University of Colorado
Department of Aerospace Engineering Sciences
ASEN 4018

Project Definition Document (PDD)

High Endurance Rapidly Deployable Collaborative UAS (HERD)

Scan for animated Flight Trajectory

Approvals

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2.1. Project Customers

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3. Problem or Need

The purpose of this project is to fill a current gap in mission capability experienced by Colorado Emergency Services. Due to rescuers needing to navigate through austere terrain to conduct rescue operations, the effectiveness of communications, reconnaissance, and status monitoring are limited to line of sight (LOS) systems. This constrains capabilities in different terrain such as valleys, canyons, crevices, and areas with heavy vegetation, reducing the effectiveness of the response team. Current technology, such as radios and 5G data stations, experience LOS communication issues in current operational environments while newer technologies, such as satellite constellations, have not provided sufficient reliability during emergency response. The High Endurance Rapidly Deployable Collaborative UAS project (HERD-CU) attempts to fill this capability gap and allow responders to have a reliable and easily deployable solution to these problems.

The average flying time of a professional (non-typical customer) drone is approximately an hour [6]. The Boulder Rescue Team currently has a drone with a flying time of about thirty minutes. The UAS aims to have a continuous flight time of four hours and that presents a significant benefit as rescue missions are unpredictable and some assignments may exceed the thirty-minute to one-hour flight duration accessible from a typical drone. In addition, usual drones have an expected lifetime of 150-800 hours [7]. This short lifetime could raise an inconvenience to the rescue team as they would need to purchase new drones rather than use the money towards other technologies or equipment. The UAS, however, is focused to have a service flight time of a minimum of 1000 hours, which makes it convenient for the rescue team. Nonetheless, a long lifetime requires durable and strong materials in case the UAS encounters weather conditions such as light rain/snow, and winds up to 30 mph. Given that usual drones are splashproof and not waterproof [8], the UAS provides the notable benefit of surviving increased environmental severity and removing climatic barriers during missions.

With these benefits, it is salient to consider the size and weight of the aircraft. Usual drones are lightweight and portable meaning that there must be some tradeoffs between a common drone and the UAS. A lightweight drone does not necessarily mean greater performance. Components such as a smaller battery and weaker rotors can diminish the flight time and endurance (particularly in windy weather conditions) of the drone [9]. The UAS must acquire ample mobility and minimum weight for the team to easily transport and deploy it. Therefore, the size and weight of the UAS will be optimized in a way in which it will remain to provide superior performance.

Photos 1 & 2: *Drone photos of a flood rescue operation (left* [10]*) and a winter mountain rescue (right* [11]*) highlight the need for drones in austere environments.*

4. Previous Work

HERD-CU Phase 1A and 1B

The CARROT UAS design is a continuation of the TALON UAS design created by the HERD-CU team led by PM Jason Peloquin [5]. The TALON design focused on optimizing the aerodynamics, structure, and propulsion for a high endurance while minimizing the weight of the UAS.

1. High endurance aerodynamics

The TALON UAS was designed to have a highly efficient aerodynamic structure. It consists of a NACA 4412 at the root and a NACA 4406 at the tip with an Aspect ratio of 14.25. The high aspect ratio was a key factor for keeping the efficiency of the vehicle, but it put the total wingspan at 3.12 meters. In phase 1-C, the CARROT team will look at designs that reduce the size and weight of the TALON while further optimizing the endurance so that the UAS can be more easily stored and transported during use.

2. Structure

The TALON structure consists of XPS foam wings reinforced with carbon fiber rods and strips. This resulted in a maximum tensile and compressive bending stress of 192.2 kPa and 205.7 kPa respectively. The decisions on the structure helped minimize weight while staying capable of handling the maximum loads required. It is important for the CARROT design to maintain the updated maximum load requirements on the wings after minimizing the size.

3. Propulsion

To optimize the propulsion system for the TALON, the system needed to draw as little amperage as possible. The amperage draw depends on the propellor, motor, and thrust requirements for the propulsion system. The TALON propellor is a lightweight and economical plastic capable of enough RPM to achieve maximum thrust requirements. The chosen motor draws little amperes with an idle current of 2.1 amperes at 20 volts. The propeller and motor combined is capable of generating over 16 pounds of thrust, satisfying the maximum thrust requirements for climbout as well as headwinds. The CARROT team will have to design a propulsion system that will satisfy updated requirements for thrust during climbout and headwinds while further reducing the weight and size.

