CDR

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Agenda

1. Mission Statement
2. PDR Recap
3. Design Compatibility
4. Initial design - Design Pros and Cons
5. Action Items from PDR
6. Design
7. Stability
8. Model and Manufacturing
9. Risk Assessment
10. Testing
11. Cost
12. Market Analysis & Business Plan

Mission

The US Army is soliciting proposals for the design, development and deployment of an unmanned aircraft surveillance system. The United States Army - Surveillance Unmanned Reconnaissance Vehicle (USA SURV) is intended for use in behind the lines theatre operations over land mass areas. This vehicle is intended to be used to gather battlefield information including troop locations, supply lines, communication facilities, command and control centers, unknown geographical features (such as rivers, landing zones, topographical info, etc.), battlefield damage, maintenance facilities, radar facilities, etc. The mission of this vehicle is to replace other information gathering systems (satellite, high altitude manned aircraft, etc.) during period of bad weather in the theatre. The final design can consist of multiple vehicles such as a larger vehicle for range requirements and smaller expendable data gathering vehicles for actual surveillance activities.

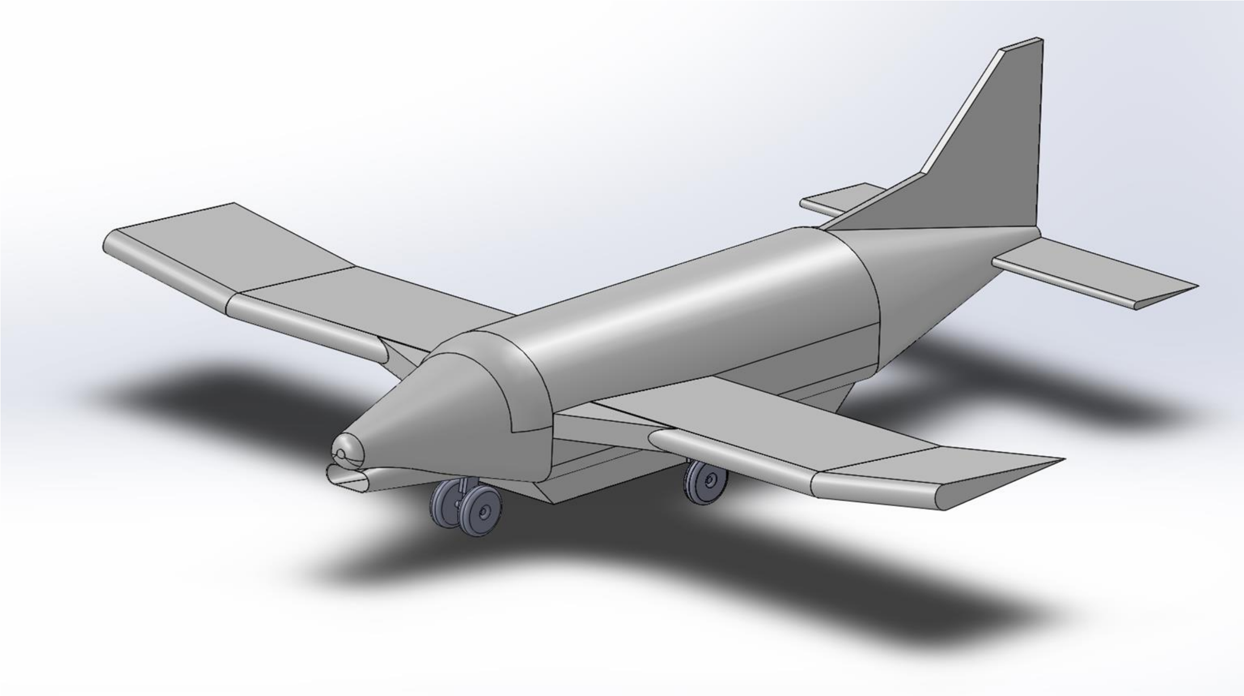
Requirement		Meeting
1	The larger vehicle shall be reusable for a period of 10,000 flights.	Yes
2	Data from smaller vehicle shall be telemetered to the larger vehicle.	Yes
3	The aircraft system shall be able to perform system warm up and system checks in a period of 10 minutes	Yes
4	The aircraft system shall takeoff within an 800 foot clearing with a 38 foot obstacle present	Yes
5	The aircraft system shall climb at the best rate of climb to its cruising altitude	Yes
6	The aircraft system shall be able to cruise for 500 nautical miles at a speed and altitude which minimizes station and fuel burn	Yes
7	The aircraft system shall be able to then climb at best rate of climb to 25000 feet	Yes
8	The aircraft system shall be able to proceed to gather nape of the earth (50 feet above local level) data in near real time for a period of 24 hours at the best endurance speed	See Alternative Solutions

Requirement		Meeting
9	After the data collection period is completed, the aircraft system shall descend to best cruise altitude, with no credit for range	Yes
10	The aircraft system shall then perform a return cruise segment of 500 nautical miles while minimizing fuel burn	Yes
11	Once all other mission requirements are met, the aircraft system shall descend with no credit for range and land within an 800 foot clearing with a 38 foot obstacle present	Yes
12	The aircraft system shall have 10% fuel reserve after mission completion	Yes
13	The aircraft system shall be able to carry 400 pounds of payload not including any secondary aircraft designed for the mission	Yes
14	The aircraft system shall be capable of performing a sustained 2.4 g maneuver at speed for minimum power setting and at 25000 feet altitude	Yes
15	The aircraft system shall be capable of 5 minutes taxi time	Yes
16	Any secondary aircraft designed for the mission shall be lighter than 20 pounds and shall only require one person to manipulate and prepare for flight in the primary aircraft system	Yes

