Figure 1: An Infected Launch, Illustration by Hannah Rose

AMID THE CORONAVIRUS, A MISSION WAS ABORTED

Aerospace Engineers embarked on a mission before the pandemic. What will they do, now that they are stuck at the launch pad?

By Aaron Landon

May 14, 2020

You step out of an 8 a.m. linguistics lecture on a Monday morning. The sun is shining and everyone is out on the quad for Week of Welcome at California State University, Long Beach. Tents are pitched around the entire perimeter of the grassy yard. Clubs, honor societies, student government, and Greek organizations are out on the prowl for new members.

You walk through the crowd of some very enthusiastic sorority sisters as electronic music blasts like a V2 bomber. Make your way to the other side of the yard and finally you can hear yourself think. You come across a yellow canopy with the name *ESRA* written across the front in bold black letters. Underneath it reads: *The Experimental Sounding Rocket Association.* An easel holds up a recruitment poster enlisting the help of science, technology, engineering, mathematics, and even liberal arts majors.

"What do you guys do here," you ask.

"We are the Experimental Sounding Rocket Association. We focus on projects regarding aerospace and rocketry. This semester we're trying to launch a hybrid rocket."

"No Kidding?"

"We've planned a Mojave Desert launch in June."

"Are you looking for extra help," you ask.

Figure 2: Experimental Sounding Rocket Association's Insignia

"As a matter of fact we are looking for potential members with diverse educational backgrounds. ESRA's projects are multi-faceted, and we require members with an array of different skill sets. Right now we are looking for students to help us write public relations documents, and social media posts. Does this sound like a project for you?"

"Yeah, I can help you guys out."

"Great." He takes off his glasses and hands you a flyer with the location, date, and time of the next meeting. "The name's David," he says. You jam the flyer in a spiral notebook and put it in your backpack.

The meeting is to be held at the Vivian Engineering Center off of Deukmejian way in the lower campus of Long Beach State. You had passed by the building dozens of times on your way to the recreation center. It stands five stories high. Windows and a red-brick façade overlook a small courtyard with steps leading up to swinging glass doors. In front of the steps, stands a statue of a theodolite optical instrument with Greek letters inscribed into a metal plaque, representing the Chi Epsilon Civil Engineering Honor Society.

You open the double-doors and take the elevator up to the third floor and enter the lecture hall. "Welcome. Welcome. Please take a seat," David says. "I am glad you could all make it to our first meeting." He pulls down the projection screen and queues a PowerPoint.

“Our last launch was a success,” he says. He shows us photographs of the previous launch from last year, where the ESRA team gathered in front of a launch-pad in the desert.

“This year,” he says, “We are planning an even bigger launch which will exceed 10,000 feet!”

Students applaud the idea. They are ready, and you are ready to get to work. You begin a briefing with the Public Relations team. The next day, you meet at the computer lab, where they grant you access to ESRA’s Facebook, Twitter, and Instagram. Your job is to develop content through social media and visual designs.

The next meeting is a required safety seminar held on the following Wednesday. David familiarizes you with lab procedures and safety precautions. You listen carefully. You must pass the online safety exam to gain access to the lab in order to observe the process of building a rocket for yourself. You figure that the more familiar you are with the process, the easier it will be to create accurate public relations documents, social-media content, and news-releases for ESRA.

You ride your bike back to your apartment that night and access the school website, where you review the handbook regarding all safety procedures. Some rules are basic, such as tying one’s hair up in the laboratory, or wearing closed-toed shoes. Eye and face-protection are a must, and one is even required to wear gloves while working with chemicals. Between that, and the various warning symbols on chemical barrels: such as a skull and crossbones, or a yellow biohazard symbol, you would think these young scientists and engineers were preparing for the apocalypse. After studying the handbook, learning safety precautions, and passing the online safety exam on your laptop, you contact David to gain access to the laboratory. You agree to meet the following Wednesday.

★★★

Wednesday morning comes, and you receive a concerned phone call from your mother. “Have you seen the news lately,” she asks.

“Why?”

“There’s a deadly virus infecting people all over the world.”

As a matter of fact, you had heard the news. Every news source had been covering COVID-19, an infectious disease caused by a novel-coronavirus.

“You’re really worried about that,” you ask.

“A lot of people are infected. I heard the virus comes from an animal reservoir,” she says. “They’re thinking it’s most likely bats.”

"Bats?"

"Yes, bats. I was reading about it. Scientists believe the virus most likely comes from bats, and the infection began spreading late 2019 in a meat-marketplace in Wuhan, China."

You tell her not to worry. A few years ago it was swine flu, then Ebola, Zika, MERS, and SARS. You tell her that this whole situation will pass, and humanity will be focused on the next media-driven crisis.

"Just be careful," she says. She hangs up the phone and you chuckle to yourself.

★★★

That afternoon you meet David at the Engineering and Computer Science (ECS) building, room 108. The door is locked and a special key-card is required to gain access. You knock on the door. David opens, shakes your hand, and you walk inside for the first time.

