TU STUDENTS SWEEP UAV DESIGN COMPETITION

To design a high-altitude long-endurance UAV to fly a twenty-hour reconnaissance mission at an altitude of 80,000ft, was the assignment for this year's undergraduate design competition. The competition was organized by the American Institute of Aeronautics and Astronautics (AIAA). Three students from Delft demonstrated superior design skills, winning the first, second, and third prizes.

TEXT **Raphael Klein, Steve Brust, Malcolm Brown and Dr. ir. Roelof Vos (FPP)**

Every year the American Institute of Aeronautics and Astronautics (AIAA) organizes an airplane design competition aimed towards undergraduate students from all over the world. All participants are asked to propose an airplane design in response to a given design specification. This year's specification asked individuals to develop an extremely flexible lightweight aircraft to carry out twenty-hour reconnaissance missions at an altitude of 80,000ft. Additional requirements included a payload weight of 400lb, a maximum take-off weight below 7500lb, a landing distance below 3600ft, and a wing span of no more than 300ft. Furthermore, the airplane structure had to be sized for the gust spectra of MIL-F-8785B and the steady maneuver loads defined in FAR 25.331, 25.349, and 25.351. As a final requirement, the airplane had to be transportable within a standard shipping container.

Three third-year students (Raphael Klein, Malcolm Brown and Steve Brust) took up this challenge and started in the fall of 2012 on their individual designs. All designs turned out very differently, but each of them ranked in the top three. We present an overview of the three winning designs.

HELP (1ST PLACE)

High Endurance Lightweight Program (H.E.L.P.) has been designed by Raphael Klein. It has a peculiar configuration: it is a twin-boom tail dragger with an inverted V-tail (see background image). This configuration came very late into the design process. It was only two weeks before the deadline that the configuration was finalized. The H.E.L.P. started as a flying wing. In the initial weeks, only the performance requirements were considered. The idea was to make a highly efficient flying wing with a very large aspect ratio that would perform well at very high altitude and would allow a large lift to drag ratio. However, several weeks into the design, new and more specific requirements were provided by AIAA. Two of these requirements became crucial: the aircraft should be able

