Department of Aerospace Engineering Sciences
Senior Projects – ASEN 4018

CUDBF
Project Definition Document (PDD)

Document History

Release	Date	Description	Name
Initial	9/6/2007	Preliminary Draft	Michelle Tamayo
1.0	9/13/2007	Final Draft	Michelle Tamayo

Approval

Title	Name	Signature	Date
Customer			
Advisor #1			
Advisor #2			
CC			

1.0 Information

1.1 Project Title

University of Colorado Design, Build, and Fly (CUDBF)

1.2 Project Customer

Research and Engineering Center for Unmanned Vehicles (RECUV)
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1.3 Group Members

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2.0 Background & Context

Many current small unmanned aerial systems (20-40 lbs) are based on previously designed R/C aircraft that were never designed to carry research payloads. This situation severely limits the size of payloads that can be flown by a single aircraft. Therefore, an aircraft with the ability to carry a high-volume payload would be a valuable research tool at the University of Colorado. As an example, RECUV designed and now operates the ARES family of aircraft for communications research. This aircraft has become the main workhorse of RECUV, but its payload is limited to only two or three circuit boards, as seen in Figure 1.

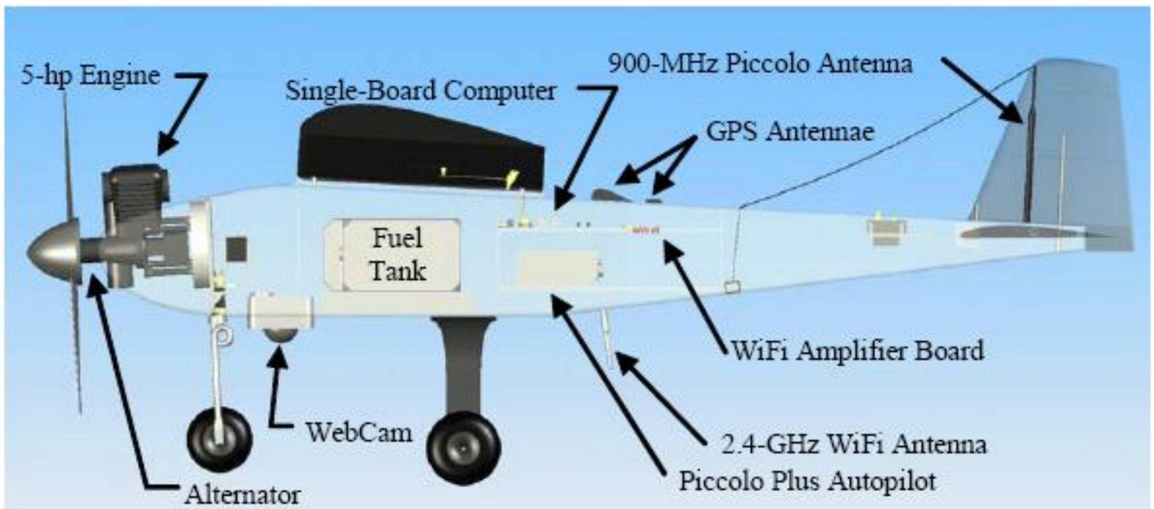


Figure 1: ARES UAV[1]

The required flight equipment in Figure 1 (fuel tank, autopilot, etc) is what takes up most of the interior volume of the ARES aircraft. An aircraft designed to accommodate high-volume payloads would allow most RECUV research payloads to be flown, while the size of the aircraft would allow for rapid deployment and easy management by the University.

The American Institute of Aeronautics & Astronautics (AIAA), Cessna Aircraft Company, and Raytheon Missile Systems sponsor an annual Aircraft Design competition that simulates many design problems faced by engineers. This year's rules deal specifically with the high-volume payload problem. The focus of the competition is for each team to design, build, and test an aircraft that is able to carry a heavy high-volume payload while following stringent requirements for takeoff distance and aircraft footprint. The competition also requires teams to accurately predict the performance of the aircraft and describe design methodologies.

For further competition information and rules, see reference 2.

3.0 Goal

The goal of the CUDBF team is to successfully design, build, test & verify, and fly a remotely controlled aircraft able to complete the mission set out in the AIAA Design, Build, and Fly Competition rules. The goal includes landing without significant damage to the

[1] RECUV Website

aircraft, which will be provided to RECUV to fill their high-volume payload requirements after the completion of the competition in April.