The University's Aerospace laboratory is a wide room in the ECS building. Two students are studying at a metal workbench in the middle of the room. One student coughs deeply. "Why don't your cover your mouth," says another student next to him.

David leads you to a glass-enclosed analytical lab display near the door and wipes off remnants of expo-marker sketches from the glass.

"So are you familiar at all with the basic principles of rocketry?"

You tell him that it's been years since your high-school science class.

He smiles. "That's okay, that's what we're here for. So the idea of rocketry is to move things into space. Generally—or in missile systems— however you want to look at it." He begins drawing models with the marker on the glass.

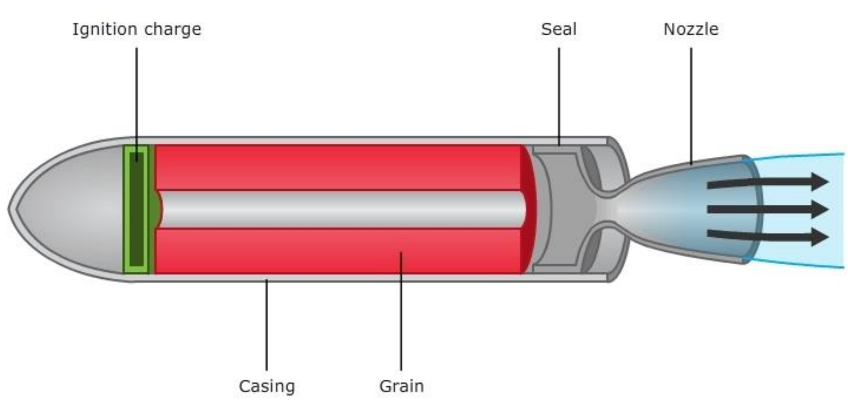

Figure 3: Solid Model Rocket

“There are three types of rockets,” he says. “Two of which are major players. Solid Rockets are made from sturdy rubber and contain polymer which binds the materials together like a cake. Inside that cake, are the chemicals which act as the fuel. The combination of aluminum, ammonium perchlorate, and other additives cause the rocket to combust. For durability, a solid rocket is great. Much like the material on your shoes, a solid rocket responds well to shock and absorbs impact. The absorption of force is similar to stepping in sneakers or rubber shoes. Solid rockets are powered by a polymer which combines aluminum fuel with ammonium perchlorate oxidizer. When you ignite the bottom of it, it goes.”

“Actually,” he says. “A Piccolo Pete is a great example of a solid rocket. Have you ever seen those little fireworks that screech? You light them and they make a really loud noise? You know the ones I’m talking about?”

He asks you this when in fact—just last summer—you had seen kids playing with those rockets in your neighborhood on the Fourth of July. They looked like little bottle rockets that you launch from the ground.

“Have you ever seen someone break the back of the firework, and use it as a little rocket? You can actually take it off the stand, flip the Piccolo Pete sideways, and it will just take off. That’s kind of like a solid rocket. You light it, and it launches.”

You know that a low-explosive pyrotechnic, such as the Piccolo Pete, is just one elementary example of solid rocketry. You recall reading that the first rockets designed were the result of an accidental discovery by thirteenth-century Chinese Taoist alchemists and were, in fact, solid-rockets. Frank H. Winter, retired Curator of Rocketry of the National Air and Space Museum of the Smithsonian Institution of Washington D.C., said it was ironic that the aim of their studies and experiments was not to produce incendiary weapons, but was instead a “search for mortal longevity— an elixir of life.” It was said the alchemists mixed sulfur, charcoal, saltpeter, and potassium nitrate. The addition of saltpeter to the other ingredients made the mixture either an explosive or a propellant. Eventually they realized that if the mixture were put in the bottom of a bamboo tube enclosed at the forward end and lit at the bottom, the escaping combustion gasses would propel the tube forward. Aside from the launch, there is no evidence that the alchemists were familiar with fundamental principles of rocket propulsion—nor were they aware of the process of combustion. As a matter of fact, until the late seventeenth century, the Chinese adhered to

Figure 4: Chinese "fire arrow" war rockets. From the Wu Pei Chih (Treatise on Military Equipment) by Mao Yuan-i, 1628, (S.I. A5372D)

the ancient *yin-yang* philosophy, which posited that all forces in the universe "result from a balance of *yin* (female, or passive) and *yang* (male, or active) elements." David tells you that all solid-rockets contain what is called an *oxidizer,* carrying oxygen atoms for supporting combustion, and a *fuel,* the substance which is burned. When combined, these two elements create a propellant.

"The downside to solid rockets though," says David. "There's no real control. You can't turn it on and off. It's like a candle. When you light the candle, it just burns until the end. You don't turn down the burning of the candle. It just does what it does and it burns. That's a solid rocket."

Liquid rockets, on the other hand, contain a liquid oxidizer and propellant. "Imagine you have two tanks. There's a gasoline (liquid oxygen) tank, and a water (liquid hydrogen) tank. More realistically, hydrogen acts as fuel, where oxygen acts as the *oxidizer*— the chemical agent required for the fuel to burn."

