An RC Airplane Design Approach to Teaching Aerospace Principles

AYURG | Natural Sciences and Engineering (NSE) | *Tags: Design/Build*

This cover page is meant to focus your reading of the sample proposal, summarizing important aspects of proposal writing that the author did well or could have improved. ***Review the following sections before reading the sample.*** *The proposal is also annotated throughout to highlight key elements of the proposal's structure and content.* **Proposals now require the following subheadings: Introduction, Background/Lit Review, Methodology, and Qualifications. Your research question/hypothesis should be in bold.**

Proposal Strengths	Areas for Improvement
The introduction briefly contextualizes the research and clearly states what the project is.	The qualifications section should also end with a sentence about how the project relates to your future goals.
The background section follows a logical flow from a broad concept to the specific gap in knowledge.	While the proposal includes a works cited/references page, as all proposals should, the citations are inconsistent. Citations formatting should be consistent and in a style that is most common in your field, and the style used should be indicated. Northwestern Libraries host workshops for citation management software to help you navigate using citations and building works cited pages.
There is an explicit research question and/or hypothesis at the end of the background section that is justified by the lit review.	
The researcher provides a detailed description of their methodology and analysis plan, explaining the purpose of each step.	
Jargon is defined throughout, which makes the proposal accessible to the review committee, which is a smart but non-expert audience.	

Other Key Features to Consider

While figures are not mandatory, they can be included in an appendix. If you choose to include a figure or preliminary results, please see the "Drafting Appendices" tab under the "Developing Your Application Package" heading on the URG pages of the OUR website. This particular researcher includes a table demonstrating the qualities they want demonstrated in their final design and systems/communication methods that contribute those qualities. Figures should be complementary, but not necessary, to understanding your proposal.

All Academic Year URGs require a budget, which you will submit separate from your proposal as part of your application. We provide a template on our website to help you think through potential expenses. The scope of the proposal should focus on the project work for which you are requesting money.

The Academic Year URG application process encourages researchers to revise & resubmit their proposals if initially turned down. This researcher has made changes to their proposal based on the feedback they received from an earlier submission and does well to address changes that happened in the meantime. For research that has been in progress since before your AYURG application, you should discuss your previous work in the background section.

Much of this researcher's work is in progress at the time of writing the application, and they do well to use it to contextualize their request for AYURG funding for the upcoming expenses of materials to build the testbed. The AYURG can be used for research expenses during the same quarter it is received, but only if the AYURG is granted *before* any purchases are made.

While the researcher does well to identify a gap in knowledge, this should come later in the paragraph, after you have provided context and explained the importance of the topic.

Introduction: An unmet need exists for a physical platform that allows hands-on learning in the aerospace classroom that is affordable, interactive, and supports students' understanding of how physics translates to aerospace engineering design [1]. Therefore, I propose the design of a specialized "testbed" that involves a modified remote-controlled (RC) airplane. This unique model will enable the observation of various flight parameters through the use of interchangeable wings designed by students, thereby influencing different flight behaviors. The testbed aims to fulfill essential criteria such as flight capability, usability, durability, and data acquisition, setting it apart from traditional educational models. Ultimately, my testbed will be integrated into an "Intro to Aerospace" college prep course to spark interest in aerospace engineering by offering practical experience in design, aerodynamics, and manufacturing.

Clear research/project statement occurs in intro

Background: Traditionally, aerospace engineering education centers around collegiate settings with didactic, "lecture-style" lessons [2]. However, "active learning," which encompasses discussion, group projects, and short teacher demonstrations, is more effective in STEM education and helps narrow achievement gaps for underrepresented groups in the science and engineering fields [3, 4]. Moreover, the physical and financial constraints of traditional aerospace education tools, like wind tunnels, pose significant barriers [1].

Justifies filling gap in knowledge

RC planes have been used effectively to teach students how the physical features of the plane work during flight, such as the flaps moving opposite each other to cause the plane to turn [5]. However, basic understanding does not teach the impact of engineering design on individual plane components. Airplanes, from RC to commercial, have a smooth and contoured shape that reduces air resistance ("drag"), which allows air to flow efficiently over the body ("fuselage") [6]. Lift, the force that pushes the plane upward and is the minimum requirement for flight, must be greater than the plane's weight, so the plane can get off the ground and stay in the air [7]. Finally, wing shape and size also serve as crucial variables that impact flight behaviors because airflow over the wings generates lift. Moreover, flight takeoff velocity and landing force can be directly measured to demonstrate how these parameters are influenced by different plane design features, like changes to the wing, which is a simple change that students can make.

