FEATURE

"DOWN TO THE **LAST DETAIL**"

Using rigorous analysis, simulation, and testing criteria, a student team from the University of Calgary topped the field at the inaugural SAE AeroConnect Challenge in 2020.

Shown is the Schulich UAV team's unmanned aerial vehicle that was originally designed for maritime rescue, surveillance, and remote monitoring applications. The design of this aircraft was modified for better performance and used to develop new surveillance and communication systems for the SAE AeroConnect Challenge. Fabrication of the UAV was sponsored by ICARUS Aerospace.

IT WAS THE MIDDLE OF MARCH, and we (members of Schulich UAV, a team from the University of Calgary) were less than a week away from flying out to California to attend the inaugural SAE AeroConnect Challenge. It was our first year competing at an SAE event, and we didn't know what to expect once we got there. Nevertheless, we were excited to see how we would fare on an international stage. Confident we could win big, we packed our bags and raced to put finishing touches on our presentation when we were suddenly stopped in our tracks by the emergence of a new pandemic. The competition—and our hopes of winning—had just been suspended.

While nothing could have fully prepared us for the pandemic, we did our best to adapt to the circumstances. The competition had been moved online, and we faced our own challenges with trying to meet, work, and compete in this new virtual environment. Despite the changes, our approach to solving problems had remained the same throughout the year. We would always start by asking difficult questions and went searching for detailed answers. Looking back, it was this very attitude that had led to most of our growth and success as a team. In fact, it was a seemingly

The SAE AeroConnect Challenge is a design-only collegiate competition, but the Calgary team had already built a drone (shown) for a university capstone project.

simple question we had asked ourselves in the beginning that started it all: could we compete at AeroConnect 2020?

Back in November 2019, I stumbled across an advertisement for this competition and was immediately enthralled by the idea of it: design a system of unmanned aerial vehicles (UAVs) to support fire-fighting missions in California. In light of circumstances at the time, mainly the Australian bushfires, this seemed like a call to action to help solve a pressing global issue. Excited by the idea of a new project, I soon took it up with my team and to my surprise, it was met with hesitation. They were rightfully worried that the design of this UAV system would be too complicated, given how much we already had on our plates. This was because several months earlier we had set our sights on a completely different SAE competition (SAE Aero Design West, Advanced Class), and all our resources were directed towards it. Suddenly shifting our focus and increasing our scope in the middle of the fall semester would be an incredibly difficult task.

Nevertheless, we took this idea of a new project seriously and started to review the competition rules. It soon became apparent that our experience building similar surveillance drones for a capstone project would lend itself well to a project of this nature. This seemed like the perfect opportunity to figure out how well our previous experience would carry over in a competitive setting. With that in mind, we set our sights on competing in the first ever AeroConnect Challenge.

As we were starting to work on our overall design, we quickly realized that there were some major obstacles ahead of us. The first was the fact that we had never actually designed a plane to operate in conditions as dangerous as the ones we faced. We had no idea how we were supposed to accurately find the fire front. In addition to that, we didn't know how we were going to send any of the data that we could get a hold of to ground crews and fire suppression aircraft. Not to mention that all this had to be done autonomously in a fifty nautical mile operation radius without visual line of sight. It seemed like there were too many questions we needed to answer in too little time. We soon found ourselves overwhelmed and understaffed at this point, so we started to rapidly recruit people to help us find solutions to our design problems.

With a larger team that was better equipped to handle the tasks ahead of us, we decided to split our focus down the middle. There would be two sub-teams for this project, one for the mechanical design and one for the electrical/software design. We then began to solve our first major problem—seeing the fire. While we would perform grid searches of the mission area to roughly find where the fire was, we quickly figured out that a standard camera wouldn't be able to see through the smoke produced by an active forest fire, preventing us from locating it accurately.

In order to see through the smoke, our best option was to use an infrared (IR) camera. The IR camera also needed to capture specific wavelengths of light to stop us from picking up noise from unrelated heat signatures such

Landing gear and propulsion assemblies mounted to the fuselage during manufacturing. Materials were provided by ICARUS Aerospace.