The benefit of a liquid rocket is its level of controllability. "It's kind of like a car," says David. "A liquid rocket contains a valve linked to a remote-controlled computerized throttle which can change the rate at which you use your liquid *oxidizer,* or fuel."

"You can basically control how much thrust is generated with a liquid rocket," David says. "Similar to when you press on the accelerator of a car, a valve controls the passage of fluid through a pipe, as more *oxidizer*, or fuel, is pulled through the fuel-duct."

You ask him if all configurations are performed via remote control. "So," he says. "It is called an avionic system. A computer reads all the parameters of the rocket; whether it be speed, altitude, or the buildup of pressure or heat." He walks you over to the other side of the room and shows you a glass-enclosed display case.

"Usually, configuring one's level of control of the aircraft with the avionic system is accomplished through a test stand. You wouldn't want to launch a rocket without knowing how it will perform, so you build a stand in a fume hood, or a ventilated glass-enclosure."

With a system such as this, scientists test their rockets. They look for changes in oxygen and hydrogen levels, or any other physical variable associated with the rocket system, such as air pressure.

You realize that teams of scientists must have run a multitude of tests to develop a working model of a liquid rocket. You do, however, remember reading excerpts from *The History of Rocket Technology* years ago in community college. It credits the first successful liquid-propellant rocket launch to American engineer and professor, Dr. Robert H. Goddard, dubbed the founding father of modern rocket science. However, experts in rocketry such as World War Two German Army artillery officer, Walter R. Dornberger, said there is no *actual* inventor, and that "All branches of science and technology, bring into being a new type of collective inventor, the team; a successful perseverance of all workers.”

Neither Dornberger's German V2, nor Goddard’s 1926 liquid-fuel rocket launch were solo ventures. On March 16, 1926, Goddard, along with a team of engineers, launched the first liquid propellant rocket, on a farm near Auburn, Massachusetts. Two years later, Goddard implemented history’s first rocket-borne instrumentation system—an

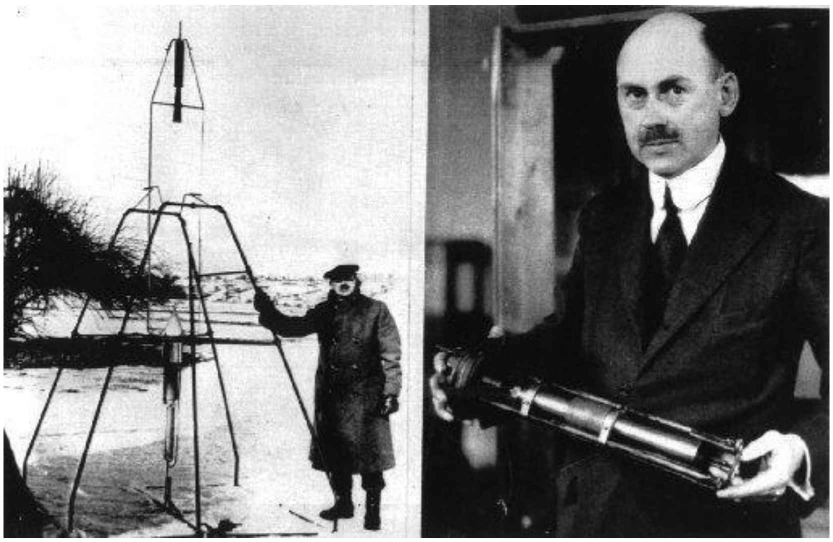

Figure 5: Dr. Robert H. Goddard and a liquid oxygen gasoline rocket at, Auburn Massachusetts

aneroid barometer, a scientific instrument to measure air pressure, a thermometer, and a camera to record their readings. From 1930 to 1941, Goddard solidified his liquid rocket design through the development of controllable launch and flight variables including gyro-controls (navigation), thrust-vectoring (individually manipulated thrusters), and gimbal-mounted tail sections, allowing the vessel to maintain proper direction and guidance.

David tells you that controllable variables enable the liquid-fuel rocket to maintain proper flight direction, however its design is costly. A liquid rocket requires a plumbing system to regulate the passage of fluid.