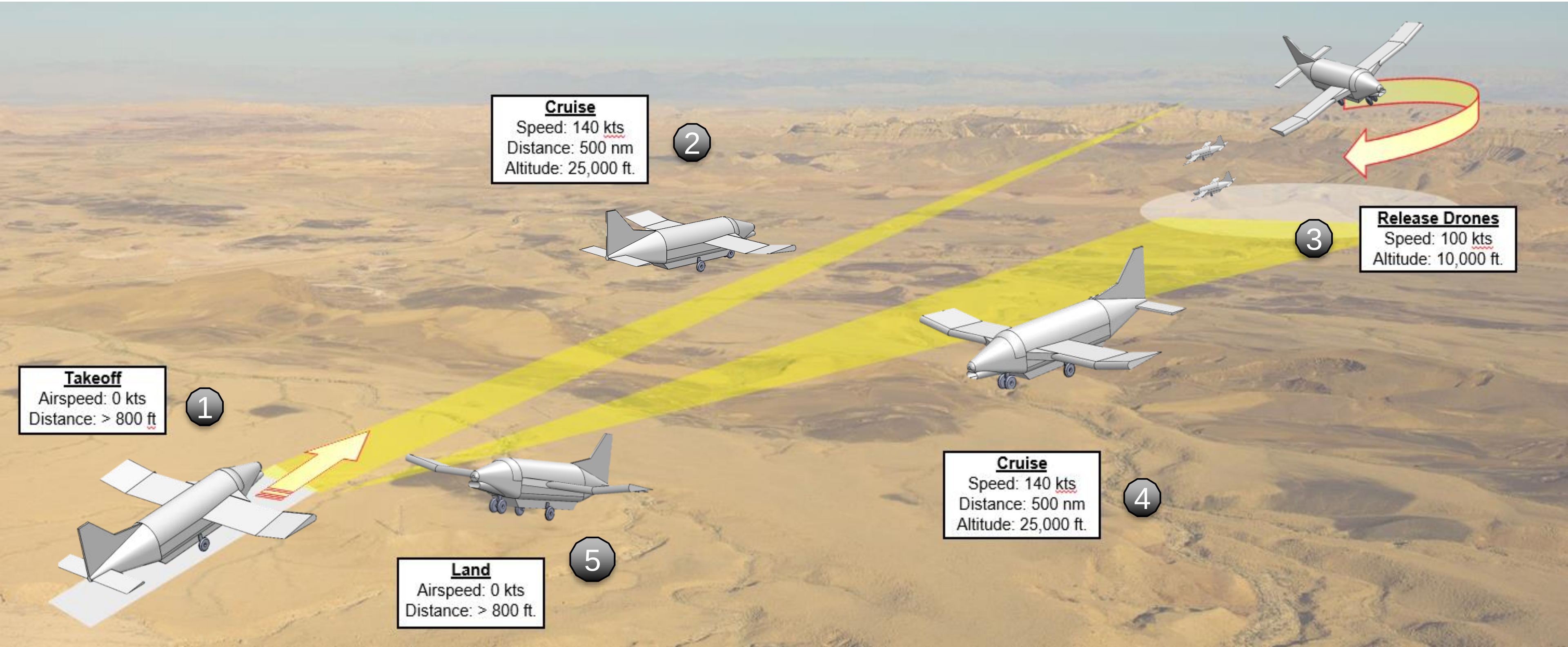
Customers

- US Military - Surveillance, combat, target decoys
- Farmers - Aerial video/photo for inventory data
- First Responders - Survey disaster area
- Construction Companies - Topographic mapping, security, land surveying
- Shipping Companies - Autopilot cargo transport
- Environmental Companies - Animal habitat and population observation
- Media - News, sports, television

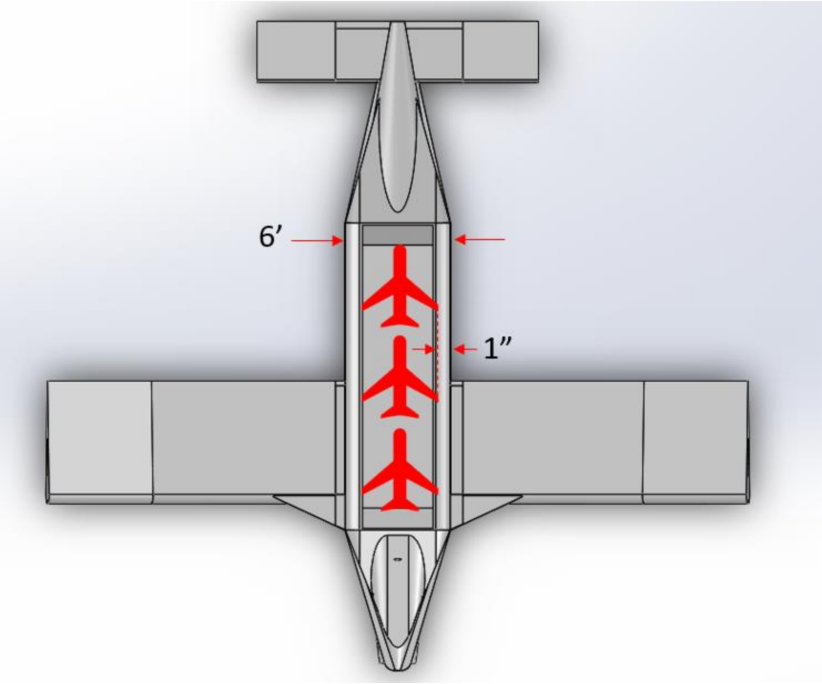
Large Aircraft Model

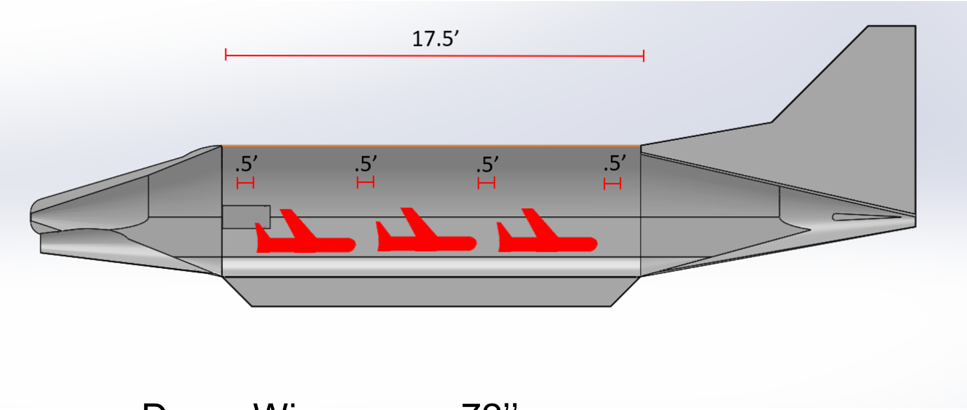


Mission Definition (1 Flight)



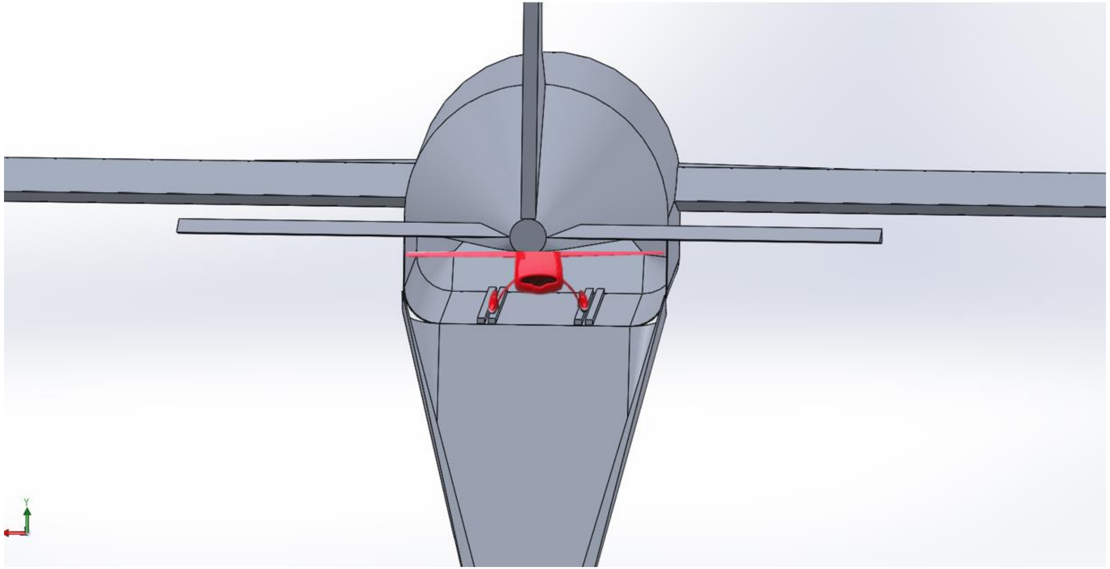
Interior Design





- Drone Wingspan = 72’’
- Drone Length = 52’’

