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SOAPdrones

Unmanned Aerial Systems Flight and Payload Challenge

Abstract

SOAPdrones was created in 2014 by an American with the singular goal of creating drones with lifting capacity for aerial transportation and logistics. We focus on reliable software, electronics, and engineering capability for the end goal of building complete drone systems carrying larger payloads autonomously with a view to commercialization by 2020.

Our team's approach has been to combine the speed of drones systems with the strength of helicopters systems. While this approach is not unique - many other groups are working on this around the world - the solutions we have devised to deliver the improvements detailed in this concept paper are unique.

The potential impact of our approach will allow drones to carry significantly more weight than any other current drone system available and with the autonomy that helicopters lack. Our technology will help emergency services, search, surveillance, communication, and associated supply delivery, be executed autonomously.

We propose to meet the goals of the Challenge by expanding on our existing design, the Heavy Lift Vertical Takeoff Drone (HLVTD). The HLVTD system is already well developed, with a Technology Readiness Level between 3–6, as detailed in this concept paper. With our well progressed design, dedicated staff, a world-class team of support staff and in-house workshop capabilities, SOAPdrones is ready to achieve the full capability as directed within the Challenge goals and timeframe.

To achieve the goals of the Challenge our team will have a target flight time for each payload:

- 10lbs 4 to 6 hours
- 15lbs 2 to 4 hours
- 20lbs 1 to 2 hours

The fuel source is unleaded gasoline, the energy densities of these system is still superior to batteries and this fuel source makes the drones an easy firefighter and law enforcement scenarios.

SOAPdrones is an US-Australian company. If this Phase 1 concept paper is accepted, Phase 2 of the Challenge will be executed in Canberra, Australia.

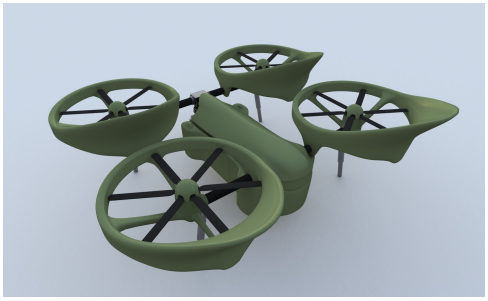
The Challenge goals and end-beneficiaries resonate strongly with SOAPdrones' business goals and align with our current level of technology development. Our team is excited to showcase our heavy lift drone capability against Challenge goals, collaborate on best drone technology outcomes, and enhance our profile and networks.

Project Description

Philosophy

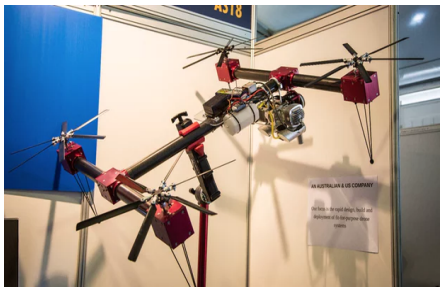
Our team has been working on heavy lift drone systems for four years. During this time we have learned that hobbyists, computer programmers, and aeronautical engineers think very differently, with all of them having their biases and strengths in their approach to solving autonomous heavy lift flight challenges. We recognise the importance of bringing these different groups together to find new solutions of payload carrying drone systems and focus on collaborating, where possible, in our work.

The Drone



The current drone system we have been developing is an experimental UAV we call the Heavy Lift Vertical Takeoff Drone (HLVTD). The HLVTD is a combination of drone and helicopter systems. The HLVTD is a H configuration drone with variable thrust to control pitch, yaw, and roll (see pictures). The software in the system is ArduPilot;we are currently working with the lead developers of ArduPilot.

The main advantage of using this configuration is that it gives us the ability to use gas-driven engines with computer control found in battery-powered drones. Furthermore, we can speed up the reaction time of standard helicopter systems from 3 to 7 inputs/second to 300 inputs/second. What this all means is that our drone system has lifting capacity similar to a helicopter but the autonomy and footprint of smaller drone systems.



For the Challenge, we would modify our current prototype to fit the Challenge payload goals and increase our current system's reliability, allowing us to not only perform better in the Challenge but to take us one step closer to commercialization and integration into law enforcement and emergency services capability.

Collaboration

SOAPdrones' ultimate goal is commercialization, however, the technology is moving way too fast not to collaborate with others. We focus on collaboration because we believe that the world will be a better place with improved autonomous, heavy lift drone technology. We are working with Canberra UAV, the winners of the UAV Outback Challenge and the developers of the open source project ArduPilot. In working with ArduPilot we are supporting open source software development for the industry while improving our own systems. We pursue mutual support opportunities with universities and other reputable UAV organizations, allowing us to further our heavy lift drone technology and partner in progressing the overall industry. We also travel internationally to others working toward the same goals in heavy lift drone systems (see team pictures) and are looking forward to meeting other participants in the Challenge.

