Bringing Accessibility to Aviation and Flight Physics

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1. Introduction

Typically, in the United States, the cost to obtain a Private Pilot License can range from $6,000 to $20,000, with a large percentage of the costs coming from necessary “ground school” fines and exam fees (*Jeppesen Aviation Pilot Shop - Aviation Training Bundles*, n.d.). Ground school, which covers aeronautical knowledge needed to safely fly, requires thousands of study hours and spans many subjects including aeronautical instruments, weather patterns, navigation, emergency procedures, and flight maneuver safety, all of which necessitate study materials (*Become a Pilot*, 2022). Unfortunately, many such study materials are created privately and sold at high ticket prices, with several companies monopolizing the market. These substantial initial expenses associated with aviation often serve as a barrier for many individuals, preventing them from pursuing their interests (*5 Challenges of Being an Airline Pilot - AAG Philippines*, 2023).

Simultaneously, the demand for such individuals in roles such as pilot positions continues to increase, with a daily average of 87 pilots needing to be trained to keep up with the rate of demand (*Airline and Commercial Pilots: Occupational Outlook Handbook: U.S*, n.d.). While currently there are 159,000 registered active airplane transport pilots, the number has seen a precipitous drop as the rapidly aging pilot population phases into retirement. Many companies who hire pilots have even begun to offer large starting bonuses of over $250,000, finding the incentive to still not be enough to urge aviation lovers to begin the costly journey (*Some Pilots Offered $250K Signing Bonus to Join Regional Airline Carrier*, 2023). Such a trend persists not only on a global scale but is also intensified within the United States, where flight programs are found to be, on average, up to 50% more expensive than the global average.

To connect interested individuals with an easier pathway to obtaining such job opportunities, I hoped to address the large gap in accessibility of low-cost or public resources for

introduction and study in aviation as such a step is critical in bolstering the aviation industry and encouraging the enthusiasm of young pilots. Through my project, I aimed to create a product that could be distributed to not only my local community in Virginia Beach but also throughout the country or globally, hoping to provide a resource accessible to all of those who seek such.

2. What I Knew, What I Wanted to Know

Coming into this project, I had little knowledge of the world of aviation in terms of flight experience. Instead, the majority of my knowledge regarding aviation was centered around physics principles, namely flight physics. I had done some investigation into the forces that rule over flight, such as thrust, lift, and gravity, and was curious to learn more. Additionally, I participated in the Virginia Aerospace Science and Technology Scholars (VASTS) program, learning about aerodynamics and aerospace engineering for NASA missions to Mars, and obtaining a holistic understanding of the processes necessary to keep rockets and other spacecraft in orbit and safely flying through the sky.

Through six months of module courses and a week's residential stay at NASA Langley, I found myself more and more curious about flight, both through a scientific lens and through a personal one. I sought to learn more about the interactions between machines and the environment, on a quantum scale and a macro scale. Additionally, I wished to learn more about flight in the practical sense, hoping to learn the basics of flight through training. For my journey beyond, I chose to guide my path mainly by looking at how applied physics finds applications in aviation, while also considering how aspects of such applications are centered around improving human health and safety.

3. My Story

During the summer between my junior and senior year, I chose to immerse myself in a variety of programs that related to the topics I sought to learn more about. From a friend, I was first recommended the Tidewater Soaring Society Scholarship (TSS) program, an opportunity for students aged 15 to 20 to learn how to fly a glider through 35 pilot hours and 10 days of ground schooling. I had the honor of being selected for this program and spent the beginning of June in the air. At this point, I was interested in finding out the process of learning how to get a license, as well as the underlying principles of flight both in theory and in action.

