. SDSU Rocket Project official team logo**

## Nomenclature

| | | |
|---|---|---|
| SDSU | = | San Diego State University |
| RRS | = | Reaction Research Society |
| FAR | = | Friends of Amateur Rocketry |
| LOX | = | Liquid Oxygen |
| COTS | = | Commercial Off The Shelf |
| SSF | = | Student Success Fee |
| GAH | = | Galactic Aztec Heavy |
| CSULB | = | California State University Long Beach |

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# I. Introduction

Like any organization, SDSU Rocket Project has experienced many ups and downs over the years. This behavior is accelerated by the frequency at which students come and go at a four-year university where a certain group of students can be much more motivated, collaborative, and dedicated than the next. Building a club that lasts is difficult and takes a significant amount of effort to uphold. For this reason, building a student run organization that lasts for nearly two decades is a feat worth examining and celebrating. There seems to be two separate "modes" in Rocket Project, one that is constantly plagued by failures, resulting in slow progress and low motivation, and one that is at the cusp of a launch or breakthrough resulting in rapid progress within a matter of weeks. Discerning ways in which the latter mode can be promoted is important to keeping Rocket Project vibrant and strong for many years to come.

It is interesting to see the trend of collegiate liquid rocketry and its relationship with the maturity of SDSU Rocket Project. As more student groups design and build new advanced rocket technologies, allowing amateur rockets to reach higher altitudes at a lower cost, the collegiate rocketry community grows larger with more universities supporting student-led liquid rocketry programs. SDSU Rocket Project, being one of the earliest adopters, only becomes more established as competition grows, giving more people the confidence that college students can indeed engineer complex liquid rockets. Over the nearly 20 years that Rocket Project has been an organization, 10 student designed and built liquid bi-propellant rockets have been launched, accumulating over 40,000 feet of flying altitude. Support from well known industry professionals such as Virgin Galactic has not only helped develop our team more but has also amplified the impact Rocket Project has on student members. With recently renewed interest in the space industry, support from San Diego State University and the private community has given Rocket Project the freedom to develop new and interesting rocket technologies and allow the imagination of students to execute unique ideas. We apologize for anyone we have left out of this article due to the magnitude of alumni and members that the Rocket Project has graciously grown to have. We will instead focus on the many teams and rockets that SDSU Rocket Project has had and the accomplishments and the setbacks that each team has achieved or encountered.