4. Launch Requirements

The launch goal of TALON was to design a UAS that shall be able to take off in an open clearing with a TBD ft. radius and clear a 20 ft. obstacle at the end of the launch radius. The CARROT team intends to improve on launch capabilities. Past work has launched from the top of a vehicle. In this iteration of the design, the launch will be performed directly by the customer. Tested and proven methods of launching UASs include the simple, parachute-assisted, boom, hardpoint, tow-line, ship-ratio, catapult, and submarine launch [1]. Since the UAS will need to be launched with ease, by hand, in a multitude of conditions, the CARROT team is investigating launch methods that will satisfy these requirements. Past UAS designs that have hand launch capability provide inspiration for new designs. Launch from a handheld device has also been successful in past work, which pulls concepts from a fixed rail launcher and applies them to a smaller scale model.

5. Portability

The TALON team focused on creating a UAS that shall be less than TBD feet in the longest linear dimension with a weight less than 11 lbs. CARROT is focusing efforts towards creating a UAS that minimizes the weight without compromising other capabilities of the UAS. The Boulder Emergency Squad is able to carry 40 to 50 lbs per person. The majority of this weight will come from pre-existing gear, leaving little room for added weight to each rescuer. Therefore, it is pertinent to design a UAS that caters to the portability needs of the customer. Past Lightweight UAS designs utilize materials such as plastic, aluminum alloys, and composites [2]. Plastics are common in UAS design due to their capability to mold and conform into desired shapes. Aluminum alloys are used most frequently due to their low density with respect to high strength. Aluminum alloys do not corrode easily, which is pertinent for the use of a UAS in flight conditions in extreme environments. Composites are another viable option for the construction of the UAS. Composites range from 15-45 percent lighter than aluminum alloys. Composites do not produce as much noise as the previous material options. Composites are resistant to corrosion, however they do absorb the impacts if the material is hit. This impact will affect how the UAS flies, instead of transferring the blow to another part of the UAS. Specific composite materials to investigate further include carbon fiber reinforced polymers, glass fiber reinforced polymers, boron fiber reinforced polymers, and aramid fiber reinforced polymers. Other benefits of composites include high maximum stiffness and strength, ease of machining, low values of thermal expansion at varying altitudes, and low maintenance. Disadvantages of composites with respect to metals include expense, labor-intensive building processes, and degrading performance at high temperatures and wet conditions.

6. Payload

The payload system is expected to be able to support a specific weight and volume. The payload shall make up less of the weight compared to the TALON design. Technological advancements have made new systems (ie. cameras) smaller and lighter. The CARROT team will assess an appropriate payload system at the specified budget of 4,000 USD. The specifications of what the payload shall be will determine the ultimate weight and size necessary for the drone. The Boulder Emergency Squad requests for capability to utilize a camera on the UAS. Previous UAS designs have used a camera that is attached to a gimbal, so that the camera may pan to various views. Other common payload materials include extra sensors and packages for delivery. In this project, the camera is the only added weight to the UAS.

7. Aircraft Stability

TALON'S UAS goal was to demonstrate positive static stability and to have the control authority to stabilize in a TBD ft/s lateral wind condition. CARROT'S goal is the same, to have positive static and dynamic stability design.

8. Reusability

The TALON team focused efforts towards reusability, more specifically creating a UAS capable of making 4+ flights. The CARROT team has a similar goal, and will optimize the endurance and efficiency of the UAS for reusable purposes. Rechargeable batteries will be investigated for feasibility in the CARROT'S iteration of the design. The customer expresses a need for a UAS that has capability to be stored and charged, to be deployed at a moment's notice.

9. FAA Compliance

TALON designed their UAS to comply with FAA 14 CFR Part 107, Small Unmanned Aircraft Systems, contingent on waivers. The CARROT team has the same FAA compliance requirement.

