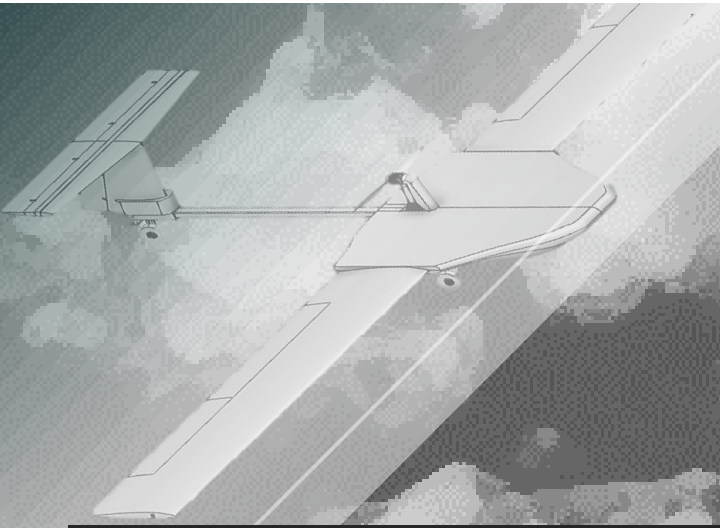


Project Summary

- Mission Definition
- Management
- Design
- Manufacturing
- Test & Evaluation

April 17th, 2020

Mission Profile

Robin Trindelle	Lindsey Flynn	Dan Evans	Jennifer Winters
Biological, Administrator, Florida Fish and Wildlife	*Supervisor, Sea Turtle Conservancy*	*Senior Biologist, Sea Turtle Conservancy*	*Environmental Specialist, Volusia County Habitat Conservation Plan*
UAV's are controversial when dealing with these species	Lighting is an issue	Can determine species with tracks	Tampering with eggs is a problem in high population areas
Not to interfere with other wildlife	Ease of use	Endurance	

Setup *<30 minutes*	Launch	Autonomous Search *30 minutes*	Landing	Reserve *15 minutes*	Takedown *<30 minutes*
• *Assemble aircraft* • *Setup ground station* • *Preflight checklists*	• *Takeoff on beach access driveway* • *Autonomously ascends*	• *Begins imaging along flight path with 14 CFR part 107 waiver* • *Image processing offboard via LTE link* • *Cruise altitude of 196-ft*	*Decrease altitude and land in predefined landing zone*	*Extra flight time available*	• *Post flight checklists* • *Wings are removed* • *Ground station shut down* • *Components packed in hard shell case for transport*

Team organization

Semester 1 team organization

Stakeholders

Boeing Mentors
Marilyn, Matt

Faculty Advisors
Phil, Dr. Jensen

Project Manager
Dylan

Chief Engineer
Kayla

<u>Mechanical</u>
David (lead)
Allen
Josh Norris

<u>Aerodynamics</u>
Jake (lead)
Evan
Jaehyeok
Josh Neumann
Stanley

Semester 2 team organization

Stakeholders

Boeing Mentors
Marilyn, Matt

Faculty Advisors
Phil, Dr. Jensen

Project Manager
Dylan

Chief Engineer
Kayla

<u>Programming</u>
Design, develop, and test the vision system as well as the flight controls

Personnel
Jake (lead), Josh Norris, Jaehyeok, Stanley (PT)

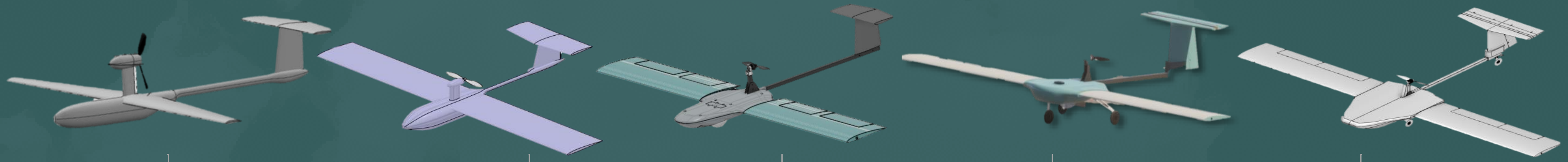
<u>Manufacturing Programs</u>
Coordinate manufacturing work allocation, create job instructions, communicate with EVCC, respond to manufacturing emergencies, create manufacturing at scale plans

Personnel
Allen (lead), Evan, David, Josh Neumann (PT)

<u>Test & Evaluation</u>
Refine the test plan, develop schedule for system & sub system test (sans vision), coordinate testing

Personnel
Josh Neumann (lead), Stanley

Project Schedule



8/30: Request for Proposal

9/20: Mission Concept Review

10/25: Preliminary Design Review

12/6: Final Report Submission

1/31: Manufacturing Readiness Review

4/1: End of Development (internal)

4/17: Final Report & Presentation

August	September	October	November	December	January	February	March	April

Mission, requirement, & stakeholder development	Preliminary sizing & configuration trade studies	Detailed sizing, CAD design, glider building, & glider testing	CAD Design & analysis	Build UAS, develop vision processing, subsystem test	UAS system testing

Detailed design decisions & CAD became behind schedule, stretching into Winter break.

Cause:

- Unfamiliarity with CAD software
- Understaffed CAD team
- Not understanding iteration as aero was developing

Result:

- Necessary to work over break
- Significant errors caught week of MRR
- FEA delayed until after MRR

Construction & Shipping

2/3	2/10	2/17	2/24	3/2	3/9	3/16	3/23	3/30

Fuselage, wing, tail construction 1/31-2/21	Shipping window 2/21-3/1	Final Assembly 3/2-3/19

▲ Actual fuselage ship date: 2/24

▲ Actual wing ship date: 3/2

▲ Actual final assembly complete: 3/23

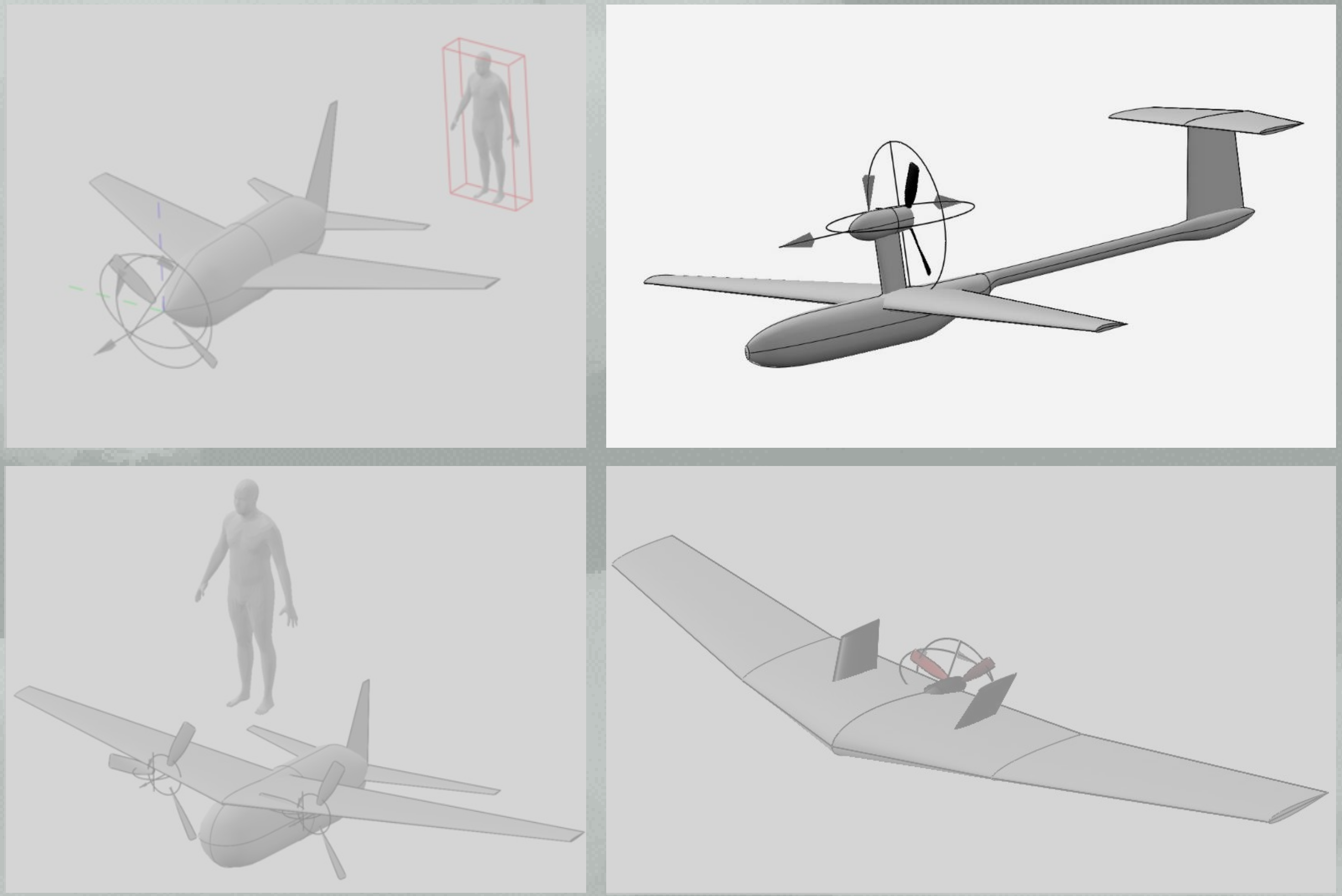
Requirements

- Stakeholder discussions
- Technical needs
  - System requirements
  - Subsystem requirements
  - Operational requirements
  - Payload requirements