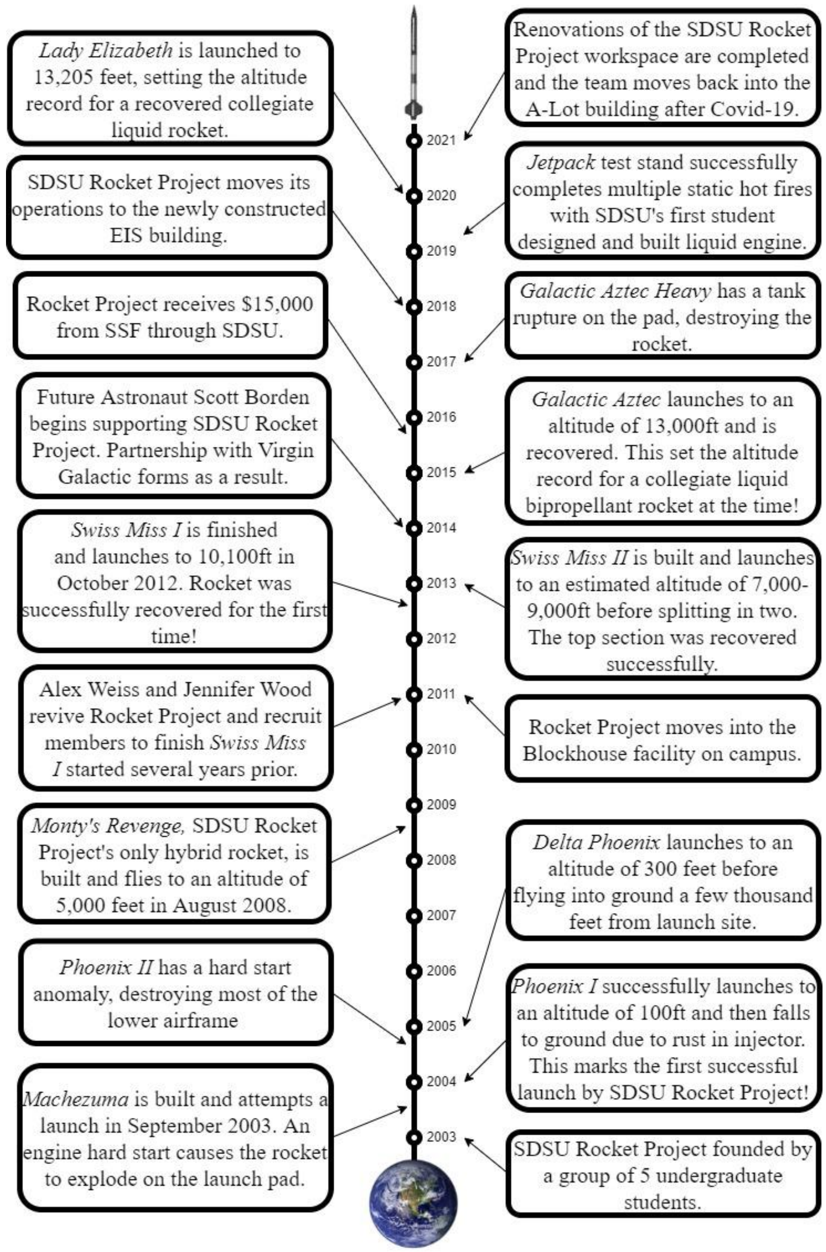


**Figure 2. Timeline of significant events**

## II. The Beginning

San Diego State University has had a strong aerospace engineering presence for more than half a century[1-2], with facilities such as low speed and high speed wind tunnels to support its mission. These wind tunnels are not only the site for thousands of aerodynamic tests, but have also come to be de-facto museums of many different aerospace artifacts. In 1999, Dr. Steve Harrington (founder of Flometrics and an SDSU doctoral student at the time) found a Rocketdyne LR-101[3] in the basement of the low-speed wind tunnel lab. An LR-101 is a liquid bi-propellant rocket engine used as a vernier thruster on NASA's Atlas and Delta rockets dating back to the 1950's. Vernier thrusters help control the attitude of a rocket to keep the flight in its intended direction and help support the overall thrust. LR-101's were designed to be used on much larger rockets, but because of their size, thrust profile and standardized fuels they were perfect to be used as a main engine for amateur liquid rockets. Dr. Harrington began using the engine in advanced thermodynamics lectures at SDSU that attracted the interest of a few students including a graduate student named Carl Tedesco.

At the time of Dr. Harrington's discovery, few universities were designing, developing and building liquid fueled rockets and their related technologies. Universities like Caltech[4] had been developing new and advanced liquid rocket engines for many years, but no colleges had established student-led liquid rocketry clubs. The rocket industry was in decline and had been so for many years, and the school administration was not ready to entertain the idea of a liquid rocketry club they deemed dangerous. Carl and Dr. Harrington borrowed the LR-101 engine from the school as a starting point for building a liquid rocket and began characterizing the engine. Carl and Dr. Harrington leveraged the expertise and facilities within Flometrics to help research and develop the project in a warehouse in Solana Beach, a 25 minute drive from the SDSU campus.

After 4 years of building different liquid fueled rockets, two students named Joey Brown and Justin Gillen found some posts made online by Flometrics and were interested in gaining their support to develop a liquid rocketry club at SDSU. Joey, Justin, Carl and Dr. Harrington devised a plan to build a demonstrator for a liquid rocket that could fly to 100 miles in altitude. Flometrics agreed to help and the LR-101 was returned to campus, marking the beginning of the SDSU Rocket Project in 2003. At the time, SDSU Rocket Project was a group of 8 students that would travel to Flometrics in Solana Beach to help develop and build liquid rockets based around the LR-101. Only two colleges had well known liquid rocketry clubs, San Diego State University and California State University Long Beach, and thus competition sparked an unavoidable rivalry between the teams.

To understand why SDSU and CSULB were some of the first colleges to develop liquid rocketry teams, we must first introduce the Reaction Research Society (RRS) founded in 1943 based in the Mojave desert[5]. In 1991, RRS launched its first ever amateur liquid rocket, a first for the state of California as well. The amateur liquid rocket community grew rapidly in the following years and RRS became an essential launchpad for many inspirational engineers including the likes of Tom Mueller, who would later go on to be the Vice President of Propulsions at SpaceX. The Mojave, only 4-5 hours north of San Diego, gave Southern California universities backyard access to crucial testing facilities such as RRS and later the Friends of Amateur Rocketry (FAR). Carl and the SDSU Rocket Project team quickly became a part of this community and would often talk with other amateur rocketry enthusiasts and pioneers like Tom for inspiration and guidance.

Collegiate rocketry at the time was centered around the payload, not the rocket itself. Student teams around the country were primarily launching prebuilt solid rockets with their custom payloads attached. Competitions, goals and objectives were all concentrated on custom built payloads. Rocket Project's focus on rocket design represented a paradigm shift in the collegiate rocket community and thus expectations at first were low. Getting a rocket off the pad constituted a successful launch regardless of altitude, and the concrete goals for the program were not well defined beyond building liquid fueled rockets.

**Figure 3. *Machezuma* exploding on launch rail**

Funding for the club was tight. Little financial support from the college coupled with the expensive costs custom liquid rockets can incur forced the initial student team to be scrappy and use what they could find. SDSU Rocket Project's first liquid rocket, *Machezuma*, was built from parts made of wood and included modified fire extinguishers as its propellant tanks. As the total estimated cost of *Machezuma* neared $2500, numerous Home Depot runs, Ebay bids and sponsorship emails went a long way in keeping expenses low. Part donations from Flometrics and other local companies were crucial, but in the end Carl and many of SDSU Rocket Project's students spent thousands of dollars of their own money to see the project through.