Drone Release

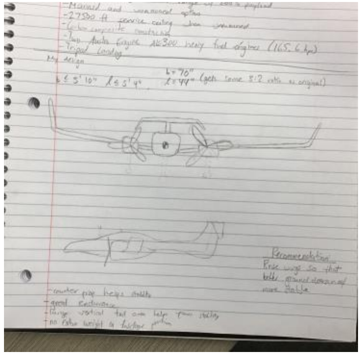


- Linear Ratchet (anti-rollback)
- Launch Track (Similar to roller coasters)
- Extra momentum helps with propulsion of the drone.
- Rack system for drone storage.

Design Compatibility

- Drone can be deployed by throwing or ground takeoff (good for alternate customers).
- Each drone equipped with a receiver and transmitter.
- Smaller drone size allows for nine drones to be carried inside of the larger aircraft (3x3 stack).
- Large cargo bay that can be utilized as storage for alternative customers.

Initial Designs

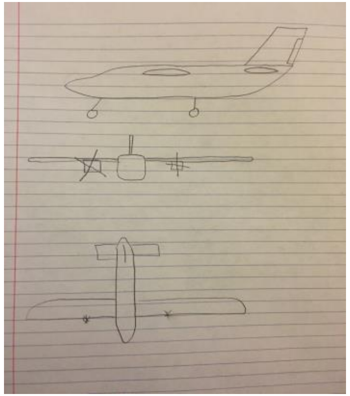


Pros
- Counter rotating propellers
- Good endurance
- Large vertical tail

Cons
- Complex Manufacturing
- Low wing

Pros
- Easy to manufacture
- High wing

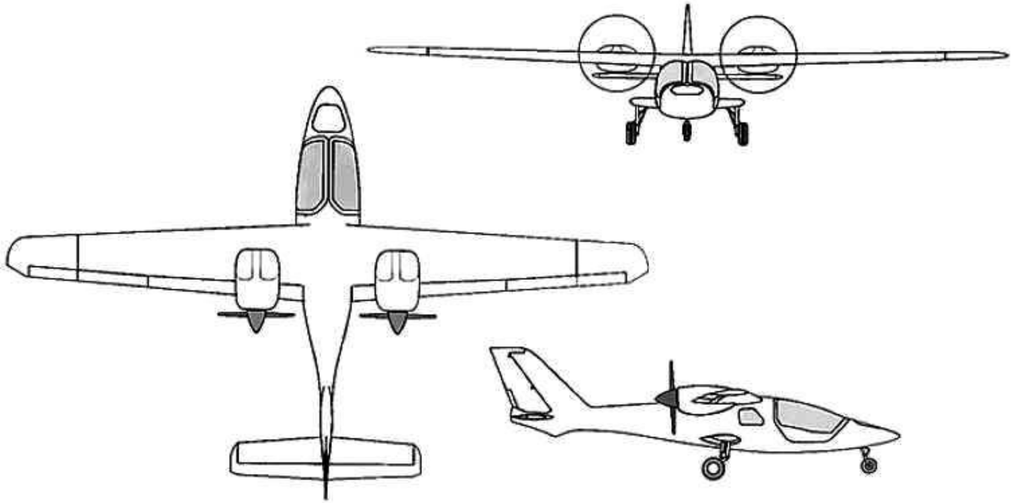
Cons
- Single propellor
- Low cargo space



Pros
- Easy to manufacture
- Large cargo area
- High wing

Cons
- Heavy
- Less endurance

Initial Design Sketch



Pros
• Counter rotating propellers
• Good endurance
• Stable high wing
• More cargo space (for alternative customers)
• High vertical tail provides greater roll stability
• High wing allows for better prop clearance from the ground

Cons
• Two engines increase cost and weight
• More difficult to achieve proper center of thrust
• Heavier engine mounts for wing mounted engines

Pusher Propeller Design Choice

Pros

- Shaft is loaded in compression.
- Pushes wings and control surfaces through undisturbed air.
- More efficient at cruising speed and less wing loading.
- Better room for radar and optical forward looking system.
- Props in general are slower and better for slow-moving surveillance.
- Lose prop efficiency, but gain aero efficiency from slower airflow over wings.

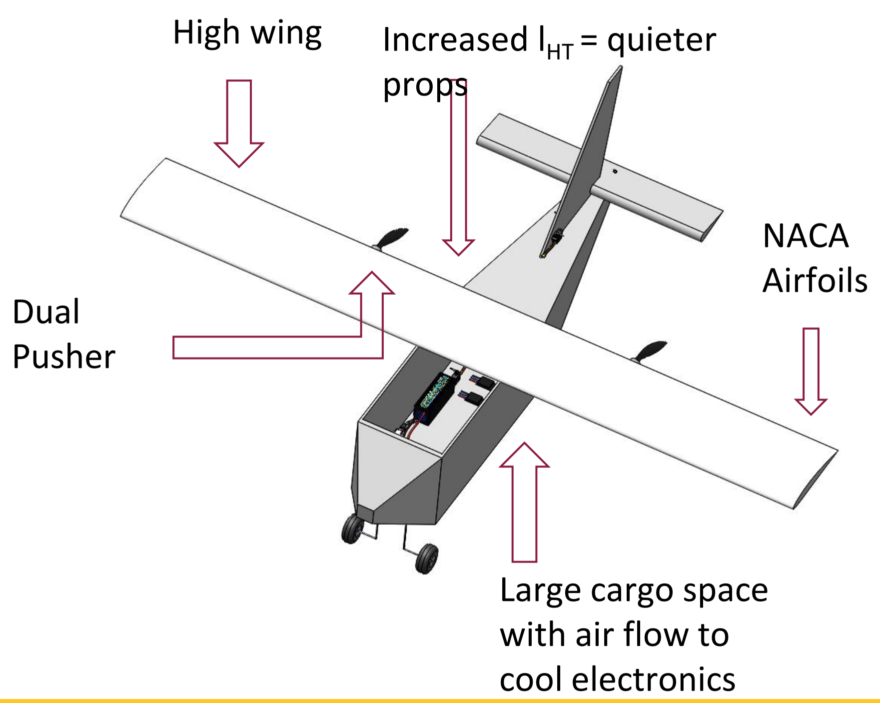
Cons

- Propellers in a disturbed airflow, causes increased vibration and noise.
- Small propeller clearance on takeoff.
- Lower propellor efficiency and susceptible to fatigue.
- Less maneuverability because thrust vector is closer to rear of aircraft.
- Center of thrust is more difficult to balance.
- Possible loss of stability if one engine fails.