10. Cost

The CARROT team will optimize all aspects of the UAS to create a low-cost solution, without compromising UAS design components. Similarly to the TALON team, CARROT will create a UAS in which the launch and recovery system costs no more than 4,000 USD. To ensure no overspending, the Chief Financial Officer will oversee all transactions and minimize unnecessary spending. Past UAS reports show a wide range of costs. UAS design ranges from a few hundred to millions of dollars. Depending on the mission, the UAS can be produced in differing ways to maximize the cost-to-output ratio. The CU-RAAVEN is similar to the CARROT project because it will be launched in extreme weather conditions. For comparison, the RAAVEN team currently has a 1.5 million dollar grant. It will be a challenge to design a UAS that totals less than 4,000 USD, in which the team will narrow down the project scope to account for just the necessities of the customer.

Other designs

Albatross UAS

The Albatross UAS from Applied Aeronautics [4] has specifications that are similar to the CARROT product design description. The Albatross is a modular fixed-wing UAS designed for efficiency and high endurance. It's entirely electric, utilizing custom lithium-ion batteries to power it. The battery is capable of powering the UAS for over four hours. The system is capable of carrying over 4.4 kg of payload. The Albatross is made from honeycomb composite and carbon fiber, allowing for high durability while maintaining a low weight. It has a dry weight of 4.4 kg. Other design features include a wingspan of 3 meters and a modular payload attachment compatible with most cameras and sensors. Although the albatross is designed for commercial use, many of its features are important in other applications. The drone is nearly silent above 60 meters, allowing it to be useful in reconnaissance missions or other military applications. It has a telemetry range of up to 40 kilometers which can be useful in many applications including search and rescue or other emergency situations where data transmission is crucial. The subsystem designs of the Albatross UAS can be further researched for the purpose of designing the CARROT.

High Endurance Aerodynamics

In 2014, The Korea Aerospace Research Institute [3] performed a CFD analysis on different airfoils with low Reynolds numbers. Their purpose was to investigate airfoils and propulsion systems that will optimize aerodynamic endurance, specifically for UASs. The Institute looked at 6 different low Reynolds number airfoils and experimented with a target lift value of 1.0. To maximize endurance, they also looked at which airfoil produced the smallest amount of drag at the target lift value. After choosing three candidate airfoils that produced the least amount of drag, the Institute performed a full-scale CFD analysis. The results showed that all three airfoils produced around the same amount of drag whereas two of the three produced a slightly higher amount of lift. Their final decision involved determining which of the two airfoils were easier to manufacture and implement. The airfoil that was not chosen had a high camber and thin trailing edge, which creates potential challenges in manufacturing. In conclusion, the Institute determined that these low Reynolds number airfoils are optimal when designing high endurance aircraft due to their low drag at targeted lift speeds.

5. Specific Objectives

Success for this project is achieved by reaching at least the minimum requirements the customer has for the Unmanned Aircraft System (UAS). Meeting the minimum requirements is achieving the wants the customer can think of for their mission to be successful, however, to further build a reliable UAS more objectives can be explored and possibly achieved in the design. These two types of objectives, customer required and secondary goals, are discussed below in *Level 1* and *Level 2*, respectively.

Level 1:

The most prominent objective in this design is endurance. The UAS must be able to continuously fly for 4 hours with a 1.5-3 kilogram payload. The payload and 4-hour flight time denote that the airframe must be strong enough to withstand carrying the payload alongside whatever driving mechanism is used to propel the aircraft. Both of these objectives can be analyzed in flight testing since observations can be made to measure flight time duration with the payload and strength of the airframe itself.

Related to the payload and airframe requirements above is the airframe's size requirement. The UAS is to weigh less than 35 pounds, be transportable enough to fit in a 50 in. x 46 in. x 39 in. emergency rescue vehicle compartment, and be light enough so that two UAS can be carried by a single person including any required equipment for its launch. These requirements can be tested by weighing the UAS and making sure its weight does not exceed the maximum 35 pounds requirement. The design's concepts should always have the vehicle's compartment size as guidance to not exceed the available space for its transportation. As for physically transporting the UAS, every team member should be able to carry the aircraft and all of its required equipment for launch to meet the transport requirements.