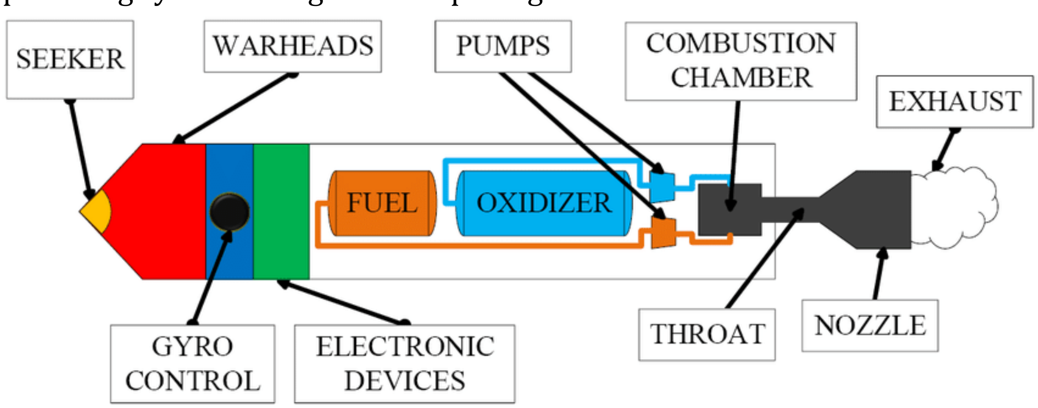

Figure 5: Liquid Model Rocket

"Liquid rockets rely on pumps to send oxygen through the fuel-duct. With more parts, more can break. It's also very expensive. You have to rely on plumbing and ventilation to keep hydrogen (fuel) and oxidizer cold in order to remain in liquid form."

"How do you manage to keep it cold," you ask. "Especially as the system heats up?"

"That's the tricky part," says David. "Have you ever seen one of the Apollos? Or Space-X rockets? You see them on these stands, and they look like they have gas emerging from them."

He asks you this, when in fact you have seen cryogenic ventilation before in a YouTube video documenting NASA's launch of the Saturn-V, where liquid hydrogen and oxygen were shown escaping from bleeder-valves in order to minimize the risk of pressure blowing seals or damaging other components.

"As a mechanism extracts heat like a refrigerator," says David, "The internal system cools down. However, as soon as the system turns off, the liquids inside will return to a normal atmospheric temperature. And as a liquid heats up, it tends to expand. Liquid molecules are close and compact but when turned to gas, the molecules spread out and flow easily. If someone were to disconnect the cooling mechanism from the tank, the liquid hydrogen and oxidizer would return to a normal temperature as chemicals expand within the fuel-chamber. As pressure goes up, the system may turn into a bomb."

"To protect against combustion, liquid rockets contain boil-off valves, which release excess gaseous pressure. One of the challenges with a liquid rocket is keeping all of the hydrogen and oxygen molecules cool while the rocket is in space. A normal refrigeration system hooks up to a wall to generate power, but in space the rocket would have to rely on solar energy."

"Think about the solar panels on your roof to power your house," he says. "In this case, you're trying to keep an entire rocket below freezing."

"So," you say, "Liquid rockets contain some sort of air-conditioning system, right?"

"Precisely. However, trying to accomplish this in space remains a challenge. You would require a ridiculous amount of solar panels and you would need to be in view of the sun in order to harness solar energy. Liquid rockets are far from ideal for interplanetary travel because one cannot keep the system at a regulated cool temperature for the entire duration of its flight."

"That's limiting to you guys. Is it not?"

"Well that brings us to our third option," he says. "You have a hybrid rocket, which is essentially a combination between solid and liquid propellant rockets. In a hybrid, you have a tank of oxygen connected to a unit of hydroxyl-terminated polybutadiene

(HTPB) solid propellant. A hybrid rocket is kind of like a hose. You know how the nozzle on your hose has a mist function?"

"Yeah."

"Well, pressurized gas sends the liquid oxidizer through an oxidizer control valve, where the liquid atomizes into a mist-like substance. Particles then react to the fuel itself, which burns within the fuel-grain like a candle due the influx of the oxygen. It

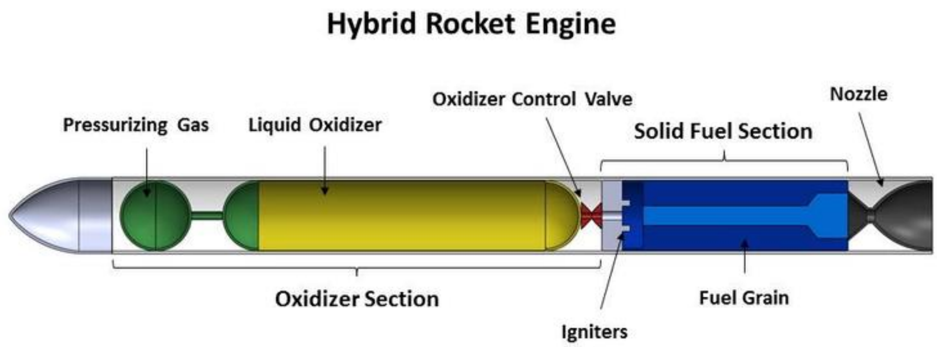

Figure 6: Hybrid Model Rocket

combines with the HTPB and burns out. Oxygen feeds fire. It's an oxidizer and anything that burns needs oxygen. The fuel grain at the end of the rocket actually has a center cut out in the middle, where the oxidizer feeds through and burns with the fuel. It's almost like lighting a roll of toilet paper on fire. The contents burn radially and start expanding, burning from the inside out. The oxygen combusts with the HTPB in the fuel grain, accelerates out of the rear end, and creates a thrust propulsion."

