An Inter-Campus Capstone Design Project on VTOL

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Abstract

Since 2012, the Boeing Company has sponsored a multidisciplinary, inter-campus senior capstone design project to design futuristic vertical take-off and landing (VTOL) aircrafts. Each year, students from Iowa State University (ISU) and North Carolina A&T State University (NC A&T) team together to work on a different VTOL project. Two collaborative teams of students from ISU and N.C. A&T are formed to compete, and each team has seven aerospace engineering seniors from ISU and an equal number of students from N.C. A&T (from three majors: mechanical engineering, industrial engineering, and electrical engineering). The two teams design and build prototype VTOLs to compete. Student teams are judged on designs and prototype demonstrations, by a panel of professors from both universities and experts from Boeing.

Each year, the design competition is focused on a different futuristic VTOL aircraft based on probable technologies available for production in 2040: medical evacuation VTOL in 2012, high-rise rescue VTOL in 2013, personal air vehicle VTOL in 2014, and a hybrid airship for leisure cruising in 2015. Students from both campuses gained valuable collaborative experience in this meaningful and challenging project.

Keywords

Capstone design, multidisciplinary, industry-sponsored project

An Inter-campus Capstone Design Project

Industry-sponsored capstone design projects has been an effective method of achieving open-ended, real world, multidisciplinary, and team-based design experiences[1,2,3]. In the past four years, the Boeing Company has sponsored a multidisciplinary, inter-campus senior capstone design project to design a futuristic vertical takeoff and landing (VTOL) aircraft based on probable technologies available for production in 2040. Each year, students from Iowa State University (ISU) and North Carolina A&T State University (NC A&T) team together to work a on a different VTOL project: Medical Evacuation VTOL in 2012, High-Rise Rescue VTOL in 2013, Personal Air Vehicle (PAV) VTOL in 2014, and a hybrid airship for leisure cruising (LuxAir) in 2015.

The collaborative teams are primarily from two departments: Aerospace Engineering at ISU and Mechanical Engineering at NC A&T. The Aerospace Engineering Department at ISU is a large department with over 800 undergraduate students, while Mechanical Engineering Department at NC A&T has about 300 undergraduate students. ISU's Aerospace Engineering Department ranks top 20 in the nation. NC A&T is one of the nation's Historically Black Colleges and Universities (HBCU), and has been the nation's leading producer of African American engineers. The two

universities are separated by a distance of over a thousand miles and in different time zones, posing logistic challenges to collaborate.

Each year, two collaborative teams of students from ISU and N.C. A&T are formed to compete. Each team has seven aerospace engineering seniors from ISU and an equal number of students from N.C. A&T. The majority of students from N.C. A&T are mechanical engineering seniors (many of them are in aerospace option) along with industrial engineering seniors and electrical engineering seniors. The interdisciplinary makeup helps students tackle this challenging project.

In the beginning of each academic year, the project starts with a virtual kick-off meeting using videoconference facilities in both campuses and Boeing. This is followed by an on-site kick-off meeting at Boeing's Philadelphia facility in early September. The on-site meeting provides an opportunity for students from two universities to meet face to face, setting the stage for long-distance collaboration afterwards. Additionally, in this kick-off meeting, Boeing gives several presentations on technical aspects of VTOL and a tour of its wind tunnel facility and helicopter production facility. Following this on-site meeting, Boeing offered several teleconference seminars to address additional background information on VTOL.

There are two formal design reviews in the form of design competitions of the two student teams (blue and white): a conceptual design competition in November and a final design review with a prototype VTOL demonstration/competition in April. These two design reviews are held on alternate college campuses. Students were judged on designs and technical demonstrations by a panel of experts from Boeing along with professors from both universities. This unusual senior design projects enrich and expand students' design experience in the real world situation. In the following section, the technical requirements of these projects are detailed.

VTOL 2040 Projects

The VTOL projects are based on probable technologies available for production in 2040. Students are encouraged to explore how things are like 25+ years from now, and the trend of applicable technology headed. To help the design process, students are required to use QFD (Quality Function Deployment) diagram to lay out what's and how's, and are urged to use Systems Engineering V model to go through the steps of requirements formulation, concept generation and selection, trade studies, preliminary and detailed designs, as well as component and sub-system tests and system integration.