Frequently the UAS is going to encounter rain, snow, extreme temperatures, and other climatic conditions that could impact its performance, for this reason, the aircraft is specified to be able to operate in temperature ranges of -20 to 120 degrees Fahrenheit and also withstand vertical wind gusts of up to 30 feet per second, and loiter winds of up to 30 miles per hour. There are various ways the vertical wind speed can be created to test if the aircraft's airframe can sustain such speeds; The ideal way is to use a wind tunnel, but finding one that can accommodate for the aircraft's size can become a problem, for this reason, there are two other options for testing this. The first option is to use a fan strong enough for it to approximate the windspeed requirements, the second option is to find a safe location where the airframe can be mounted and secured onto a vehicle to be driven at the expected windspeeds it would encounter in flight. To test and verify that the aircraft can operate in the required temperature range a heat source can be used to heat up the airframe as well as a cooling system where the aircraft's structure can be studied. The heat source can be a heating gun or a home heater, while the cooling system can be as simple as pouring ice in a compartment big enough to hold the aircraft with a temperature gauge.

Further requirements are defined by FAA regulations under 14 CFR Part 107 in order to be operated by the end user. The aircraft may be flown at night, so FAA regulations mandate anti-collision lights, visible for 3 statute miles when flying at night or IMC flight conditions. Testing of these lights can be done either by directly measuring the distance that the light can be seen or by purchasing light systems that have already been validated by the FAA through a Technical Standard Order Authorisation (TSOA).

Another requirement from the customer that is significantly related to the endurance and efficiency of the aircraft is the landing gear. The customer has no need for landing wheels and specified a skid plate is sufficient for landing the aircraft. From an aerodynamic point of view, having no landing gear reduces drag which overall increases the flight time since the propelling mechanism of the aircraft will not have to operate more to overcome the drag on the landing gear. To test if the skid plate can withstand different landing scenarios, the plate's material composition can be analyzed and its maximum tensile strength and shear force limits can be found to see if the aircraft's weight plus payload do not exceed its maximum strength boundaries. A more physical testing approach is to put the overall expected weight of the aircraft on top of the plate, and skid it along a typical mission landscape it would encounter to see if it can endure the impacts.

In order to accomplish all of the previously stated requirements, the aircraft needs a power source for flight. The power supply is required to provide a 12-volt output while at 10 watts for the entirety of the flight. Power supply performance can be verified using bench testing to evaluate the power output of the supply throughout a 4-hour simulated flight.

Level 2:

To improve the end-user experience, it would be the ultimate goal to create a modular UAS vehicle, allowing the vehicle to be more space efficient and improve the ability to transport the vehicle on foot and through difficult terrain. While there is no quantitative measurement for determining if a vehicle is easier for the operator to carry, there are still qualitative methods to determine if the actual design has been improved such as field tests.

Because the vehicle needs to last at least 1,000 flight hours, it becomes very important to ensure that the vehicle won't get damaged during all stages of its mission. The most likely flight stage to inflict damage to the vehicle is the landing stage. Since the vehicle will be flown in a vast variety of terrain, it would be foolish to assume that the vehicle will be landing in smooth and soft terrain such as grass. That is why landing gear would improve the vehicle's design as it would lower the chances of damage to the vehicle during landing, allowing for reinforced contact with the ground, limiting the possibility of damage. However, landing gear may not be the ideal design. There are other factors that may inhibit the ability of landing gear to protect the vehicle such as boulder fields. In cases like this, it may be necessary to look into other landing designs such as nets or deployable landing strips that could essentially make it possible to land virtually everywhere.

It is virtually impossible to take off a fixed-wing UAS in a densely forested area as the trees make it impossible for the UAS to fly and also to gain altitude above the tree level. This team believes it worthwhile to look into Vertical Take Off and Landing designs which would allow the UAS to take off in more sky-restricting regions.

6. High Level Functional Requirements

HERD-CU Phase 1C Direct Requirements:

Requirement 1: Over the course of a single deployment, two drones must be able to provide coverage of an area for 12 consecutive hours without any interruption

Requirement 2: A total of 2 UAS (including all supporting equipment) shall be transported, launched, recovered, and operated by a single person.

Requirement 3: UAS shall be configured and capable of launch within 5 minutes.

Requirement 4: UAS shall have short takeoff and landing capabilities to deploy in areas with unprepared launch surfaces and obstructed climb windows as specified by the customer.

Requirement 5: UAS shall house a payload with weight ranging from 1.5-3 kg.

Requirement 6: UAS shall provide continuous 12 Volt, 10 Watt power supply to mission payload throughout the flight envelope.