In September of 2003, 9 months after SDSU Rocket Project's inception, the team attempted to launch *Machezuma* from RRS in the Mojave desert. Weighing nearly 300 pounds fully fueled, *Machezuma* burst into flames following a large explosion from a hard start anomaly when attempting to ignite its engine for liftoff. A column of flames surrounded the rocket over 20 feet in height that damaged many of the rocket's external and internal componentry. While *Machezuma* did not succeed in taking flight, the project was instrumental in developing some of the key methods and design principles that Rocket Project still uses today. In retrospect, the project was a success and is an important stepping stone in Rocket Project's past. SDSU students not only proved they could design and operate a liquid rocket and the systems to control it, but also helped demonstrate that building liquid rockets as a collegiate team was possible.

## III. Early Growth

The success of *Machezuma's* launch attempt was invigorating, the team knew they were close to flying a rocket. They salvaged what they could from the remains of *Machezuma* and quickly began work on their second rocket, Phoenix I. Lessons learned from *Machezuma* developed new ideas for Phoenix I that started to make a larger impact on the amateur rocket community. At the time, expensive phenolic tubes were the standard choice for the airframe body. Learning how to roll aluminum and use rivets made the airframe much cheaper and stiffer, a tactic many other rocketry teams began to employ soon after. In addition to the advancements in rocket technology and manufacturing processes, SDSU Rocket Project quickly grew in size. Joey Brown, Justin Gillen, Nils Sedano, Mark Jeffery, Chris Roberts, Devin Norrell, Brandon Florow, and Nicky Dugue (members of the founding team), took the partially built Phoenix I rocket to an on-campus engineering promotional event in the Spring semester of 2004. The spectacle was effective, and the team expanded from the initial 8 to around 40. While this may seem like a large influx, one must note that not every member commits to the project equally. While some students dedicate more time to Rocket Project than their school studies, others may only want to contribute a few wrench turns and be an extra set of hands when needed. As is the case with many student teams, the former personality is usually part of a core group of individuals that drive project development and make many of the critical design decisions. This core group can be anywhere from 10-20 students at any given time and can often be ascribed as the "heartbeat" of Rocket Project. Regardless of their affiliation, these 40 new students brought immense prestige and support to Rocket Project and helped it thrive in what was to be its strongest membership for quite some time. Only 7 years later in the Spring of 2012, did Rocket Project reach this level of involvement and resulting technical strength again.

In March of 2004, 6 months after the explosion of *Machezuma*, *Phoenix I* was ready to launch and was taken to RRS for Rocket Project's 2nd attempt at flying a liquid rocket. After a promising takeoff, *Phoenix I* fell to the ground due to reduced thrust from rust in the engine injector, culminating in only 100ft of flying altitude. Most of the airframe was destroyed on ground impact. Although this might be seen as a failure to some, Rocket Project had just launched its first liquid rocket! This was an exciting achievement for the team and a good indication of the rapid progress the team had made in just over 1 year.

**Figure 4. *Phoenix I* Falling to the ground after liftoff**

Even with *Phoenix I's* flight anomaly, morale was still high and the team's membership was still strong. But with two successive failures due to engine issues, the team had to try something new. In

June of 2004, 3 months after *Phoenix I's* flight anomaly, SDSU Rocket Project performed its first "static fire test". The intent of a static test is to validate that all of the main rocket fluid components and engine work as intended without the hassle of preparing the rocket for flight. Additionally, many of the performance characteristics of the vehicle can be measured and compared against expected thrust, engine-on time, and system pressures. The static fire was completed successfully with no large failures and the team was confident they would have a successful flight.


**Figure 5. *Phoenix II* at Flometrics ready for its trip to RRS in the Mojave Desert**

In October of 2004, 7 months after the successful static fire, *Phoenix II* was ready to fly and the team was eager to launch. SDSU Rocket Project had little money to rent proper traveling equipment and relied heavily on the ingenuity of its members to find scrappy solutions to the many day to day problems they experienced. Figure 5 perfectly depicts how the team jumped through many of these hurdles in a cheap and effective manner. Small logistical issues are always overcome by the passion and excitement Rocket Project's members have to launch rockets.

A failure with the engine caused a hard start and an explosion damaged some of the lower parts of the vehicle. While the destruction to the lower airframe was significant, many of the parts on *Phoenix II* were untouched and in perfect condition. These parts would later be used in the build of *Delta Phoenix*, the successor and benefactor of many of *Phoenix II's* mistakes.

