Albatross

Integrated Autonomous Oceanic Surveillance

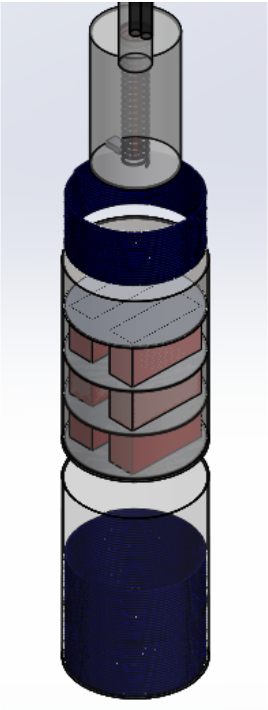
Preliminary Design Review

MITMECHE

MIT AEROASTRO

Albatross is an integrated pod and UAV system

Pod

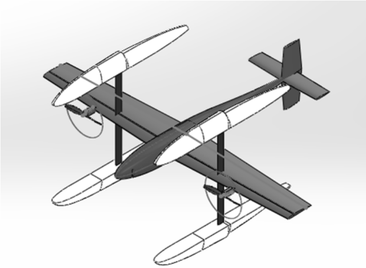


Interface:

Docking
Data Transfer
Charging

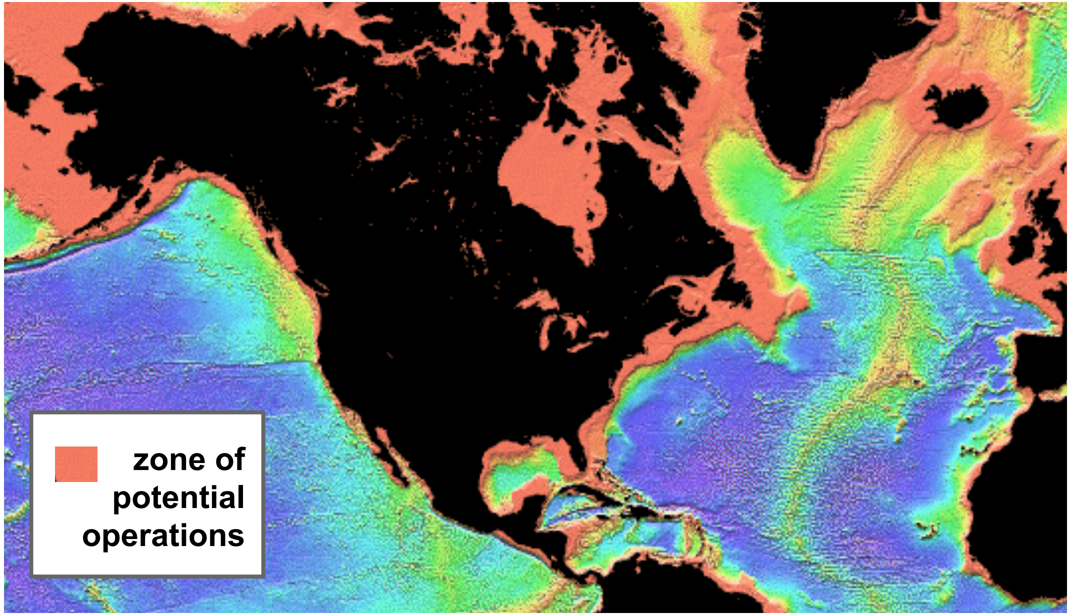
UAV 1: Blimp

UAV 2: Seaplane



Nathan Miller

Project Motivation



Need for maritime surveillance via an autonomous system that is quick-to-deploy and adaptive

Show capability to recharge a UAV using the pod platform in the field (extending mission life)

Potential to capture a large area of operation for maximized benefit

System Functional Requirements

- An automated maritime reconnaissance mission (includes docking)
- Receive and execute mission profile commands
- UAV sub-system will perform the reconnaissance
- Submersible sub-system will supply energy and data transfer system
- UAV will carry minimum payload of reconnaissance equipment
- System’s robustness allows it to survive in sea-state 3
- Sufficient network bandwidth to transfer data
- Complete designated endurance or range mission

Requirement: Endurance vs. Range Mission

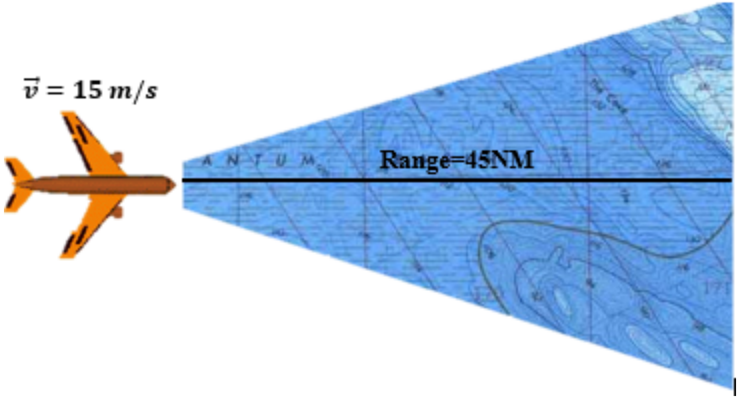
The UAV system must satisfy at least one of two mission profiles:

Endurance Mission:

- Speed: 10 m/s (20 knots)
- Duration: 2 hours

Range Mission :

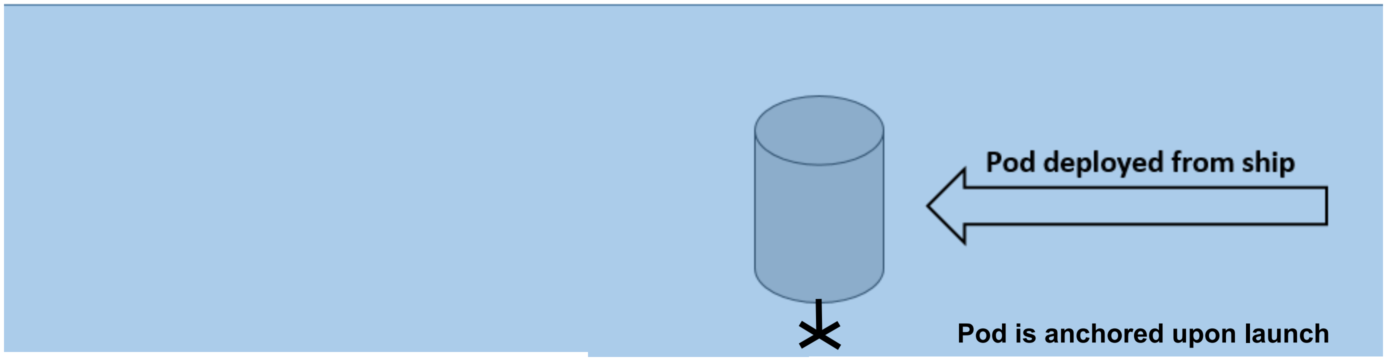
- Speed: 15 m/s (30 knots)
- Duration: 1.5 hours