Action Items from PDR

- Drone data transmitting range - Will be discussed later in presentation
- Release mechanism - Held by rails inside cargo bay and released with conveyor belt
- Propeller Interference - Mitigated by pusher design
- Risk Mitigation - Discussed later in presentation

Structural Design - Overall Design



Key Features

1. Easy to manufacture and mass produce
2. Cheap and disposable
3. Low risk to national security
4. Sustainable business model

Design Considerations

1. Cost
2. Simplicity of Manufacturing
3. Time deadlines
4. Reliability (of materials, testing data, proven flight worthiness of similar a/c)

Structural Design - Sizing

Aileron

Typically 10-15% of total wing area (higher for more maneuverable aircraft)

Given that our design has no dihedral and no sweep, it is necessary to use “larger” ailerons, about 20-25%.

Advantage

- **Greater control authority in roll**

Rudder

Typically 10-15% of total vertical stabilizer area (higher for more maneuverable aircraft)

Yaw stability is good so the sizing of a typical RC aircraft is acceptable.

Advantage

- **Avoids difficulties when landing into a cross wind**

Elevator

Typically 15-20% of total horizontal stabilizer area (higher for more maneuverable aircraft)

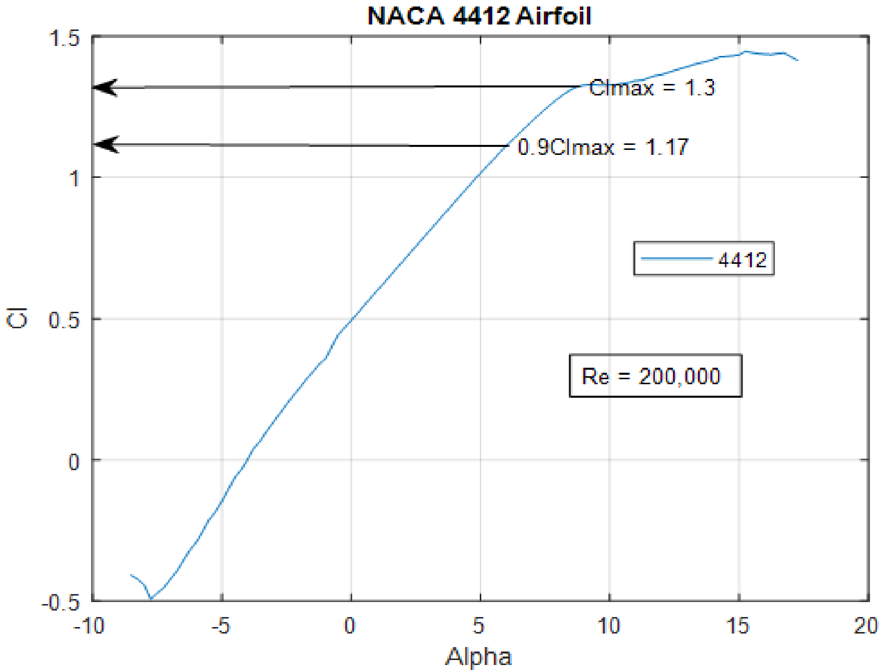
An increase in distance from the aircraft’s CG to the AC of the elevator lets us keep the sizing at 15-20%

Advantage

- **Larger moment arm increases effect of elevator**

Aero - Estimating Lift

- Assuming zero-alt, STD
- 30mph, ρ = 1.23kg/m3
- μ = 1.789*10^-5
- Re = 200,000
- Clmax ≅0.9Clmax (for large AR)
- Clmax = 1.17

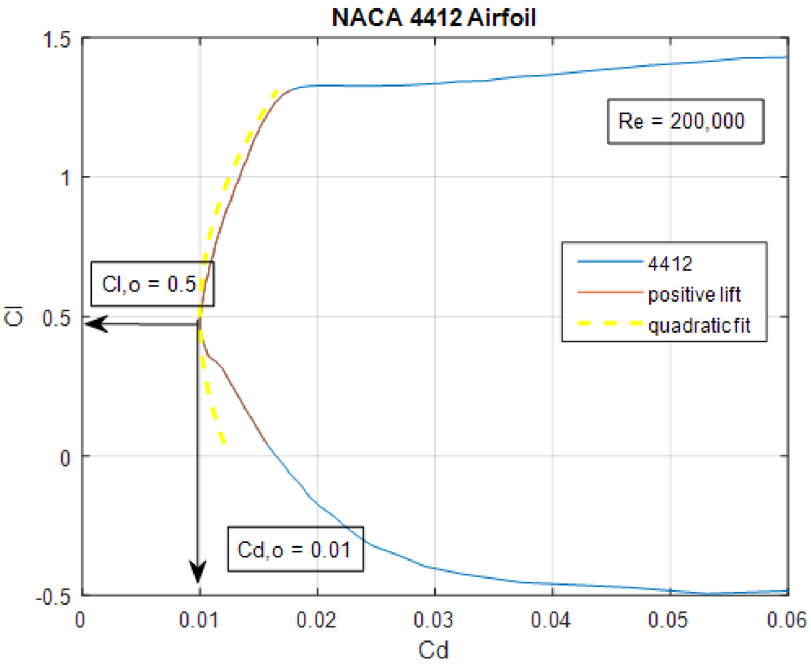


Aero - Estimating Wing Drag

- Drag Polar Equation:

$$C_D = C_{D,o} + \frac{C_L^2}{\pi\, AR\, e} + k(C_L - C_{l,0})^2$$

- Cl,o = 0.5
- Cd,o = 0.01
- k =0.01
- e = 0.9 (common for RC planes)



Aero - Estimating Model Drag

Total drag is the sum of all component drag (with wing drag being the largest)

Component	Drag based on estimate Form Factor data
Fuselage	0.0060
Wing	0.0100
Horizontal Tail	0.0012
Vertical Tail	0.0006
Landing Gear	0.0065
Engines	0.0054
Cdo total:	**0.0297**

- Note as a sanity check, a Cessna 172 has a Cdo of 0.0260

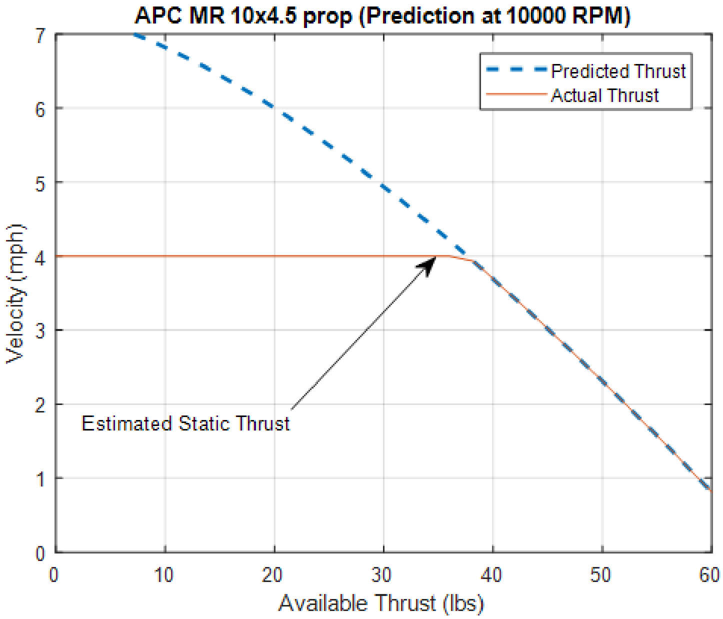
Performance - Takeoff

$$V_{to} = \left(\frac{2W}{S\rho * 0.8 * Cl_{max}}\right)^{\frac{1}{2}}$$

- (0.8Clmax is acceptable value with margin for gust, over rotation, maneuver, etc.)
- Using an approximate weight of 10 lbs to account for any extra payload and STD
- **Vto = 33 mph**
- Next - takeoff ground roll distance is the distance from V=0 to Vto, rotate to 0.8Clmax, and have L=W.