Requirement 7: UAS shall operate in the altitude range of 6,000 ft - 10,000 ft. MSL.
UAS must be able to operate at different mission specific altitude blocks, providing for a larger mission envelope while operating within FAA 14 CFR Part 107 regulations.

Requirement 8: UAS shall adhere to FAA 14 CFR Part 107, SMALL UNMANNED AIRCRAFT SYSTEMS, contingent on waivers.
UAS shall fit within the operating envelope defined in this FAA regulation in order to fly legally.

Requirement 9: UAS shall have a service life of at least 1000 hours.

Requirement 10: UAS shall operate in weather conditions ranging from -20 to 120 degrees Fahrenheit.

Requirement 11: UAS shall maintain a minimum of 80% operational capabilities in Instrument Meteorological Conditions from -20 to 120 degrees Fahrenheit.

Requirement 12: UAS shall be able to take off during 20 mph sustained winds.

Requirement 13: UAS shall maintain flight position during 30 mph sustained winds

Requirement 14: UAS shall maintain structural integrity through 20 mph vertical gusts

Adverse operating conditions require the UAS to be able to self-stabilize and maintain mission capabilities with minimal feedback from the operator.

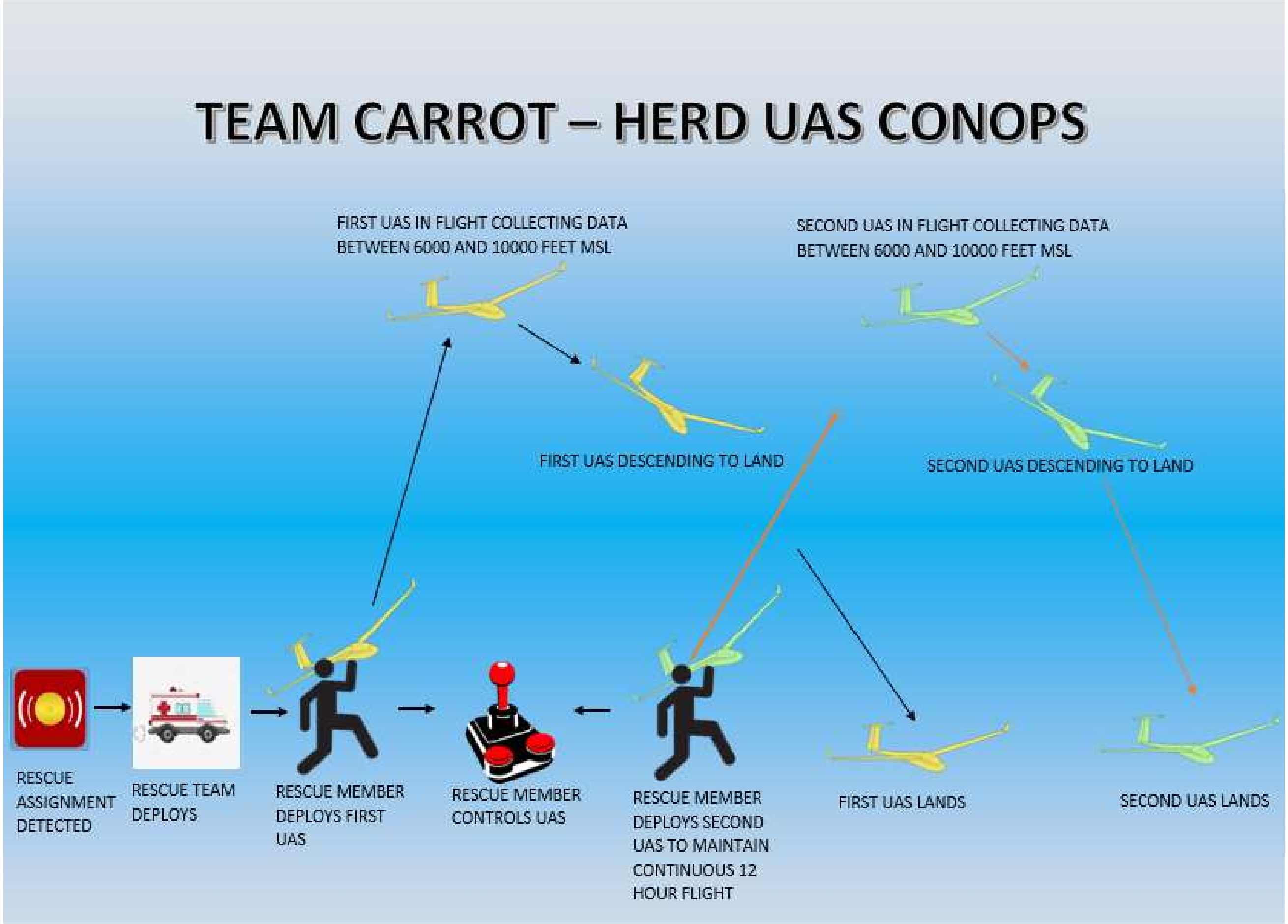
Requirement 15: UAS will maintain a FMC standby posture.