The overall system architecture of this VTOL project is divided in five subsystems (focus areas). Four focus areas are common to all four VTOL projects, and they are:

- Lift / Propulsion / Aerodynamics
- Structure / Landing Gear
- Flight and Guidance Control System
- Communications and Navigation Systems

The mission specific focus area in each year is:

- Medevac in 2012 – Cabin / Patient Area / Medical

- Urban High-Rise Rescue in 2013– Services Rescue system and compartment
- PAV in 2014 – Roadable Characteristics (ground transportation and storage)
- LuxAir in 2015 – Passenger and Staff Accommodations (rooms, common areas, services, safety/health concerns, meals, plumbing, noise, etc.)

The VTOL project also specifies key performance requirements in each year. In the 1st year, Medevac VTOL 2040 is required to:

- 100 nautical mile (nm) mission radius to recover (2) personnel in (1) hour back to base facility
- Stabilizing medical services to be available in aircraft, and medical communications to receiving doctors required from point of recovery to medical facility delivery

In the 2nd year, key performance requirements of the Urban High-Rise Rescue VTOL 2040 are:

- Rescue up to 6 people per trip from the side of a high-rise building, urban setting
- Deliver rescued people to disaster relief coordination site up to 1 mile away
- Conduct at least 5 trips before 'refuelling' required
- One on-board rescue crew member with limited/no pilot skills,
- Aerial deployment to rescue site, up to 10 miles from storage at a regional first responder facility
- No carbon-based emissions allowed from the aircraft

In the 3rd year, key performance requirements of the PAV VTOL are:

- Transport up to 4 people per trip from point to point of at least 60 miles in range
- The vehicle shall be "roadable", fit within a single lane, and capable of driving in neighborhood settings to available take-off and landing sites (35 mph max speed)
- The vehicle shall be capable of fitting into a single car garage spot
- Take-off and landing sites shall be no larger than 50 feet in diameter, and the aircraft shall be able to fit within that area during take-off and landing
- Vehicle shall be driveable/flyable by automobile driver's license holders after 40 hours of additional education and instruction
- Refuelling and/or charging shall occur in no more than 2 hours' time
- 80% of PAV materials by mass shall be recyclable. Environmentally hazardous materials shall make up no more than 5% of the PAV mass.

In the 4th year, key performance requirements of the hybrid airship for leisure cruising LuxAir are:

- The vehicle shall be capable of Vertical or Short Take-Off and Landing (V/STOL) maneuvers, based on probable technologies available for production in 2040
- The vehicle shall transport up to 50 passengers (including their belongings), and any necessary staff (the number of which is undefined) per trip with a minimum unfueled range of up to 4,000 nm

- The vehicle shall provide overnight accommodations to the passengers including, but not limited to, meal services, entertainment, and sleeping quarters, with maximum 2 days between resupply.
- The vehicle shall have a maximum speed capability of 80 KTAS to avoid weather while airborne
- The vehicle shall be capable of takeoffs and landings at designated maintenance, refueling, and resupplying ports in or near urban centers where passengers will begin or end their voyage. Loading of passengers and supplies shall be done within an 8 hour window.
- The vehicle shall be capable of loading and unloading passengers in remote locations that have limited infrastructure support.
- 80% of LuxAir materials by mass shall be recyclable. Environmentally hazardous materials shall make up no more than 5% of the LuxAir mass.

Prototype/Demonstrator

The project culminates in a final design review with a technology demonstration. Scale model prototypes of the VTOL are built as shown in the following figures. Figure 1 shows the flying drone of one model in the year 2 – a high-rise rescue VTOL, and Figure 2 shows its CAD model and the drone skeleton. Figure 3 shows the CAD model, CFD model of another design (8-rotors) in the same year. Figure 4 shows the picture of this drone.