Safety, Licensing & Regulations

Being a US-Australian company entering a US-run Challenge, safety practices and procedures will follow Federal Aviation Administration (FAA) and Civil Aviation and Safety Authority (CASA) guidelines and regulations. We hold both FAA 107 and CASA RePL licensing.

All of the safety requirements detailed in the Challenge specifications are satisfied in our design. A drone kill switch and computer fail-safe procedure will be implemented. No parachute is needed as auto rotation software will be implemented. Structural integrity, manual override, kill switch performance, and auto-rotation performance will all be physically tested while radio system compliance will be performed by analysis of documentation. Pre-flight checklists and detailed safety

analyses will be conducted before flight tests. In addition to our own safety protocols and procedures, SOAPdrones will execute any safety procedure required by Challenger organizers and the relevant Government authorities.

Advantages and Capabilities

We currently have a working prototype and have developed the software to fly and control the HLVTD. We have shop facilities that include 3D printers and CNC machines to build these complicated and specialized systems. We have extensive experience in building drone systems and prototyping for purpose.

Location

Most of the team is located in Canberra, Australia, and the team leader (and company owner) is a US citizen for competition entry purposes. While proximity to the US is a challenge, being based in Australia's capital city provides real advantage for progressing drone systems technology.

The Canberra region is an international hub for UAV and aviation technology development. Teams located in the Canberra area include Google Project Wing, Pixhawk and the lead developers for ArduPilot and Mission Planner.

CASA, Australia's FAA equivalent, is based in Canberra, allowing for opportunities to collaborate on and influence evolving UAV regulations.CASA regularly hold conferences bringing drone company giants such as DJI, Boeing, General Atomics, Thales, Lockheed Martin, Northrop Grumman together with emerging companies like our own, allowing us unique direct networking and influencing opportunities.

The city of Canberra is set within the Australian Capital Territory, a low population density region that allows for horizon flights and associated testing.

Our team will cover any extra travel costs associated with successful progression to Phase 3.

Funding & Growth

Currently, the development of our systems is mostly voluntary and self-funded with a few grants and participating investors. The lack of funds slow and limit the speed and scope of development. However, we are currently in negotiations for funding with the Australian Defence Organisation (ADO) to further this technology and are talking to DARPA and the US Defense Forces for additional financing. Any money received from the Challenge will speed up and contribute to our HLVTD technology.

Media

https://newatlas.com/soapdrones-variable-pitch-multirotor-endurance/48202/
http://www.smh.com.au/technology/gadgets-on-the-go/humansized-pilotless-drones-could-save-lives-in-regional-australia-20161004-grv09g.html

The Challenge

Our commitment

SOAPdrones is in contract negotiations with the ADO for funding to further HLVTD technology with an estimated project start date of August 2018. Until then, we plan to work on the Challenge full time. The Challenge dates coincide very well with our company's current development cycle and goals or future commercialization into law enforcement and emergency services fields.

What will be produced

Our team will produce two HLVTD drones with payload attachments and accompanying ground tracking equipment, and two two-stroke engines with modifications to meet Challenge goals. We will also produce software modifications (which we'll release to the ArduPilot community to help others) and a modified ground control station.

Baseline Capability

Our current baseline has been established by the build of a small working prototype. Challenge goal is to reach a Technology Readiness Level (TRL - https://en.wikipedia.org/wiki/Technology_readiness_level) of 6 in each category.

Drone Systems	**Note**	**TRL**
Software	Working but not tuned	4
Frame	Working but not robust	3
Electronics	Working no improvement needed	6
Autopilot	Working no improvement needed	6
Ground Control	Working minor modifications	5
GPS	Working minor modifications	5
Engine	Working needs modification for endurance	3
Drivetrain	Working needs refinement	4
Fuel	Working but limited by frame and Engine development	3
Payload attachment	Not working or tested	2

Systems Engineering

SOAPdrones will develop the HLVTD through our Systems Engineering Management Process. This process, developed in accordance with ISO 15288, allows us to ensure our designs meet the ultimate goals of the project at every design phase.