Now it is to your understanding that a hybrid rocket system is controllable. An oxidizer control valve dictates the amount of liquid oxygen entering the solid fuel grain. In addition, a hybrid rocket system is significantly less expensive than a liquid propellant because it eliminates the need to keep the oxidizer in liquid form once it infiltrates the fuel grain. Less parts mean less room for error and minimizes the potential of a combustion-related injury. Hybrid systems provide a safer alternative to liquid or solid propellants. Liquid oxidizer and HTPB fuel are kept separate from each other.

"It's safer and more controllable than when these chemicals are combined," says David. "And do you remember how the liquid rocket must keep both compartments cold?"

"How could I forget?"

“Well with a hybrid, only the liquid oxidizer section must remain cold, so it reduces the rocket's use of power in that regard. ESRA is aiming to build a hybrid rocket because it is safe enough to actually assemble on campus and—”

At that moment the door to the laboratory swings open and all eyes turn toward him; a tall man in jeans and a collared shirt, with round eyeglasses nestled on his face.

“Oh, hello Dr. Seymour,” David says.

“How’s it going?”

“It’s going great. Now, I’ve got a question. Do you know of any labs on campus that have gaseous oxygen?”

Dr. Seymour takes off his glasses, puts them in his shirt pocket, and crosses his arms. “Chemical Engineering did at one time. I mean, they had a tank right near where the fire was. It was a little-small one, but luckily it didn’t go off.”

“Is that something we’re allowed to have on campus,” David asks.

“It has to be approved.”

“As long as it’s approved right?”

“Well, we have to look into the situation. It depends where the chemical is going and how it will be used.”

“So, Dr. Seymour is our Facilities and Equipment Coordinator—”

“And temporary safety person,” Dr. Seymour says with a smile. “In this laboratory,” says David, “We like making things blow up. Well, I won’t say blow up, blowing up would be bad. *Combust*. Basically, we put different energetic materials in the glass-enclosed display station, use electrical current to ignite them, and then study how they burn because you can learn a lot about a material by examining how it burns. That’s what we do with these high-speed cameras here.” He pointed to the Camera mounted on the tripod.

“We take high-speed video of these materials burning, and we analyze them. With that being said, on campus it’s not really—we had an accident probably about two

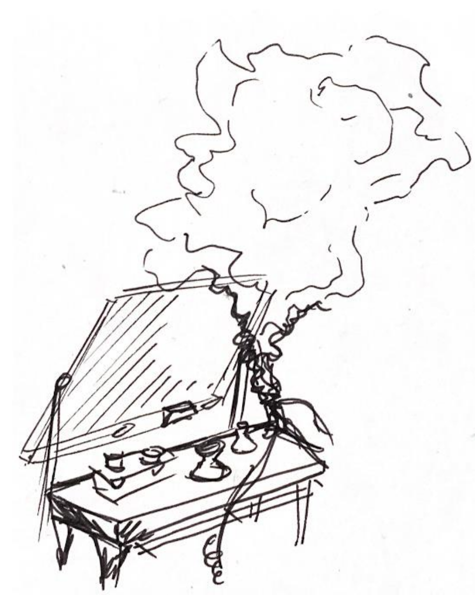

Figure 7: An explosion in a Lab, illustration by Hannah Rose

years ago in the Chemical Engineering Department where, I think we had a battery explosion."

"Yeah," says Dr. Seymour. "Well, they were dealing with lithium and they were trying to neutralize some chemical process they had. I don't know what they mixed exactly, but they had an explosion. Thankfully, no one was blinded permanently, but he could have been. No one died. People could have died. We came pretty darn close. We were very lucky. And so now, we make sure everything that goes in and out of the lab is checked and approved. We cannot afford to have any more accidents because that's when the university looks at canceling things, or stopping things, and then—before you know it—pretty much all we're doing is playing around with water."

"Yeah and that kind of sucks," says David. "There's no fun in that, I can do that at home."

"Water and lemon juice." They laugh at the thought of it.

"So, with that in mind," says David. "Solid rockets really cannot be built on campus because they're classified as energetic material on their own. You have the fuel and oxidizer in one system. Liquid rocket fuel— and I've talked to professors here from rocket teams— is not permitted on campus."

"You can't have liquid oxygen, unless the operation is approved," says Seymour. "Only then, do we buy the chemicals. And for liquid propellant rockets, all materials are delivered directly to the launch-site in the Mojave Desert, the only exception being the high pressure helium tank. But even just trucking out the high pressure helium tank involves risk. It's under 6,000 pounds of pressure per square inch."

"A hybrid rocket on the other hand is safer because you're limited to just gas," David tells you. "We're currently awaiting approval to build a test-stand on campus, plus we already have access to gaseous oxygen. I've been talking to the lab administrators and we figure it's a safe observational study."