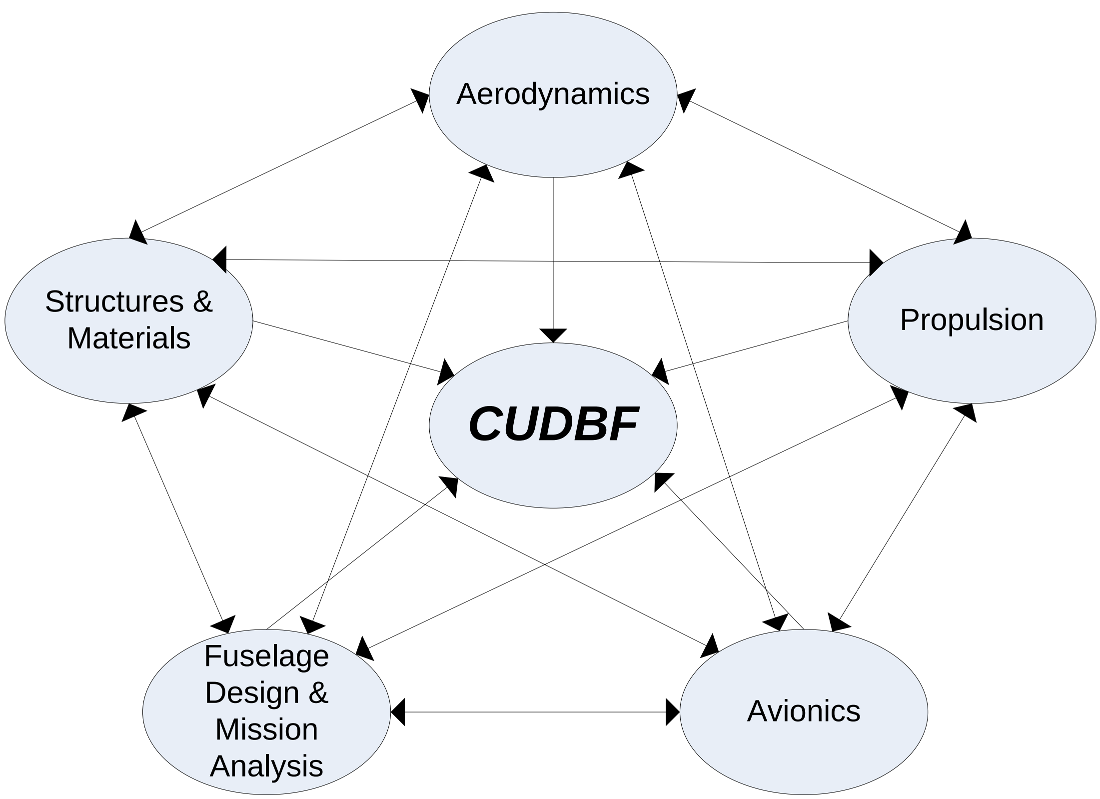
4.0 Objectives

The objective of this project is to develop an Unmanned Air Vehicle that is capable of competing in the AIAA Design, Build and Fly competition. To accomplish this objective our team must design a fixed-wing, electric powered UAV with high volume payload capability that meets all AIAA standard competition requirements and is capable of passing a technical inspection. Additionally, with this design our team hopes to develop a robust and versatile vehicle capable of delivering high volume payloads to be contributed to the RECUV fleet.

In compliance with the competition standards, our group is also required to manage a team of at least four underclassmen for a minimum of two hours a week. The purpose of this objective is both to vertically integrate the less experienced students with designing and manufacturing aircrafts and to contract them to aide in trade studies, fabrication and testing of the final aircraft.

Finally, through this project our team hopes to gain insight and understanding of the design process and gain the critical skills and experience needed in developing integrated aerospace systems. For our team to consider this project a full mission success we hope to achieve all of these objectives and use our respective skills to fully integrate and deliver a high volume payload UAV.

5.0 Functional Block Diagram



6.0 System Operational Timeline (concept of operations)

The concept of operations for this vehicle outlines the timeline of operation for the aircraft both as a data acquisition test flight and the operation of the vehicle during a competition day.

7.0 Project Requirements

The following requirements are necessary for the project to accomplish the required missions.