Through the TSS program, I learned the fundamentals of glider flight, beginning to study aeronautics and training how to fly. The program began by familiarizing me with primary controls and the rudiments of flying, illustrating the role of pitch, roll, and yaw control to give me a deeper understanding of the glider's responsiveness to control inputs. As I grew more knowledgeable on these topics, I was able to control the glider myself, flying with an instructor to practice general steady flight as well as other moves such as steep turns and steering to direct headings of a compass. Slowly, as I grew more comfortable with flying and controlling the glider, I was taught about the context of flight as well, studying Bernoulli's Principle and theories of lift to understand how gliders, specifically, operate. Additionally, I was allowed to learn the airfield and to set up the markings for the flights of the day, serving as a wing runner, or one who assists with the takeoff and landing of the aircraft, and helping to run positive control checks on the gliders, making sure that all of the controls worked properly. Through my many flight hours, I was able to refine maneuverability with aspects like steeper turns with the guidance of my instructor and gain a deeper comprehension of banking the glider at sharper angles while sustaining consistent altitude. I learned a balance between control inputs and steering, allowing me to have more control of the glider, how to use thermals for lift, and how to use the

emergency checklist for gliders. Finally, after mastering such, I started to transition into autonomous flight.

Under observation from my mentor, I engaged in independent launches, navigation, and landings, practicing a range of simulated scenarios, including canopy malfunctions and cable failures. Finally, on the ninth day, I flew solo, leaving me wanting to learn more about how I could further my path.

Unfortunately, after the program's conclusion, I found myself with few resources to continue such a journey. To obtain my license, I would have to buy costly study materials, purchase practice tests, and then pay to obtain my FAA written exam certification. Following such, paying for a check ride with an FAA-approved pilot was required, adding yet another expense. Unable to find any low-cost, publicly accessible resources to study, I turned to applying for yet another program: Space Grant Consortium Pathways.

During the Pathways program, I learned to fly the Cessna 152 through a two-week course, soloing once again, and participating in a month-long ground school course. Through the collective time spent in Pathways, I was able to obtain my Private Pilot’s License, learning the fundamentals necessary to pass my FAA written exam for gliders as well. Suddenly, I held not one, but two written certifications, motivating me to create the opportunity for other students to do the same.

Still curious about the science behind flight, I also took on studying physics through the SPINWIP program at Stanford, researching the Eightfold method. I was interested in finding out more about how applied physics related to aviation, leading me to approach the program to find out more about aerodynamics, movement of air, and interactions between mechanisms and surroundings. Under Professor Wechsler and Professor Schleier-Smith, I investigated fluid

motion and modern theories for particle interaction, leading to the writing and presenting of a research paper to the virtual class. By delving into the interactions between hadrons and baryons, I was fascinated at the micro-scale and further interested in finding answers to my initial questions, motivating me to join the Old Dominion University REYES Nuclear Physics Mentorship.

With Dr. Jackura and Dr. Briceno, we looked at the Strong Nuclear Forces, looking at the fundamental theory of Quantum Chromodynamics, or QCD, the driving force for reactions from stellar evolution to deducing hadron nuclear structure and describing quarks and gluons. Additionally, I researched the role of complex numbers as fundamentals for calculating aspects of fluid dynamics such as scattered amplitudes, calculating probability through wave functions, and the use of S matrices to deduce the cases of no interactions happening between particles (as seen in Appendix A.) Finally, I learned about Lorentz invariance and internal symmetry, looking at relative movements between how mechanisms function and the air around them, tying back to aviation.

Overall, through my summer, the majority of my work was focused around my main guiding question: how applied physics finds applications in aviation, yet my experiences inspired me to create a product that tied back to the idea of human-factors-related studies instead of an engineering project. With these questions in mind, I then began to ponder how I could create an impact with the knowledge I had acquired.

From my research, I found that while topics such as flight, flight education, and the physics of flight were ideas that could be easily communicated, others, going into quarks and particle physics, may be fields that I would love to explore at a later date. Quarks and particle physics are topics that require a college-level course and expert to teach and hence they would be

much harder to break down into an accessible program for all to use. Instead, I wanted to integrate my studies of fluid mechanics and flight physics into a solution that addressed the lack of accessible and cost-friendly resources to study flight physics, especially looking at the path toward obtaining a Private Pilot and Glider Pilot license.