Our design phases will be:

1. **Plan & Design.** During this phase, we set our own internal specification derived from the provided UAS specification. The specification sets our design goals, determines the division of subsystems and informs the test and verification methods. From the specification, we will conduct extensive design work on the drone system towards those goals. This phase also includes the formalisation of risk and safety analyses, and assigning roles and responsibilities for the build phase. The Plan & Design phase concludes with a Preliminary Design Review where the CAD, electronic, and software designs are scrutinised to ensure their compliance with the goals of the project.
2. **Build.** The Build phase carries out the physical construction of the drone. During this phase, the team constantly monitors the progress of the construction of each subsystem, ensuring compliance with the design. Bench testing and subsystem functional testing are used during this phase.
3. **Test & Rebuild.** The Testing and Rebuild phase tests the complete system against the requirements set by the specification. Unique to SOAPdrones is the ability to rapidly redesign and Rebuild after Testing. The extremely fast product development cycle, characterized by the maxim 'crash on Monday, fly again on Friday', allows us to rapidly iterate through multiple build and test cycles in order to improve performance well beyond the minimum specifications.

Timing & Cost

Our team has broken down our three design phases over 12 weeks (see chart below), allowing three weeks for unforeseen complications across the Challenge. The cost is a conservative estimate and will be reported on weekly with any significant changes being reported immediately.

Project Phase	Dates	Produced and Reports	Cost
Plan & Design	February 5 to February 26 3 weeks	CAD models, software simulations, finalized designs, safety reports, Risk Analysis and parts ordered.	$8,000 - parts and materials (engine servos, flight controls, carbon fiber tubes, belts, pulleys, etc)
Build	February 26 to March 12 2 weeks	CNC, 3D printing, engine modification,vehicle build, electronics integration, bench testing.	$5,000 - materials (titanium 3D printing filament, aluminum for CNC, etc)
Test & Rebuild	March 12 to April 30 7 one week cycles	Weekly flight test and reporting, baseline capabilities testing - payload, weight capability, flight time.	$7,000 - replacement parts
Final challenge flight report and Video Test & Evaluation	April 30 to May 24 3 weeks	All final reports and final challenge Video completed and submitted	$0

Interim Performance Metrics

In order to meet the specifications of the challenge, SOAPdrones' internal test plans will include metrics to assess the following performance measures:

1. Altitude positional accuracy, measuring the vertical height above ground of the drone. Not to exceed the 50±5ft Challenge requirement.
2. Horizontal positional accuracy, measuring the variance both horizontal axes. Not to exceed a radius of 5ft.
3. Take off performance, measuring the total load on the drone system during vertical take-off to ensure it is safely within its flight envelope.
4. Take off positional accuracy, measuring the actual route of the drone against its planned route. Not to exceed 10ft variance.
5. Landing performance, measuring the g-loading of a landing. Not to exceed 3g.
6. Landing performance accuracy, measuring the variance in the actual route of the drone against its planned route, as well as the location of landing. Not to exceed 10ft variance in route or 5ft variance in final location.
7. Performance of auto-rotation safety system, measuring the g-loading of a crash landing after fuel safety shut-off at 50ft. Not to exceed 6g.

The flight and payload performance of the drone system, like all aircraft, is a balance between payload, total system weight and flight time. Within the 55lb limit, our design goals are to achieve the following payloads:

- 10lbs 4 to 6 hours
- 15lbs 2 to 4 hours
- 20lbs 1 to 2 hours

We expect to achieve a score in the range of 1000–1800 points.

Verification

Each stage of our systems engineering process includes verification that the design is meeting its stated goals. The process of communicating our verification to Challenge organizers will be in the form of a short weekly report, and a more in-depth Project Phase report with video (Youtube). All money spent will be reported on, and accounting will be certified by a licensed accountant from a reputable firm. Reporting on SOAPdrones from two independent groups - Canberra UAV and ECLIPS Engineering - can be arranged if needed, with the challenge organizer having separate contact with these groups if required.

Resume Information for Key Team Members

The Team

Our team has three full-time members and one part-time plus several supporting personnel, each with many years experience in the UAV field (see attached resumes). The main categories of expertise is software, systems engineering, electronics, build (3D printing & CNC), design, and administration. Our team has met with, and worked with, others working on heavy lift drones both in the hobbyist and commercial fields (see photos). A quick description of each team member is listed below.

From left to right:

Matthew Altenburg (Team leader) - Software, Electronics & AI
Aidan Cavanagh - 3D Printing & Neural Networks (AI)
Paul Riess - Design Lead, CAD, CNC & Build
Ben Chaplin (not shown) - Systems Engineer & Electronics

References

Andrew Tridgell	(Lead ArduPilot)	andrew@tridgell.net
James Owens	(President of Canberra UAV	(+61) 419 572965) scoobydrive@hotmail.com
Richard Blakeley	(ECLIPS)	+61 430 561 943 richard@eclips.engineering
Chantal Fleming	(fpvaustralia)	+61 2 6112 8551 chantal@fpvaustralia.com.au

Links

Outback Joe Challenge - https://uavchallenge.org/ https://en.wikipedia.org/wiki/UAV_Outback_Challenge