Figure 1 Rescue VTOL-3 Rotors

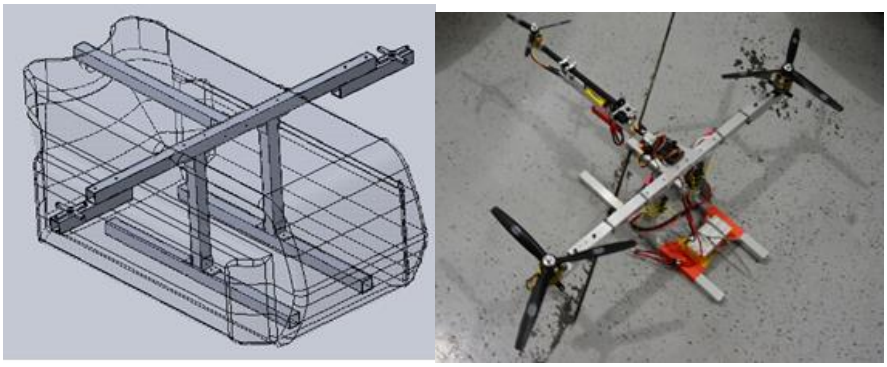

Figure 2 Rescue VTOL-3 Rotors

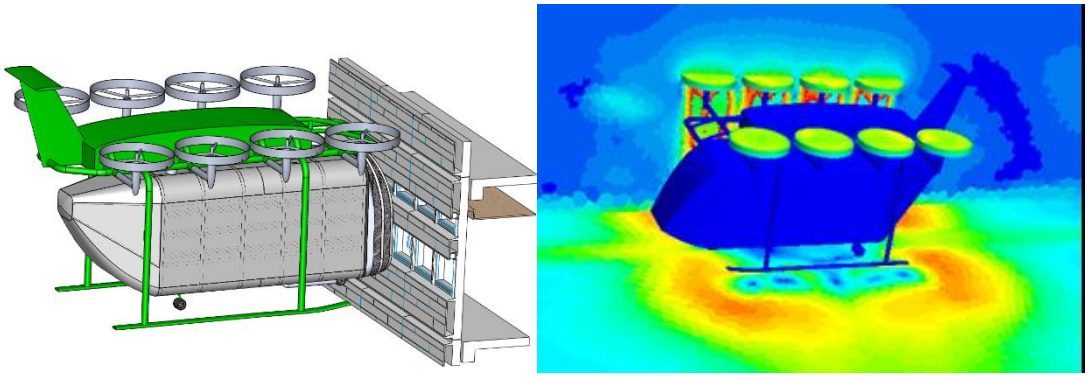

Figure 3 Rescue VTOL-8 Rotors

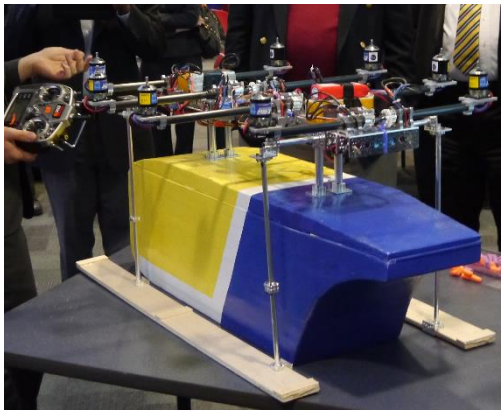

Figure 4 Rescue VTOL-8 Rotors

Figure 5, 6, and 7 show the CAD model of a PAV VTOL in the driving, VTOL, and flying mode respectively.