Jargon is defined throughout

However, existing hobby RC planes are not conducive to educational settings because they come with fixed wings that do not allow for wing shape or size alterations. One study on RC planes as an educational tool used 12 different planes to illustrate the effect of wing design choices on flight [5]! Furthermore, hobby RC planes lack critical data acquisition (DAQ) systems to collect takeoff velocity and landing force, which are vital for in-depth aerodynamic studies and analysis. This means that students miss out on the opportunity to observe, record, and analyze the quantitative impact of design changes on flight patterns. There is, therefore, an unmet need to design a specialized testbed utilizing a modified RC airplane, distinct from traditional models by observing various flight parameters by allowing for interchangeable wings, which influences different flight behaviors.

Identifies gap in knowledge & justifies filling gap

Additionally, the testbed's unorthodox design, which includes DAQ sensors and modular wings, reduces the aerodynamic efficiency of the overall testbed, which increases drag. These sensors also add weight, which means that more lift must be generated for the testbed to take off. **To overcome the aerodynamic inefficiencies caused by sensors and modular wings, what is the optimal configuration such that the plane meets the minimum requirements for flight while collecting and transmitting flight parameter data? Secondly, when a full-fidelity prototype meeting these theoretical criteria is built, does it meet criteria such as usability and durability?**

Background section ends with an explicit research question and/or hypothesis

Methodology: Since submitting my initial proposal in November, I developed an alternatives matrix to guide the testbed's design, which is a chart where one axis is a list of fundamental design requirements and the other axis is a list of researched solutions that fulfill these criteria (see Appendix A). I used this strategy to select the best velocity and force DAQ systems and communication methods. For example, when deciding on the velocity instrument for my preliminary design, I selected a device called a Pitot tube because it met all 13 of my necessary criteria. I used this method to select a force load cell and Arduino data logging for the other

References figure/appendix in body text

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instruments as well. However, given the uncertainty of incorporating unconventional components into an RC plane, it may be necessary to replace these components with others on the needs matrix to satisfy the testbed’s functional requirements when tested via simulation and physical prototype.

Point-first writing ("To…I will…")is used to describe and justify steps.

Currently, I am assessing the best wing configuration that simultaneously allows for a variety of cross-sectional wing shapes (the element that would be student-designed) while enabling the important requirement of flight. To determine the most optimal underlying wing design, I am creating SolidWorks computer-aided design (CAD) models of different wing configurations, including different motor and flap placements, supporting structure shapes, and the process of creating the three-dimensional wing from the shape. To compensate for the testbed’s unusual design, I am over-engineering the design process by running computer simulations to verify and optimize the performance of the testbed. Because the sensors and interchangeability of wings create unfavorable aerodynamic conditions, I will run computational fluid dynamics (CFD) simulations. CFD is a tool that simulates the airflow around a body; by using it, I will verify that the testbed can still generate enough upward lift force to enable flight even though it has decreased aerodynamic performance. To complete the necessary over-engineering, finite element analysis (FEA), which demonstrates how objects deform as a result of loads applied, allows me to visualize which components in the wing structure and fuselage can be reduced in size and weight without excessive deformation and fracture to accommodate for the additional DAQ weight.

Methods are clearly defined and each step is justified

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Moreover, I am in the process of iterating between CAD models and physical prototypes. Creating CAD models enables me to see the dynamics of how a system, such as the testbed’s wing flap, behaves in an ideal environment, whereas building an ensuing prototype allows me to understand how the system actually moves. As I make design changes, generating CFD and FEA studies can determine whether these changes are functionally acceptable. Once I determine from the CFD, FEA, and physical prototypes what the optimal wing structure and design and array of sensors are such that the testbed can still fly, interchange wings, and communicate parameters to users, I will construct a full, high-fidelity prototype and begin the testing stage.

The success of the prototype is qualified by the functionality of the testbed: control of different moving parts, interchangeability of sample wings, data acquisition from wind speed and contact force sensors, and control of the propeller's spin and speed. The testbed must then complete a maiden flight, defined as the testbed taking off from the ground, staying in the air while being maneuvered for 30 to 60 seconds, and landing back on the ground as directed. The testbed must also be usable and durable. To this extent, I will define a maximum set-up time of 5 minutes to ensure that the testbed can be assembled quickly for use in between student groups’ designs. To ensure durability, dynamic crash simulations will be performed in SolidWorks to demonstrate that the testbed will not fail upon impact at maximum operating velocities. I will repeat these tests on our physical model, and success will be defined as the ability of the testbed to repeat a flight sequence after enduring each crash scenario. Failure to meet any of these criteria means I will consult my alternatives matrix, determine what component or system needs to change to meet my base requirements and revisit the process of CAD, physical prototyping, and simulation.