Performance - Takeoff (Cont.)

- Thrust Estimations based off engine and pro
- Park 450 Brushless Motor 890Kv x2
- 11.1V Lip0 2100mAh batteries x2
- 10x4.5 APCMR Propellers x2



Performance - Takeoff (Cont.)

- Takeoff acceleration:

$$a = \left(\frac{g}{W}\right)[(T - D) - F_c(W - L)]$$

- Where Fc is coeff. of rolling friction
- Assuming Fc = 0.3 (This can be tested with a fish scale during testing phase)

$$S_g = \frac{V_{to}^2}{2 * a_{mean}}$$

- Where a_mean = 0.7 Vto
- a_mean = 14.42 ft/s^2
- **Sg = 39.8 ft** (with total weight of 10 lbs)

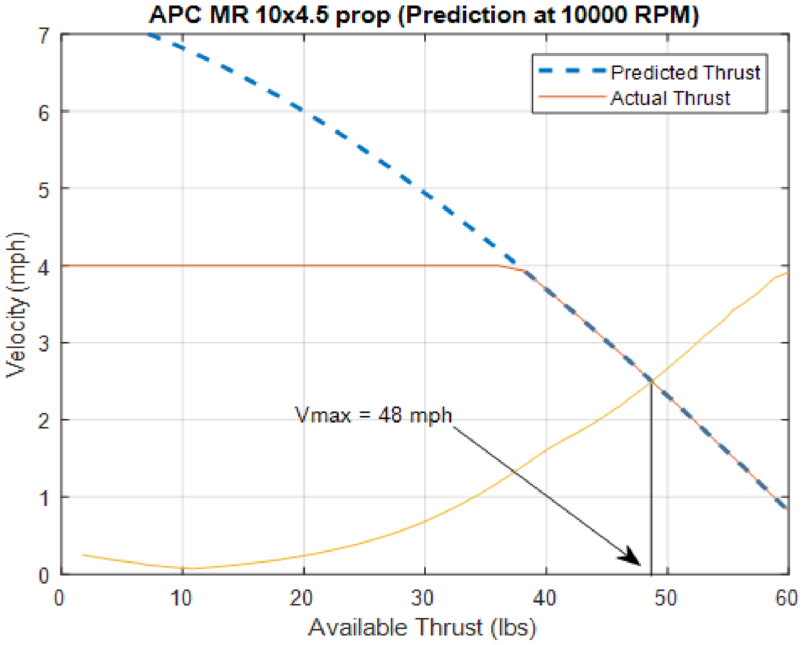
East Valley Aviators Runway - 650’ x 100’

Motors, Propellers, & Landing Gear

- Motor was chosen based off needed thrust for maximum payload
- Propellers are rated for chosen motor and produce optimal Advance Ratio
- Landing gear is chosen as single piece to increase robustness
- (**model does not currently reflect the actual landing gear)

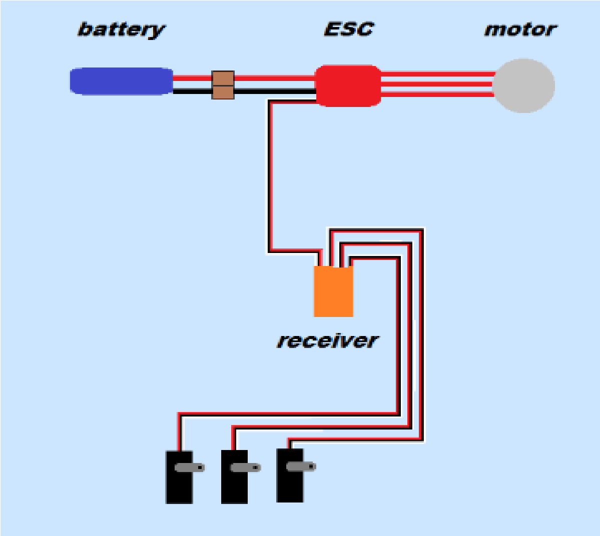
Maximum Flight Conditions

- Maximum Flight Speed (Vmax) = **48 mph**
- Flight time (for current batteries) = **12 min**
- Range for 2.4Ghz RC Transmitter = **0.75 mi**
- Service Ceiling - the service ceiling is limited to **400 ft** according to FAA regulations. The actual service ceiling is limited not by ROC, but the range of receiver.



Electrical- Subsystems/Wiring

- Each small a/c is equipped with RF transmitter and receiver in order to relay information up the chain.. Due to the low cost large aircraft, we can invest in higher quality transmitters.