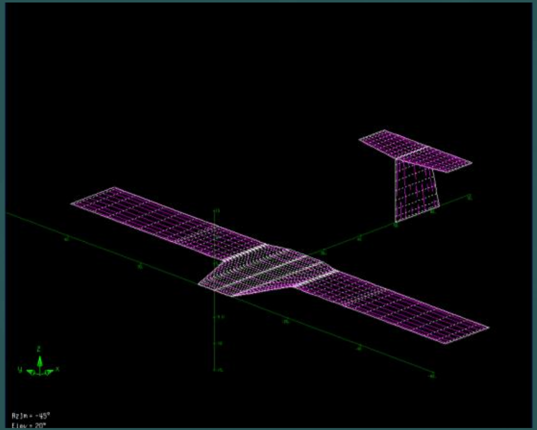
Title	Details
SDR-003: Weight	Weight less than 12-lbs
SDR-004: Transportation Size	The UAS shall be easily transportable (fit within a box 20" x 24" x 100")
SDR-005: Cost	Cost less than $4,000
SDR-006: Autopilot	The UAS shall be able to fly with autopilot to established mission profiles
SDR-009: Takeoff	Wheeled takeoff from surface <200-ft
SDR-011: Detecting Sea Turtle Nests	The UAS shall carry a payload capable of aiding in detection of sea turtle nests
SDR-014: Maintenance	The UAS shall be capable of handling multiple flights/operations without need for replacement or significant repair.
SDR-021: Range-distance	The UAS shall have a range of at least 15 miles
SDR-023: Setup Time	The UAS structure shall have a setup time (out of box to launch) of no greater than 30 minutes
SDR-024: Setup Tools	The UAS structure shall not require more than 2 external tools to set up for flight
SDR-026: Handbook	A detailed pilots operating (POH) & maintenance handbook shall be included with every UAS
SDR-030: Noise	The UAS shall produce no more than 50 dB of noise at a distance of 200-ft altitude
SDR-036: Stowing Time	The UAS shall have a stowing time (controls disarmed & disassembled) no greater than 30 minutes

Determining Configurations

- All members created initial concept designs
- Narrowed selection to 4 primary designs
- Optimal design was identified using weighted decision matrix.
  - 10 criteria were considered
  - Criteria weights were taken as the average of each members' opinions
  - Designs scores were completed by all team members independently



Flight Performance and Stability



Stability Analysis Result	
Neutral Point (in)	17.38
Center of Gravity (in)	**15.58**
Chord Length (in)	12.00
Stability Margin	15 %

Weight and Balance Result			
		CAD	**Aircraft**
Total Mass (lbs)		11.64	10.5
Center of Gravity Coordinate	X (in)	**13.25**	**14.50**
	Y (in)	2.75	0.00
	Z (in)	0.26	-3.00

Flight Performance	
Takeoff Speed (mph)	20.00
Stall Speed (mph)	16.68
Cruise Speed (mph)	40.00
Expected Flight Time	30-minute mission + 15-minute reserve
	Total 57-minute 41-second

- AVL and 3D Experience used to conduct analysis
- Discrepancy observed for center of gravity
  - Change of mass distribution during final design and construction

Propulsion: Technical Specifications

Propulsion Performance							
Cruise				Takeoff			
Thrust	1.44 lbf	**Current Draw (6s)**	8.6 A	**Thrust**	3.59 lbf	**Current Draw (6s)**	22.6 A

Components:

Motor:
KDE 2814XF-515 (515 kV)

Propeller:
APC B11x8E (11x8)

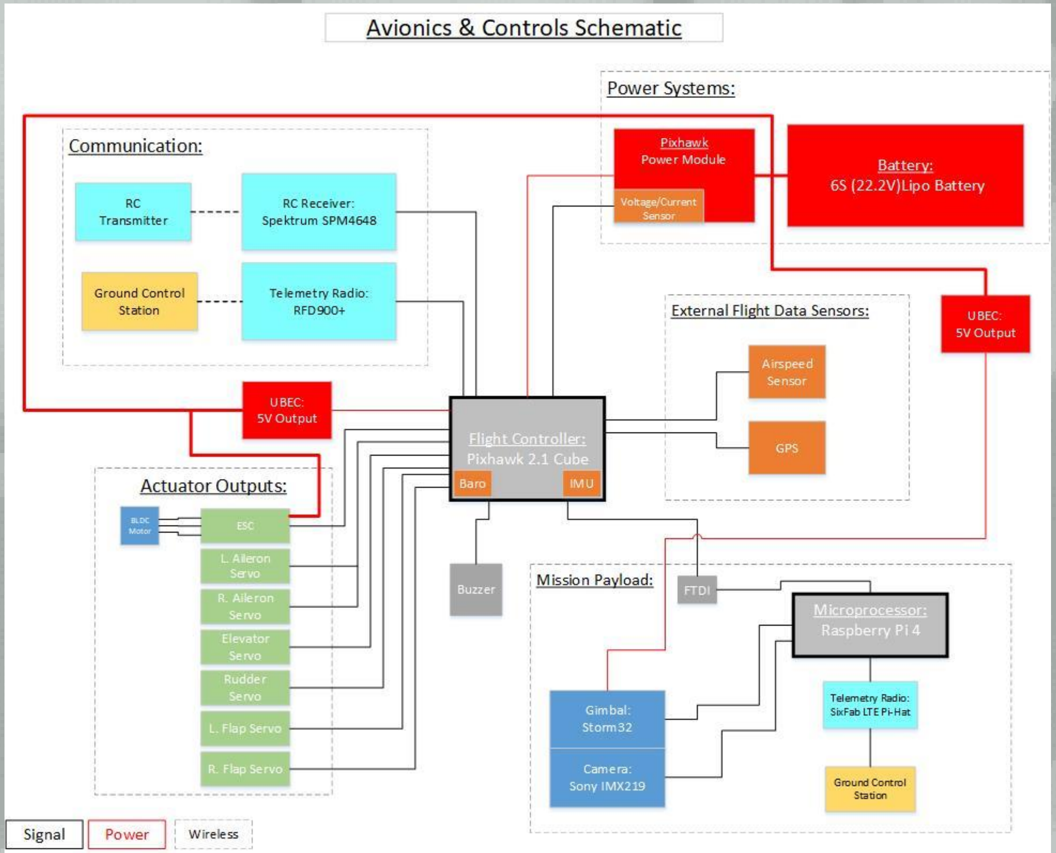
ESC: KDEXF-UAS35 (35A+)

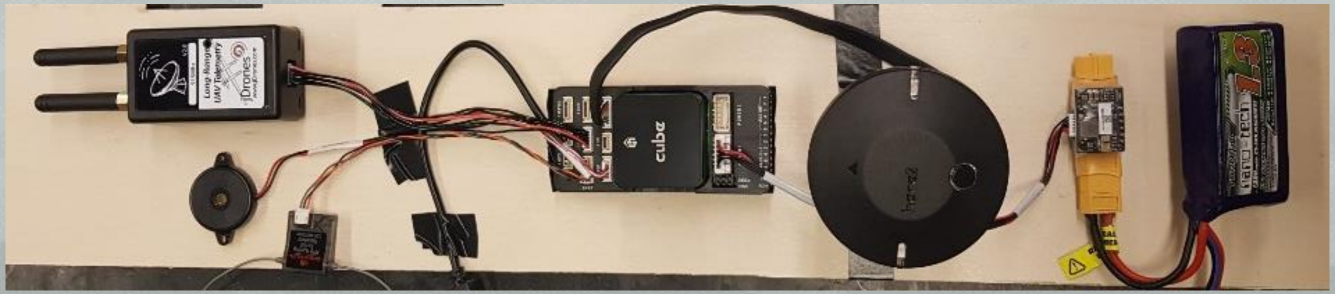
Battery:
Lumenier 8000 mAh 6S 25C LiPo

Mission Required Current: 7690 mAh

Detailed Design: Payload & Electronics

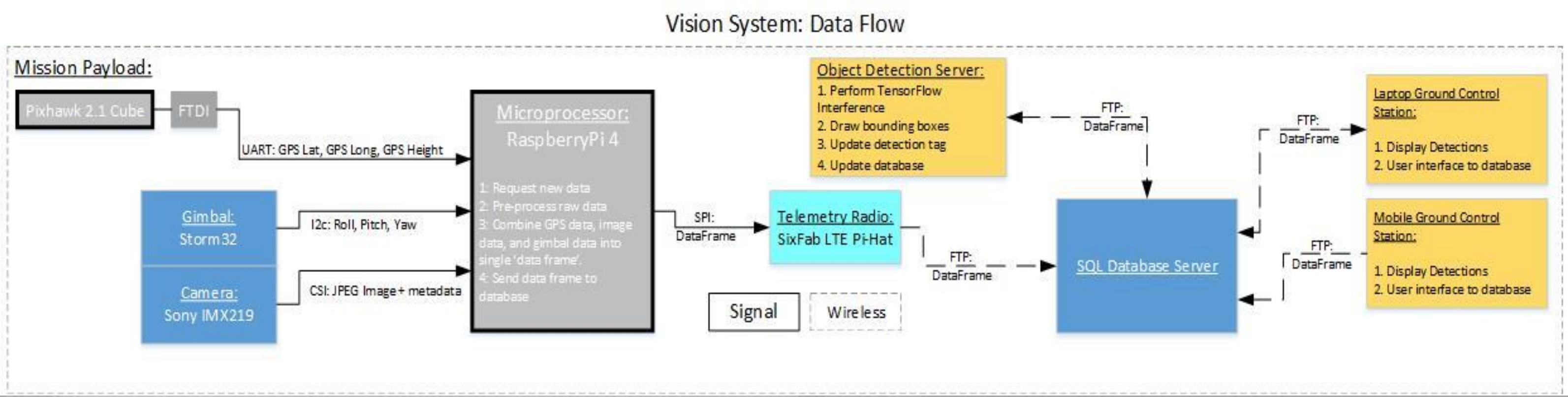
- Pixhawk based flight controller running PX4 firmware
- Standard fixed-wing aircraft flight data sensors
- Raspberry Pi 4 controls vision system data collection, pre-processing and storage
- Separate data streams for aircraft and mission data