Event unpredictability requires the UAS to be fully deployable at all times with no workup phase.

Requirement 16: 90% of UAS airframe & launch system structural components shall be fully manufacturable, replaceable, or repairable by end user.

Requirement 17: UAS total flyaway cost shall not exceed 4,000 USD for a single air vehicle along with the required launch and recovery system.

The UAS must be affordable to smaller EMS departments and provide a cost effective solution that can be left in the field if conditions on the ground become unsafe.

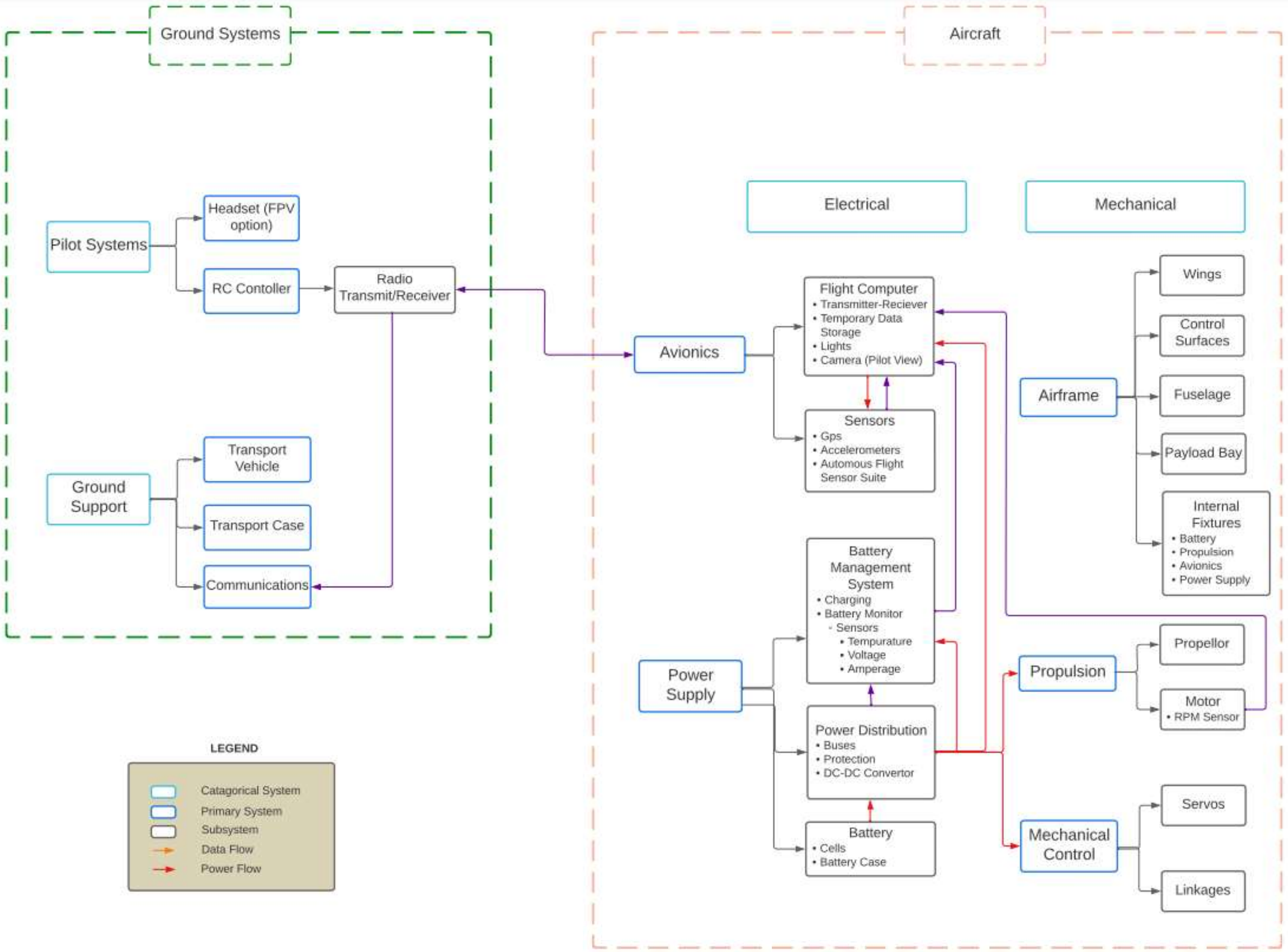


Conops Diagram [12], [13], [14], [15], [16]

7. Critical Project Elements

	Element	Description
E1	**Airframe**	The airframe needs to be sized such that two aircraft can be carried by one person, and it must be able to be stored on the emergency vehicles. Any required assembly to prepare the aircraft for flight must take less than 5 minutes and be done with only one person. While airborne, the UAS must be able to withstand 20 mph winds during take off and landing as well as 30 mph when in loiter. Additionally, the aircraft must withstand updrafts of up to 30 ft/s throughout the flight envelope. The design shall also be simple enough to be manufactured using COTS additive manufacturing methods.
E2	**Avionics**	An easily accessible yet secure avionics bay needs to be included in the airframe design. This space will hold the power supply and battery management system, flight controller, and any other required electrical systems. The power supply must be secure in the event of a crash to prevent any dangerous articles from being damaged. The flight controller must also provide simple and easy to use controls.
E3	**Aerodynamics**	Design needs to be optimized for endurance time to meet program requirements, while still maintaining static stability. Additionally, the airframe must be sized properly to generate enough lift to carry payload, particularly on takeoff. Wind tunnel testing and CFD data will be required to demonstrate aerodynamic performance and static stability.