Analysis plan is clearly defined and approach is justified

Describes parameters of success and plan of action in the case of failure

Qualifications: My professional, extracurricular, and academic experiences will significantly support my success in this project. I am Co-President of the Northwestern University Robotics Club (NURC) as well as an intern at Medtronic, the world's largest medical device company, and Hendrickson, a semi-truck suspension manufacturing company. Through these varied experiences, I have developed a solid foundation in engineering design, mechatronics and controls, and manufacturing processes, skills that are invaluable to completing this project. By building the RC airplane testbed, I will have a hands-on opportunity to implement the concepts I've learned, as such projects are not typically available in the standard Northwestern Engineering curriculum.

Describes relevant experiences and how they have prepared the researcher to conduct this research

The qualifications section should also end with a sentence about how the project relates to your future goals.

Budget

Table 1 outlines the estimated cost of building the RC airplane testbed system and students' wing prototypes.

Table 1: Line Item Budget

Item	**Estimated Cost**
Mechanical	
Balsa Wood	$180.00
Foam Board	$170.00
Carbon-Fiber PLA Plastic	$100.00
Carbon-Fiber Rods	$30.00
Steel wire (for flaps)	$10.00
Glue Gun and Hot Glue	$20.00
3x Frictionless Bearing (for wheels)	$12.00
Packing Tape	$6.00
Hotwire Cutter	$60.00
Electrical	
2x Li-Po Rechargeable Battery	$60.00
FlySky Transmitter and Receiver	$60.00
2x Brushless Motor and ESC	$60.00
10x Servo Motor	$20.00
2x ESP32 Microcontroller	$32.00
Gyroscope and Accelerometer	$40.00
Wires, Male to Female	$10.00
GPS Module	$30.00
Estimated Taxes	$100.00
Total	**$1000.00**

Appendix A

Appendix A shows a visual of the alternatives matrix.

	GPS	Pitot Tube	Pixhawk	Doppler Radar	Anemometer	Optical Flow Ser	Accelerometer	Radar Gun	Onboard Camer	Timing Gate
Accurate at low speeds		x		x	x			x		x
Accurate at low altitude		x		x	x		x	x	x	x
Real time data transmission	x	x	x	x	x	x	x	x		
No post-processing	x	x	x	x	x	x	x	x		
Data logging	x	x	x		x	x	x			
Lightweight		x	x		x	x	x			x
Physically small	x	x	x			x	x			x
Relatively cheap		x			x		x			
Implementation with Arduino/Flysky	x	x			x	x	x			
No interference susceptibility		x					x	x		x
User friendliness		x			x		x			
Low power consumption		x						x	x	x
Accuracy over distance	x	x	x		x		x		x	
Total	6	13	6	4	10	6	11	6	5	6

Citations are inconsistently formatted. Citations formatting should be consistent and in a style that is most common in your field, and the style used should be indicated.

References

[1] D. L. Newman, M. Stefkovich, C. Clasen, M. A. Franzen, and L. K. Wright, “Physical models can provide superior learning opportunities beyond the benefits of active engagements.” *Biochemistry and Molecular Biology Education*, vol. 46, no. 5, pp. 435-444, 2018, doi: 10.1002/bmb.21159.

[2] Gohardani, Omid, et al. “Aeronautical Engineering and aerospace engineering: A learner-centered teaching perspective in higher education.” *Journal of College Science Teaching*, vol. 044, no. 01, 2014, https://doi.org/10.2505/4/jcst14_044_01_64.

[3] E. J. Theobald, “Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math.” *Proceedings of the National Academy of Sciences*, vol. 117, no. 12, pp. 6476-6483, 2020, doi: 10.1073/pnas.1916903117.

[4] *[PDF] Online Wind Tunnel Laboratory | Semantic Scholar*, www.semanticscholar.org/paper/Online-Wind-Tunnel-Laboratory-Aziz-Chassapis/6a1bdccb874c27dd3055a337598cc2f2eb60cefb. Accessed 12 Feb. 2024.

[5] Jackson, Kathy, et al. “The role of radio-controlled model airplanes in the education of Aerospace Engineers.” *2015 ASEE Annual Conference and Exposition Proceedings*, https://doi.org/10.18260/p.24909.

[6] Dodbele, S., et al. “Shaping of airplane fuselages for minimum drag.” *24th Aerospace Sciences Meeting*, 6 Jan. 1986, https://doi.org/10.2514/6.1986-316.

[7] Wegener, Peter P. “Aerodynamic lift.” *What Makes Airplanes Fly?*, 1997, pp. 127–152, https://doi.org/10.1007/978-1-4612-2254-5_8.