4. My Product

To create a cost-effective and accessible resource on aviation education, I worked with my Pathways program instructor, Barry King, to outline the topics necessary to successfully pass an FAA written exam. The FAA, or Federal Aviation Association, written exam is an exam all pilots must complete and pass with a score of at least 70 percent to be eligible to then obtain their pilot's license, making it the critical first step to entering the aviation industry.

In the outline, Basic Aerodynamics, Instrumentation, Weather & Weather Systems, Aircraft Systems, Regulations & Airport Procedure, and In Sky Navigation & Communication were chosen as the six major necessary components. For Basic Aerodynamics, we decided it was best to cover basics, including topics like principles for flight, general terminology, as well as an overview of clearing turns, slow flight, steep turns, s-turns, turns around a point, stalls, power-off stalls, power-on stalls, rectangular courses, forward slip, emergency descent, unusual altitudes, and traffic patterns. After a fundamental understanding was built, Aircraft Systems covered how to implement the basics, focusing on how to begin the engine (for powered airplanes), the operation of systems, flight controls, how to navigate the engine, the components of the landing gear, how to fill airplane fuel and its use, as well as how to navigate the environment.

This component gave more context into the basics and led into the third, Instrumentation. In Instrumentation, specific instruments like the G1000 system, the magnetic compass, gyros, and the Pitot-Static system were provided more explanation, as they are necessary tools that the

pilot must not only know how to operate but also know their inner workings. The fourth component was chosen to be Regulations & Airport Procedures as these restrictions needed the previous understanding of basics, usage, and instrumentation to properly comprehend. Within Regulations & Airport Procedures, airspace basics, collision avoidance, taxiing rules, how to use a checklist, cockpit needs, normal and crosswind take-offs, normal and crosswind landings, airport signals, boxing the wake, managing wake turbulence, and emergency procedures were included, explaining not just how to operate in the air but also when landing in airports and when preparing to take-off. Finally, Weather & Weather Reporting as well as In Sky Navigation & Communication were added as a conclusion, covering weather fronts, weather layers, weather stability, when one should fly, the decision-making process necessary for safe flying, as well as how to communicate to others, such as over the radio or on airtower frequencies.

I chose to present such content on a website platform to make it easy to share and access for all. Each of the components was created into “modules” with their respective topics names as “sections”, and over 400 flashcards with practice questions for the FAA exam were created. By including not only the necessary information but also flashcards which could be used to practice and gain insights into the level of understanding that is expected on the exam, users could master each module without having to pay over three hundred dollars for the practice tests currently provided on the internet for the same material, giving them a much less costly way to ensure they will pass the exam. Additionally, users can download the flashcards and upload them to a platform such as Quizlet, where they will be able to create their own practice tests if they wish.

Finally, to make the material more accessible for people who are unable to spend large amounts of time reading over pages of module information, I also embedded my own podcast within the pages, allowing users to listen to the material in a story-like form to learn more about

aviation while doing other activities such as driving or exercising. In this way, people would be able to pursue the topics they are interested in in a way that fits in with their day-to-day schedule and does not necessarily take away a large amount of their already scarce free time.

For users who found the podcast first, before the website, the website with practice tests and flashcards was also linked, giving two points of access. Such a format was different from what is currently available as it not only gave information but also a way to access more unpaid resources to practice the context in a way that did not commercialize the learning process.

Overall, through both platforms, my goal was to reach one thousand people in the span of the year 2024 and to do so by presenting the resources to students at Connect-In-Place, a virtual learning environment for children in underprivileged areas, where I had worked before.

5. Results

In an attempt to reach the Connect-In-Place community, I learned that the center had stopped operating in 2023 following the end of the pandemic. Instead, I opted to share it with a variety of programs and possible students interested through more organic means. Through a friend's popular study blog and YouTube channel, I shared my website and podcast with an audience of over four thousand followers, garnering an audience of over 12,000 viewers, meaning that the platform was not just reached by the common viewers of the blog, but also individuals interested in the topic from outside of the previous audience. Additionally, I reached out to the Pathways program where I learned my knowledge, sending the website through their monthly newsletter to over 800 students interested in the topic. Finally, I embedded my website within the Tidewater Soaring Society learning resources page, allowing future students years to come to use it if they see it necessary.