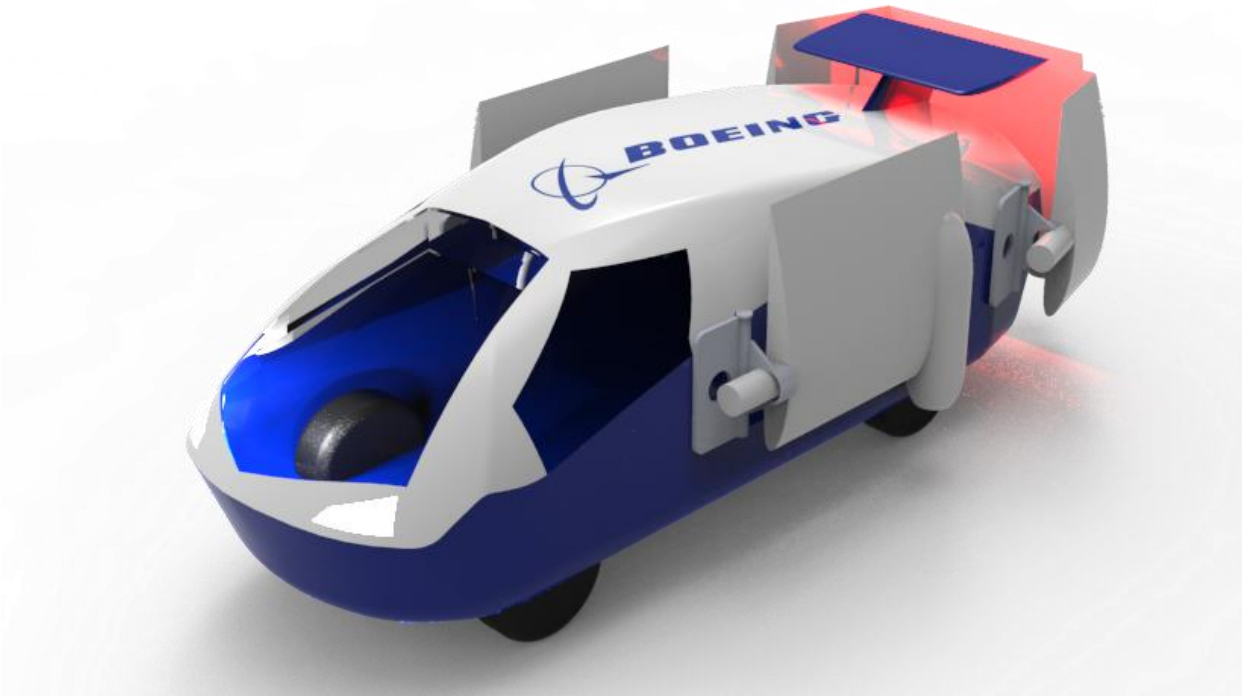

Figure 5 PAV Quad-Copter (tilt wing) in the driving mode

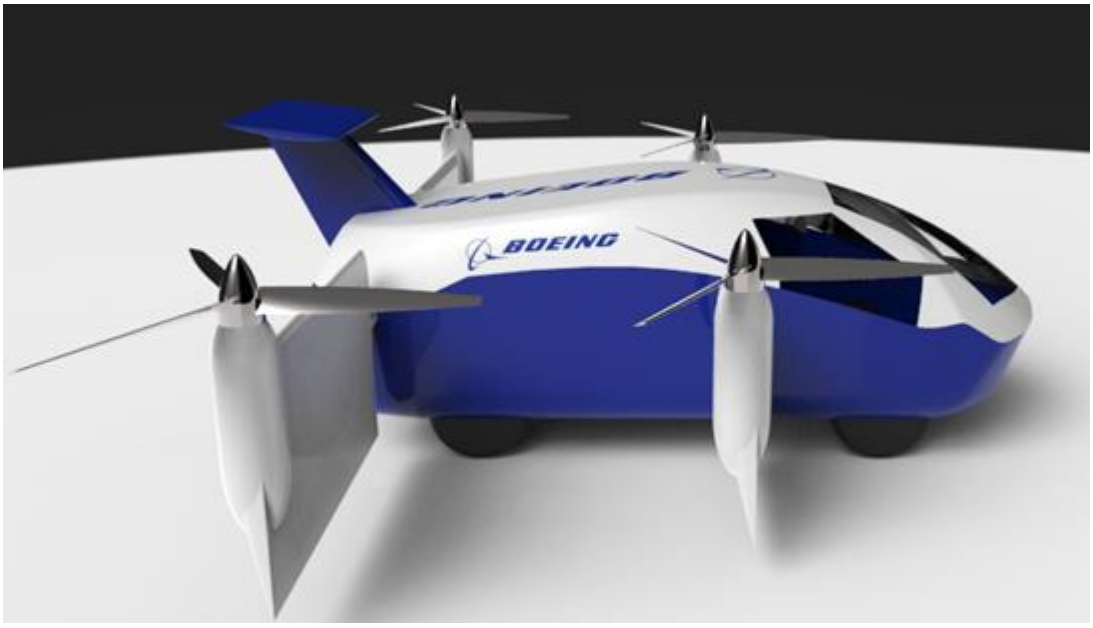

Figure 6 PAV Quad-Copter (take-off and landing)