E4	**Payload**	The UAS will be required to carry different types of payload that range in weight from 1.5-3 kg. Since the mission of this aircraft is highly modular, the payload compartment will have to accommodate several different payload footprints and configurations, ideally being field-swappable.
E5	**Software**	While automatic flight controls and stability augmentation is not a requirement for this project, ease-of-use when flying is desirable. Additionally, the flight controller will be constrained to FAA 14 CFR Part 107 regulations. We will be using CAD tools such as SolidWorks to create virtual models of our aircraft for analysis as well as providing the STEP files to 3D print the aircraft. We will also use programs such as MATLAB to verify calculations and stability, and use Advanced Aircraft Analysis for designing and sizing of our UAS.
E6	**Manufacturing**	At minimum 90% of the airframe must be able to be manufactured using COTS additive manufacturing methods. This requires simplification of the airframe, particularly with regards to the complexity of airfoil that can be used. The specific materials and printing methods used will be evaluated in order to maximize the strength of the airframe while minimizing weight.

8. Sub- System Breakdown and Interdependencies Elena and Lucas



9. Team Skills and Interests

Critical Project Elements	Team member(s) and associated skills/interests
Airframe	Chris Lolkema, Tyler McKay, Kushal Kedia, Eric Lozano, Talen Fischer, Luis Alvidrez, Jared Seefried, Marguerite Adwan, Elena Bauer, Carson Sexton, Abigail Moonan, Lucas Pereira
Avionics	Tyler McKay, Talen Fischer, Eric Lozano, Jared Seefried, Elena Bauer
Aerodynamics	Luis Alvidrez, Chris Lolkema, Marguerite Adwan, Tyler McKay, Jared Seefried, Elena Bauer, Carson Sexton, Abigail Moonan, Lucas Pereira
Payload	Tyler McKay, Eric Lozano, Luis Alvidrez, Marguerite Adwan, Talen Fischer, Carson Sexton
Software	Eric Lozano, Jared Seefried, Chris Lolkema, Elena Bauer
Manufacturing	Chris Lolkema, Marguerite Adwan, Kushal Kedia, Luis Alvidrez, Eric Lozano, Jared Seefried, Talen Fischer, Elena Bauer, Carson Sexton, Abigail Moonan, Lucas Pereira