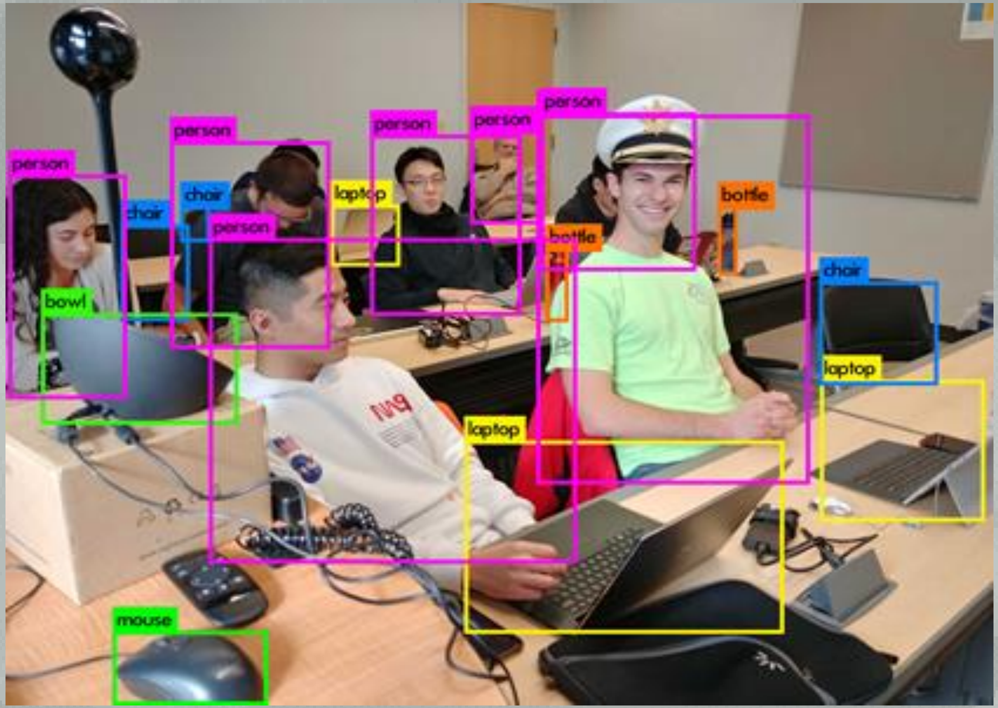




Detailed Design: Vision System

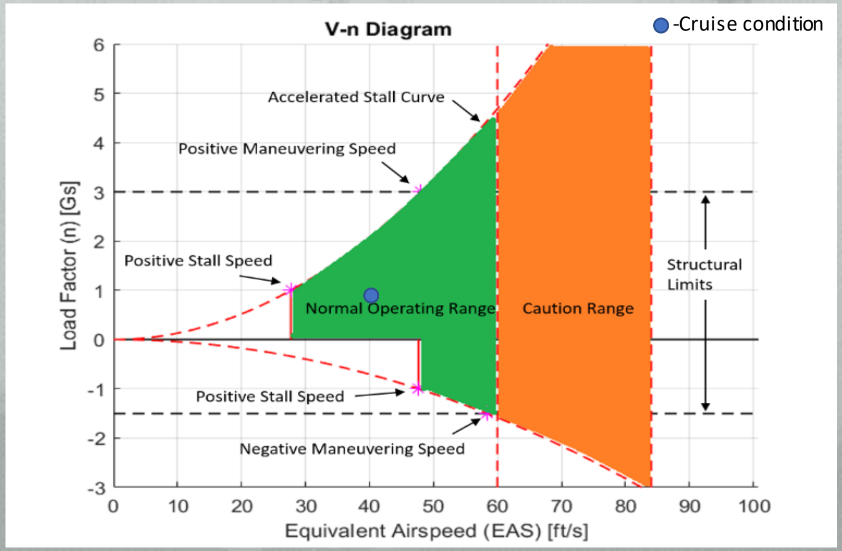
- Main function of vision system is to detect sea turtle using a convolutional neural network(CNN)
- Uses Tensorflow2.0 and YOLOV3 to implement the CNN
- Model to be trained on turtle test object(foam turtle)
- SQL database for scalability
- Sony IMX219 Camera:
  Sensor: ¼”CMOS
  Resolution: 1920x1080 pixels
  Field of view: 82’
  Pixel ground width: 0.5”
  (Turtle track width: 2.5-3.25’)
  Frame overlap: 93% at 15 FPS, cruise

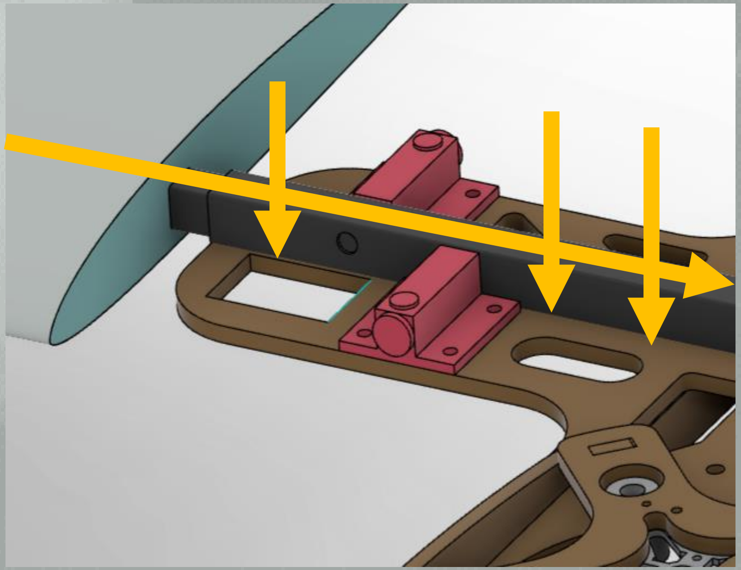


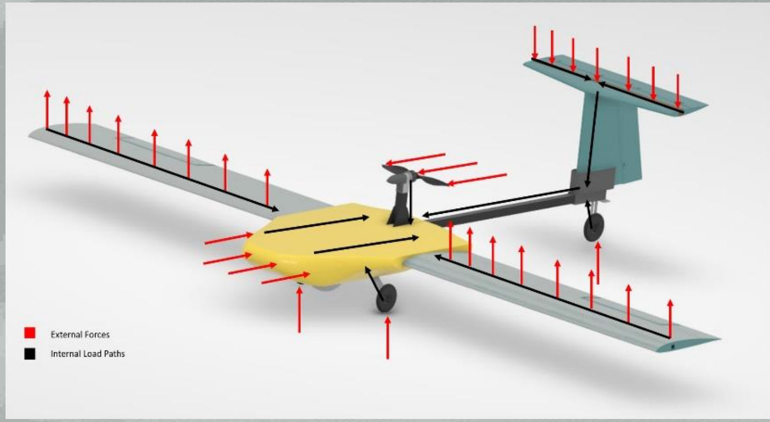


Detailed Design: Structural Design

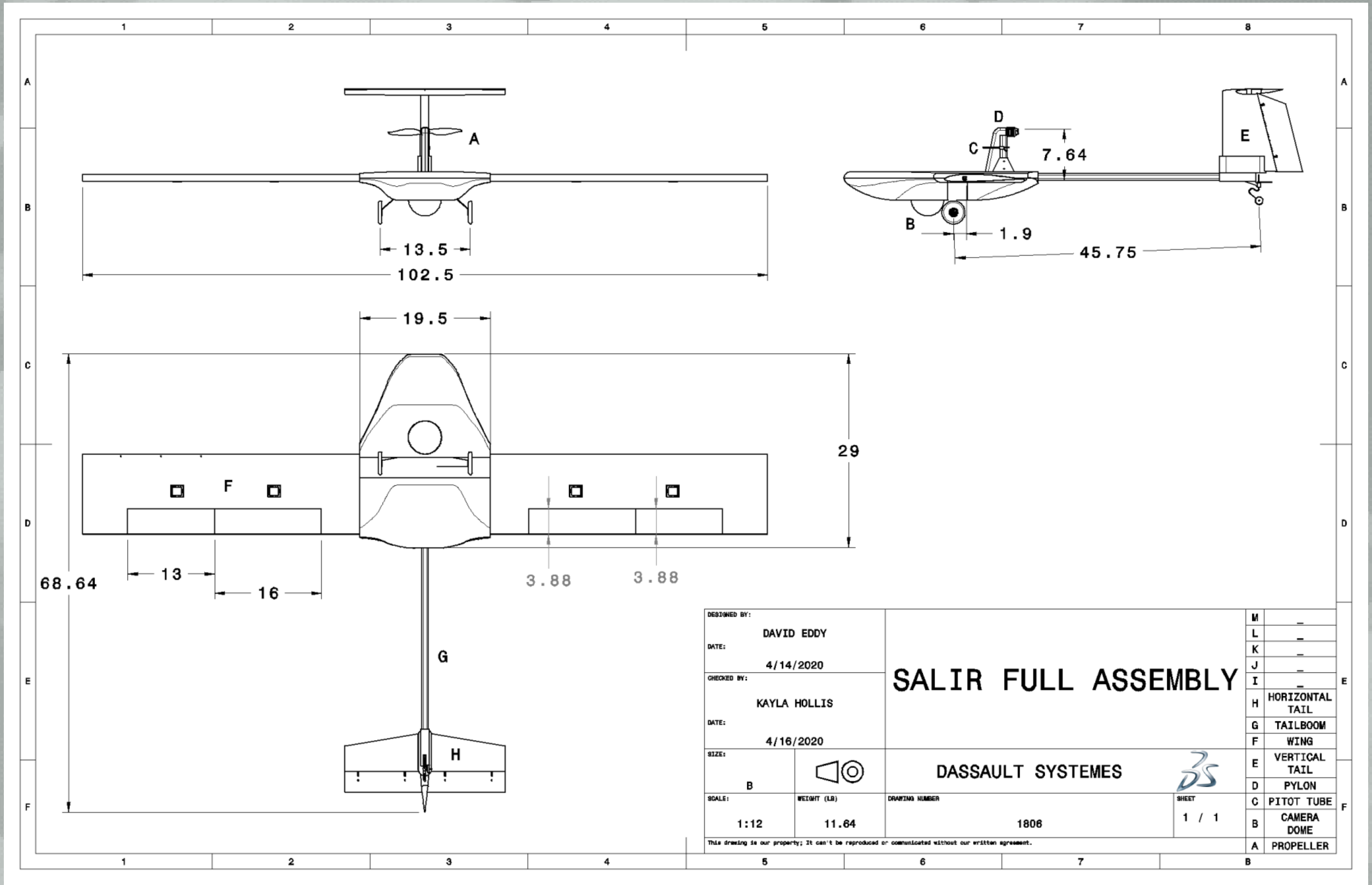
- Hand-Calculations used for sizing and verified with SIMULIA FEA
- Wing – Main Structure Connection: Detents
- Aerodynamic cover fully removable.
- Integrated electronics board and main structure