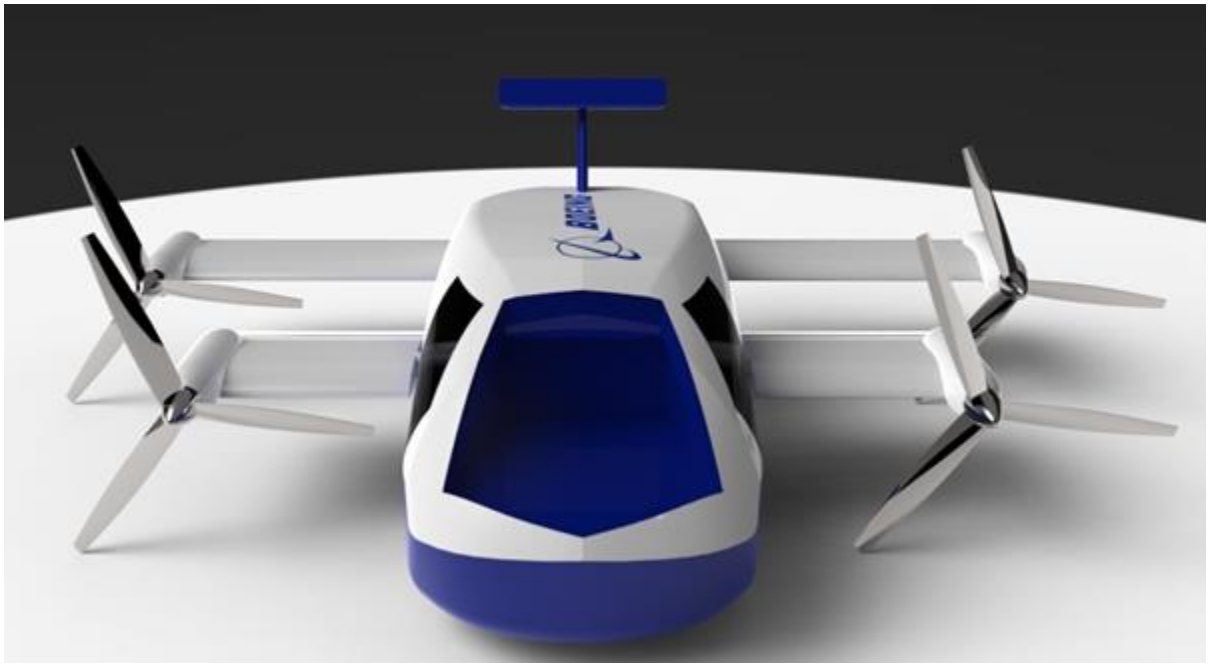

Figure 7 PAV Quad-Copter (cruising)

Figure 8, 9 and 10 show the PAV prototype, innards, and flying respectively.