v

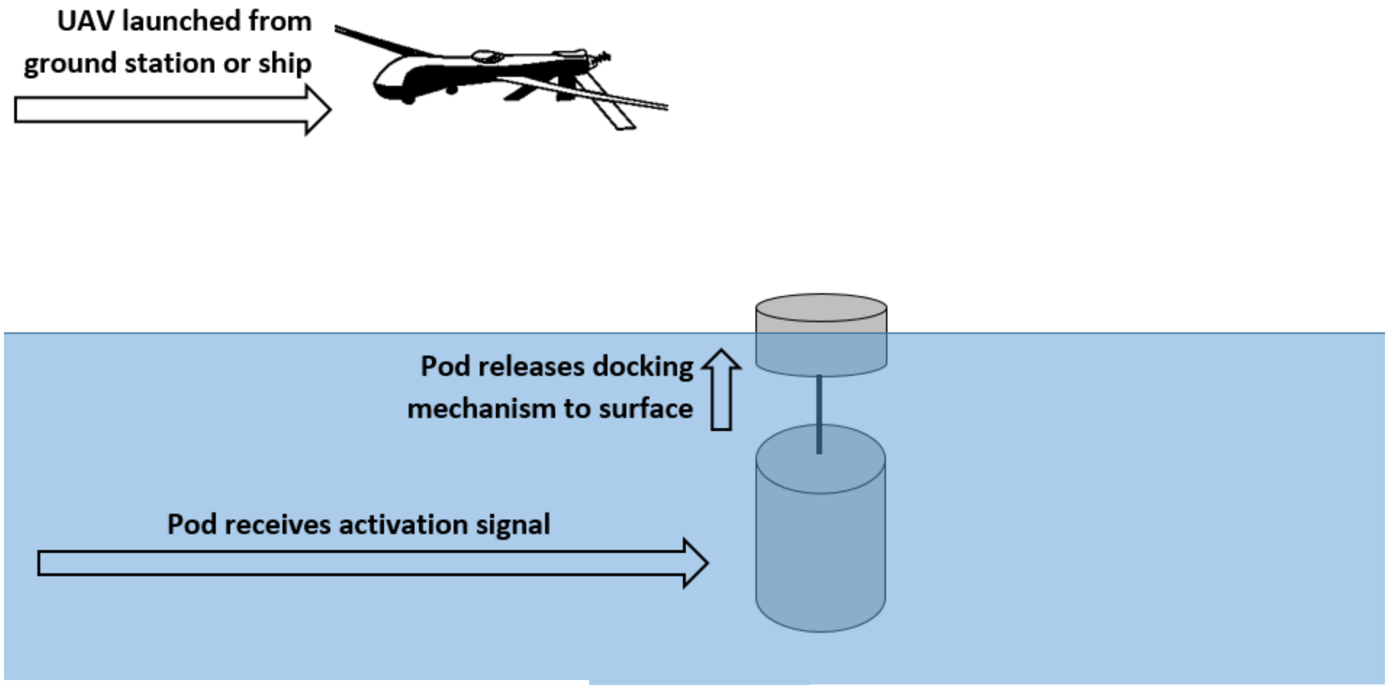
Nathan Miller

A ship launches the pod and it idles at depth



Note: not to scale, shapes are representations of actual system

Mission begins: pod activation and UAV launch



Note: not to scale, shapes are representations of actual system

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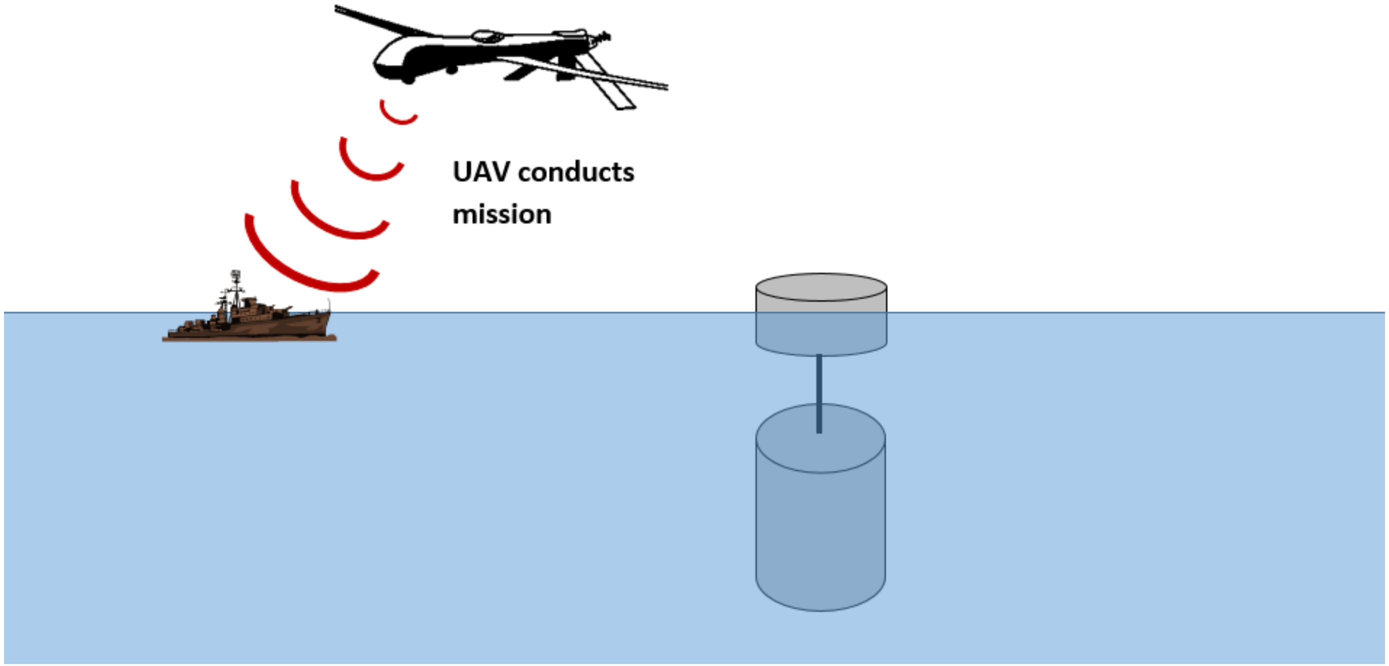
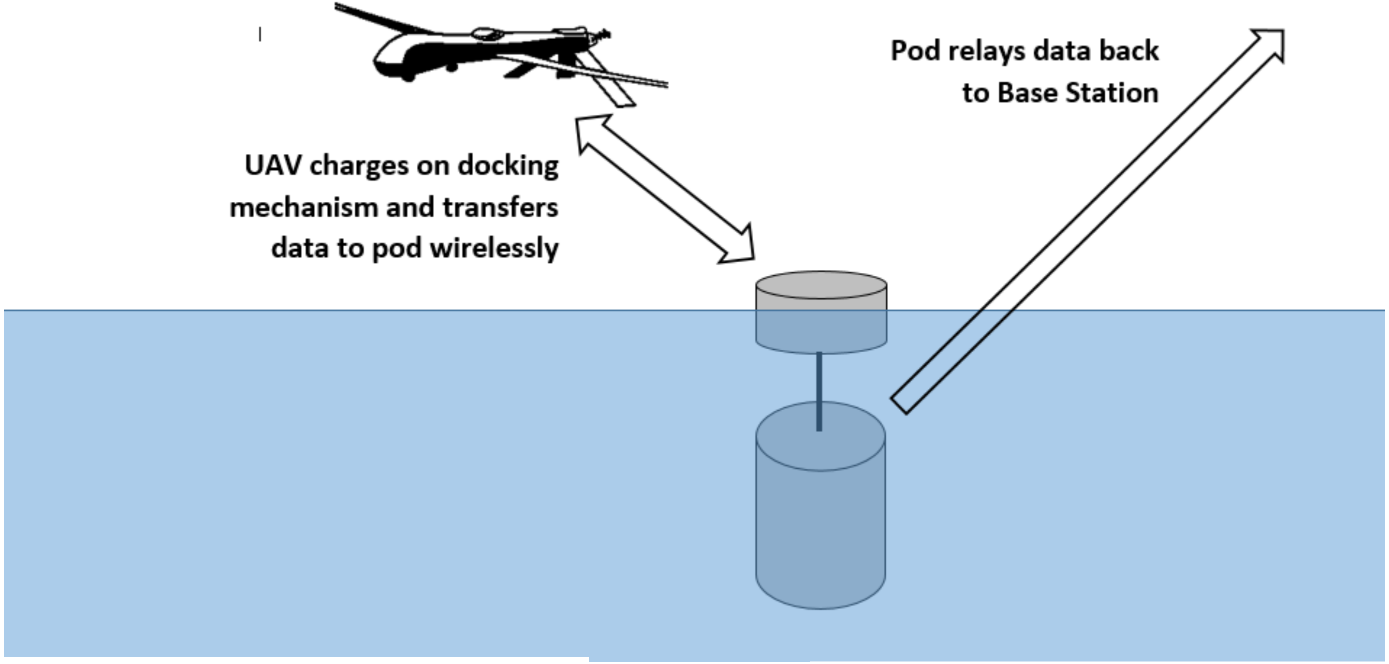
The UAV carries out the assigned mission