7.1 Minimum Safe Altitude

7.1.1 Aircraft must cruise at an altitude of at least 50ft
7.1.2 Aircraft must perform entire mission at an altitude of at least 50ft
7.1.3 Parent: Minimum Requirement
7.1.4 Method of verification: altitude sensor or GPS during testing

7.2 Electrical Components

7.2.1 All electrical components must be “off the shelf”
- 7.2.1.1 Off the shelf refers to unmodified, original components

7.2.2 Motor, RC controls and batteries must be off the shelf and unmodified
- 7.2.2.1 Batteries must have clear manufacturer label

7.2.3 Parent: Competition Requirement
7.2.4 Method of verification: retain receipts, do not remove labels from components

7.3 Payload Variety

7.3.1 Aircraft must accommodate all mission defined payloads

Table 7.1: Payload Combinations

Possible Payload Combinations[2]			
	Payload		**Estimated Weight**
	0.5 liter bottles	1/2 brick	
Combination 1	14	0	7
Combination 2	0	4	7.2
Combination 3	10	1	6.8
Combination 4	7	2	7.1
Combination 5	3	3	6.9

7.3.2 Required payload for flight will be randomly chosen by competition officials, but will be one of the above combinations
7.3.3 Parent: Competition Requirement
7.3.4 Method of verification: fly all possibilities during testing

7.4 Payload Restraints

7.4.1 All payloads must be mechanically restrained

[2] Competition Rules

7.4.2 Internal cargo bay must secure payload by means other than Velcro, tape or packing material[2]
7.4.3 Parent: Competition Requirement
7.4.4 Method of verification: hold loaded aircraft so that open hatch is down

7.5 Delivery Flight

7.5.1 Aircraft must complete Delivery mission[2]
7.5.2 Aircraft must take off, fly at least one lap and land. Aircraft must not crash. Aircraft is unloaded for this mission.
7.5.3 Parent: Minimal Requirement
7.5.4 Method of verification: scoring

7.6 Payload Flights

7.6.1 Aircraft must complete Payload mission (refer to reference 2)
7.6.2 Aircraft must be loaded with assigned payload combination, take off, fly two laps and land. Aircraft must not crash. Payload is randomly assigned at start of mission and the loading is timed.
7.6.3 Parent: Competition Requirement
7.6.4 Method of verification: scoring

8.0 Top Level System Requirement

8.1 Battery Weight

8.1.1 Maximum battery weight is 4lbs
8.1.2 A battery pack must weigh less than 4lbs; however, separate packs, of other sizes (< 4 lbs) for each mission are allowed
8.1.3 Parent: competition requirement
8.1.4 Method of verification: measure weight of battery packs

8.2 Aircraft Classification

8.2.1 Aircraft must be of fixed-wing type
8.2.2 Fixed-wing is any design other than rotary or lighter-than-air
8.2.3 Parent: minimal requirement for success
8.2.4 Method of verification: inspection

8.3 Aircraft Dimension

8.3.1 Aircraft footprint must no larger than 5ft by 4ft
8.3.2 Height is unrestricted
8.3.3 Parent: competition requirement
8.3.4 Method of verification: ensure final product can be contained within a 5x4 rectangle

8.4 Aircraft Weight

8.4.1 Aircraft must weigh less than 55lbs
8.4.2 AMA regulations require gross takeoff weight with payload to be less than 55lbs
8.4.3 Parent: AMA regulations
8.4.4 Method of verification: measure weight of final product

8.5 Takeoff Distance

8.5.1 Aircraft must take off in 75ft
8.5.2 Once moving, the aircraft must be completely off the ground before it reaches 75ft downrange

8.5.3 Parent: competition requirement
8.5.4 Method of verification: set distance markers along runway during testing

8.6 Vehicle Endurance

8.6.1 System must keep airplane aloft for at least 5 minutes
8.6.2 To complete the delivery mission the aircraft must fly for at least 5 minutes
8.6.3 Parent: competition requirement
8.6.4 Verifiable through component testing and demonstration

8.7 Motor Specification

8.7.1 Motor must be either a commercial brush or brushless electric motor
8.7.2 These are the two most common types of motors found on RC aircraft
8.7.3 Parent: Competition Requirement
8.7.4 Verifiable through inspection

8.8 Structural Integrity

8.8.1 Must support fully loaded weight of plane when held by wingtips (2.5g)
8.8.2 A load of 2.5g's is comparable to forces seen in a steady level turn
8.8.3 Parent: Competition requirement
8.8.4 Verifiable through structural analysis, testing, and demonstration

8.9 Maneuverability

8.9.1 Control surfaces must provide directional control with and without payloads
8.9.2 Aircraft must be capable of maneuvering to complete all mission phases
8.9.3 Parent: Minimum Requirement
8.9.4 Verifiable through testing and demonstration

8.10 Instrumentation

8.10.1 Removable telemetry package must record airspeed, altitude and takeoff range
8.10.2 Necessary to verify proper function of other components
8.10.3 Parent: Minimum Requirement
8.10.4 Verifiable through testing

8.11 Battery Chemistry

8.11.1 Batteries must be commercially available Nickel Metal Hydride (NiMH) or Nickel Cadmium (NiCad)
8.11.2 These are the two battery types allowed by competition rules
8.11.3 Parent: Competition Requirement
8.11.4 Verifiable through inspection

9.0 Minimum Requirements for Success

The following requirements shall be met in order for the project to be considered a success.