10. Resources

Critical Project Elements	Resource/Source
Airframe	SolidWorks, Ansys Mechanical, Advanced Aircraft Analysis, Aero Machine Shop
Avionics	Aero Electronics Shop, AutoCAD
Aerodynamics	ANSYS Fluent, Siemens Star-CCM+, MATLAB, Python
Payload	MATLAB, SolidWorks
Software	TBD
Manufacturing	ITLL, Aero Machine Shop, Aero Wood/Composites Shop

11. References

[1] Editorial, "Eight ways to launch an Unmanned Aerial Vehicle (UAV)," *RoboticsBiz* Available: https://roboticsbiz.com/eight-ways-to-launch-an-unmanned-aerial-vehicle-UAV/.

[2] Editorial, "Everything about drone airframes and their lightweight, composite materials," *RoboticsBiz* Available: https://roboticsbiz.com/everything-about-UAV-airframes-and-their-lightweight-composite-materials/.

[3] Jin, Wonjin, and Yung-Gyo Lee. "Computational Analysis of the Aerodynamic Performance of a

Long-Endurance UAV." *International Journal of Aeronautical and Space Sciences*, vol. 15, no. 4, The Korean Society for Aeronautical & Space Sciences, 30 Dec. 2014, pp. 374–382. *Crossref*, doi:10.5139/ijass.2014.15.4.374.

[4] "Albatross UAS : Long Range Drone." *Applied Aeronautics*, https://www.appliedaeronautics.com/albatross-UAV.

[5] Peloquin Jason, et al. "TALON: Tactical Autopilot Long-term Overwatch Network)" *Ann and H.J. Smead Aerospace Engineering Sciences,* 02 Dec. 2021.

[6] "22 drones with longest flight time in 2021 (graphic comparison)," *Dronesgator* Available: https://dronesgator.com/drones-with-long-flight-time/#:~:text=A%20typical%20consumer%20drone%20can,even%20an%20hour%20or%20more.

[7] Ciobanu, E., "Drone life expectancy (how long do drones last?)," *Droneblog* Available: https://www.droneblog.com/drone-life-expectancy/#:~:text=A%20good%20drone%20should%20last,quality%20often%20correlates%20with%20price.

[8] Ciobanu, E., "Are drones waterproof? (5 best waterproof drones)," *Droneblog* Available: https://www.droneblog.com/are-drones-waterproof-5-best-waterproof-drones/.

[9] Ciobanu, E., "Average weights of common types of drones," *Droneblog* Available: https://www.droneblog.com/average-weights-of-common-types-of-drones/#:~:text=In%20most%20cases%2C%20toy%20drones,What%20is%20this%3F.

[10] "DJI Drones save the day during Texas Flood Rescue," *DJI Official* Available: https://www.dji.com/newsroom/news/dji-drones-save-the-day-during-texas-flood-rescue.

[11] Karaca, Y., Cicek, M., Tatli, O., Sahin, A., Pasli, S., Beser, M. F., and Turedi, S., "The potential use of Unmanned Aircraft Systems (drones) in Mountain Search and rescue operations," *The American Journal of Emergency Medicine* Available: https://ajemjournal-test.com.marlin-prod.literatumonline.com/article/S0735-6757(17)30750-7/fulltext.

[12] *Cartoon Glider*, 2012. Available:

small-40039_640.png (640×320) (pixabay.com)

[13] *Stick-Man*, 2014. Available:

stick-man-295293_960_720.png (752×720) (pixabay.com)

[14] *Alarm Symbol* Available:

ALARM.png (600×600) (freesvg.org)

[15] *Video Game Joystick*. Available:

brunurb_Retro_Joystick_001.png (600×600) (freesvg.org)

[16] "Cartoon Ambulance Car Cartoon Car Medical Vehicle, ambulance clipart, rescue patient, nurse png transparent clipart image and PSD file for free download: Rescue vehicles, car cartoon, ambulance," *Pinterest* Available: https://in.pinterest.com/pin/cartoon-ambulance-car-cartoon-car-medical-vehicle-ambulance-clipart-rescue-patient-nurse-png-transparent-clipart-image-and-psd-file-for-free-download--686869380677414911/

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