Creation of the UAHuntsville Aircraft Design Handbook

by

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Abstract

The UAHuntsville Aircraft Design Handbook was created to fulfill a need for students entering the Aircraft Design course to have a guideline to follow based upon the experiences and failures of previous students. The suggestions outlined within the handbook were derived from the author's personal experience, as well as testimonies and analysis provided by members of the 2011/2012 UAHuntsville Aircraft Design course. The topics covered include the basic organization of the team as well as methods of improving communication during the design and production phases of the project.

Honors Thesis Advisor: Dr. David Landrum
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Advisor Date

Department Chair Date

Honors Program Director Date

This Honors Thesis is a description of the creation of the UAHuntsville Aircraft Design Handbook for use in the senior level Aircraft Design course in the Department of Mechanical and Aerospace Engineering. The handbook was thought up as a useful tool for future students to use in order to avoid repeating the mistakes of past Aircraft Design students. The author, Joshua Crook, was a student in the 2011/2012 Aircraft Design course and used his experience as well as the evaluations of the other members of that same course to identify the major problems in the organization and operations of that team. In this thesis, the process of evaluating the problematic areas of the 2011/2012 Aircraft Design course is explained as well as an overview of the recommendations provided for each area.

The process for the eventual creation of this handbook began late in the final semester of the 2011/2012 Aircraft Design course. The author, Joshua Crook, approached the course advisor, Dr. David Landrum, about the possibility of performing a review of the actions performed by the students of the design team during the entire design process. Dr. Landrum believed that this was a good idea, but desired a document that future teams could use to help streamline their design process.

The author began the process of evaluating the performance of the 2011/2012 design team by holding a meeting with the team and discussing what they thought the most glaring problems were during the two semesters that they participated in the design process. The two areas that were repeated over and over in that meeting were the areas of time management, communication, and team structure. These two areas then became the primary focus of the Aircraft Design Handbook.

When discussing the problems encountered with respect to time management, the team was able to pinpoint the inactivity at the beginning of the first semester of the course. The team was in a holding pattern, waiting for the American Institute for Aeronautics and Astronautics (AIAA) to finalize the competition rules for the 2011/2012 Design/Build/Fly competition before the team began to put any concrete dimensions on their design. The handbook goes into further detail about the problem and outlines solutions for future teams to implement and hopefully avoid these problems.

When discussing the problems encountered with respect to communication, the team was able to pinpoint the lack of a definitive final design process and a lack of a process to implement design alterations. The team was creating designs without checking whether or not the design of one component was compatible with another component that had already been designed or even manufactured. The team was also making design changes during the manufacturing process, again without having a process to ensure that the change would function when the component was incorporated as part of the entire aircraft. The handbook goes into further detail about the problem and outlines solutions for future teams to implement and hopefully avoid these problems.

When discussing the problems encountered with respect to team structure, the team found that the structure put in place had too much overlap in responsibilities. The team was divided into multiple subsystem groups, however they made the error of placing the responsibility of designing the tail surfaces with the fuselage group instead of with the wing group, which is renamed the aerodynamics group in the handbook to better reflect its true responsibility. The overlap of responsibilities made it difficult for the team to keep track of all of the dimensions of the different features of the aircraft. This resulted in components not working in the manner in which they were designed, as well as requiring one member of the wing group and one member of the fuselage group to make their own little team-group to design the tail surfaces using the moment and lift data that was generated by the wing group. Because of this failure, the aircraft was longitudinally unstable in flight and crashed multiple times. The handbook goes into further detail about the problem and outlines solutions for future teams to implement and hopefully avoid these problems.

The author is not considering the possibility of publishing the handbook or this thesis report as it is designed to improve the UAHuntsville Aircraft Design course and allow the students to take advantage of a class who came before them and made mistakes without having the benefit of having that previous experience to look to for guidance. The handbook is attached in the Appendix of this document. The author has learned much about how to make the design team that he was a part of better, and it is his hope that future students will take these lessons to heart in their quest to become aerospace engineers.