"You guys will need to put together a procedure, and we will have to review it," says Dr. Seymour. "Campus Environmental Health and Safety will have to sign off on it as well. And the reason is: whenever we have an accident, it jacks up our insurance rate. It's not an extra $100,000 a year, it would be several hundred thousand. Basically an extra house every year. Every time you have an accident, insurance rates spike and they never go down."

"They stay there," says David.

"Yup. Accidents cost the University a lot of money. Then we have hundreds of thousands less to spend on aerospace programs. Just one check you're writing out—and poof— you might as well put the money in a barrel and throw in a match. Once the word is out of an experiment gone wrong, the university could face serious criticism and negative publicity which damages the university's public image."

Liability is always an issue. You remember coming across *The Rocketmakers,* a novel by Harry Wulforst, when you were bored one day at the library stacks last semester. According to Wulforst, even renowned aerospace engineers such as Dr. Robert H. Goddard faced opposition in regard to safety concerns from university faculty, not to mention the media. In the summer of 1929, in Worcester, Massachusetts, the switchboard in the Worcester Police headquarters had been buzzing. Callers reported a fire and airplane crash on a hill just outside of town. No one was hurt, but senior faculty member of Clark University, Dr. Goddard, was caught in an awkward situation due to a routine experiment gone awry. A reporter smelled a good story, took some pictures, and wrote about the vegetation which had been burned where the twisted remains of Goddard's small rocket had crashed. *Evening Gazette* headlines blared: "GODDARD EXPERIMENTAL ROCKET EXPLODES IN AIR… FALLING EMBERS LED TO BELIEF THAT MAJOR AIR CATASTROPHE HAD TAKEN PLACE." After that day, Goddard was portrayed in the public eye as a crazy mad scientist who shoots rockets.

Dr. Seymour tells you that to protect the University from conducting any experiments or launches which may result in a dangerous accident sparking negative publicity, the California State University Chancellor Office has allocated additional resources to the Environmental Health and Safety program at Long Beach State.

"Now we have a full-time safety manager budgeted for 40 hours per week," says Dr. Seymour. "Their sole job is to implement, track, and teach safety procedures related to any experiments or tests carried out under the name of the university. One accident, and— because of that— everything is tightened up. It's a good thing, but it's also a pain in the butt and everyone just loves paperwork, don't they? One accident creates a lot of paperwork, another accident; and there's an avalanche of paperwork and you won't get anything done, all you'll be doing is paperwork! Your thesis will be on how to do the paperwork!"

"That's kind of the reason we want to move toward a hybrid system," says David. "Because we increase our level of safety. It still may serve as a challenge to get the ball rolling, but it is safer. Our long-term goal is to build this hybrid rocket. A lot of us are new to the building process, so what we intend to do is to start off building a solid rocket for students to gain experience, and then build a test stand here in the lab to observe our engines in a controlled environment. In regard to the solid rocket, we will have to manage avionic and recovery subsystems. We have to implement a subsystem which logs altitude, showing us when to deploy a parachute in order to recover the rocket. The computer can be programmed to pop off the ends of our rocket and deploy our parachute when it reaches 10,000 feet above the launch-site. Bringing our rocket down slowly will ensure that all the work we put in building it doesn't just get wiped out on the ground."

"So you can reuse the rocket?"

"We can reutilize the shell, the motor, the nose cone, and really; we can reuse just about everything. That's the purpose of an avionic recovery system. To do this, however, calculations must be made to determine our parachute requirements, track how high we are going, and at what point we are falling down. All this is done through programing, force analysis, and systems analysis."

You know that they are taking into account aerodynamic structures. When they make the rocket, they're not going to make it out of cardboard because then the motor will shoot right through the cardboard and the buildup of heat will light the cardboard on fire.

"Our aero-structures team determines which materials we are going to use," says David. "For example, if we are going to use carbon fiber, how many wraps of carbon fiber? How thick do we have to make the shells? How dense do the walls have to be in order to make sure we don't fall apart at launch? Our aero-structures side of the team decides the shape of our rocket. Have you ever put your hand out of the window of a moving car and felt the air alter the orientation of your hand?"

"Yeah."

"That's kind of what we are doing in terms of aero-structure; we are determining the best way to cut through air. Obviously the hand out of the window is a drastic example, you would not want anything with a blunt, or flat edge like that, because the air-resistance would interfere with your flight path. However, there are also various degrees of acicular edges. Some are pointier, some are more curved, others are parabolic— which is kind of in the middle— and that is what our aero-structures team does. They figure out how fast we will be traveling based on preliminary calculations, and determine an ideal nose cone shape for best performance."

"What other factors are considered," you ask.

"So, there is drag for one, and that's basically the force acting opposite to the direction we are going. Such as the force against your hand sticking out of a moving vehicle. That's drag force, and we want to minimize that. We also want to ensure that our design can withstand a lot of heat because you're traveling really fast; we're talking about 900 feet per second. I can't put that in miles, but if you're doing 900 of those in a second—"

"You're going really fast."