Since many of the programs with which I shared the resource are ones that operate in the summer, there was a little bit of a challenge in getting engagement during the school year, when these programs are not operational, especially for the Tidewater Soaring Society. While it is expected that the engagement from students in those certain programs will naturally increase as the programs begin the summer, such challenges served to negatively impact the current results. Another slightly unexpected challenge in the tracking of the results was the inability to view responses and audience numbers past a seven-day timeline on the Square application over which the website was running. To counteract this, I began to check the statistics every seven days and record the numbers for the audience and submissions to the in-website questions to track the results in terms of engagement.

Overall, for the time that the website and podcast were running, 1073 people were reached, with 289 of them being people who were reached through Spotify impressions only and directed to the podcast, and 784 of them being from engagement on the website. From those who visited the website, only 27 individuals submitted the questionnaire, yet the website counted over 600 unique visits. The highest number of views was from January 1st - January 18th, with the number being over 315 individuals, and the top number of views in one day was 102 on February 2nd.

It may be notable to also note that some of the engagement could have been made on the side of college admissions officers since the link was also shared on all college applications submitted and the review of materials submitted fits within the same timeline as the tracking period for engagement. Still, the actual yield does reach the goal of reaching 1000 individuals, as the total overlap in the viewers can not be proven and the admissions officers would still be counted as individuals reached.

In the future, I plan to improve the results and the product by expanding the material that is currently available on the platform by including more information about how to pass the flight test portion of the FAA exam as well. By giving video training on maneuvers, providing affordable locations to do in-simulation flight, which is generally very inexpensive, and giving users more pathways through which they can gain flight hours, the platform could become not just a starting point for those interested in aviation, but rather a hub for all that they would need to learn on an elementary level. Furthermore, the podcast side could be more comprehensive and include more episodes, covering a larger scope.

Unfortunately, due to the time constraints and the time required to create each episode, I was not able to create an episode for each topic covered, but if given more time and resources, this could be possible. Another possible improvement would be to start a social media channel dedicated to the resource, specifically looking at TikTok. Since TikTok sends out content to users who are typically interested in such topics, the resource could authentically find users who would not otherwise be reachable through this social media platform. Still, creating TikTok videos, posting, editing, and promoting take a significant time commitment and a level of consistency which I was not able to provide at this point of my senior year. In the future, this could be done to reach hundreds of thousands of people who would be interested in learning more.

Another possible improvement for the future would be to reach outside of the Virginia NASA programs hub, branching out of just the Virginia Pathways Pilot program and instead seeking out, through email or other means, the Pathways programs of all states, if they do have such, to maximize the usage of the resource. On the same note, the Soaring Society's national organization could also be contacted to locate all glider clubs with student members and those

clubs could be reached out to inquire about their interest in free resources for obtaining a pilot's license as well.

For me, this project bolstered my curiosity about physics in application, specifically engineering physics and human-factors-related mechanisms, while informing me that while I enjoyed aviation, it was most likely a field that I would not like to go into as a career in the future. I was fortunate enough to also earn my pilot's license through my senior project journey, and although, as I mentioned, I am not interested in pursuing commercial flight, it was an accomplishment I was very proud of. Instead, in the future, I wish to be able to create new technology and to help others through physics, and while pilots do indirectly do so, I felt that my specific skill set would best be utilized doing the process more directly instead. Still, I hope to continue promoting lower barriers to aviation in the future and encouraging others with an interest in the field to pursue such.

Furthermore, I value my experience with aviation greatly as it not only taught me about flight but also fostered personal growth. Through challenges, I was pressed to learn to trust myself and to put my education from theory into practice, navigating the skies. In emergency situations, I also discovered the importance of being comfortable asking for help and the essentiality of making quick decisions in times of urgency, allowing me to be more prepared for the obstacles that I will face in the future.