Note: not to scale, shapes are representations of actual system

UAV docks with pod to charge and transfer data



Note: not to scale, shapes are representations of actual system

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Several key factors drove the design of 2 UAVs

Difficulty of UAV docking with the pod

Docking/recharge is the highest risk stage of mission

Seaplane design follows a traditional land and taxi strategy

Blimp design attempts to simplify problem by avoiding ocean landing

Each UAV presents advantages and tradeoffs

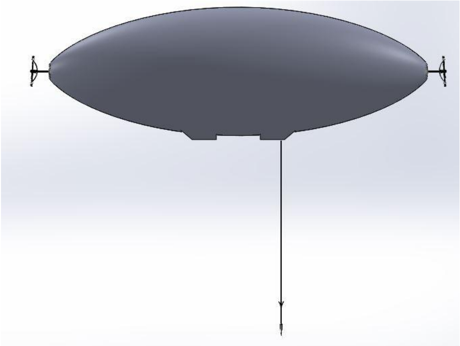
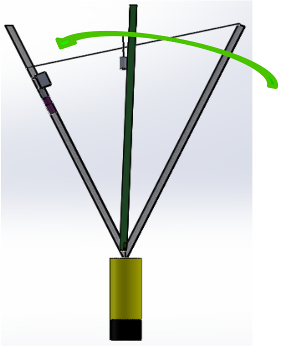
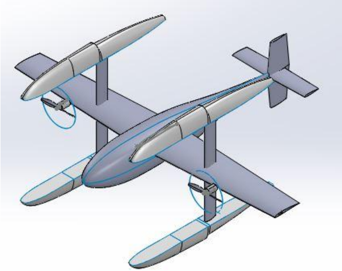
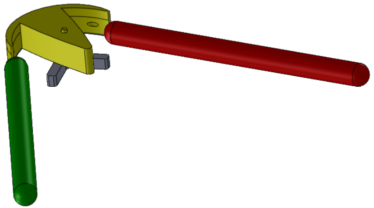
Blimp can support a much longer duration mission (time)

Seaplane has higher maximum speed and improved maneuverability

Seaplane has longer range (distance)

Nathan Miller

Two designs retained to determine viability

UAV	Docking mechanism	Dock station
	**Capture above water surface** Tether-catching line, clamp via rotating arm	
	**Capture on water surface** V-shaped pontoon guidance system, magnetic alignment	