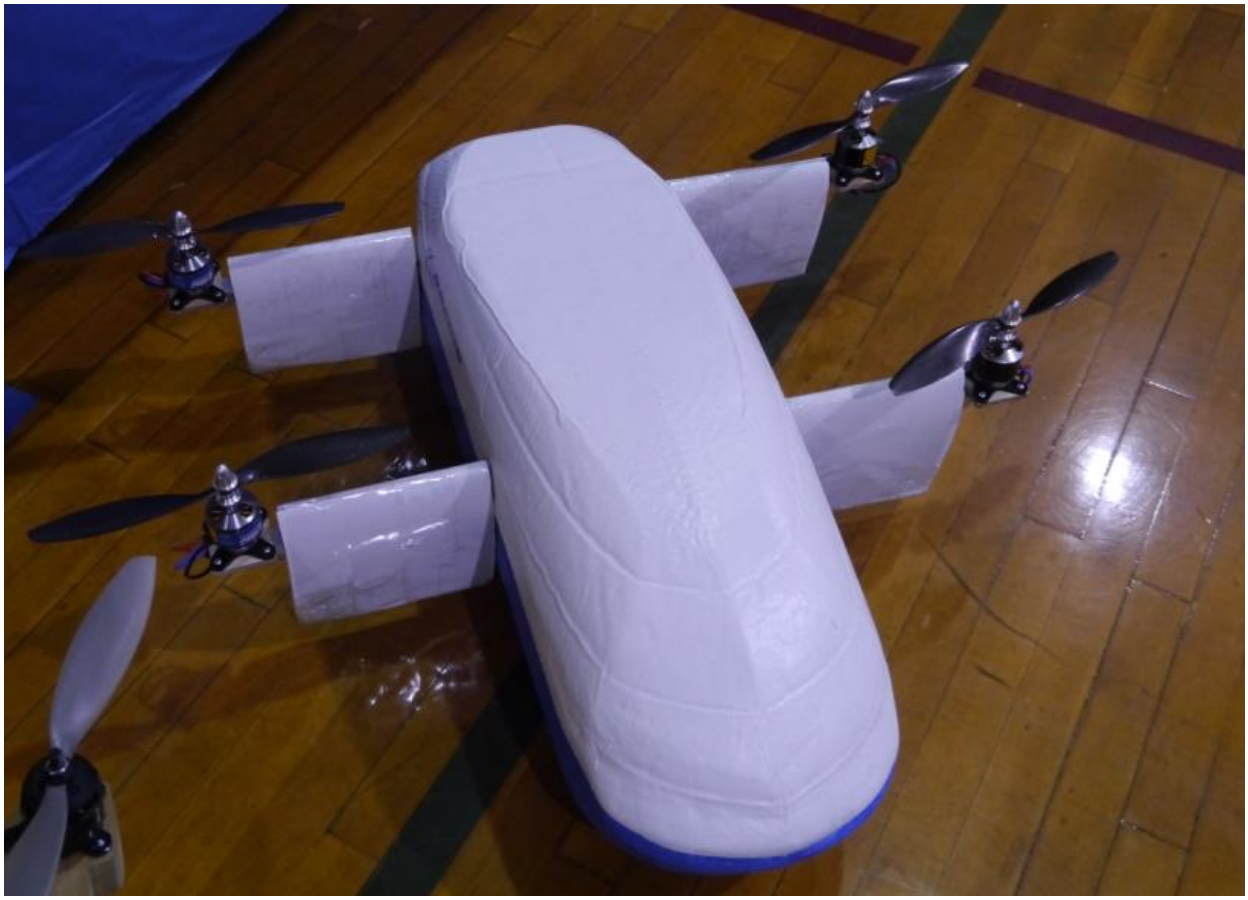

Figure 8 PAV Quad-Copter (tilt wing)

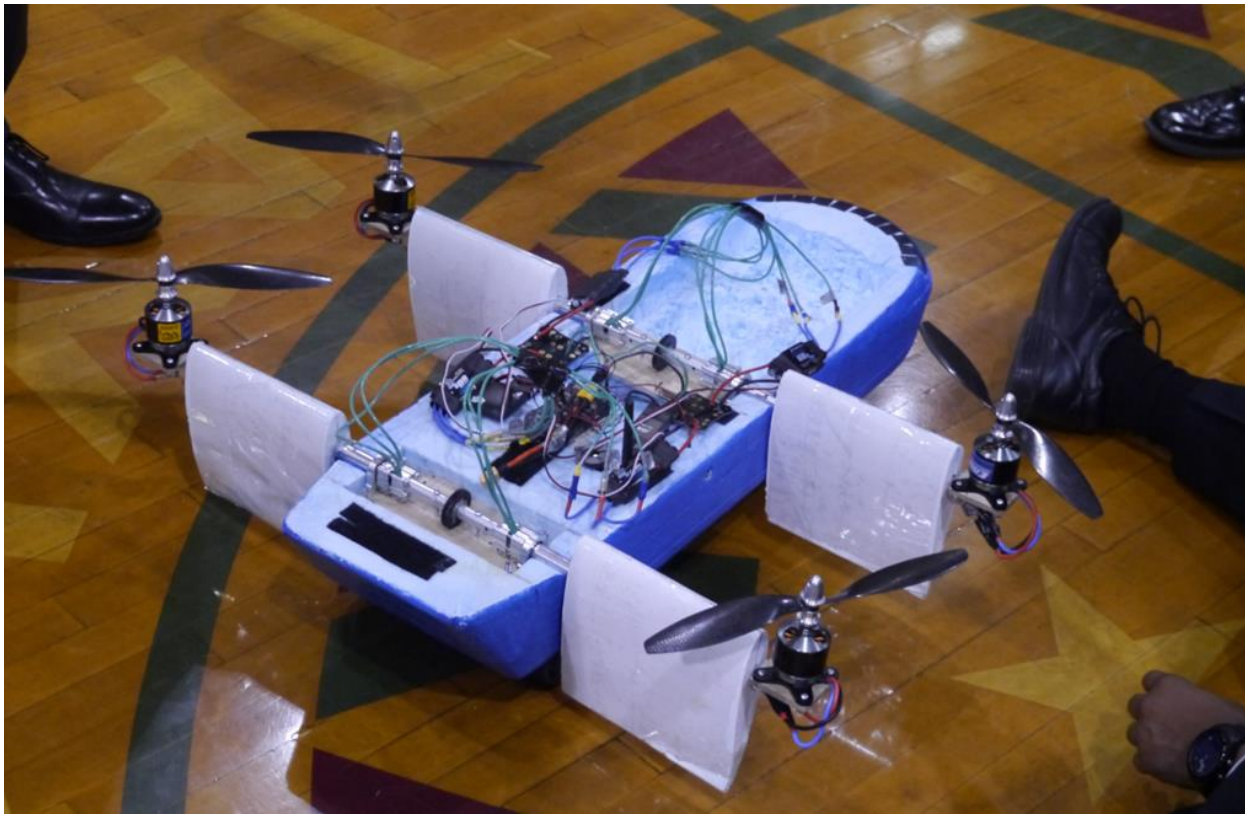

Figure 9 PAV Quad-Copter (innards)