The University of Alabama in Huntsville

Aircraft Design Handbook

Author: Joshua Crook

Advisor: Dr. David Landrum

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1.0 Introduction

This handbook is the brainchild of the author, Joshua Crook, and his advisor, Dr. David Landrum, for the express purpose of improving the performance of the students in the Aircraft Design course at the University of Alabama in Huntsville (UAH). Joshua Crook was the Project Manager of the 2011/2012 UAH Design/Build/Fly (DBF) team which participated in the Aircraft Design course during that time. His experiences, as well as the experiences of the entire team, are taken into account in this handbook and all recommendations that the author makes in this handbook are based upon these experiences.

This handbook will not be a step-by-step instruction booklet on how to design an aircraft. In fact, there will be precious little in the way of equations or mathematical models presented in this handbook, as it is the responsibility of the students of the Aircraft Design course to draw upon their knowledge obtained in their other engineering courses to decide how to proceed with the evaluation of their chosen design. There will be plenty of tips for the students of the Aircraft Design class to consider with regard to how to go about beginning and progressing the design through its various phases, all of which are based upon the experiences of the 2011/2012 DBF team.

This handbook will begin with recommendations on organizing the team structure/hierarchy, discussing the particulars of each role within the team. It will then cover the necessity of time management, as well as giving some guidance in the design process. As stated previously, it is up to the students of the Aircraft Design course to ultimately determine how to manage their time and create their design, but it is the hope of the author that this handbook might help to streamline the process for them.

2.0 Team Structure

The UAH Design/Build/Fly 2011/2012 team consisted of 13 team members. The desired team size for future teams is approximately 10 team members, as there were times when some team members had nothing to do with 13 team members. Therefore, the recommended team structure is based upon this 10 member expectation.

2.1 Organization

The team organizational chart is located below in Figure 1, which shows that the team will have five subsystem design groups which will work in coordination with the Course Advisor, Project Manager, Chief Engineer, and Chief Financial Officer. The specific roles will be outlined in section 2.2.

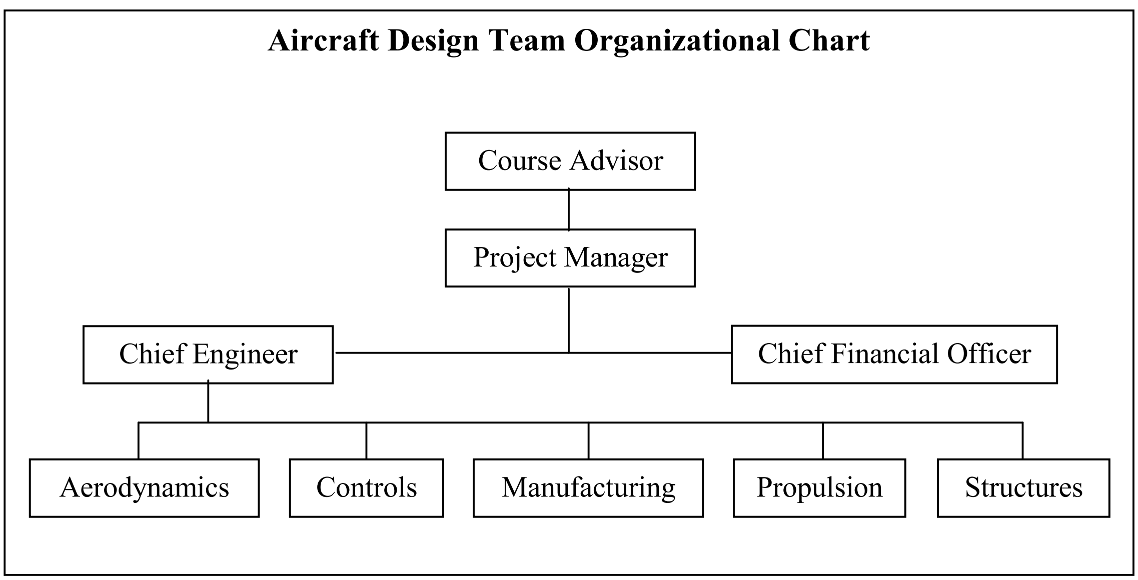

Figure 1: Team Organizational Chart

2.2 Team Member Roles

Please keep in mind that the following roles are solely a recommendation made by the author and should not be considered to be the only way to organize a design team.