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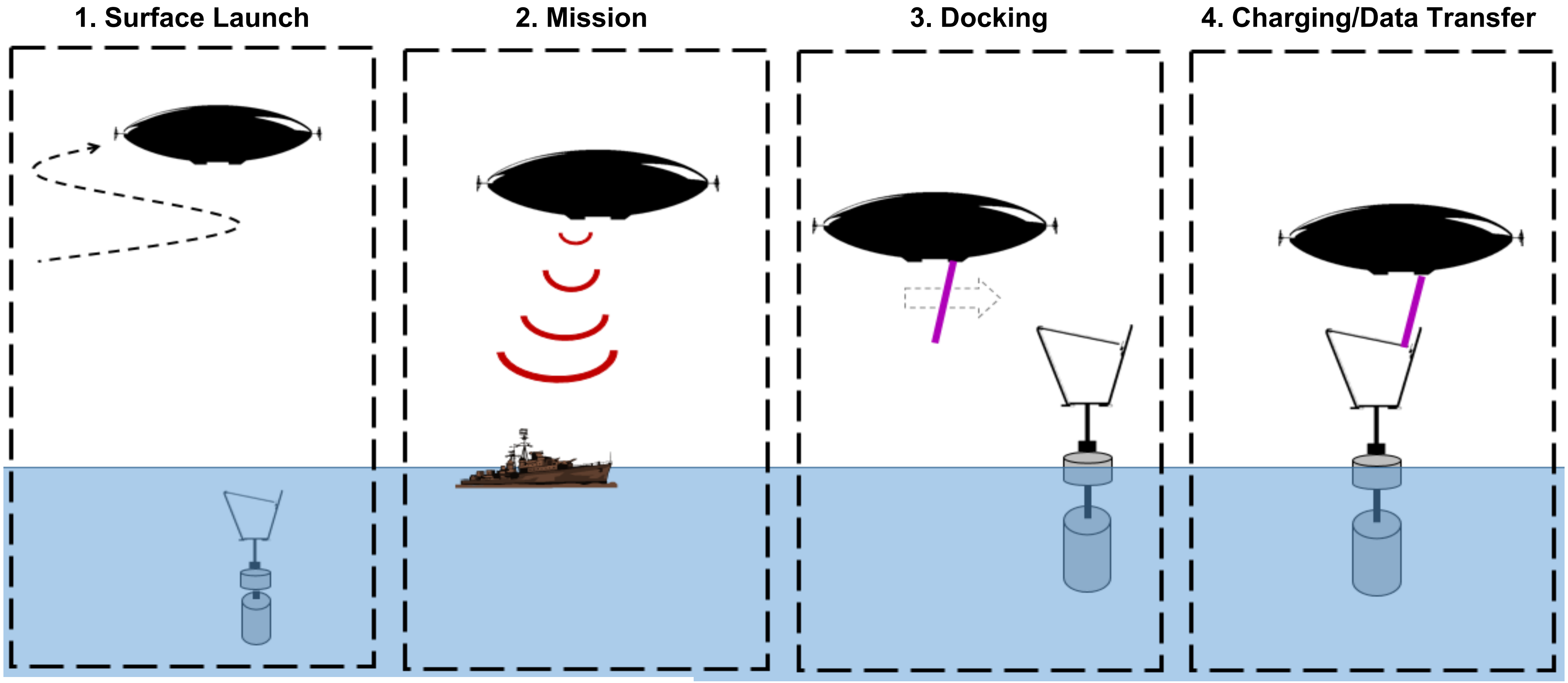
Blimp Deployment, Mission & Docking