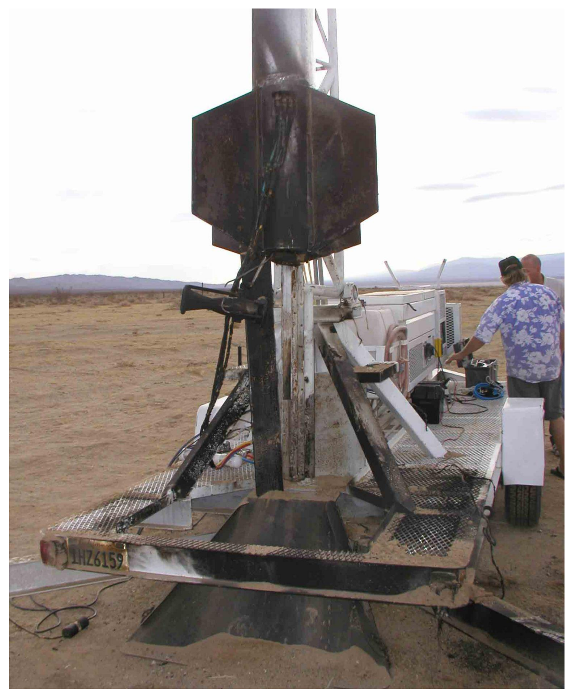

**Figure 6. *Phoenix II* aftermath of engine hard start/explosion**

As Rocket Project entered its 3rd year of existence and began work on its fourth rocket, *Delta Phoenix*, some of the initial founding members began to graduate and leave Rocket Project. The heartbeat that sustained the rapid innovation and build of the rockets had started to weaken. The necessary influx of new, dedicated and excited members did not match the departure of senior ones, and the club began to shrink. It seems counterintuitive that an organization experiencing steady progress would start to peter out, especially after coming so close to a successful launch. A number of factors contributed to the steady decline of Rocket Project from 2004-2006. At the time, SDSU was seen as an "aircraft school" that did not focus much research and engineering around space vehicles, including rockets. School faculty attempted to shut down Rocket Project multiple times, deeming it too dangerous for students. Because Rocket Project was not a recognized organization at SDSU and continued to do all of its design and assembly of rockets off campus at Flometrics, the most faculty could do was suggest the students join other engineering clubs. Regardless, the lack of school recognition coupled with no financial or facility support made it difficult for new students to become involved and contribute regularly. Additionally, Rocket Project did not establish a habit of seeking new members early on. Instead of building a pipeline of new students to keep the organization growing, the team focused on engineering and building rockets. Rocket Project dwindled to ~12 members in May of 2005 and to ~5 members soon after the launch of *Delta Phoenix*.

In May of 2005, 7 months after the failure of *Phoenix II*, the damaged lower airframe was replaced and upgraded. The resulting rocket was named *Delta Phoenix* and was taken to the Friends of Amateur Rocketry (FAR) launch site. FAR was a new organization with a facility directly adjacent to RRS in the Mojave desert. *Delta Phoenix* successfully cleared the launch rail and soared to a height of ~300ft before veering off course. The thrust to weight of the rocket resulted in a slow ascent, making the passive control features ineffective and eventually driving the rocket into the ground, shattering it into hundreds of pieces. Although a small group of students continued to make slow progress on hybrid and liquid rockets under the Rocket Project banner from 2005-2010, this would be the last liquid bi-propellant rocket SDSU Rocket Project would launch for 7 years.


**Figure 7.** ***Delta Phoenix*** **taking flight**

## IV. A New Era (2011-Present)

The success of new innovative aerospace companies in the private space sector such as Virgin Galactic, SpaceX and Blue Origin drew the interest of many engineering students looking to gain skills for jobs after graduation. New collegiate teams began to form as the success and notoriety of SDSU Rocket Project and other collegiate liquid rocketry teams became more widespread. However, with the increase in participation, so too did competition. The LR-101, the most popular engine to use on liquid rockets due to its declassified design and scale, became more and more expensive and rare as new collegiate teams began purchasing and using them on their own liquid rocket programs. LR-101s were no longer being manufactured, and the price to purchase one went from a few hundred dollars to over $1000. Carl knew people who were willing to donate their extra custom rocket engines (not LR-101s) that would save Rocket Project thousands of dollars. These engines were often in bad shape when donated and had to undergo significant refurbishment, but the savings in cost and effort to build or source an engine were instrumental to the success of the next series of vehicles. The *Swiss Miss* rockets (named appropriately for all the holes they featured), used a 660 lbf LOX/Ethanol carbon nozzle ablative lined rocket engine designed and donated by Paul Breed, who built it using an RRS blueprint for a FAR designed rocket.

In 2011, *Swiss Miss I*, Rocket Project's 6th liquid rocket, had been sitting on the shelf for over 2 years, left behind by a group of graduating seniors. Alex Weiss and Jennifer Wood, two aerospace engineering students in their Junior year, grew interested in reviving the project and took on the responsibility of seeing it through. At this time, Rocket Project had been given space in the "Blockhouse", a small engineering room on campus to be shared with the AIAA Design Build Fly club. The blockhouse was barely large enough to fit a fully stacked rocket and would often need to be assembled with part of the rocket protruding from the entry door. Regardless, this new space helped reduce Rocket Project's burden on Flometrics and allowed more casual students to contribute to the day to day activities of Rocket Project.

Alex and Jennifer went classroom to classroom, recruiting members for Rocket Project and got 10-15 students to join. After about a year of preparations, *Swiss Miss I* was launched and recovered to an altitude of 10,100 feet on October 21st, 2012. This was not only the first successful recovery of a liquid rocket by SDSU, but also rekindled Rocket Project's popularity and recognition at SDSU and prompted a steady growth in membership. After *Swiss Miss I*, Rocket Project began to turn into a functional group with an established management structure. An executive board with democratically elected leaders was put in place to keep the team responsible and provide student led direction. The leadership team helped build an infrastructure that

**Figure 8. SDSU Rocket Project's first successful recovery with** ***Swiss Miss I***

handled the acceptance and management of new students onto the team. A culture and precedent of acceptance and recruitment of new members was formed, ensuring growth and sustainment of Rocket Project membership for many years to come.