Hardware

11.1V 2100mAh 3S 20C LiPo Battery: T-Plug

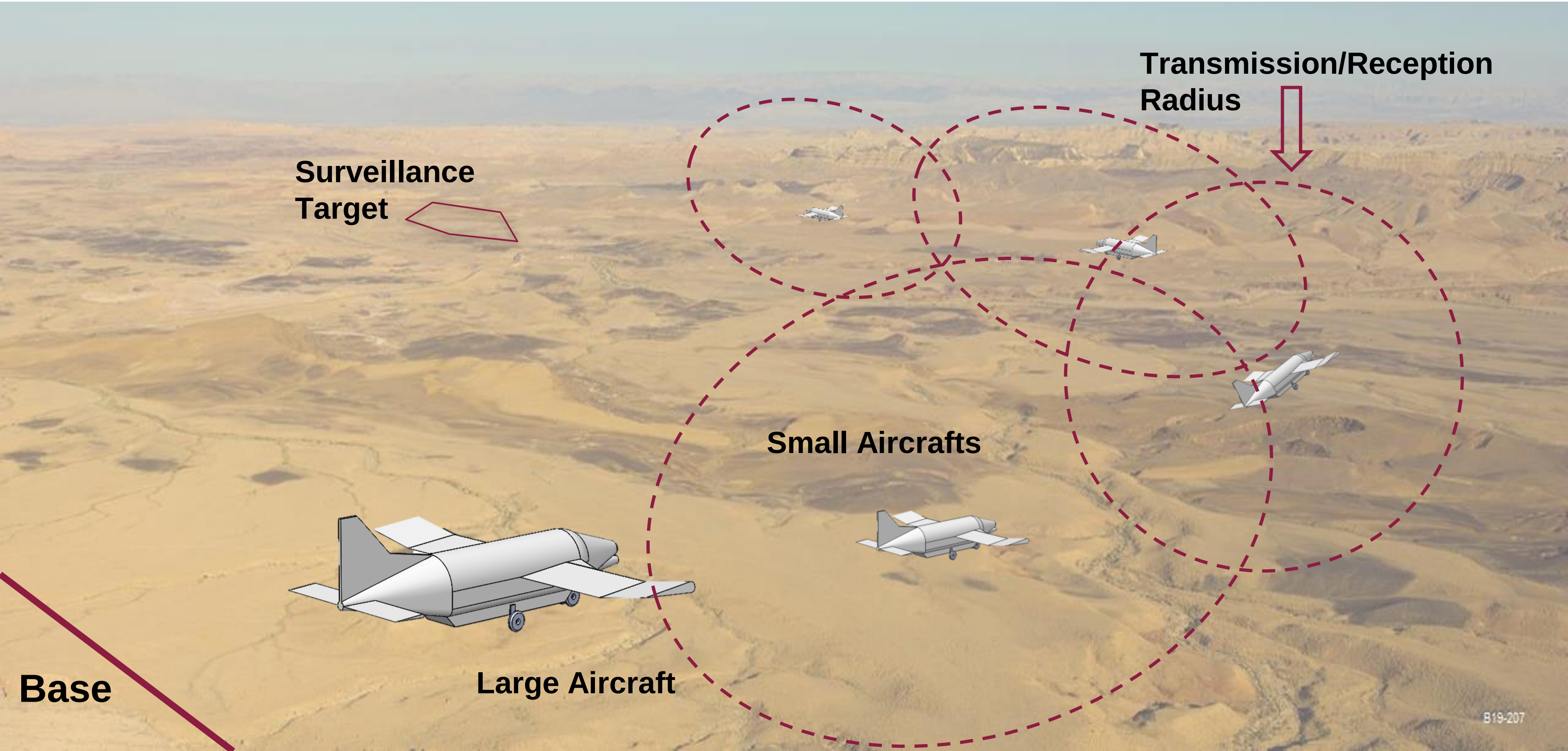
FLZA6162

20A ESC Predator 20A ESC, XT60

FMMPRESC0041

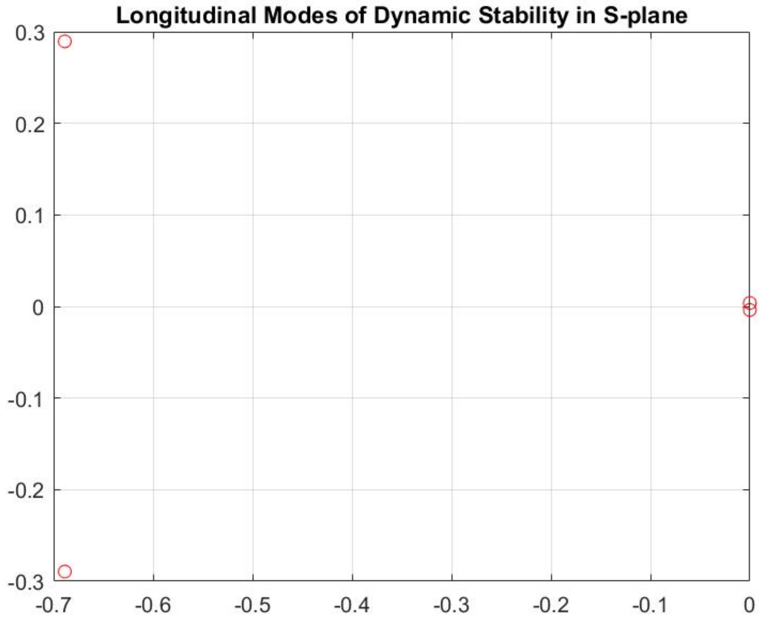
TSX10 Micro Digital High Torque Metal Gear Servo TACM0210

Surveillance/Data Collection Method



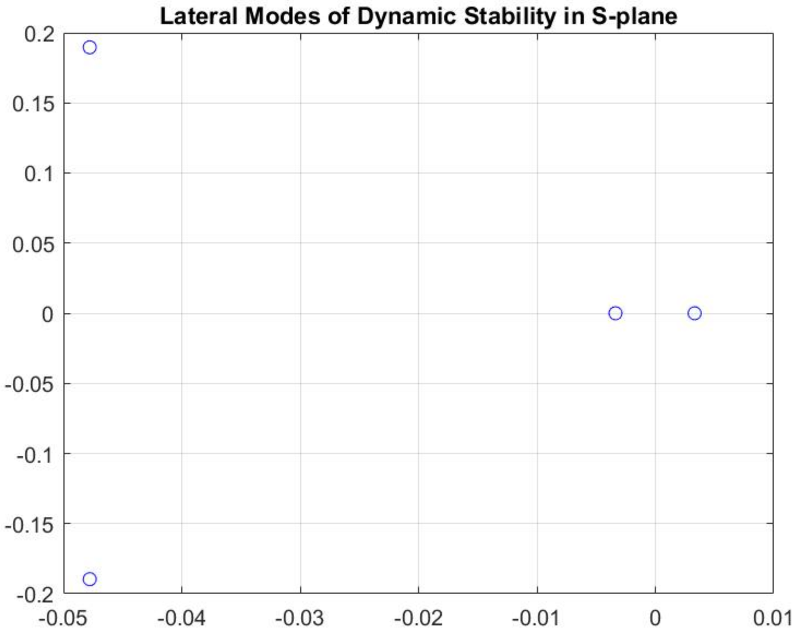
Longitudinal Stability

- $\tau \cong$ 16 mins (phugoid mode)
- $\zeta \cong$ 0.92 (short period)
- $\zeta \cong$ 0.026 (phugoid)
  - Ideally, larger than 0.04



Lateral Stability

- Roll has a longer period than expected and is overdamped
- Spiral is unstable as expected with $\tau \cong 5$ mins
- $\zeta \cong 0.24$ (dutch roll)