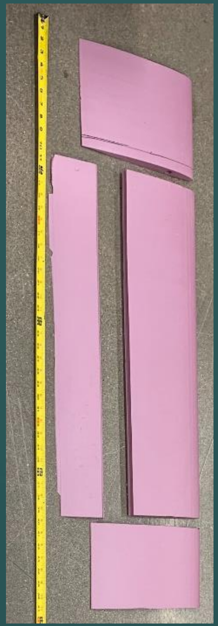
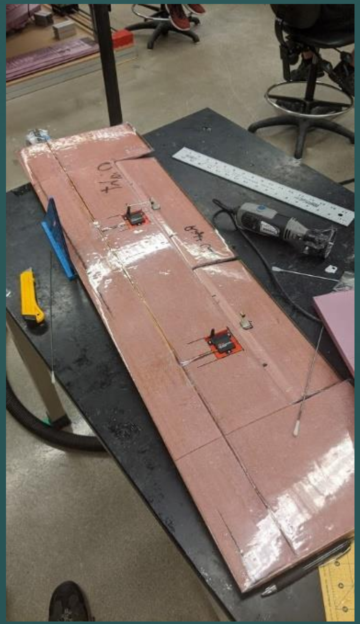
3-View Drawing

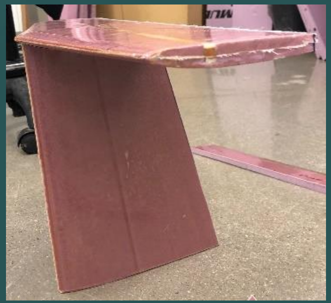


Manufacturing Plan and Execution

Glass Slipper Wings & Tail:

1. Foamular XPS 250 was cut using a CNC hot wire
2. Each wing was cut in 3 parts: root, control surfaces, and tip
   a. Designed for manufacturability, moving the flaps out changed from needing 5 cuts to 3 cuts to shape the wing
3. Control surfaces were cut with CNC hot wire
4. 3oz plain weave fiberglass layup with epoxy and vacuum bag
5. 3 spars channels and 6 servo pockets were cut
6. Main spars were extended by combination of interference and tight tolerance fits.

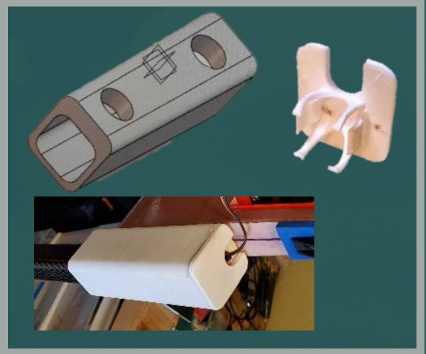






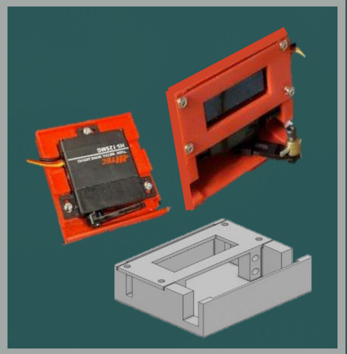

Additive Manufacturing:

- Parts were designed using 3DExperience
- Prints were executed on Qidi X Pro and Delta-style printers
- All prints were ABS or PLA plastics

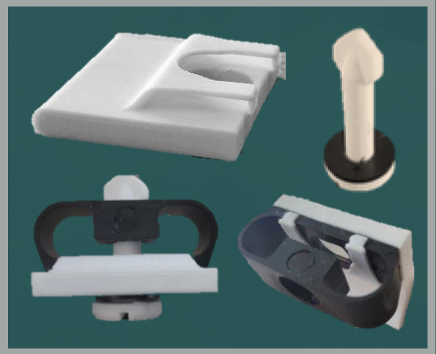
Tail Connector



Servo Trays



Replicated DZUS Fasteners



Fairing

Manufacturing Plan and Execution

Fuselage:

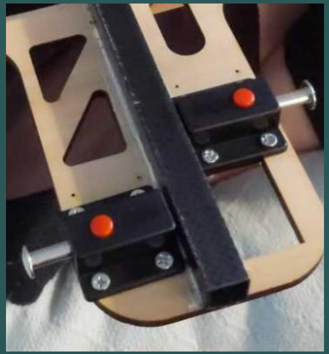
1. 1/4-inch honeycomb and fiberglass were cut to size
2. Honeycomb was scored to allow for bending
3. 2 part (top and bottom) positive mold was created
4. Epoxy was applied with a brush to adhere the fiberglass to the honeycomb
5. The sandwich structure was vacuum bagged
6. Weight totaled 2 lb. 6 oz. (overweight)
    1. A less dense 1/8-inch honeycomb was used
    2. Epoxy was weighed before application
    3. **Final fuselage weight of 10.5 oz**
7. Cuts were made for fitting around the electronics board, wings, and landing gear

Motor Mount:

- Made from a 2”x 2” block of aluminum
- CNC milled
- Fit into carbon fiber pylon

Detents:

- Purchased to attach wings
- Spar hole tolerance of +0.025”



Electronics Board:

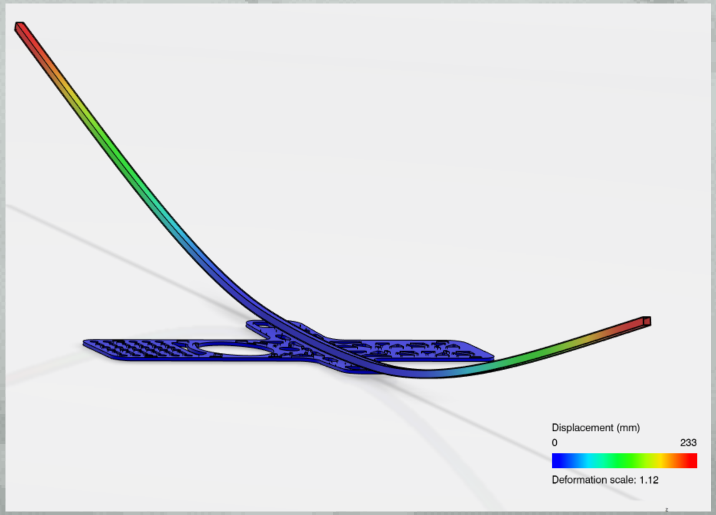
1. ¼ inch Birch wood was purchased
2. The part was laser cut
3. Support beams on top and bottom were replaced to increase stiffness