The successful recovery of *Swiss Miss I* allowed for a quick turnaround and relaunch of the vehicle 10 months later (*Swiss Miss II*). Before launching, various upgrades to the fins, body tubes and avionics were made. The flight computer consisted of an Android phone activated and controlled by a custom app on another Android phone. Travis Wyatt, the pioneer of this technology, helped Rocket Project develop an avionics team that did more than build to requirements. Interesting new technologies in avionics would eventually attract more electrical and computer engineering students, fueling a more diverse set of skills and students on the team.

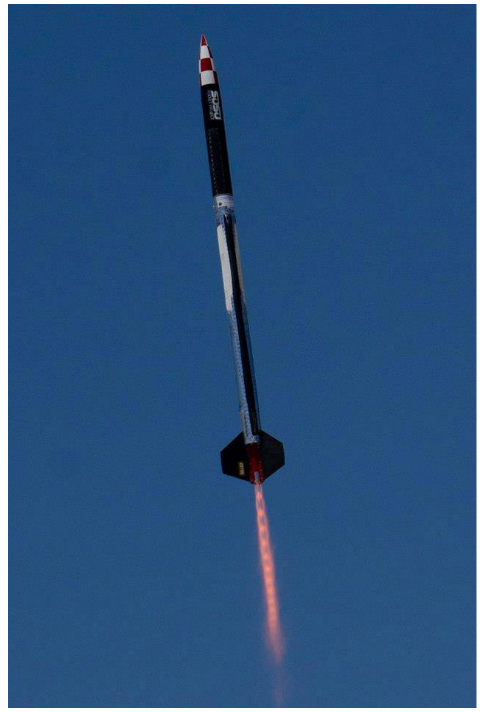

**Figure 9. *Swiss Miss II* taking flight**

Ambitions grew larger with every successful flight, and with it grew the requirements for better technology and more funding. *Swiss Miss II* featured a new carbon fiber body tube in favor of the heavier aluminum one used on *Swiss Miss I*. This improvement alone made the rocket 5-10x more expensive than its predecessor. Funds were still tight, so many of the materials necessary to make these improvements were donated. On August 17th, 2013, *Swiss Miss II* launched and reached an estimated altitude of 7,000-9,000ft before two of its three fins were believed to have collapsed inward on the vehicle after violently spinning, forcing it to lose control and split into two pieces[6]. The recovery system attached to the upper section deployed as expected and was gently recovered while the lower section was found cratered a mile away.

The success of the *Swiss Miss* rockets continued to help support Rocket Project's growth. In 2014, around 50-60 students were registered members of Rocket Project with varying levels of involvement. Although there was significant interest, funding was still tight. An LR-101 engine that had been in storage for several years was chosen to power the next rocket and many "door to door" sponsorship requests helped lower costs. As 3D printing became more widely available, Rocket Project used 3D printed parts in favor of traditionally machined ones. Parts for pneumatic interfaces, avionics mounting hardware, and other complex geometries were all made using a 3D printer, further reducing potential costs.

**Figure 10. Team carries *Galactic Aztec* to the launch rail**

In 2014, Scott Borden, a future astronaut and strong advocate for Virgin Galactic and their mission to send people to space, began consistently supporting the team through scholarships, mentorships, materials, and monetary donations. Scott was a critical lifeline for the project and continues to be a source of guidance, mentorship and financial support as of this writing. The next set of rockets included "Galactic Aztec" in their names in honor of Virgin Galactic and Scott Borden and their tremendous support of the projects and its student engineers. Additionally, Rocket Project was now a recognized organization at SDSU and could apply for the newly implemented Student Success Fee (SSF)[7], an SDSU funding program dedicated to enhancing student success through expanded Academic Related Programs. This new fund allowed student organizations to apply for money from the school to financially support operations. On November 15th, as is now tradition after every successful test or launch, the team gathered at the diner named "Glorias" in the Mojave desert to celebrate. During the dinner, the team received word from the school that SSF had awarded Rocket Project $15,000 in funds to help support the project. This was the largest monetary donation Rocket Project had received from the school to date. Five months later on April 18th, 2015, *Galactic Aztec* was launched and recovered to 13,000ft, setting an altitude record for a collegiate liquid bipropellant rocket[7]. Spirits were high and the team was thriving.

Work on the next project, *Galactic Aztec Mk II*, also known as *Galactic Aztec Heavy* (GAH), had already begun development. Excitement from the success of *Galactic Aztec* boiled over into even larger ambitions for GAH. The rocket was to continue to use an LR-101 engine but featured much bigger tanks to increase the burntime. Three static fires were performed over the course of a year between April 16th of 2016 and March 18th of 2017. The last static featured a fully functional thrust vector control system that demonstrated the possibility of an actively controlled rocket during flight. This technology was not included in the final flight configuration of GAH as weight/complexity concerns outweighed the potential benefits the system would bring. Six months and one failed launch attempt later, GAH was finally ready to fly on September 16th, 2017. On the day of launch, everything seemed to be going smoothly and the launch countdown was initiated after everyone was safely in the bunkers. Suddenly, a loud bang was heard as the LOX tank ruptured, destroying part of the launch rail it was attached to. Because of poor welds, hundreds of pressure cycles and a slight overpressurization event, the welds holding the rolled aluminum tanks failed. This failure was something Immanuel Marinas (the president of Rocket Project at the beginning of GAH) had predicted and warned the team of several months prior. Although saddening, the team was weary of the almost two years it took to design, build and launch GAH and were ready to move on from the project. Regardless of the outcome, Rocket Project members had learned a lot from GAH and were ready to apply their newly learned skills on the development of the next project to compete in the newly announced FAR/Mars competition.