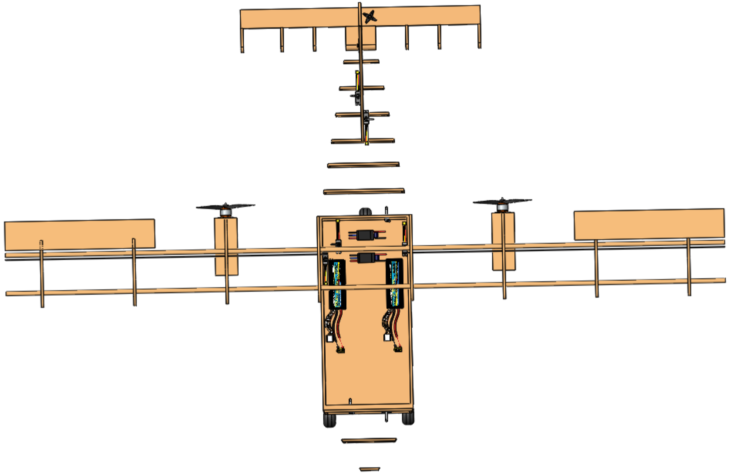
Stability Derivatives

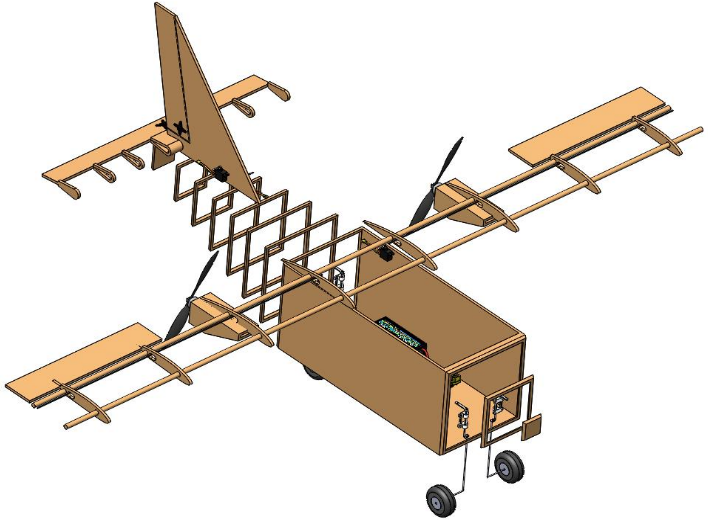
Derivative	Value
$C_{m\alpha}$	-0.0623/°
C_{mo}	0.0969
$C_{l\beta}$	-0.0014/°
$C_{n\beta}$	0.0277/°

Conclusions:

1. Yields a favorable 1.5° trim angle of attack
2. A more balanced yaw and roll stability has yielded better modes
   a. Avoided issue by using Sherpa Optimization Method which revealed that it was necessary to push stabilizers back further and increase height of vertical stabilizer relative to aircraft CG
3. A tail incidence of 1° needed to provide pitch stability

Solidworks Model - Balsa Wood Structure





- Balsa wood use throughout model for increased structural support
- Large cargo area supported by Balsa box to allow for additions of extra cargo
- Control surfaces made of Balsa for control accuracy
- Electronic components can be moved throughout the cargo bay to adjust CG

Solidworks Model - Balsa Wood Structure

Configuration: Default
Coordinate system: -- default --

Mass = 3.78 pounds

Volume = 329.90 cubic inches

Surface area = 2770.93 square inches

Center of mass: (inches)
X = 0.01
Y = -1.89
Z = -6.21

Principal axes of inertia and principal moments of inertia: (pounds * square inches)
Taken at the center of mass.

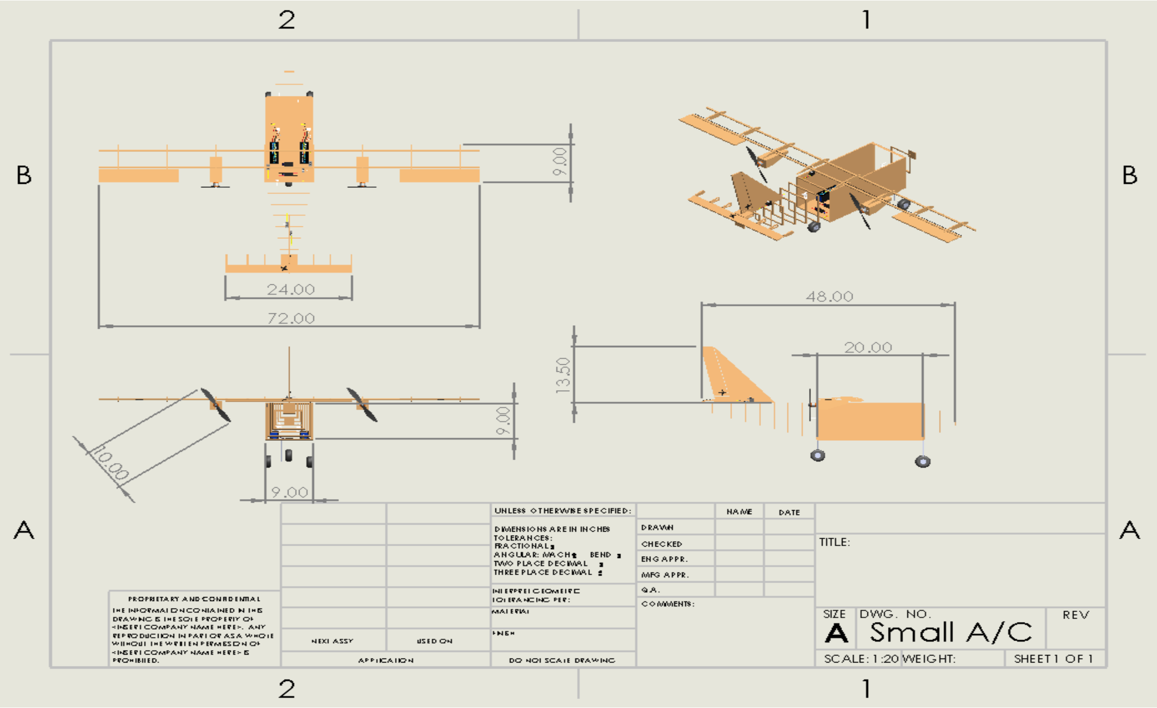
Ix = (0.00, 0.38, 0.92)	Px = 337.68
Iy = (1.00, 0.00, 0.00)	Py = 443.11
Iz = (0.00, 0.92, -0.38)	Pz = 669.42

Moments of inertia: (pounds * square inches)
Taken at the center of mass and aligned with the output coordinate system.

Lxx = 443.11	Lxy = 0.19	Lxz = -0.21
Lyx = 0.19	Lyy = 620.76	Lyz = 117.36
Lzx = -0.21	Lzy = 117.36	Lzz = 386.34

Moments of inertia: (pounds * square inches)
Taken at the output coordinate system.

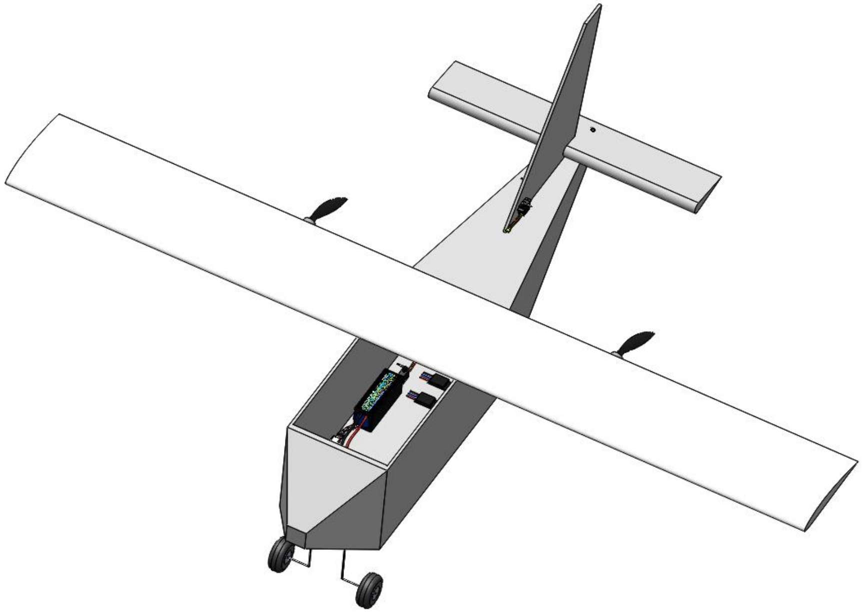
Ixx = 602.61	Ixy = 0.11	Ixz = -0.46
Iyx = 0.11	Iyy = 766.81	Iyz = 161.69
Izx = -0.46	Izy = 161.69	Izz = 399.80



Solidworks Model - After Foam Coverage

Model will be lined with foam.