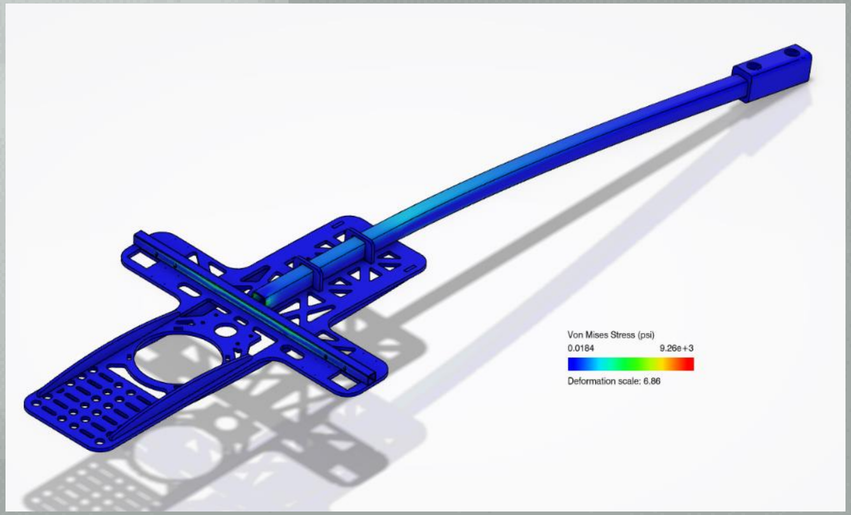
Testing Plan

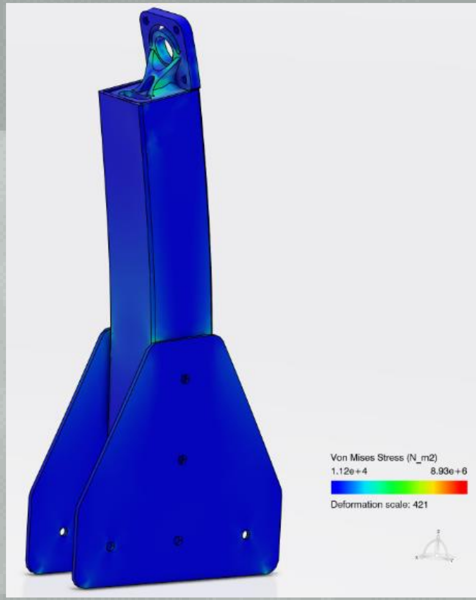
- Preliminary Test Plans
  - Tail Bending – FEA 🟢
  - Tail Bending – Physical 🟢
  - Wing Bending – FEA 🟢
  - Wing Bending – Physical 🔴
  - Motor Pylon – FEA 🟢
  - Static Thrust 🟢
  - Dynamic Thrust 🟢
  - Noise Mitigation 🔴
  - Manual Flight Test 🔴
  - Autonomy Test 🟢
  - FRR Shake Test 🔴

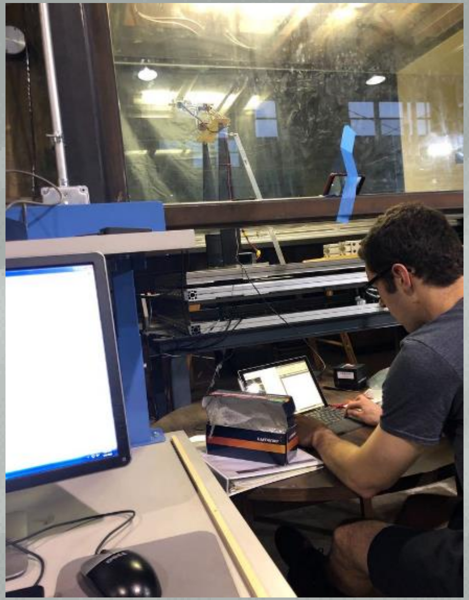
Complete - 🟢

Incomplete due to COVID-19 - 🔴





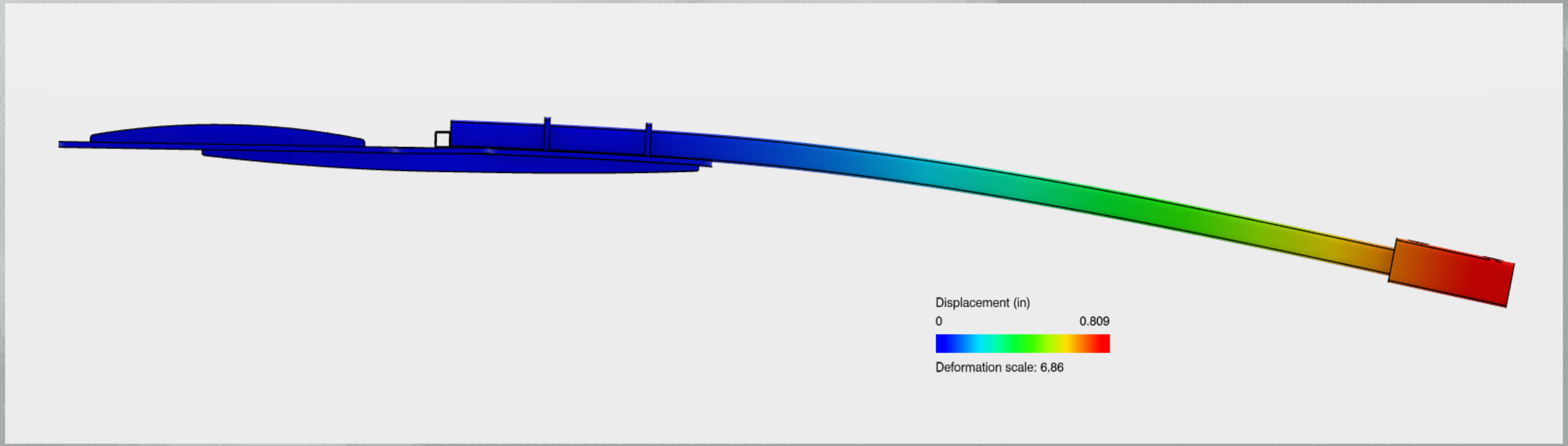




Performance Results

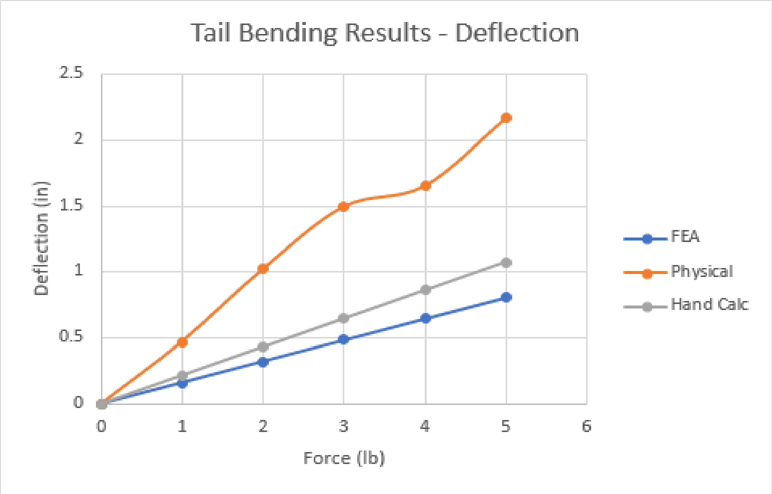
Tail Bending

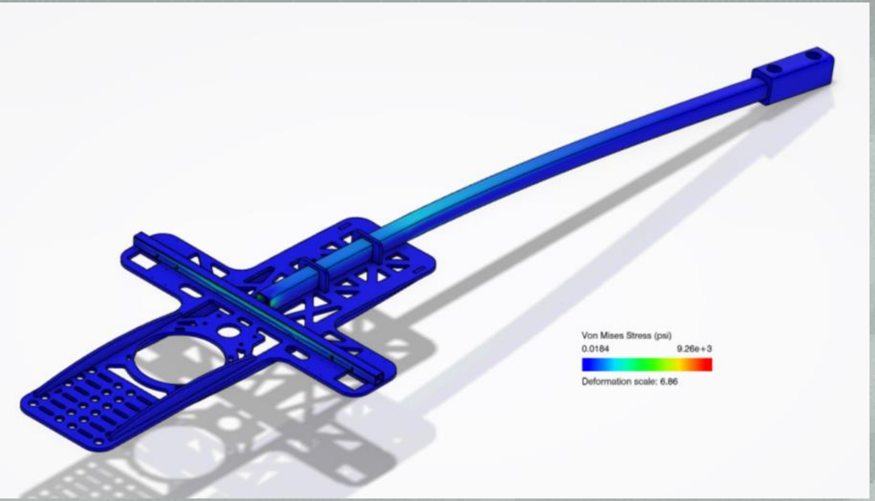
- FEA w/ SIMULIA Static Study
- Physical test conducted
- Downward force applied on tail connector over range of 1-5 lbf



Results

- Max Stress of 9.26 ksi
- Deflection greater by factor of 2.68 compared to FEA
- Possible Causes:
  - Constraints
  - Add'l flex in payload board in physical test