**Figure 11. Carl examining *Galactic Aztec Heavy* after LOX tank rupture**

## V. SDSU Rocket Project Today

Announced in January of 2017, the FAR/Mars competition sought to “get college and university students fired up about rocketry, which is the key to space travel and making humanity a multi-planetary species,” in the words of Robert Zubrin, the president of the Mars Society[9]. While previous rockets constructed by the team made use of simpler ablative or commercial off the shelf (COTS) engines like the LR-101, Rocket Project decided to use a student designed and built engine for the first time. Few collegiate teams have designed, built and tested liquid rocket engines to be used on amateur rockets, and Rocket Project was excited to be a leader in this area. This would also allow the FAR/Mars competition rocket to use liquid methane and liquid oxygen as propellants, a requirement of the FAR/Mars competition. Initial testing saw the creation of a test stand aptly named “Jetpack” for its appearance. This testing platform would go on to perform 12 separate cryogenic and static fire tests between January and October of 2018 culminating in a successful full-duration burn and characterization of the regeneratively cooled FAR/Mars engine.

**Figure 12. *Jetpack* test stand after a successful static hot fire on July 28th, 2018**

Design of the FAR/Mars rocket continued to make progress in parallel with the development of it's engine. The rocket was soon named *Lady Elizabeth* in memory of the late Elizabeth Jackson-Woodcock, wife of Richard Woodcock, who are both passionate supporters of SDSU Rocket Project and its students. Their generosity continues to allow Rocket Project to have more creative freedom, enable more students to get involved without financial burden, and build a platform to apply classroom knowledge to an engineering project.

As the design of *Lady Elizabeth* neared completion and the build and testing phase began, problems with freezing of the vent valves from the cryogenic liquid propellants (below −150°C) stalled progress for over 9 months. The team performed 11 separate cryogenic and static fire tests to fix these issues between February and November of 2019. Long awaited excitement began to grow after a successful static fire on November 2nd, 2019 and the rocket was finally validated to launch. *Galactic Aztec* had been the last liquid rocket to launch by SDSU over 4 years prior. Since 2015, the students who had worked on *Galactic Aztec* graduated and were replaced with new ones, and thus none of the Rocket Project members had seen one of their rockets fly. The team was anxious to get a rocket off the ground, and on February 1, 2020, Rocket Project successfully flew and recovered *Lady Elizabeth* to 13,205 feet, setting the altitude record for a recovered collegiate liquid rocket.

**Figure 13. *Lady Elizabeth's* nose cone ejection after parachute deployment at ~13,205 feet over the Mojave desert**

Prior to the launch of *Lady Elizabeth*, Rocket Project signed up for the Base11 Space Challenge, a nationwide collegiate competition with the goal of reaching the Kármán Line (100km) using a liquid rocket. However, due to timeline issues and the desire to complete *Lady Elizabeth*, Rocket Project could not meet deadlines and opted out of competing. After finishing *Lady Elizabeth*, the exciting goal of reaching space (100km) inspired Rocket Project's currently in development rocket named *Kármán San Diego*, a two-stage rocket with a liquid booster and a solid second stage. In March of 2020, San Diego State University decided to send students and staff home to work and learn remotely in response to the Covid-19 pandemic. While necessary to ensure the safety of the SDSU community, the unfortunate consequence of remote learning was that Rocket Project's progress slowed down. Regardless, the team was resilient and continued to work on the design of the rocket remotely. Rocket Project has since returned to the SDSU campus in Fall 2021 after lab renovations were completed and Covid restrictions loosened. Looking forward, Rocket Project hopes to complete major flight hardware in the 2021-2022 school year and is preparing to resume testing in Spring of 2022.


**Figure 14. New lab space in the A-Lot building dedicated to SDSU Rocket Project in 2019**

Safety continues to be a top priority within Rocket Project as new methods of ensuring lab safety are implemented with designated trained personnel appointed to oversee potentially hazardous activities. Investments in the proper personal protective equipment, training sessions, written tests, and referencing the appropriate safety data sheets all help contribute to keeping students safe and upholding Rocket Project's impeccable safety record. Recruiting events, weekly meetings and division of student members into subsections help keep the club organized and on a cohesive schedule. Today, SDSU Rocket Project continues to be one of the largest student organizations at San Diego State University with active membership ranging from 50 to 100 members each semester. The club is a prominent advocate for the SDSU Aerospace Engineering program, with successes bringing attention to the school from both donors and potential students alike. The club's history of accomplishments fuels continued success, as generous donations and new members enthusiastic about Rocket Project's mission contribute to recent, current and future successes.

## VI. Conclusion

What keeps a club or project from dissolving? Especially one entirely dependent on students who have various responsibilities, little time and money, and a high turnover rate as seniors graduate. While searching for the ingredients necessary to sustain an organization such as Rocket Project, four main factors emerge. This includes the importance of promoting Rocket Project, financial/facility support, exciting but feasible projects and a strong core group. All of these factors are crucial in building a club that can continue to grow and thrive over several decades.