"You're hauling ass! You're generating heat on the nose cone just from all the air hitting the front. We also have to consider stability. When we make the rocket, we want to ensure that this thing is going to go straight up. We don't want it to go up, then sideways, and then crash because that can happen. You have to determine proper weight distribution and your rocket's center; a pivot-point around which all of its mass is located. The center of mass determines the dexterity of the rocket. The aero-structures team is responsible for determining the stability of the rocket in the air, its ability to endure heat without falling apart, and its capability to fly straight. Figuring out all of these aerodynamic factors involves a bunch of calculations, as well as modeling on computers, and research to determine the most appropriate shape for the nose cone."

"We also have a payload team," David says. He tells you that once the rocket reaches its peak height, the parachute will deploy. "Once the rocket descends to 400 feet above the launch-site, a drone will be released and it will fly somewhere predetermined for the competition. Payload is responsible for designing the mechanism which releases the drone. We have to ensure that when we release the drone in mid-descent, it deploys in such a way that it doesn't just come out and fall to the ground."

"So when the rocket descends via parachute, it must be at an orientation conducive to flying the drone?"

"Yeah that's a big challenge there."

"And you mentioned this is all part of a competition?"

"Yeah," he says. "This is for the Friends of Amateur Rocketry 1035R Competition. Around 15 teams are going to design, test, and launch a rocket."

"So you're competing against other schools?"

"Yeah."

"What are some of the schools you're competing against?"

"In the past there's been Cal-State Universities, and even Universities of California such as UCLA. When the day of the competition comes, we are aiming for a height of 10,000 feet. To get to 10,000 feet, all our systems must work together. This includes the shape of the rocket and the level of thrust, or the force acting downward out of the end of the rocket."

"The next step is to build a test-stand and start designing our hybrid rocket from the ground up. It will take approximately a year and a half to test the propulsion and avionics system, but we are going to require money; a lot of money. I'm talking about almost 60 thousand dollars on the high end. We do have many of the gaseous substances we need, as well as workbenches, sensors, fume hoods, and data systems readily available in the lab; and this will reduce the cost by a bit."

ESRA leaders will go in front of a committee to request a grant from Associated Students Incorporated. "We want to be the first rocket team on campus to have a test stand, so students can come in here and familiarize themselves with rocketry, and actually see it at their home-campus under the fume hood, rather than driving out to the Mojave. Students can put their prototypes into a clamp-stand, ignite the motor, and record data to visualize the performance of the rocket."

"And a computer collects all the data?"

"Yeah. We use a sensor array to process the data. We have a sensor called a load-cell which can tell how much force is coming out the back-end by the amount of pressure pushing against the load-cell. The computer then converts this energy into an electrical response, represented by a sequence of numbers which are analyzed using digital signal processing algorithms."

"We want to have this test stand to try out things here and get students interested in rocketry. I don't know if you follow the news, but Space-X just purchased a place out in the Port of Los Angeles and Virgin Galactic and SpinLaunch have facilities in Long Beach now. There's a lot of space companies coming to LA. Industry leaders are foreseeing that LA and Long Beach will be the new space-port hub, kind of like Florida. After we build a test-stand, and gain experience through our Mojave launch, maybe we can all get jobs at Space-X!"

You take a deep breath. "I know it's a lot to follow," David says.

★★★

After going through your first science lesson since freshman year of college, you find yourself overwhelmed. You thank David for meeting with you and you head to your next class. Upon entering the classroom you notice your teacher has an anxious look on his face and his hands are fidgeting.

"Okay class," he says. "I hope you all had a restful weekend, but I have some troubling news to share. I've received word from the University that administrators are monitoring the current situation regarding COVID-19, the novel-coronavirus, and they are concerned for the health and safety of students. As of now, nothing has changed in regard to class schedules and university facilities, but the continuation of school as we know it, is resting on the nationwide prognosis of the disease. I will keep you all posted on any new developments."

Two hours later you exit the classroom with a lousy feeling in the pit of your stomach. You hop on a bus bound to your street. The bus circles the roundabout and pulls up in front of your apartment complex. Upon entry, you go straight to your computer and begin research.

You perform a google search of COVID-19. According to the Center of Disease Control and Prevention (CDC), COVID-19 is a "respiratory disease spreading from person-to-person caused by a novel (new) coronavirus." Coronaviruses are a group of related RNA viruses which have spread diseases in birds and mammals. Lethal cases of coronavirus have caused SARS, MERS, and now COVID-19. The CDC stated that the federal government is working toward a response to the situation, and the disease poses the greatest threat to individuals over 65, or those with underlying health problems.

The CDC recommends you practice social distancing. Stay at least six feet apart from others, do not gather in groups, and stay away from crowded gatherings. You know this is impossible. You already bought concert tickets for March 20th, and with the amount of people who come in and out of your dumpy apartment, there is no tangible way to distance yourself physically. You shake your head, let out a sigh, and close your laptop.

The next night you turn your TV to KTLA News where anchor Micah Ohlman talks about social distancing and how to protect yourself from COVID-19.

“Stay at home, save lives,” he says.