- *Course Advisor*: The Course Advisor is the instructor of the Aircraft Design course. The Advisor assists the students with determining the requirements for the aircraft and guiding their time management.
- *Project Manager*: The Project Manager is the student chosen by the entire team that will be the leader of the project. The Project Manager is responsible for final decisions on design considerations and is responsible for creating and maintaining a schedule to keep the team on a reasonable timeframe for completion of the project. The Project Manager may serve on one additional subsystem group, but may not act as the group lead.
- *Chief Engineer*: The Chief Engineer is responsible for maintaining a current list of dimensions, weights, and important calculable results (such as maximum lift or velocity) for the design. The Chief Engineer also must sign off on all detailed designs, computer aided design (CAD) models, and design changes before submitting them to the Project Manager for final approval. The purpose for this is to have the "second set of eyes" look over the math and design considerations for any change so that when it is submitted to the Manager for approval, the Manager knows that the math is correct and that the design or correction will function appropriately. The Chief Engineer may serve on one additional subsystem group, but may not act as the group lead.
- *Chief Financial Officer*: The Chief Financial Officer, or simply the Finance Officer, is responsible for maintaining the budget. The Finance Officer will work closely with the Project Manager to provide the Manager with budget considerations when a design finalization or correction comes to the consideration of the Manager. The Finance Officer will also work with the Manager and Chief Engineer to determine the budget allotment for each subsystem group. The Chief Financial Officer may serve

on up to two additional subsystem groups, but may not act as the group lead for either.

- *Aerodynamics Group*: The Aerodynamics Group (AG) is responsible for the design and CAD models of the airfoil and wing dimensions, fuselage exterior, and tail surfaces. The AG lead must work in close coordination with the Propulsion lead to determine the thrust that the aircraft will generate. The AG lead also must work in close coordination with the Controls and Structures leads to ensure that the aircraft will be able to support itself and its payload as well as maneuver under the necessary loads. All designs created by the AG must be submitted to the Chief Engineer for preliminary approval. The AG should consist of a minimum of two team members, and it would be a good idea to include the Chief Engineer in this subsystem if it is feasible as the Chief Engineer is responsible for keeping track of the weights and balances of the aircraft.
- *Controls Group*: The Controls Group (ConG) is responsible for all of the electronics and linkages, from the radio transmitter to the servo linkage, required to actually operate the aircraft in flight. The ConG lead must ensure that he has accurate weights of all equipment, even including servo extensions or nylon clevises for control horns. These miniscule weights can add up faster than expected and can really throw off the weight balance equations. The weights and locations of all the electronic equipment should be provided to the Chief Engineer so that an accurate weight and balance can be maintained. The ConG is not responsible for the propulsion battery pack (in fact, it is not responsible for anything in the Propulsion subsystem beyond the connection from the Electronic Speed Controller [ESC] to the receiver), but it is responsible for the backup receiver battery pack. The ConG should strive to have its battery pack and receiver be mobile to affect the center of gravity (CG) of the aircraft. The ConG can be only one person if personnel are stretched thin, as it is not an intensive group. However, if the ConG consists of only one person, that person should be knowledgeable in remote-controlled aircraft electronic equipment.
- *Manufacturing Group*: The Manufacturing Group (MG) is responsible for taking the detailed CAD drawings that have been approved by the Chief Engineer and Project Manager and procuring the necessary materials to manufacture the aircraft. The MG

is expected to follow the designs given to them when manufacturing and not "engineering on the fly," which basically means that the MG should not be making changes based upon what they think will be an improvement to the design. The MG should communicate with the Project Manager to ensure that designs are given to them on schedule. The MG can have as many people as necessary, but probably will not need more than four people.