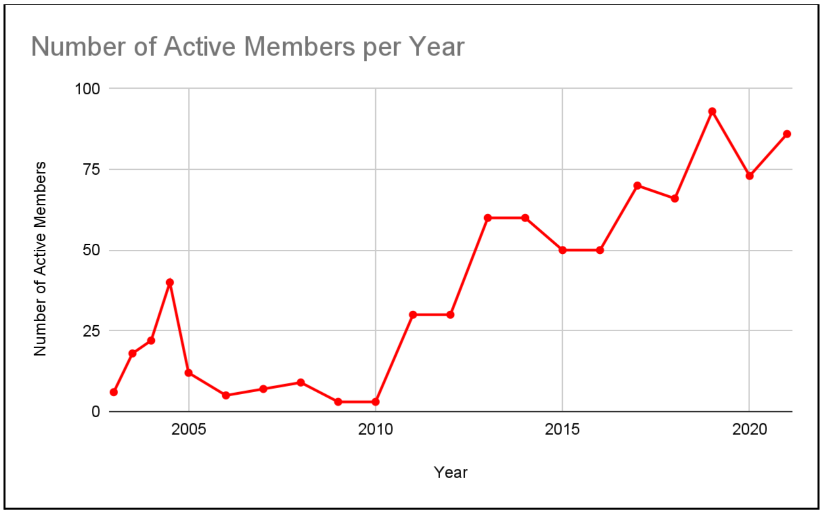


**Figure 15. Rocket Project estimated membership from 2003-2021**

With a club like Rocket Project, engineering ability and passion drives progress, but networking and convincing others to share this passion creates longevity. As was seen in 2006, a pipeline of new students was not established to replace graduating seniors, and the project dwindled as a result. Only in 2011 did Jennifer Wood and Alex Weiss begin a culture of seeking/inducting new members as part of leadership's expected responsibilities. A consistent source of new members and the passing of knowledge from generation to generation has become a tradition at Rocket Project and has helped it continue to have a strong presence at SDSU.

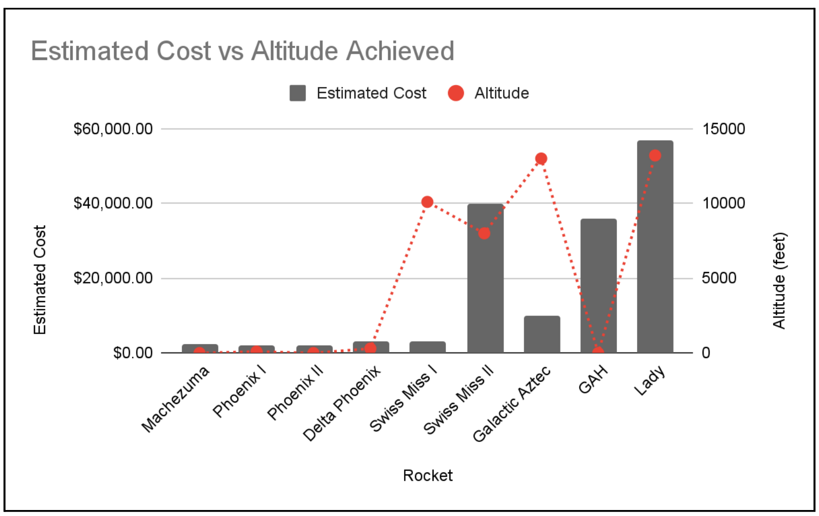


**Figure 16. Rocket Project estimated material cost vs. altitude**

While financial support can be garnered through means of sponsorships and fundraisers, facility support is a crucial factor in keeping Rocket Project productive. Leaders on the team need to work hard to promote ways of allowing students to easily contribute and do so in a meaningful way. Having a facility to host engineering activities and funding to pay for those activities is crucial to the project's success and lowers the barrier to entry for many students. Starting in 2011, funding from the school and a dedicated location on campus has allowed more students to contribute on a casual basis. As can be seen in Fig. 15 and Fig. 16, increased funding from the school and donors has allowed students to focus more on engineering rockets and testing them without worrying about financial burdens. This ultimately resulted in better engineered rockets that could not only fly higher, but also impact a greater number of students at SDSU.

One of the most important factors is the necessity for a strong core group of students/faculty that lead and push the project forward. Carl Tedesco, Dr. Steve Harrington and Dr. Ahmad Bani Younes have all been strong advocates and advisors of Rocket Project for many years. This, coupled with a core group of members who are both dedicated to Rocket Project and are experienced enough to teach others are instrumental to Rocket Project's success. It is also important to have members who have had internships to provide a frame of reference about how industry works. Building projects that are exciting and instilling confidence in others to make decisions and inevitable mistakes will provide value and a sense of loyalty to a project. All of these factors have allowed SDSU Rocket Project to sustain nearly a decade of significant growth as shown in Fig. 15. As Rocket Project becomes more well established, these factors will continue to help SDSU Rocket Project thrive for many years to come.