Note: not to scale, shapes are representations of actual system

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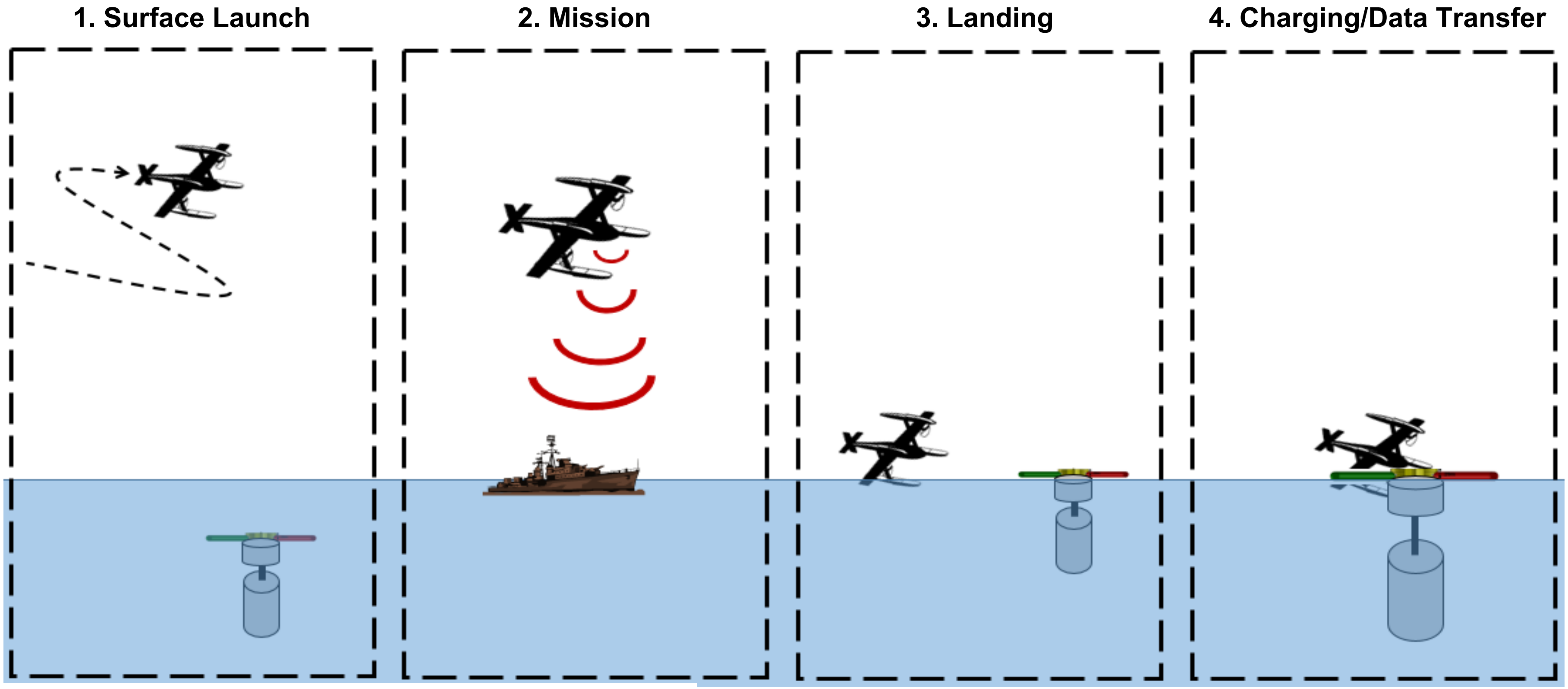
Seaplane Deployment, Mission & Docking



Note: not to scale, shapes are representations of actual system

Nathan Miller

Presentation Overview

1. Guidance, Navigation, and Control
2. UAV 1: Blimp Design
3. UAV 2: Seaplane Design
4. Power Pod Design/Docking Detail

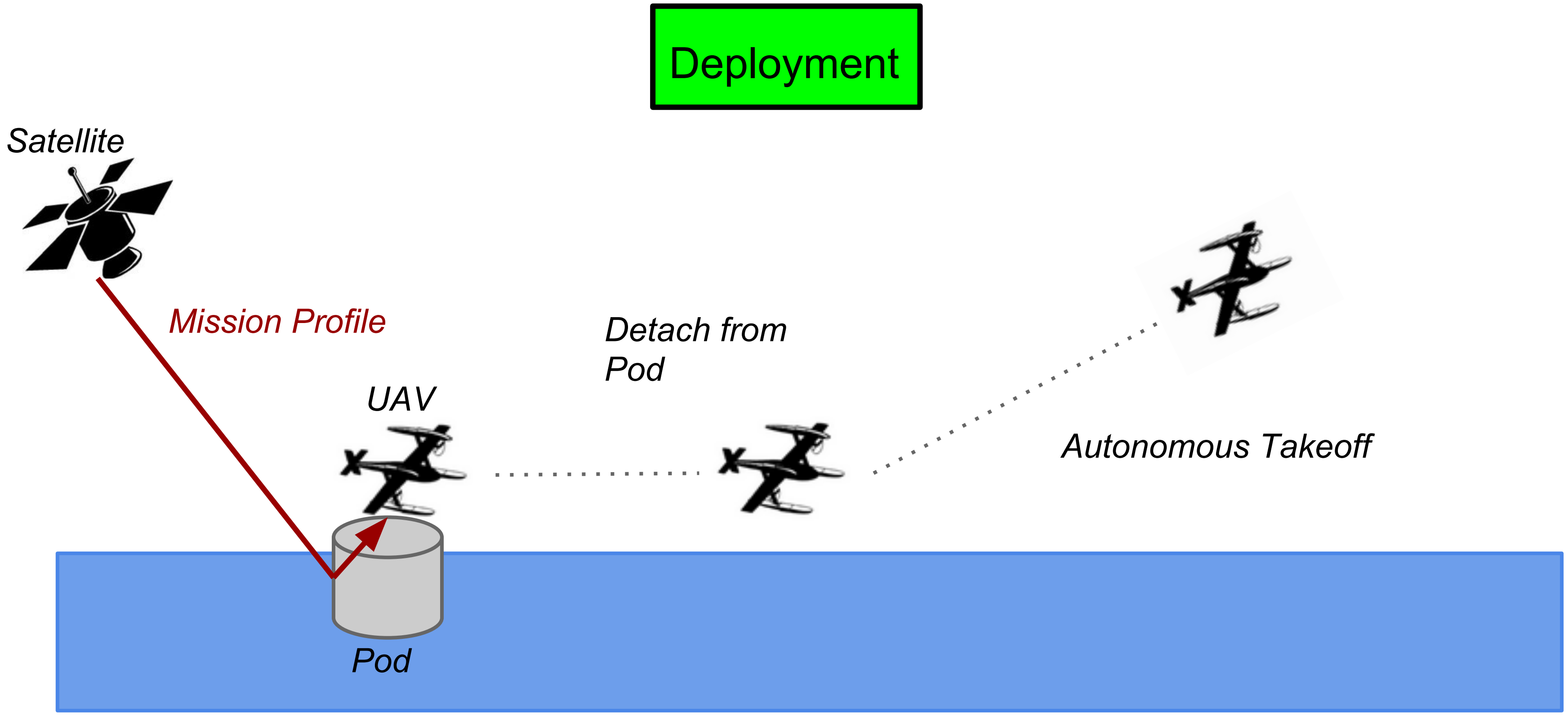
Guidance Navigation and Control (GNC)