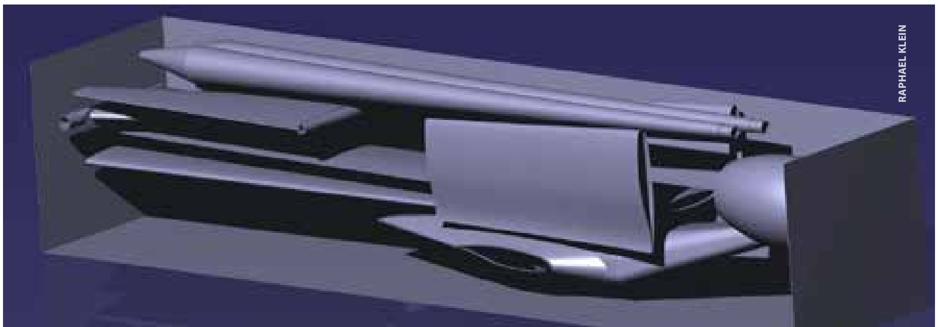

Figure 1. HELP UAV boxed in standard shipping container

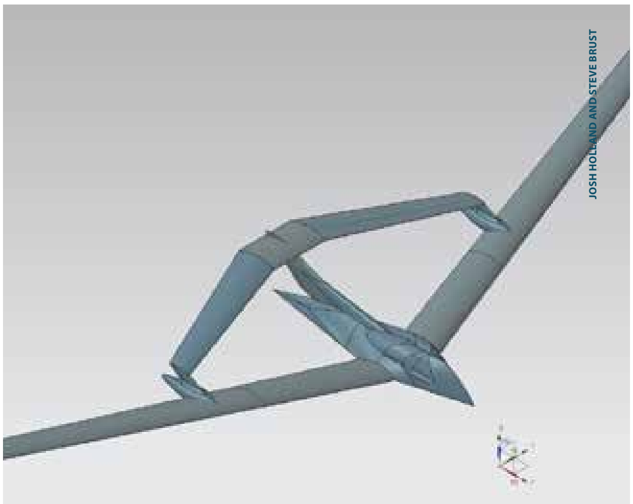

Figure 2. Isometric view of Rukh UAV

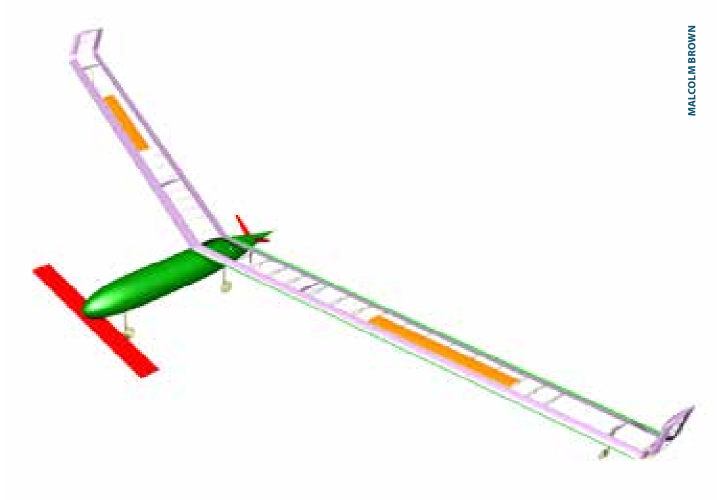

Figure 3. Structural layout of Sky-I UAV

to fit in a forty feet-shipping container and it should be structurally designed to meet jet fighter military requirements.

These new requirements led to drastic changes in the configuration as the flying wing configuration would not allow for storage in the specified container and would most certainly not meet military specifications. Slowly the span of the H.E.L.P. was shortened, the wing sweep was reduced and new features were added on to the aircraft. To maintain stability and controllability of the aircraft, a large tail was added at the end of twin booms and the engine was moved forward. The centerpiece of the H.E.L.P. was kept just long enough to fit as a whole in a container while carrying a payload of 400lb and having a large down-facing window. The other parts of the aircraft were all attached to this centerpiece by means of easily removable fixtures. Finally, the booms were connected through the tail for an increased flutter resistance.

The result is an aircraft that can withstand load factors of 9g's that can fit in a container (see Figure 1) while performing all the other requirements provided by the AIAA.

RUKH (2ND PLACE)

In an effort to reduce lift-induced drag at the operating altitude, the Rukh HALE UAV (Figure 2) was designed with a very high aspect ratio wing. This was achieved structurally with a partially joined wing, undoubtedly the aircraft's most striking visual feature. In using a derivative of a joined wing configuration the aircraft benefits from dual lifting surfaces; deciding on a safe but within bounds set of stability margins proves challenging. Strength of winds aloft, variations in the gust spectra, and requirements for safety and operability in military standards all hold significance when deciding various margins for the aircraft.

Structurally, the joined wing poses the biggest design obstacle. Differences in internal forces and moments experienced within the wing differ significantly between the inboard and outboard sections relative to the joint; meaning in certain portions of the wing the design could get away with using less structural weight. Facing stringent weight requirements, these possibilities are fully utilized. The internal structure of both the front and rear wings along with the fuselage is fully vetted by way of a FEM structural analysis tool. A structural component of particular interest and frustration is the wing joint that joins front and rear sections because it is also the point of attachment for the landing gear. Designing for maximum landing loads on one landing gear quickly sees the allowable loads near the limit.
An added challenge in itself was the distance between teammates and the shear amount of data and analysis to be shared as the Rukh UAV has been designed by Steve Brust (TU Delft) and Josh Holland (University of Kansas). Doing the work and making decisions is one thing, attempting to convey an interpretation of that data to someone in an e-mail or Skype conversation is another.

SKY-I (3RD PLACE)

The Sky-I as shown in Figure 3 was designed by Malcom Brown. It is a canard concept with high-aspect-ratio, swept-back wings and a central, airfoil-shaped fuselage with a pusher-mounted turbocharged piston propeller engine. The canard is chosen since it adds to the lift created while the aircraft remains stable, and, since the wings are very long, its wake influence is relatively small. It is also placed below the wing to reduce the downwash on the wing. Due to the short rear fuselage, it is chosen to use the winglets as vertical stabilizers with rudders. This requires the wings to be swept backwards, also adding to aeroelastic stability and the aircraft's innovative appearance. A propeller is used due to the very large loss in jet engine thrust at 80,000ft and the very long, slow loiters. The Rotax piston engine is also cheaper and easier to procure, even though it needs to be triple turbocharged, as well as being more efficient.

In terms of structure, the aircraft has a very minimal, lightweight composite structure. To reduce production costs the wings have a taper ratio of one and no twist, making the mold constant along the span, allowing smaller and simpler molds to be used. The spars are formed from closed tubes on the leading edge and trailing edge, already in the shape of the airfoil, allowing for perfect leading edge and trailing edge flow. The hollow ribs connect the spars and are covered with a lightweight flexible plastic film, allowing the wing to be extremely flexible but still strong. In order to not interrupt the leading-edge and trailing-edge spars, differential spoilers are used for roll control and high lift devices are not needed due to the light wing loading. The wings easily split into an outboard section and a fused center section to allow for transport. Finally the bicycle landing gear is inspired by the Lockheed U-2 setup with wing-mounted outrigger wheels.

FUTURE ENDEAVORS

The three wins demonstrate the excellent airplane design capability of Aerospace Engineering students from TU Delft. We intend to participate in this competition in the coming year. Interested students who want to compete can look up the design specification at www.aiaa.org or send an email to r.vos@tudelft.nl.