## Appendix


**Figure 17. *Machezuma* Launch Team (September 2003)**
**Outcome: Explosion due to hard start in engine**


**Figure 18.** ***Phoenix I*** **Launch Team (March 2004)**
**Outcome: Flew to 100ft and then fell to ground due to rust in injector**

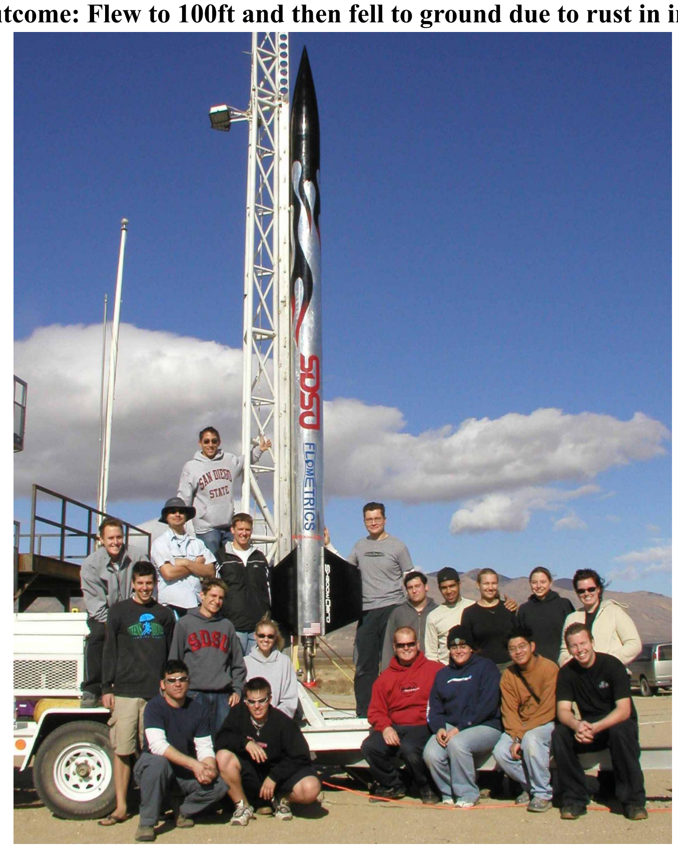


**Figure 19.** ***Phoenix II*** **Launch Team (October 2004)**
**Outcome: Explosion due to hard start in engine**

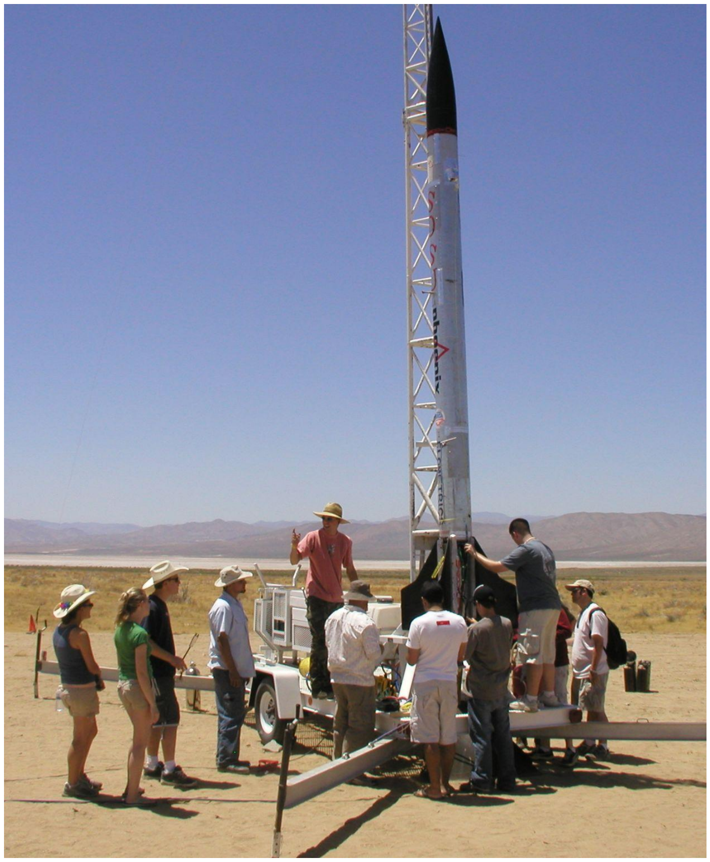

**Figure 20.** ***Delta Phoenix*** **Launch Team (May 2005)**
**Outcome: Flew to 300ft and then into ground**
**a few thousand feet from launch site**

**Figure 21.** ***Monty's Revenge*** **Launch Team (August 2008)**
**Outcome: Successful launch to 5000ft (hybrid rocket)**

**Figure 22.** ***Swiss Miss*** **Launch Team (October 2012)**
**Outcome: Successful launch and recovery to 10,100ft**

**Figure 23.** ***Swiss Miss II*** **Launch Team (August 2013)**
**Outcome: Flew to an estimate of 7,000-9,000ft before splitting in two, top section recovered successfully**

**Figure 24.** ***Galactic Aztec*** **Launch Team (April 2015)**
**Outcome: Successful launch and recovery to 13,000ft**


**Figure 25.** ***Galactic Aztec Heavy*** **Launch Team (September 2017)**
**Outcome: Tank rupture on launch pad**


**Figure 26.** ***Lady Elizabeth*** **Launch Team (February 2020)**
**Outcome: Successful launch and recovery to 13,205ft**

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