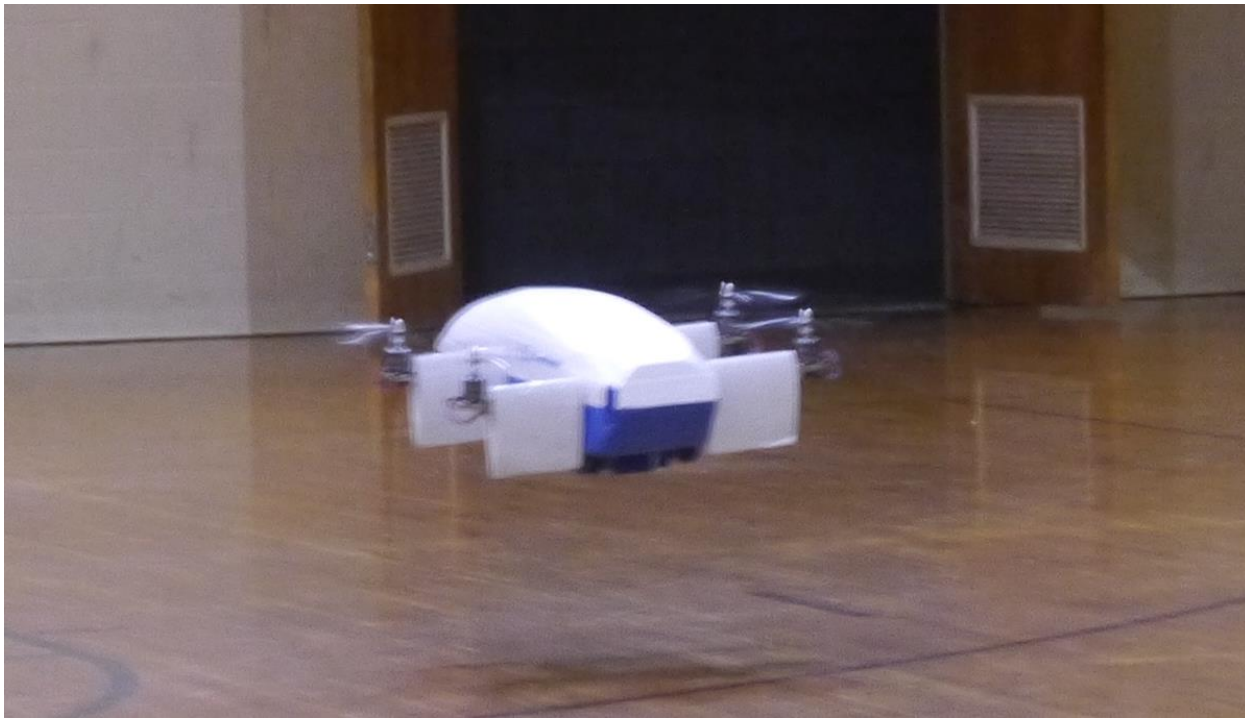

Figure 10 PAV Quad-Copter (flying)

Discussion

The ubiquitous quadcopter drones nowadays has fueled the interest of this VTOL project and available drone hardware made the prototype building easier. However, FAA rules[4,5] on flying the drone on campus severely limit locations to test the prototype.

Two aspects of this VTOL project are complementing each other and make the project unique and interesting. On one hand, students are designing futuristic VTOLs based on probable technologies available for production in 2040, and this opens up research activities to explore how things are like 25+ years from now. On the other hand, a VTOL demonstrator keeps them grounded on the fundamentals so that it can fly.

The multidisciplinary project, with team members from four majors in two universities, is a significant and challenging project to students. They all gained valuable insights on teamwork and project management through this project. The inter-campus aspect of the project, however, cannot be easily duplicated because of high travel costs, as the two universities are separated by a distance that necessitates air travel. Without corporate funding, it is highly unlikely the project will be able sustain in the current format.

Acknowledgement

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