A CAD model highlighting the modular design of the UAV.

as cars or animals. With these constraints in mind, we selected a camera that could capture medium wave infrared (MWIR) while also being lightweight and able rotate to provide flight stabilization. The camera we picked could also change its field of view so that we could have various coverage rates of the fire depending on the altitude and angle we flew at. This could be automatically adjusted using a series of on-board sensors. At the maximum coverage rate, we would be able to capture 137 square miles of imaging data per hour with a single plane. To put that into perspective, it would take about 150 hours of flight time to image the entirety of the 2019 Californian wildfires with a coverage rate of 50 square miles per hour — we had nearly three times that. While a single plane may have been sufficient, time would be a critical factor in an actual wildfire and we therefore opted to use two imaging planes per unit in our design to speed up our data collection rate.

While we had managed to sort out our issues with imaging, the next step was to process and analyze the data. In short, we needed to accomplish the following objectives:

1. Locate the fire front.
2. Stitch the images together to get an overall view of the situation.
3. Transmit the information to ground stations and first responders.

We started by setting up two types of image processing. One was more in-depth but required our imaging drones to land, while the second type of processing was less accurate but much faster and could be done in-flight using our on-board computers. This type of rapid image processing would be crucial, as it would help to reduce response times for ground crews. To process the images effectively, we first limited the rate of images that were taken to increase our operational efficiency. This would allow us to get a holistic view of the situation without slowing down our processing speeds.

Next, we would threshold the images to give us a clear picture of where the fire front was located. After compressing the image, we would then be able to transmit it live, back to our ground station for further processing using our communication drones. These two separate drones would each carry a radio repeater for land mobile radio systems and act as a relay plane for over-the-horizon communications. These acted as mobile signal extenders and helped to transmit all the information that was gathered through the imaging planes. Once these images had been transmitted, we would be able to stitch them together onto a digital elevation model using flight data. This could then be used to aid in decision making when paired with local meteorological data as we could predict where the fire was headed next. Using this information, we would then be able to optimize the flight paths of supporting fire suppression aircraft using a heuristic algorithm to best contain the fire.

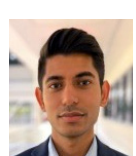
All this could be done using the information gathered through a ground station and system of four UAVs (two for imaging, two for communications). These drones were all modular, easily transportable, and could be launched into the air almost instantly using pneumatic launch rails. With a

An example of a post-processed image. The white markers indicate the location of active fires.

wingspan of seventeen feet, a cruise speed of 65 knots, and an operational ceiling of 25,000 feet, the imaging drones could fly for three hours or a distance of 195 nautical miles. The communications drones could fly for almost four times that, as they were lighter and carried more fuel in place of the camera.

The mechanical design for these UAVs was shaped by factors such as the weight and dimensions of the camera, endurance, elevation, and take-off/landing requirements. A high wing design with modular wings and tail was chosen for flight stability and transportability. This type of modular design would allow for faster on-site assembly and reduce the time needed to swap out critical components during a mission if they were to be damaged. Our attempts at creating an efficient vehicle also dictated several of our design decisions, from the composite materials we selected to the airfoil of the drones. Finally, all of our decisions were verified using rigorous analysis, simulation, and testing criteria to ensure that our drones would be able to effectively support wildfire surveillance and suppression missions.

After finishing our overall design, we shifted our focus to prepare for the competition. The transition to an online event caused us to re-evaluate our strategy. We knew that it would come down to how well we would defend our decisions down to the last detail. With that in mind, we spent weeks practicing our delivery, transitions, and timing. Leaving nothing to chance, we exceeded our own expectations when the day of the competition arrived. After the scores had been tallied, we finished the year with our first ever competitive win. Our habit of asking difficult questions and paying attention to details helped us as both individuals and as a team to learn, grow, and inevitably succeed. ■



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