- Increases durability while maintaining lightweight design
- Allows for easy routing of electrical wires
- Low cost and easily replaceable
- Can easily be modified to account for design changes



Manufacturing Steps

1. Balsa wood structure will be cut to specifications and assembled with gorilla glue.
2. Foam will line the entire structure and secured using gorilla glue.
3. Wing will be attached to body with dowels attached to underside of cargo bay using rubber bands
4. Tail control surfaces will be controlled with tail mounted servos.
5. Aileron servos will be located inside wings.

Technical Risk Assessment

Impact	Extreme (5)	Broken Comunication Chain	Release Mechanism Failure	Foam Control Surfaces		
	Very High (4)			Relying on New Technology		
	Medium (3)	Engine Failure				
	Low (2)	Damaged Components				
	Negligible (1)			Drone Recovered by Foreign Body		
		Rare (1)	Unlikely (2)	Moderate (3)	Likely (4)	Almost Certain (5)
		Likelihood				

Severity	Risk
15	Foam Control Surfaces
12	Relying on New Technology
10	Release Mechanism Failure
5	Broken Communication Chain
3	Engine Failure
3	Drone Recovered by Foreign Body
2	Damaged Components

Logistical Risk Assessment

Impact	Extreme (5)					**Loss of Funding due to Pandemic**
	Very High (4)	**Market for Our Product Goes Away**	**Manufacturing Injury**			
	Medium (3)					
	Low (2)	**Loss of funding**		**Recieiving Faulty Parts**		
	Negligible (1)					
		Rare (1)	Unlikely (2)	Moderate (3)	Likely (4)	Almost Certain (5)
		Likelihood				

Severity	Risk
25	Loss of Funding due to Pandemic
8	Manufacturing Injury
6	Recieiving Faulty Parts
4	Market for Our Product Goes Away
2	Loss of funding

Aerodynamic Testing

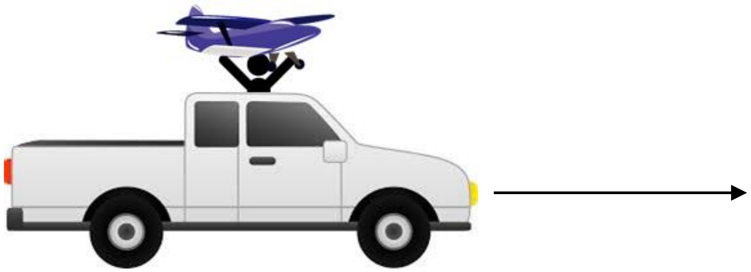
Objective:

To test the rigidity of control surfaces and aircraft structure under aerodynamic loads.

Procedure:

Test roll, pitch, and yaw control while aircraft is moving at flight speeds. Ensure foam control surfaces do not bend or flex.

Diagram:



Propulsion Testing

Objective:

Measure pounds of static thrust.

Procedure:

Use a fishing scale to estimate static thrust with both engines as well as the thrust with a single engine.

Diagram:

Release Mechanism Testing

Objective:

Prototype hold and release mechanisms will be tested for practical use.

Procedure:

Secure wheels of the drone to a moving vehicle and ensure it remains coupled under aerodynamic loads and vibrations.

Diagram:

Friction Testing

Objective:

To determine the coefficient of kinetic friction of the wheels to consider the effects of ground friction on takeoff and landing.

Procedure:

Use a fish scale to pull the aircraft and measure the amount of force required to pull the aircraft across the ground.

Diagram:

Hardware Product Specs

Motor				
Model	Voltage	Bearing Size	Weight	Diameter
Park 450 Brushless Outrunner	890 Kv	4x8x3mm	91 g	28 mm
		4x9x4		
Propeller (-10 x 4.5)				
Model	Size	Weight		
Multi-rotor propeller	10 x 4.5	22.7 g		
Batteries				
Model	Current	Voltage	Weight	
LiPo Bettery : T-Plug	2100 mA	11.1 V	190 g	
ESC				
Model	Current	Weight		
Predator ESC	20 A	68 g		
Servos				
Model	Voltage	Torgue	Weight	Size
TSX10 Micro Digital High Torque Servo	4.8 - 6.0 V	17-23 oz/in	9 g	23x12x28 mm
External BEC				
Model	Current	Input	Weight	Size
CC BEC Pro	20 A	50.4 V	29 g	43 x 33 x24 mm
Gyro				
Model	Weight (g)	Size (in)		
Hitec Stabilization Gyro System	n/a	n/a		

Costs

Item	Individual Price	Quantity	Total Cost
Motors	$47.99	2	$95.98
Propellers (~10 x 4.5)	$2.93	2	$5.86
Batteries (>2200mAh)	$54.99	2	$109.98
ESC	$16.99	2	$33.98
Servos	$15.99	6	$95.94
External BEC	$39.95	1	$39.95
Gyro	$29.99	1	$29.99
Arduino	$22.95	1	$22.95
Landing gear	$19.99	1	$19.99
Rear wheel	$6.49	1	$6.49
Foam	$2.99	10	$29.90
Fiberglass	$14.97	1	$14.97
Structural Support	$16.00	1	$16.00
		Total	**$521.98**

Cost of engineering per hour	$130.00
Cost of manufacturing per hour	$64.00
Cost of quality control per hour	$90.00
Enginering hours	1,000
Manufacturing hours	500
Quality control hours	500
Cost of manufacturing	$521.00
Cost of operation	$200.00
Total cost per aircraft	$207,721.00

Market Analysis

STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
Versatile product - can be used for multiple purposes	Short life-span	More relief opportunities for increased international disasters	Competitors
Large cargo bay	Not bulletproof	Increased defense efforts	Other drone companies
Cheap	Not long range		Little press or media coverage
High endurance			

Business Plan

Producibility Analysis
- Contract with another company that specializes in UAV parts to produce all of our hardware
- Develop a QA (Quality Assurance) to inspect all hardware to for design accuracy
- Create detailed AI (Assembly Instructions) for large scale manufacturing
- Put it all together in a factory according to the manufacturing steps

Sales Channels
- Direct to consumer sales
- Contract with military
- Trial uses

Questions?