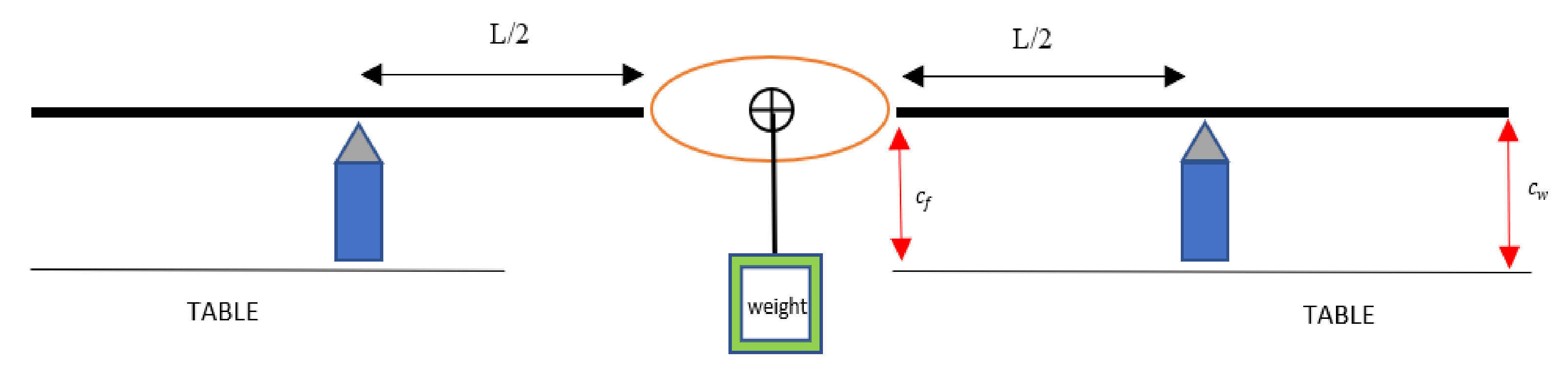




Performance Results

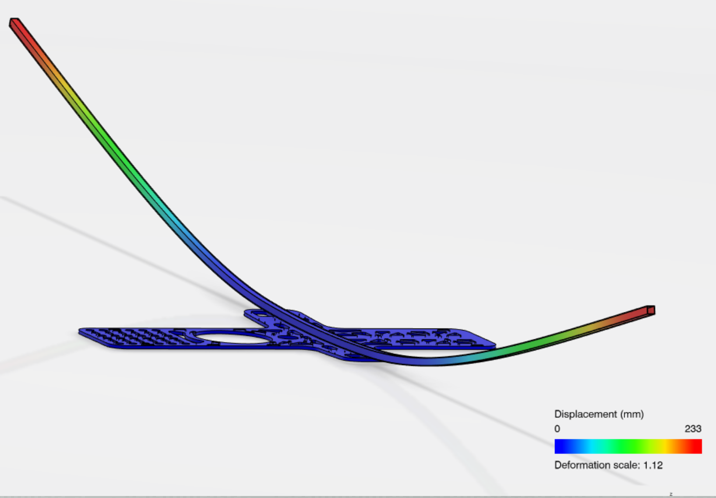
Wing Bending

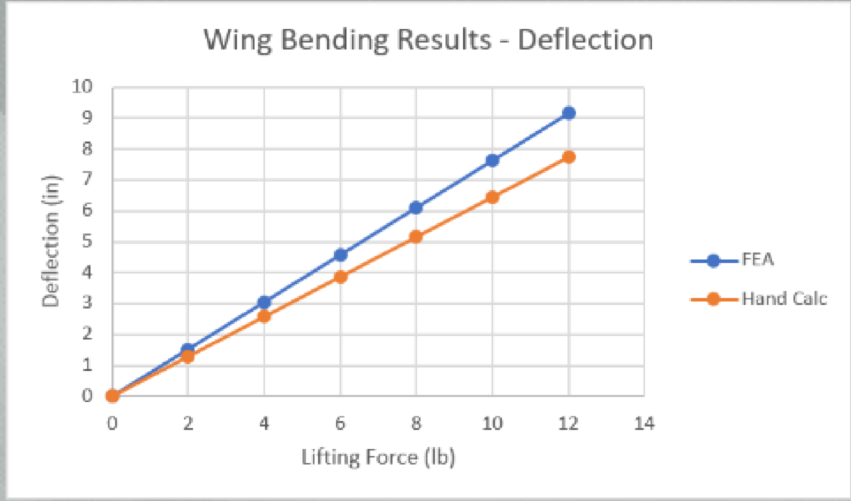
- FEA w/SIMULIA Static Study
- Physical Test not complete due to COVID-19
- Fixed front and back edges of payload board



Results

- Max deflection of 9.15 in. With 12 lb of lift
  - Did not include fiberglass or foam from wing.
- Max stress of 12.76 ksi
  - Factor of Safety = 23

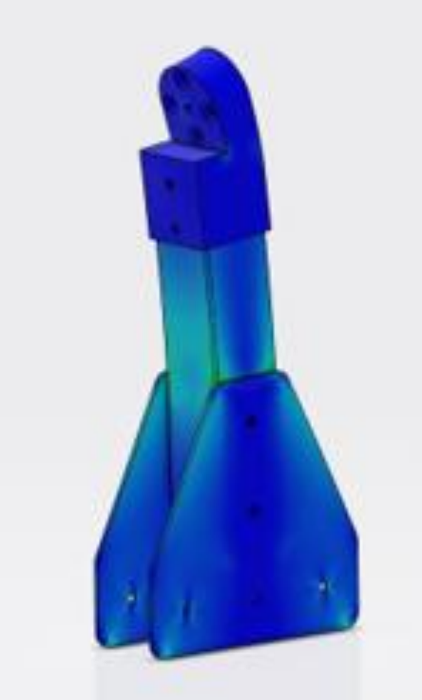


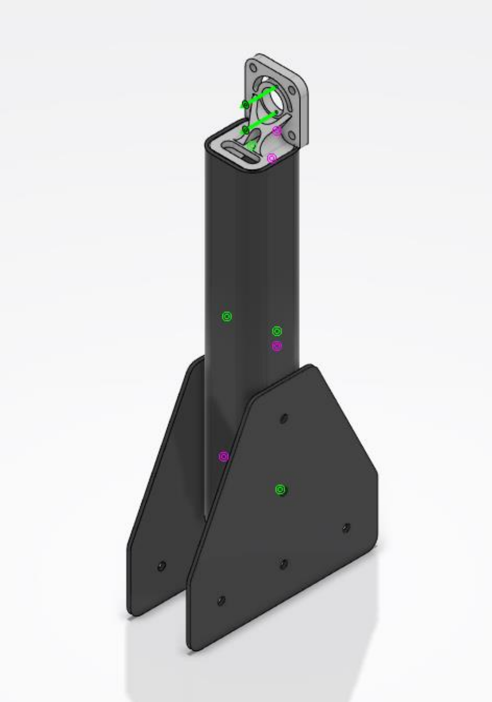


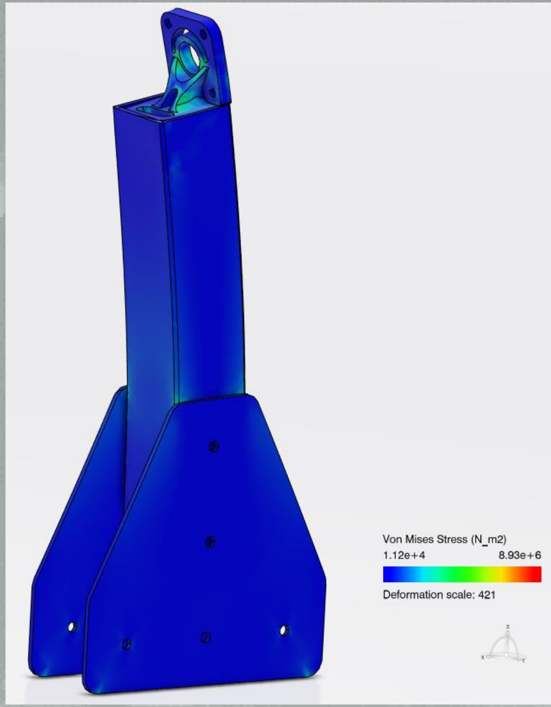
Performance Results

Motor + Pylon

- Redesigned Mount after suggestions from MRR
  - Switched material from 3D printed ABS to machined Aluminum after concerns of heat and layer delamination
- Conducted FEA using Simulia Static Study
- Constraints
  - Base fixed to aircraft spine
  - 3.59 lbf force from propulsion thrust
  - Surfaces Fully Bonded using Hisol Applicant







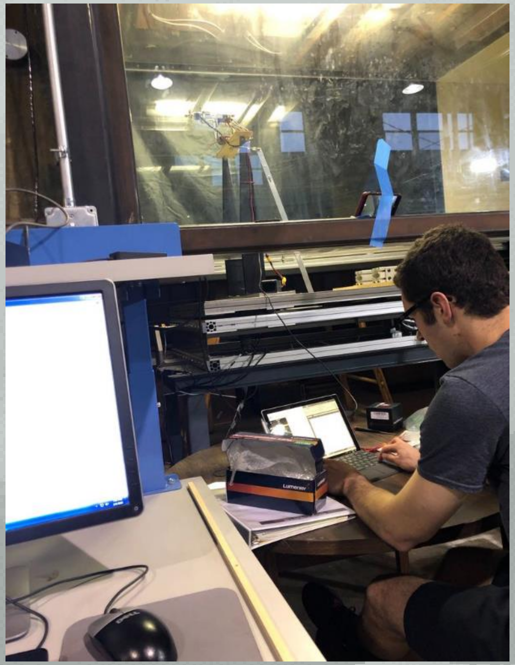
Results

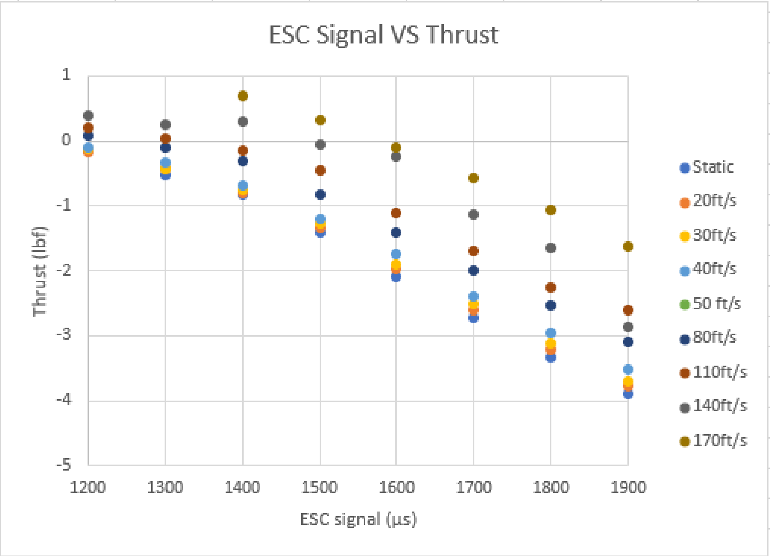
- Stress in aluminum mount
  - 0.54 ksi
    - Factor of safety: 55