- *Propulsion Group*: The Propulsion Group (PG) is responsible for designing the entire propulsion system. This includes everything necessary to power the aircraft up to the connection from the ESC to the receiver. The PG must communicate with the Structures Group to ensure that the aircraft will have adequate ground clearance if the aircraft is being powered by a propeller. The PG will be responsible for a large percentage of the weight of the aircraft, so it is vitally important that the PG consider weight in every decision being made. The PG can also be run by one person, but only if that person is knowledgeable about remote-control aircraft propulsion systems.
- *Structures Group*: The Structures Group (SG) is responsible for the rigidity and strength of the aircraft. This group has the most responsibility for designing the structure of the aircraft to be as lightweight as possible. An important consideration for this group is adhesives. Adhesives add extra weight that can amass quickly and need to be accounted for. The author would suggest adding 15-20% extra mass to any structural component that needs adhesive. The SG also is responsible for incorporating all payloads required in the manner in which they are required to be incorporated. The SG needs a minimum of 2 group members, with a maximum of 3.

3.0 Design Considerations

In this section, the author will cover topics to consider during the design process. These topics will include time management, project requirements, detail design procedures, and design modification procedures. The 2011/2012 team operated within the rules of the American Institute of Aeronautics and Astronautics (AIAA) Design/Build/Fly competition, and the author will make the assumption that the students viewing this handbook are doing likewise.

3.1 Time Management

The single most important consideration in the entire project lifetime is time management. It is the aspect of the project that the 2011/2012 team struggled with the most.

In the 2011/2012 DBF competition, the rules were posted by the start of the fall semester, but were not officially finalized until the end of October. The 2011/2012 team made the mistake of not designing anything in detail until the rules were finalized. This ended up being a huge mistake as it did not allow for enough time in the spring semester to build and test the aircraft. However, the rules and requirements did not change drastically from inception to finality. Therefore, the first recommendation in regard to time management is to accept the rules put forth at the beginning of the semester and begin to design based upon those requirements. The designs can be changed later using the process to be outlined in section 3.4.

Depending upon the budget allotted to the team in the fall semester, the author would recommend that the students attempt to manufacture their first prototype in the fall semester. In the 2011/2012 year, the budget did not allow for multiple aircraft, so if that is still the case for the students viewing this handbook, the author would recommend that a wing be produced in the fall semester for testing and use any residual budget for that semester to purchase propulsion elements or electronic components. If the budget provided is for both the fall and spring semesters, then be judicious with it as it will be all that you are given. This approach of creating as much as possible as early as possible will help the team when it comes time to test the aircraft as there are usually multiple failures that will set the team back in terms of time.

It would also be useful if the Project Manager would require short progress reports from the subsystem group leads, Chief Engineer, and Chief Financial Officer every two weeks. In this way, the Project Manager can assess the progress of each group against the proposed project schedule to determine if a group needs assistance, advice, or materials in order to get back on schedule. This will also help the Project Manager relay an accurate assessment of the project's progress to the Course Advisor. These assessments will, in turn, aid the Course Advisor in determining final grades for the team members.

One final recommendation is to set the project end date (this will include a final report with actual flight data) 60 days in advance of the end of the semester. There will be setbacks, it is unavoidable. However, if the team strives to complete the project with about two months to spare, the setbacks will not lead to much scrambling for data when it comes time to create the final report and/or presentation.

3.2 Project Requirements

The very first thing the team should do after organizing their structure is to identify all of the requirements of the project. In the 2011/2012 year, these came from the DBF competition rules. Once all requirements are identified, the team as a whole should determine what the top-level (i.e. most important) requirements are. There are probably 7-15 top-level requirements that must be focused on in order to achieve the objectives of the project. The reason for having the entire team determine the top-level requirements is so that every team member understands what the most important requirements are.