Shanelle Clarke
Janelle Mansfield
Arshia Surti
Guilherme Venturelli
Nicholas Lima

Key Driving Requirements

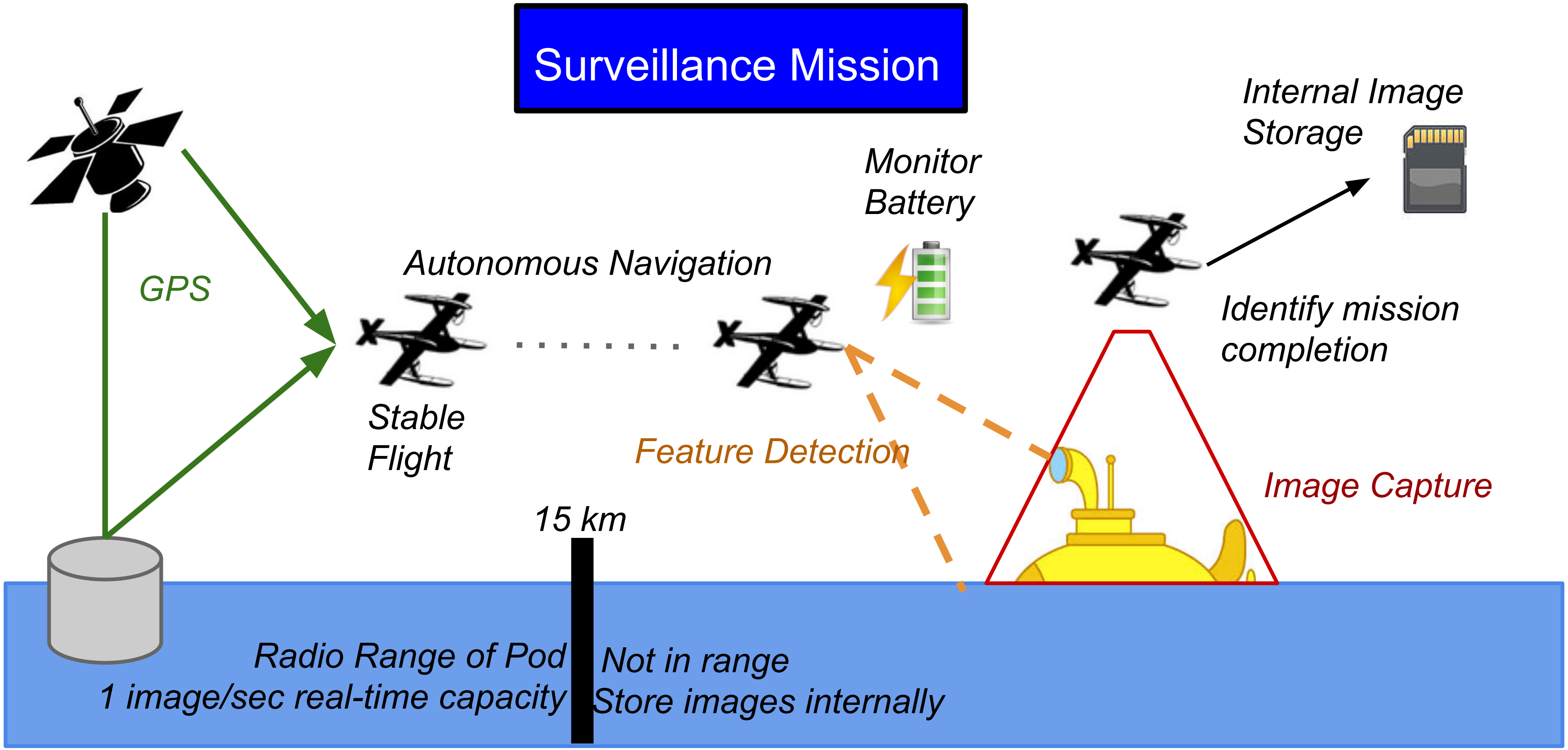
1. Autonomy
2. Payload Budget
3. Surveillance Data Quality and Rate
4. Mission Range
5. Environment/Conditions while docking
6. Variability of Mission