Appendix A

Research Done: An In-Depth Examination of the Eightfold Way and its Components

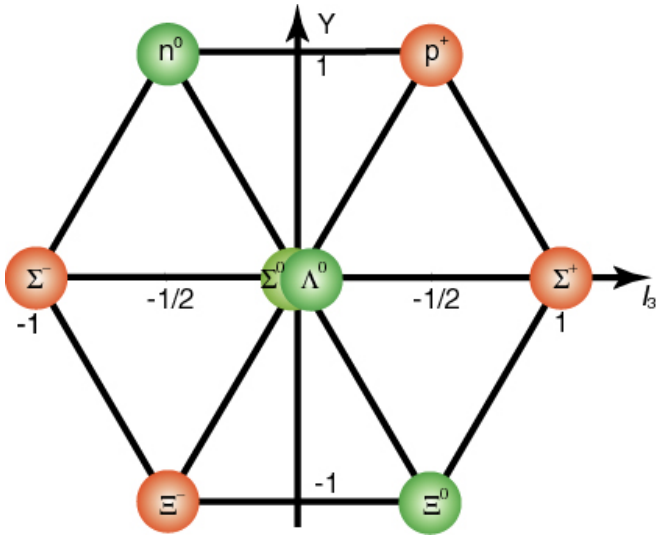
Introduction

Particle physics has long been a subject of fascination for the scientific community. The field was first popularized in the late 1940s, especially following the "particle zoo" era, a chaotic period of subatomic particle discovery (Yukawa, n.d.) As more and more particles were discovered, a need for organization and classification arose. American physicist Murray Gell-Mann and Israeli physicist Yuval Ne'eman answered such a call, proposing a new way of organization: the Eightfold Way. The Eightfold Way classified subatomic particles, also known as hadrons, based on their symmetries, creating groups of 1, 8, 10, or 27 subatomic particles (Sembroski, n.d.) Such a proposal suggested a systematic approach for comprehending both the interactions of mesons and baryons but also their properties. This investigation will examine the components of the Eightfold Way, looking at symmetry, group theory, the role of quantum numbers, and how particles are categorized into multiplets, allowing the uncovering of the impact of the Eightfold Way on particle physics as a whole as well.

Symmetry and Group Theory: The Foundation

The basis of the Eightfold Way is centered around symmetries, as well as group theory, the mathematical application of such symmetries to classify properties through groups (*Eightfold Way | Symmetry, Group Theory & Particles*, 2023). Due to the complexity of subatomic particles, typical mathematical tools failed to provide Gell-Man and Ne'eman with the system that they needed to classify the particles. Instead, classification necessitated octonion algebra, an eight-dimensional extension of quaternion algebra first introduced by John T. Graves earlier in the 19th century (Hughes, 2023). Octonion algebra allowed particles to be analyzed from a

multidimensional structure, allowing for a deeper understanding of the relationships between particles.



Quantum Numbers and Multiplets

Specifically, Gell-Man and Ne'eman utilized octonion algebra to look at deeper symmetries, looking at how they could categorize the particles into multiplets. Multiplets, groups of particles with shared attributes but varying quantum values, allowed for the Eightfold Way to systematically arrange the particles based on shared quantum values in characteristics such as isospin, strangeness, and hypercharge, while identifying and drawing connections based on the variations between them. In this way, the connections could be looked at on a broader scale while still being classified empirically. Rather than having a basis on theory, the classification was based on observation, but allowed for later theories to be developed, such as the quark model and the Standard Model of particle physics, both theories that helped to provide the explanation behind such observations and symmetries identified.

