AC 2011-943: THE UNITED STATES AIR FORCE ACADEMY DEPARTMENT OF AERONAUTICS GLIDER DESIGN WORKSHOP

Caitlin R. Thorn, United States Air Force Academy

Capt Caitlin Thorn is an instructor in the Department of Aeronautics at the United States Air Force Academy. Since commissioning from Auburn University in 2004, she has worked in the Launch and Range Program Office and the 5th Space Launch Squadron at Cape Canaveral, Florida. She holds an MS in Aeronautical Engineering from the Air Force Institute of Technology and is involved in local STEM outreach to K-12 schools in Colorado Springs.

Col Neal Barlow, U.S. Air Force Academy

Colonel Neal Barlow is the Chair of the Engineering Division, and Permanent Professor and Head of the Department of Aeronautical Engineering, United States Air Force Academy, Colorado.

Elaine M. Bryant, United States Air Force Academy

The United States Air Force Academy Department of Aeronautics Glider Design Workshop

Promoting STEM learning and development at the K-12 level is critical in fostering a desire to pursue STEM learning at the university level and beyond. Increasing student's exposure to STEM through hands-on activities and real-life applications is essential in stimulating interest and engaging students in the STEM disciplines, and also serves to encourage active learning in the classroom environment.

The United States Air Force Academy offers a Summer Seminar program in which prospective students from around the country take part in numerous workshops to include the following eight STEM disciplines: Aeronautics, Astronautics, Electrical Engineering, Computer Science, Engineering Mechanics, Physics, Chemistry and Math. These workshops each provide a brief overview of the respective subject as well as a hands-on project, demonstration, or activity to engage and stimulate student learning and apply their knowledge to real life applications.

In the curriculum exchange and demonstration session, the curriculum/lesson plan of the Department of Aeronautics Glider Design Workshop will be displayed and shared among participants. The curriculum includes introducing basic aeronautics concepts that are applied by students to design, build, and test their own individual balsa wood glider.

To begin the workshop, students first learn the basics of aeronautical flight. This can be divided into six different disciplines: propulsion, aerodynamics, aircraft and engine design, experimental and computational investigations, materials and structures, and stability and control. Students briefly learn about each of the disciplines, however, stability and control is the discipline that is most relevant to this exercise as the goal of the Glider Design Workshop is for students to build a glider designed for maximum glide range. In order to design and build a glider for maximum glide range, students learn how to design their glider for maximum longitudinal, lateral, and directional static and dynamic stability. This ensures that the glider will fly straight and level, and thus achieve maximum glide range. Longitudinal stability is the pitch control of the glider. To design for positive longitudinal static stability, the center of gravity must be forward of the aerodynamic center, or neutral point. This results in a negative pitching moment coefficient, and thus a stable glider. If the aerodynamic center is forward of the center of gravity, the glider will pitch nose up. This is corrected by moving the wings back on the fuselage, or by adding ballast to the nose. If the center of gravity is too far forward of the aerodynamic center, then the glider will pitch nose down. This is corrected by moving the wings forward on the fuselage or by reducing the amount of ballast on the nose. To maximize the dynamic longitudinal stability of the glider, the student must launch the glider at its equilibrium speed and flight path angle for maximum glide range. These quantities are calculated by the student; however, they must be estimated when launching the glider in the field. If the glider is not launched at the equilibrium speed, it exhibits a phugoid mode which involves a flight-path angle/airspeed oscillation with almost no change in angle of attack.

Lateral stability is the roll control of the glider. A high wing with slight dihedral and wing sweep (10 to 15 degrees) and a tall vertical tail result in a negative rolling moment coefficient and help ensure positive lateral static and dynamic stability. If the glider rolls to the left or right, adding ballast to the opposite wing is a simple fix. Also, ensuring that the angle of the dihedral and wing sweep is equal on both sides help to control the roll of the glider. If the glider enters a spiral mode or "death spiral," it is dynamically unstable in the lateral direction. In addition to the above design considerations, reducing the horizontal width of the tail may also help to laterally stabilize the glider.

Directional stability is the yaw control of the glider. If the glider yaws to the left or right, a "sizable" vertical tail aft of the center of gravity ensures a positive yawing moment coefficient and thus positive static directional stability. If the glider enters the Dutch roll mode in which it is oscillating in a yawing/rolling motion, it is directionally dynamically unstable. To correct for this the student may reduce the height of the vertical tail, decrease dihedral or wing sweep, or mount the wings lower on the fuselage. Students must be careful when designing for lateral and directional stability because there is a trade-off between the two. If lateral stability is increased, then directional stability is decreased and vice versa. It is important to find the right combination of lateral and directional stability in order to maximize the glide range of the glider.

After students have learned how to design their glider for maximum glide range and stability, they are given an electronic glider spreadsheet to begin the design process. The spreadsheet calls for various input values such as wing span, root chord, tip chord, sweep angle, dihedral angle, placement of wings on fuselage, vertical tail height, etc. As the students input these values, a top view drawing of the glider changes with their inputs, thus allowing the students to view their design as they input the various dimensions. Students must be careful to stay within the design limits of one 4"x18" piece of balsa wood (all control surfaces must fit on this piece) and a fuselage piece of 24" long. As they input their design values, various moment coefficients are calculated accordingly. The moment coefficients highlight in red if they are undesirable, thus indicating possible instability. Students are encouraged to be creative in their design; however, they must design the glider so that all control surfaces are able to fit on one piece of balsa wood, and that all calculated coefficients are not highlighted, indicating positive static and dynamic stability.

Once the student has finished designing the glider on the spreadsheet, he/she must create a scale cut-plan of the glider on graph paper to ensure the glider can be built from one piece of balsa wood. The student then commences with building the glider. One sheet of balsa wood and one fuselage piece are provided, as well as glue, exacto knives, rulers, protractors, and clay. Once built, it is encouraged that the students test fly their gliders, and make adjustments as necessary. It is also highly recommended that the students build to the design on the spreadsheet—stability problems are often seen from students who choose to "free" build their gliders without consulting the design.

The end of the workshop culminates is a glider fly-off in which students launch their gliders from an elevated platform to evaluate how well their glider flies. It is recommended that students launch from at least 20 feet in elevation. At least 100 feet of "runway" is also recommended for the fly-off. Launching from the bleachers of a school gymnasium works well for this application. This glider design activity is effective in sparking student interest in basic aeronautical engineering concepts while applying their design knowledge to a real life glider application.

For the curriculum exchange, facilitators will hand out guided lesson plans on how to design the gliders for maximum range and stability. The lesson plan also includes common pitfalls of glider designs and how to correct for these inaccuracies. CDs of the glider spreadsheet and build directions will also be available to participants. Facilitators will have the necessary materials on display to demonstrate simple steps to building the gliders, and will have several finished glider products as examples.

If time and space allows, the facilitators will lead one or two glider design and build sessions. It is recommended that each session have a maximum of 25 participants with sign-ups to occur beforehand. Each session will last approximately 1.5-2 hours, with 30 minutes for instruction and 1-1.5 hours for designing and building. There will not be a fly-off, although participants will be able to test fly their gliders. A laptop is recommended but not required for participants. Facilitators will have all other materials on hand for designing and building the gliders. The only requirement is table space for participants to design and build on. A classroom size room works very well for this activity.