One requirement that will always be a top-level requirement is to keep the weight of the aircraft as low as possible, even when a payload is incorporated. When setting this requirement, the team should set a definitive weight that the aircraft cannot exceed. In the case of the 2011/2012 team, the weight chosen was so close to the maximum lift that the aircraft actually was unable to take off under the largest required payload. To correct this, the aircraft maximum weight should probably be set at 75% of the maximum payload weight. For example, if the maximum payload is expected to add 5 lbs to the aircraft, then the aircraft should weigh 3.75 lbs for a total weight of less than 9 lbs when fully loaded. Obviously, if the aircraft weighs less than that, it is even better. The payload weight in 2011/2012 was approximately 4.5 lbs, however when fully loaded the aircraft weighed almost 11 lbs. Something for the students to keep in mind is that when dealing with a remote-controlled aircraft, one or two lbs can make a world of difference to the performance of their aircraft.

The author would suggest placing aircraft weight at a higher priority than ease-of-manufacture. The 2011/2012 team weighted the two about the same, but the choice to build the aircraft out of balsa and light plywood added significant weight to the aircraft when there were other options available such as carbon-fiber layups and plastic injection molding. If it is possible to build it lighter, even though it is more difficult, that should be the option for the team to choose. Make the aircraft weight the number one priority.

Another requirement that should be a top-level requirement is the lift necessary for the aircraft to obtain in order to perform all of its missions. The minimum lift necessary must be higher than the maximum allowable loaded weight. How much more the lift must exceed the weight depends upon the project requirements. If the project does not have a requirement for fast climbing or steep banked turns, then the lift may only need to exceed the weight by 15-20%. Faster climbs and steeper turns will require more lift to keep the aircraft from falling out of the sky. The exception to this rule is that an aircraft can climb faster with less lift *if* its thrust is near its weight by pulling up the nose more. In the 2011/2012 competition, the thrust was so much lower than the aircraft weight that the aircraft had to climb with a very shallow upward angle on the nose, thus the need for more lift.

Whenever a design decision is made, or a correction is pending approval, it is a good idea to ask the design team which top-level requirement the design improves and which it harms. This is a good way to analyze the trade-offs of certain designs and make a determination if the design is an overall improvement to the aircraft.

3.3 Detail Design Procedures

Another problem that the 2011/2012 team encountered was a lack of detailed design drawings and components that were constantly changing size or mass and the team was unable to keep up with the changes. This has led to the realization that there must be a procedure for finalizing the design of a component.

This procedure is only in place for a detail design (i.e. the one that will be manufactured) and not for a concept or preliminary design, although the team could institute a similar process for either of those if they so desired.

First, it would be recommended that the subsystem group who puts forward a detail design to be approved must have the following materials: mass information (being total mass as well as center of mass), materials table and diagram for the manufacturing group to use when creating the component, a table of all costs associated with the component, as well as a detailed CAD assembly file and drawing with the parts of the component containing the appropriate materials properties. All of these materials should be submitted to the Chief Engineer. If the Chief Engineer looks at the design and determines that all dimensions and masses are appropriate for inclusion in the overall design, then it will be forwarded to the Project Manager. It is then incumbent upon the Project Manager to consult with the Chief Financial Officer to clear any budget considerations and to give the design a final approval or disproval notice. If the design is approved by the Project Manager, then he will send the material to the Manufacturing Group lead for production. If the design is not approved, then the material will be returned to the subsystem group with a reason for why it was not approved and the subsystem group can then adjust their design as necessary.

The Chief Engineer should always maintain an active CAD assembly file where all the component files that are submitted to him are incorporated into a comprehensive assembly of the aircraft. This comprehensive detail design as well as the component detail designs should be kept in an orderly fashion to be put into the final report.

3.4 Design Modification Procedures

The procedure for design modification is very important to adhere to. In the 2011/2012 competition year, the team had many instances where a design was modified during manufacture to work better, and then it turned out that the resulting component did not fit because there was nobody to check the new design. The proposed procedure below will help to alleviate these problems.