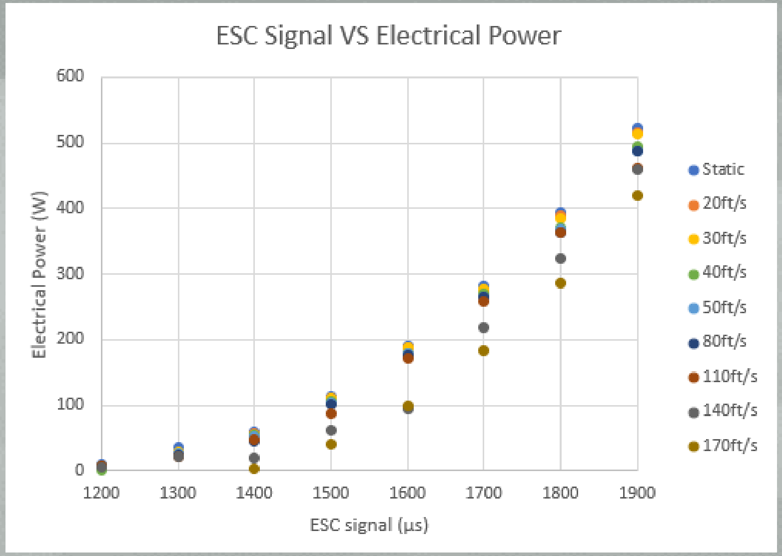
Performance Results

Thrust

- Static testing
  - Static test maximum 3.9lbf
  - Static test maximum draw 521 watt
- Dynamic Testing
  - Increase free stream velocity significantly deduces thrust output & reduce power draw
  - Max output at cruise is 3.4lbf at 50 ft/s
  - Max power draw at cruise is 487.9 watt at 50 ft/s



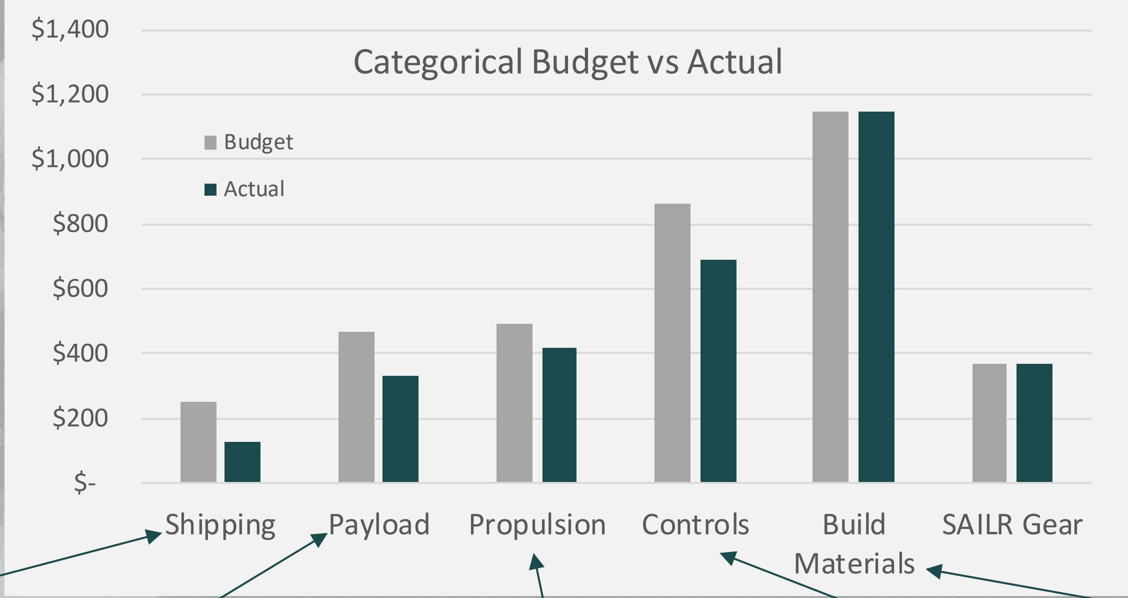




Requirements Verification

Title	Details	Verified	Reason
SDR-003: Weight	12 Pound Maximum	Yes	Weight = 10.5 lb
SDR-004: Transportation Size	Easily transportable (fit within a box 20" x 24" x 100")	Yes	Measured to fit
SDR-005: Cost	Cost less than $4,000	Yes	Total Cost = $2,579.00
SDR-006: Autopilot	Fly with autopilot to established mission profiles	Yes	Shown to work with Bixler
SDR-009: Takeoff	Wheeled takeoff from surface in less than 200-ft	Yes	Calculated Takeoff Distance = 33.6 ft
SDR-011: Detecting Sea Turtle Nests	Carry a payload capable of aiding in detection of sea turtle nests	No	Not able to identify turtle specifically
SDR-014: Maintenance	Capable of handling multiple flights/operations without need for replacement or significant repair.	No	No Study Completed
SDR-021: Range-distance	15-mile minimum range	Yes	Calculated Range = 36 Miles
SDR-023: Setup Time	Structure shall have a setup time (out of box to launch) of less than 30 minutes	Yes	Setup Time = 10 minutes
SDR-024: Setup Tools	No more than 2 external tools to set up for flight	Yes	Tools Needed = 1
SDR-026: Handbook	A detailed pilots operating (POH) & maintenance handbook shall be included with every UAS	Yes	Documents Created
SDR-030: Noise	Produce no more than 50 dB of noise at a distance of 200-ft altitude	No	Unable to Verify due to COVID-19
SDR-036: Stowing Time	Stowing time (controls disarmed & disassembled) not greater than 30 minutes	Yes	Stow Time = 10 minutes

Money



Actual Expenses

Cash Reserves $924

SAILR Gear $367 (-1%)

Build Materials $1,146 (0%)

Controls $691 (-20%)

Propulsion $415 (-15%)

Payload $329 (-29%)

Shipping $128 (-49%)

Cost to build plane: $2709

Shipping:

- FedEx actual cost cheaper than website quote
- No second wing set to ship

Payload:

- Could not develop LTE capabilities so data plan not purchased
- Unforeseen expenses include Raspberry Pi SD card and LTE antennae

Propulsion:

- Qualified for free shipping
- Purchased 2nd battery

Controls:

- Little margin used for wires, connectors

Build Materials:

- Expanded budget ($200) 2/29 with shipping funds to reimburse ISU for lab supplies
- Overbudget on Wing foam and spars offset by unused margin for shipping & misc. fasteners

Progress Needs to Delivery

<u>Current status:</u>

- Flight test ready aircraft

<u>Needs:</u>

- Obtain controller
- Coordinate with pilot
- Complete ground test plans
- Complete air test plans
- Complete sea turtle recognition
- Develop LTE communication capabilities with database
- Integration of payload
- Entire system test & rework as needed

Lessons Learned

Working effectively across backgrounds & disciplines with people of differing technical strengths

Scoping the project and individual tasks when provided open ended instruction

Understanding the impact of schedule delays on subsequent work

Communicating clearly across time zones & backgrounds

Planning requires follow up

Discussion

Configuration Decision Matrix

Criteria	Weighting	Pylon over wing	Conventional tractor	Conventional twin	Flying wing	Description
Acoustic mitigation	3.6	154.8	64.8	82.8	79.2	Does the configuration have any noise reduction design traits?
Propeller airflow	3.2	140.8	108.8	124.8	86.4	Does the propeller get a clean, undisturbed airflow?
Adverse aerodynamic interactions	4.2	117.6	134.4	147	96.6	Does the configuration have any wing/tail/prop interaction that could negatively affect the stability?
Ease of C.G. placement	4.8	163.2	192	177.6	72	Does the aircraft have the ability to place the center of gravity in various locations to provide enough static margin?
Aero dynamic modelling complexity	2.8	81.2	103.6	86.8	70	Does this aircraft possess a wing or tail configuration that is more complex to aerodynamically model.?
Flight controller configuration complexity	3	75	111	96	69	Does the configuration have any special channel mixing that would need to take place or parameters that would need special tuning?
Hand & propeller clearance	4	196	140	140	68	Is it easy to design a propeller position that would give adequate clearance from launcher?
Propeller ground clearance	1	50	25	36	16	Is there enough clearance between the propeller and the ground?
Structural design complexity	5	160	190	170	180	Does this aircraft lend itself to a robust structure? Are there parts that will likely break off? etc.
Manufacturability	3	99	117	90	114	Does this aircraft require tools not available to our universities? How long would each part of the structure take to manufacture?
Total		1237.6	1186.6	1151	851.2	