9.1 Design and deliver a fixed-wing UAV with the capacity to hold the maximum volume of the competition payload
9.2 Aircraft must be able take off at empty weight
9.3 Aircraft must be able to sustain cruise flight at a minimal altitude of 50ft AGL for a duration of at least 5 minutes
9.4 Aircraft must be electrically powered (competition requirement)
9.5 Implement telemetry system to record altitude, airspeed and takeoff distance

10.0 Deliverables

10.1 Operational Airframe

10.1.1 Functional Aircraft with associated equipment will be delivered to RECUV

10.2 Design Manual

10.2.1 Complete operational and assembly manuals for aircraft reproduction

10.3 Performance Data

10.3.1 All necessary performance data will be compressed and delivered to RECUV

11.0 Technical Risk

11.1. Battery failure

11.1.1 During flight, the batteries could run out of power, causing the plane to crash.

11.1.2 Risk will be mitigated through two levels of testing. First, endurance testing of battery packs will produce data on average battery life. This will be done with maximum current draw as a worst-case scenario. Second, full flight tests will validate power systems' ability to function in operational conditions.

11.2. Unstable aircraft

11.2.1 After fabrication, it is possible to discover that the aircraft is too unstable to safely fly with the current control systems, either due to aerodynamics or center of gravity issues.

11.2.2 Risk will be mitigated through the use of computer simulations. Prior to fabrication, airfoils can be tested using Xfoil or similar programs. Additionally, it may be possible to construct a foam prototype before CDR in order to validate aerodynamic design. A Solid Works drawing of the aircraft will provide the location of the c.g.

11.3. Landing gear placement

11.3.1 If the landing gear is too far forward, the aircraft will be unable to take off. If it is too far back, the plane will nose-down on the runway.

11.3.2 Risk will be mitigated through basic flight testing and appropriate time management. Flight testing conducted sufficiently early will allow for a relocation of landing gear if necessary.

11.4. Loss of pilot

11.4.1 Extenuating circumstances may result in the pilot being unable to perform.

11.4.2 Risk will be mitigated by contracting back-up pilot(s).

11.5 Servo Malfunction

11.5.1 Due to the nature of the complex internal workings and extreme stresses applied to servos during extreme flight or crashes, malfunctions of the servo can occur, requiring either maintenance or replacement

11.5.2 Risk will be mitigated by designing the aircraft to have replaceable servo mounts

12.0 Anticipated Engineering Expertise

Table 12.1 Expertise required for project

Technical Expertise	**Application**
Systems Design	Develop conceptual and detailed models of system components
Aerodynamic Design	Aerodynamic design of aircraft
Structural/ Material Design	Develop aircraft structure that meets need of all subsystems
Propulsion Design	Develop system to provide require thrust for design
Electrical Design	Develop aircraft power budget
Electronics Integration	Integrate off-the-self control and data collection components
Payload Design	Develop payload handling system
Composite Construction	Fabricate composite components
Mechanical Fabrication	Manufacture and assemble system parts
Electrical integration	Integrate electrical system
Data Acquisition	Measure / record test data
Propulsion Testing	Verify propulsion system design
Structure Testing	Verify structure design
Aerodynamic Testing	Verify aerodynamic design
System Testing	Verify project design
Aircraft Operation	Piloting the aircraft

13.0 Resources

13.1 Facilities

The project will make use of the RECUV Fabrication Lab, provided by Dr. Brian Argrow. In addition, the project will require the use of the Boulder Aeromodeling Society's (BAS) R/C runway. Since one member of the team is a member of BAS, this facility can be used with no adverse impact on testing.

13.2 Additional Advisors

The team will require the advising of the Aerospace faculty, especially professors focusing on aircraft design, propulsion, and composite structures. Specifically, Drs. Gerren, Mohseni, and Huessin would be of critical importance to the team.

13.3 Funds

The Department of Aerospace Engineering Sciences will contribute $4000 to the project. In order to support underclassmen work, the team will also apply for UROP and EEF funding. RECUV has indicated a willingness to contribute to the team's budget as well.

14.0 Acknowledgements

14.1 Customer Contact

We would like to thank Dr. Brian Argrow for his sponsorship of the project

14.2 Faculty Members

We would like to thank the PAB for their constructive criticism

14.3 Graduate Students

We would like to thank Jason Roadman for his expertise and advice

14.4 Underclass Students

Table 14.1: Table of Contacts

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14.5 Others

14.5.1 Pilot

Special thanks to James Mack for volunteering to fly for the team

15.0 References

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2. **Official Rules**
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