First, it would be recommended that the subsystem group who puts forward a detail design modification to be approved must have the following materials: a proposal report detailing the necessity for the modification, mass information (being total mass as well as center of mass), materials table and diagram for the manufacturing group to use when creating the component, a table of all costs associated with the component, as well as a detailed CAD assembly file and drawing with the parts of the component containing the appropriate materials properties. All of these materials should be submitted to the Chief Engineer. If the Chief Engineer looks at the design and determines that all dimensions and masses are appropriate for inclusion in the overall design, then it will be forwarded to the Project Manager. It is then incumbent upon the Project Manager to consult with the Chief Financial Officer to clear any budget considerations and to give the design a final approval or disproval notice. If the design is approved by the Project Manager, then he will send the material to the Manufacturing Group lead for production. If the design is not approved, then the material will be returned to the subsystem group with a reason for why it was not approved and the subsystem group can then adjust their design as necessary.

4.0 Final Report Considerations

Another large problem that the 2011/2012 team encountered was compiling materials for the final report. This was due to a severe lack of communication and documentation.

Communication is very important in the design process, both for ensuring that the design is appropriate (which is covered in sections 3.3 and 3.4) and for compiling materials for inclusion into the final report. When it comes time to prepare the final report, the team should divide the writing duties as evenly as possible. It worked best for the 2011/2012 team to assign sections of the final report to the subsystem groups who performed the design analysis on each system. However, the problems came when attempting to put all of the different sections together. The Project Manager, or another student if one wishes to take the lead on the report, should create a template Microsoft Word file that is set up with the correct fonts, line spacing, and headings. This file should also include an instruction section for the other students to follow when creating their sections of the report so that the person compiling the report can simply copy and paste their submissions into the final report.

Another suggestion to improve team communication with respect to the final report is to clearly define deadlines and to work with the Course Advisor to set up penalties for missing final report deadlines. The Project Manager should have a meeting with the entire team to outline when the subsystem groups must have their section drafts completed, then when they must have their final drafts submitted to the report compiler. Next on the schedule should be the compilation draft due date, then a team review of the draft report, and finally a final draft and physical report date. The Course Advisor is necessary to help enforce these deadlines as the Project Manager has very little power to enforce the deadlines set for the team.

Documentation was something that the 2011/2012 team failed to do, and it would have helped greatly when it was time to write the final report. Whenever a design decision is reached, or a component is manufactured the team should document this. The 2011/2012 team noticed instances where a component had been manufactured, but in the final report they struggled with how exactly it was manufactured. Referring back to the problems encountered when a design was changed in the middle of manufacturing, there were also problems with the overall CAD drawings not matching up with the reported manufacturing and detailed drawings. A change should not be made in the middle of manufacturing if using the proposed procedures in section 3.4, but when something is altered or if there is an error in manufacturing and more material needs to be purchased to correct it, these actions should be documented for inclusion into the final report. Another important item to document is the number of man-hours spent designing and building the aircraft. This is the time spent building or designing the aircraft multiplied by the number of people working on the construction or design of the aircraft. This will give a more realistic commercial value to the production of the aircraft when the financial statements are included in the final report.

5.0 Summary

The author has presented a bevy of suggestions for students of future Aircraft Design courses to consider when beginning their own design projects. Issues ranging from the organization of the team to the documentation of activities for the final report have been covered in the context of how the 2011/2012 team failed to live up to their full potential in each of these categories. It is the wish of the author that the future teams would read about the difficulties faced by the 2011/2012 team on which he gained firsthand experience with this project and use those errors committed by the 2011/2012 team to learn from and to improve their own team so that they can better represent the quality of aerospace engineering students at UAH.

6.0 Acknowledgements

The author would like to thank Dr. David Landrum for his guidance during the author's participation in the 2011/2012 Aircraft Design course.

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