Configuration of choice

Requirements Verification

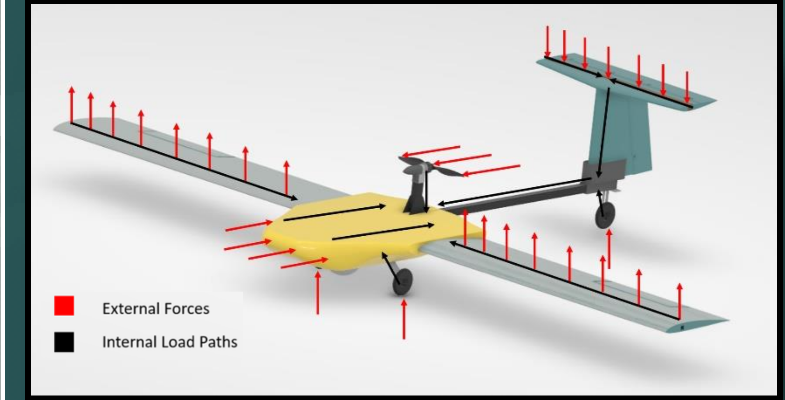
Title	Details	Verified	Reason
SDR-001: Fixed Wing	Aircraft to have fixed wing design	Yes	Fixed Wing
SDR-002: Electric Propulsion	Aircraft will have electric propulsion system	Yes	Electric Motor
SDR-003: Weight	12 Pound Maximum	Yes	Weight = 10.5 lb
SDR-004: Transportation Size	Easily transportable (fit within a box 20" x 24" x 100")	Yes	Measured to fit
SDR-005: Cost	Cost less than $4,000	Yes	Total Cost = $2,579.00
SDR-006: Autopilot	Fly with autopilot to established mission profiles	Yes	Shown to work with Bixler
SDR-009: Takeoff	Wheeled takeoff from surface in less than 200-ft	Yes	Calculated Takeoff Distance = 33.6 ft
SDR-011: Detecting Sea Turtle Nests	Carry a payload capable of aiding in detection of sea turtle nests	No	Not able to identify turtle specifically
SDR-012: Government Regulations	Aircraft complies with FAA, State, and Government Regulations	No	Waiver needed for BVLOS, operation from moving vehicle
SDR-014: Maintenance	Capable of handling multiple flights/operations without need for replacement or significant repair.	No	No Study Completed
SDR-015: Ease of Use	Easy to use and easy to setup	Yes	Intuitive access and design for easy use
SDR-016: GPS Accuracy	GPS accuracy of 5 meters or less	No	Not Verified
SDR-017: Location of Subject	GPS accuratly pinpoints the location of camera subject matching mission criteria	No	Not Verified
SDR-018: Marine Disturbance	Make any attempt to avoid marine life in the area	Yes	Mission flight altitude
SDR-019: Flight Cycles	Withstand 200 flights	No	Not Verified
SDR-021: Range-distance	15-mile minimum range	Yes	Calculated Range = 36 Miles
SDR-023: Setup Time	Structure shall have a setup time (out of box to launch) of less than 30 minutes	Yes	Setup Time = 10 minutes

Requirements Verification

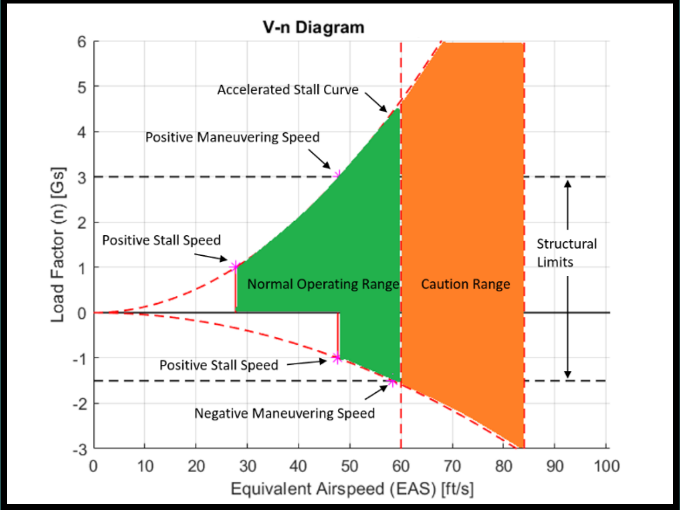
Title	Details	Verified	Reason
SDR-024: Setup Tools	No more than 2 external tools to set up for flight	Yes	Tools Needed = 1
SDR-025: Autonomous	Autonomous control for the entire mission profile	Yes	Bixler
SDR-026: Handbook	A detailed pilot operating (POH) & maintenance handbook shall be included with every UAS	Yes	Documents Created
SDR-027: Manual Control	Manual control override when in autopnomous flight	No	Manual Flight not Checked
SDR-029: Visible Lights	Aircraft should have no visual operating lights as viewed from the ground	Yes	No lights on underside
SDR-030: Noise	Produce no more than 50 dB of noise at a distance of 200-ft altitude	No	Unable to Verify due to COVID-19
SDR-031: Reliability	99% reliable with respect to component failure	No	Not Verified
SDR-033: Emergency Landing	Aircraft should have return-to-home emergency landing	No	Not Verified
SDR-036: Stowing Time	Stowing time (controls disarmed & disassembled) not greater than 30 minutes	Yes	Stow Time = 10 minutes
SSDR-001: Wing Removal	Wings shall be removable	Yes	Removable and attach with detents
SSDR-002: Bottom Facing Sensor Access	Fusdelage allows bottom facing sensor	Yes	Sensor faces downward in aircraft
PR-001: GPS Accuracy	GPS accuracy of 5 meters or less	No	Not Verified
PR-002: Multimedia Capture	Aircraft can record video and/or capture images	Yes	Camera for image capture
OR-001: People Clearance	Aircraft shall not be flown within 5 meters of another person besides the operator	Yes	Safety plan put in place for operation
OR-002: Wildlife Clearance	Aircraft shall not be flown within 5 meters of wildlife	Yes	Safety plan put in place for operation

Detailed Design & Engineering Analysis

Load Path Diagram



V-N Diagram



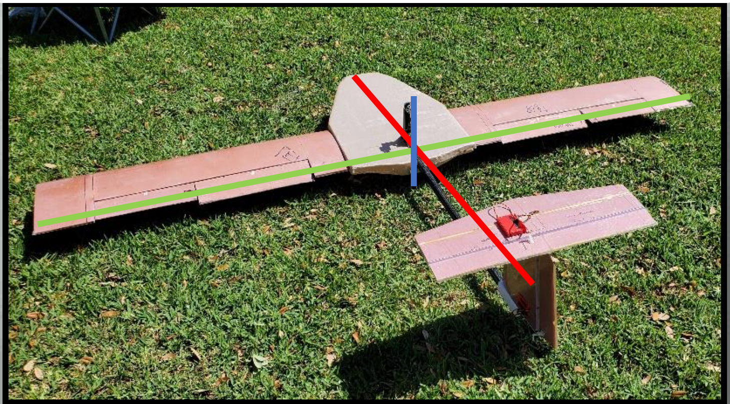
Systems and Subsystems

- Payload
  - Vision
  - Detection
- Electronics
  - Controls
  - Communication
- Tail
- Fuselage
- Wings
- Propulsion
- Landing Gear

Key Design Features:

- Large battery for flight endurance
- Quick-release connections for rapid assembly/disassembly and ease of transportation
- Powerplant mounted above fuselage to block sound

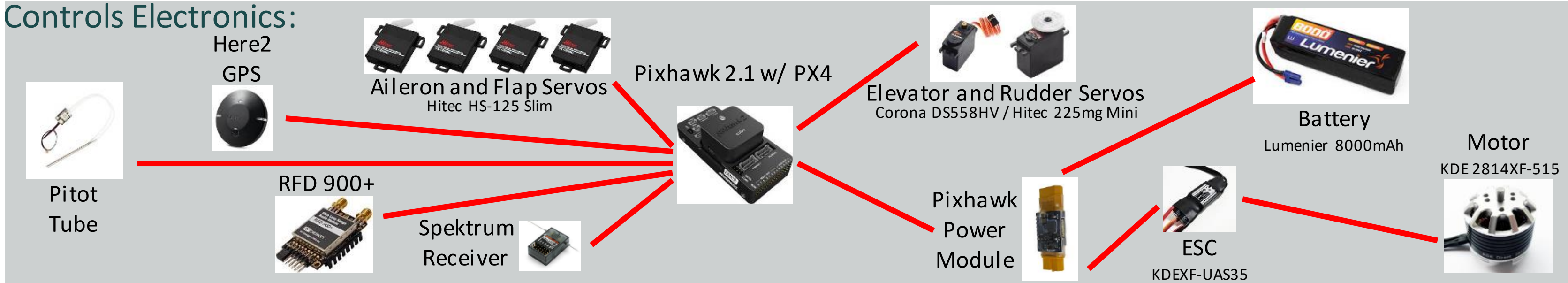
Weight and Balance



X = 14.5 in Y = 0 in Z = -3 in

10.5lbs

Controls Electronics:



Aircraft Cost

Payload	Propulsion	Controls	Build Materials
$329	$415	$691	$1,144

Project Schedule

8/30: Request for Proposal
9/20: Mission Concept Review
10/25: Preliminary Design Review
12/6: Final Report Submission
1/31: Manufacturing Readiness Review
4/1: End of Development (internal)
4/17: Final Report & Presentation

August · *September* · *October* · *November* · *December* · *January* · *February* · *March* · *April*

Mission, requirement, & stakeholder development	Preliminary sizing & configuration trade studies	Detailed sizing, CAD design, glider building, & glider testing	CAD Design & analysis	Build UAS, develop vision processing, subsystem test	UAS system testing

Detailed design decisions & CAD became behind schedule, stretching into Winter break.

Cause:

- Unfamiliarity with CAD software
- Understaffed CAD team
- Not understanding iteration as aero was developing

Result:

- Necessary to work over break
- Significant errors caught week of MRR
- FEA delayed until after MRR

Construction & Shipping

2/3 · *2/10* · *2/17* · *2/24* · *3/2* · *3/9* · *3/16* · *3/23* · *3/30*

Fuselage, wing, tail construction 1/31-2/21	Shipping window 2/21-3/1	Final Assembly 3/2-3/19

Actual fuselage ship date: 2/24

Actual wing ship date: 3/2

Actual final assembly complete: 3/23

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Phase A: Mission, requirement, & stakeholder development	Phase B: Preliminary sizing & configuration trade studies	Phase C: Detailed sizing, CAD design, glider building, & glider testing	Phase C: CAD Design & analysis	Phase C, D: Build UAS, develop vision processing, subsystem test	Phase D: UAS system testing

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