He recommends the public wear medical face masks and distance themselves from others as much as possible.

Later that day, you visit the grocery store across the street from your apartment. People are lining up to enter the store, and you notice an obese couple exiting the market with a dozen, or so, toilet paper rolls and six cartons of eggs. The majority of the people in line are wearing masks and you feel like a sore thumb.

Figure 8: Masked Woman in the Thick of the Coronavirus Outbreak, illustration by Hailey Mcquow

A few days later you hear your roommate scream out in excitement. "Check your email," he tells you. You pull up your latest email sent from the office of Jane Close Conoley, President of California State University, Long Beach.

> *"As we've communicated over the past few weeks, we've been engaged in ongoing planning since the emergence of novel coronavirus, or COVID-19. While there are no cases of COVID-19 related to our campus, as a preventative measure and with trusted medical advice, we are temporarily suspending the in-person, on-campus convening of classes."*

"This is insane," you say. "And I was so excited for this semester."

"At least we there's no more school," your roommate says. He shrugs and leaves your room. You shut the door behind him and plop back on your bed. You might as well sleep, there's nowhere to go today.

That afternoon, you receive another email from your English professor telling you that the foreseeable future has happened, and that instruction will continue through an application called Zoom, an American communications service providing video telephony and online chat services through a cloud-based peer-to-peer software program. You log on for class the next day at 5:00pm, only to find poor connection and lagging voices resonating through the tiny speakers of your 12 inch Google Chromebook.

Several days pass and you find yourself at your local fitness center, but the door is locked as they have shut down. You run a few blocks to the beach, only to find that it has been fenced off, with yellow caution tape weaved in between the chain links.

You drag your feet home and open your phone and send David a text.

> *"Hey David. I'm wondering what this COVID-related class cancellation means for ESRA."*
>
> *"I don't know yet, but we are still in communication with the machine shop. So far, it sounds like ESRA will not be able to manufacture."*
>
> *"That's a shame. Are you holding the meeting this week?"*
>
> *"I don't think we will. I'm quarantining myself."*
>
> *"Wow, is someone pressuring you to self-quarantine?"*
>
> *"No but I'm going to."*

"This is all just so crazy. Hopefully ESRA can get back on track in the near future."

"It's pushing ESRA back, that's for sure."

The next correspondence between you and David is done over a Zoom video-chat. He tells you that COVID-19 has put a stop to all ESRA activity. No one is allowed inside the campus laboratory to work on any projects, and when it does open back up, capacity will be limited to 10 people per building. All proposals and design theses are being developed at home. Building the hybrid rocket is at a stand-still, and the competition has been postponed, at least until December. Come fall, if ESRA is still in a position where they cannot perform face-to-face work, they will plan to work in isolation and comply with physical distancing guidelines.

"It's a difficult thing," says David. "You're working with your hands, and you're working in groups. It's kind of like the grocery store; you're bound to be within six feet of someone. We already wear gloves and protective eye-wear, but we're going to have to wear masks as well. If they are able to relax the rules and have two or three people in a room, which would help out a lot. Much of what we aim to do is to teach freshman, sophomores, and first-timers coming into the rocket field. How are we going to teach someone with such small numbers? It really slows down everyone's learning process."

If ESRA members were to build under these guidelines, only a finite number of participants could experience the actual construction of the rocket. Under these circumstances, it looks like Americans will continue to social distance for a considerable amount of time, as the virus slowly manifests the population.

"I don't think there's going to be a vaccine anytime soon," says David. "I think it's going to take at least a year or two. If the virus is still lingering mid-summer, then I don't see anyone going back to class in the fall, and that means our efforts will be hindered. Hopefully they move our graduation ceremony to the fall."

"So no graduation over Zoom's video-chat for you?"

"No way man. I've put a lot of work in. If they do it online, I'll just have my own graduation party. I'll invite all my friends, throw some seats down and— who knows— maybe even have a couple of our teachers come and talk, and we'll have our own little ceremony."

"What does this mean for recent graduates entering the professional world, trying to find employment opportunities?"

"I know for engineering, there are a lot of internships and job opportunities that have been rescinded. Boeing and other commercial aviation companies have laid off many of their employees. With a decline in airline travel, the demand for building new airplanes has been diminished. At the same time, Boeing is already dealing with their fiasco of the 787 Max crashes in 2018 and 2019. If you're working in a commercial area, such as Boeing, you're going to have a ripple effect because it's not just Boeing. Sure, they make airplanes, but Boeing also contracts out for airplane components such as engines or general electrical units. Airline travel is down, commercial aerospace is suffering, and private contractors who serve the commercial industry are caught between a rock and a hard pla—"

"Hello? Hello, David?"

Your video-chat freezes after your Wi-Fi disconnects. You try to load up Facebook, but a message pops up on your screen saying that you are unable to connect to the internet. After closing your laptop, all you sense is stagnant silence in your tiny empty apartment. You sit on your living room couch and stare at your blank television screen. In the center it reads: *No Signal.*