Space Craft Design
(Mechatronics)

Automation of Engineering Documentation

A Thesis Project Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree
Bachelor of Science, School of Engineering

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Fall, 2023

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Building a rocket from scratch is not easy. Intensive research, planning, and collaboration go into this momentous task. This is the assigned objective in my capstone class here at UVA. We are tasked with creating the specifications, the goals, and the functionality of a small rocket. Once all of these are created, we will transition into constructing this rocket. With the scale of this project being roughly between 8-12 feet large it is a large task that will take a long time. A project of this scale will be a multi-year capstone project with each new year improving on the designs of the previous class. Our class is the first year, the year tasked with laying all the groundwork and getting a functioning rocket into the air that can be passed down to the next class. We will plan carefully and document as many steps as we can along the way. The documentation is critically important as this is what prevents the next class from making the same mistakes that we made.

Technical Portion

The rocket design capstone project is a first-generation capstone project at UVA that has not been done before at this school. With a first-generation project, there is a lot of research and decisions that need to be made as there are no previous designs passed down. To explain the scale of this project and the need for teams I need to discuss some specifications. This rocket is going to be between 8-12 ft tall, have a goal altitude of 10 thousand feet, and have a multistage deployment sequence. To tackle this project the whole class split into three sub-teams: Propulsion, Aero Body, and Mechatronics. My Team’s role is mechatronics, controls, and communication.

Before I dive into the specifics of the rocket, I will provide an overview of the plan of the flight from launch until it lands and is recovered. The rocket will be propelled into the air until the fuel runs out around 10 thousand feet. Once this happens the rocket’s nosecone will separate from the rocket while still being attached with a shock cord. After the nosecone is deployed the payload will eject from the bay of the main body, deploy its wings and start gliding down and taking video. Then a drogue parachute will deploy slowing the rockets' descent before finally, the main parachute will deploy. The rocket and the glider will have a GPS attached to them to ensure they can be located for recovery.

For the controls of the rocket, the first decision that was to be made was choosing a fin control method. The two methods are a passive control method and an active control method. Passive control has benefits where the fins do not have to be moved and the rocket will stay stable just by having the correct static margin. A good static margin for static stability is a margin that is greater than or equal to 1(Guerrero et al., 2018).

$$Static\ Margin = \frac{(Cg - Cp)}{Rocket\ Diameter} \tag{1}$$

To keep static stability all that is required is careful choice and calculations of the center of pressure and the center of gravity. This can be contrasted to the requirements of active control. To successfully achieve active control there must be controlled fins. These fins would be controlled by servos on a constant feedback loop with input from a gyroscope collecting angle of attack data (Ferrante, n.d.).

Another branch of control is determining when the rocket will deploy its parachute. Based on similar college rocket teams and NASA, the optimal time for deploying the parachute is at apogee (the highest point of the flight). Once the rocket has reached apogee a drogue parachute will be deployed to keep the rocket stable in fall. Once the rocket has deployed the drogue parachute the main parachute will deploy to slow the rocket's descent (Burth et al., 2023). However, for the rocket to perform this sequence it needs to be able to determine when it has reached apogee.

To determine when the rocket has reached apogee multiple sensors are required. This falls into the mechatronics role of the sub-team. The sensors being used in the rocket are barometric, accelerometers, thermocouples, GPS, and strain sensors. A barometric sensor works by determining the atmospheric pressure, this pressure can be matched to a corresponding altitude based on the current pressure around the rocket (Albéri et al., 2017). To accurately determine when the rocket has reached apogee barometric sensors will be used to determine the altitude has not changed for a relatively long amount of time, and in conjunction, the accelerometer must say there is roughly zero acceleration. When both conditions are met the rocket will start the parachute deployment sequence. All the sensors will be connected to an Arduino board that will save the data on an SD card and also transmit the data to the ground for redundancy.

STS Portion

Throughout the whole process of designing this rocket for my capstone, we have had to document our steps along the way. This is essential so we can convey information and explanations for why certain decisions were made. Without this documentation, the incoming class will be left in the same position as my class was. This position involves having to conduct all the initial research with no base to build upon for our project. So, for this portion of the paper, I will dive into why we documented our project and the importance of documenting.

The Importance of Documentation

Documentation is highly important for continued growth and being able to determine when progress has been made. Without documentation how can we determine when an improvement has been made? How would we know the ways of the past without documentation? This surely cannot be left up to memory and word of mouth.