Mesons and Baryons

The Eightfold Way's application centers on the categorization of mesons and baryons—two distinct families of subatomic particles. According to the concept of color

confinement, color-charged particles such as quarks can not be isolated, hence they rather form composite particles such as baryons and mesons (Zichichi, 2023). Mesons are composed of a quark and an antiquark bound together by a strong nuclear force. Such strong nuclear force between the quark and the antiquark helps to hold together the atomic nucleus and also mediate interactions between quarks (c*onfinement in nLab*, n.d.) Typically, mesons can vary through properties such as spin and strangeness, properties which can be organized and better-made sense of through the Eightfold Way. Unlike mesons, baryons are made up of three quarks that collaborate to maintain a stable structure. Some of the most typical baryons are protons and neutrons, which make up the nucleus of the atom and provide stability (*Eightfold Way | Symmetry, Group Theory & Particles*, 2023). These mesons and baryons are organized into multiplets based on their isospin and strangeness quantum numbers in the Eightfold way, helping to make sense of these diverse participles by looking deeper into their properties and shedding light on the fundamental forces that shape matter.

Impact on Particle Physics

The contribution of the Eightfold Way has reached much further than mere categorization, rather serving as the blueprint for understanding deeply embedded symmetries governing the strong and weak nuclear forces that drive particle interactions. By organizing participles into such multiplets, the Eightfold Way has allowed scientists to anticipate the properties of yet-to-be-discovered particles as well. With this increase in predictive accuracy, experimental searches have been refined, and interest in the theoretical frameworks has also been ignited, leading to the development of the Standard Model, which covers not only interactions but also the particles mediating them (*The Standard Model*, n.d.)

Ongoing Relevancy

Even in the modern era, the Eightfold Way continues its legacy, influencing contemporary particle physics research, and guiding subsequent generations of physicians to explore exotic particles, interactions, and symmetries. As the Standard Method currently continues to be refined and better defined, the Eightfold Way's use of symmetry, group theory, and quantum numbers remains relevant even today, guiding the ever-evolving landscape of particle physics research (*The Standard Model*, n.d.)

In conclusion, the Eightfold Way's comprehensive use of symmetry, group theory, quantum numbers, and multiplets has transformed the overall understanding of subatomic particles and particle physics, systematically organizing particles based on the shared properties and relationships they hold. Through such systematic organization, new interactions and patterns have been found, playing a pivotal role in the development of the Standard Model, one which continues to shape modern research today. The Eightfold Way's reducing legacy underscores the enduring power of organized thought in unlocking the mysteries of the subatomic realm, serving as a testament to the vision and ingenuity of Gell-Mann and Ne'eman.

Appendix B

Noteworthy Terminology:

- **Aerodynamics -** Aerodynamics is the study of how air flows around and affects objects, looked at in this paper as applicable to glider flight.
- **Baryons -** Baryons are a type of hadron that is made up of three quarks which are held by strong nuclear force in order to make a stable particle. Some examples of a baryon are protons and neutrons.

- **Color Confinement -** The principle in quantum chromodynamics that states that quarks do not exist as free particles, but rather are always confined in composite particles.
- **Eightfold Way-** This is a classification system for subatomic particles that uses their symmetries and properties to systemically determine relationships and organizations, a system proposed by physicists Murray Gell-Man and Yuval Ne'eman.
- **Glider -** Gliders are aircraft designed for unpowered flight, flying without the use of an engine but rather through the use of air patterns.
- **Glide Ratios:** Glider ratios are the ratio of how much horizontal distance can be traveled per a certain vertical distance descended, currently being used in the context of unpowered flight to show the efficiency of the glider.
- **Hadrons-**Hadrons are groups of subatomic particles that are made up of quarks. They can be classified as either baryons or mesons.
- **Mesons-** Mesons are a group of subatomic particles that are made up of two quantum particles: quarks and antiquarks, which are bound together by strong nuclear force.
- **Modern Quark Model -** This is the theoretical framework for particle physics that is currently in use and was developed based on the Eightfold Way, used to describe hadrons are made up of quarks.
- **Multiplets-** Groups of particles that have shared attributes but vary in quantum values, hence have similar characteristics but different quantum properties, allowing them to be better organized in the Eightfold Way.
- **Thermal -** Thermals are upward currents of warm air that can be used to gain altitude and extend the flight duration of a glider.

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