To start on the topic of determining growth, I will talk about a grade school volunteer teacher. Rebecca Wilson was a volunteer teacher at an early childhood education center. This consisted of setting goals, observing, assessing, and adjusting her support and guidance to the needs of each child. Keeping track of a large number of kids would be extremely overwhelming, except Rebecca had documentation to help her (Helm & Beneke,2003, pp.97-99). To determine if the child is improving Rebecca took work samples and tests and then created photos and notes. This drastically made her job easier by having a basis to compare the students' current standings. Without this documentation, Rebecca would have most likely forgotten about the children's progress (Helm & Beneke, 2003, pp. 97-99).

Looking at how documentation is implemented into the education field shows how it alleviates the burden of remembering every detail. So how does documentation impact the engineering field, an arguably much more complex field? In engineering, documentation is the main means of exchanging information on projects. It is needed at each stage of a project to follow compliance, obey safety parameters, and keep track of costs (Consulting, 2021). Some important forms engineers create are status reports, project plans, change requests, and other various forms. With the clear significance of documentation in the engineering field is imperative to analyze the downside of documentation and what could go wrong.

Issues with Documentation

Some downsides of documentation are too much time and resources taken up while documenting and having an information overload. An information overload is when there is so much relevant and potentially useful information available that it becomes a hindrance. This has led to taking up way too much searching for documentation and has become a confusion with the number of choices (Bawden & Robinson, 2020).

The other issue surrounding documentation is the amount of time it takes to fill out documentation. In the engineering field spending excessive time documenting can be an issue. This time could be better spent by the engineers doing more specialized tasks such as designing and researching. A study done at a medium-sized aerospace company found that on average the engineers spent 23.1 percent of their time creating documentation (Crabtree et al., n.d., P. 1). While 23 percent is not too high, it is still a large enough amount to be worthy of investigation to lower the amount. This paper will aim to find and solve these problems in the engineering field, however, a good place to look into is the medical field. The medical field has a high volume of required documentation. In a survey of 5000 general practitioners, 84 percent said they feel their workload is too excessive. On average, 55 percent of this workload is clinical documentation (Willis & Jarrahi, 2019, p.202).

With such a high volume of documentation required in the medical field, it is worth investigating how they handle creating documentation.

Solutions and Counter Argument

In this study by Willis & Jarrahi, it was considered to implement artificial intelligence (AI) to create documents for the medical field. Artificial intelligence could be used for completing repetitive documentation that would otherwise require a significant amount of time for humans (Willis & Jarrahi, 2019, p.202). The AI requires an upfront cost but after that, it is a zero-cost, quick option for creating documentation, it can fill out forms and create meeting notes using voice detection. In the engineering field documentation is used as communication, so being able to create documentation faster with AI would lead to faster communication. Engineers could save time using AI, which in turn they could spend on designing or conducting research for their projects. This in turn would speed up the project timeline. Another common solution in the medical field is having a scribe.

Scribes could also save time in addition to AI in the same ways by taking the responsibilities of documentation off the engineer. A major downside of scribes is the duration of time they work and their status as a student. In the medical field, most scribes are students who are working and taking classes. These scribes will only work for the short duration they are in school for (Shultz & Holmstrom, 2015, p. 372). In the engineering field, especially in classified projects, this would pose an issue. The process to get a security clearance can take over half a year, and this process would not be practical to bring in an extra hand to take notes. However one can argue that this is what companies do with engineering interns with a bit more design work. Regardless of the views of interns and scribes, I will stick with the less variable solution of AI.

Although AI does not have to go through a long background check like a human would, there are still serious security concerns associated with its usage. If AI were to be used on a classified project, it would be subject to cyber attackers trying to obtain classified information. This would essentially add an extra avenue for attackers trying to access the project's data (*The Impact and Associated Risks of AI on Future Military Operations*, 2023). Despite these concerns, with enough testing, policy-making, and verifying AI can be successfully implemented. Additionally, there are concerns about AI making mistakes on the documents. While it is true AI will make a mistake at some point, the best way to implement AI and mitigate this issue is to check the AI's documents. By checking the documents, the engineers would make sure no mistakes were made and would be familiarized with what is in the documentation.

Conclusion

All in all, documentation is extremely important in the engineering field for proper communication and ensuring the safety of the public. The process of documenting can be tedious and time-consuming leading to engineers spending less time designing. To combat this, I suggest the use of AI to help create documents like status reports, project plans, change requests, and other repetitive forms. If the AI is verified and double-checked by engineers, it can lead to a significant reduction in documentation time and an increase in productivity.

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