Concept of Operation - Deployment



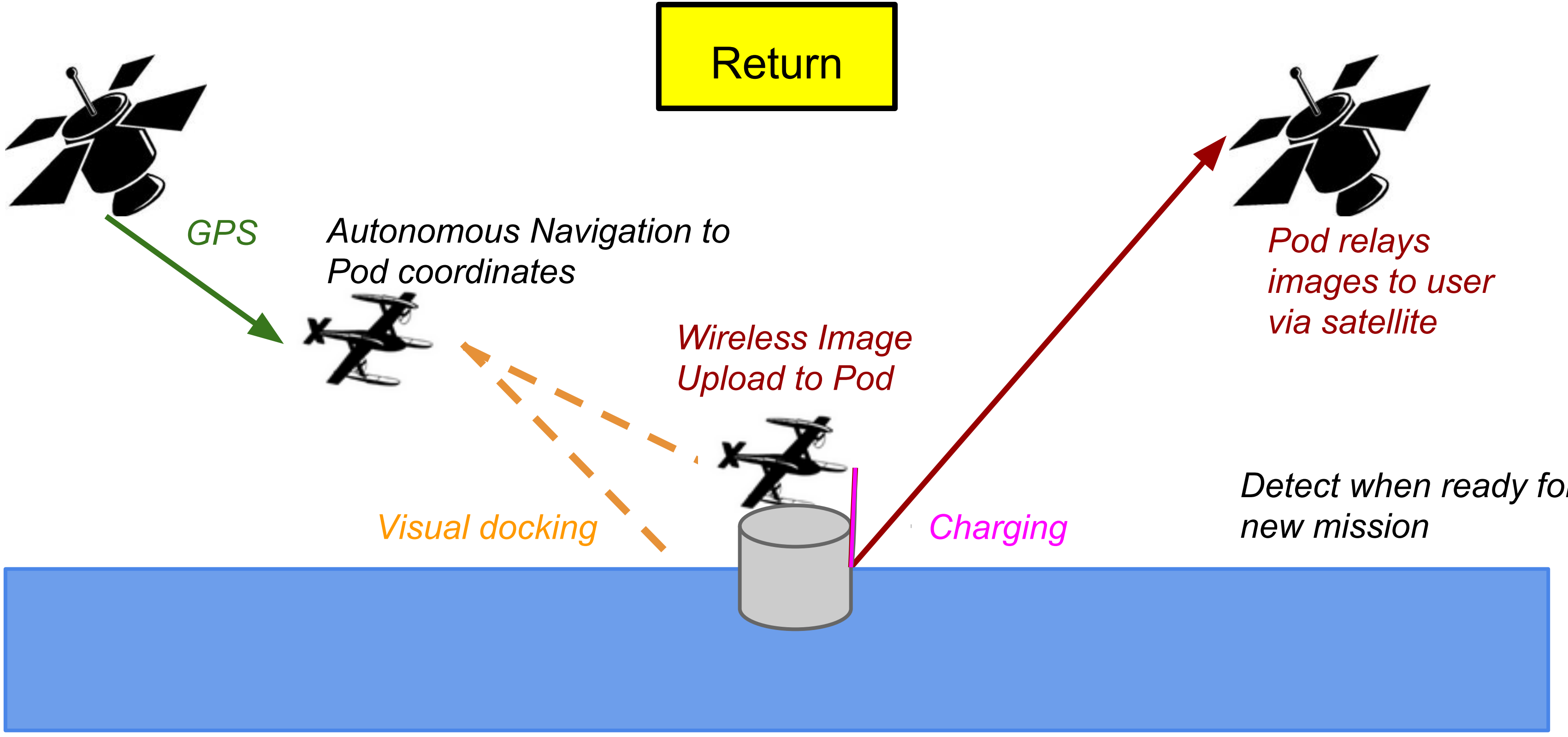
Nicholas Lima

Concept of Operation - Surveillance



Nicholas Lima

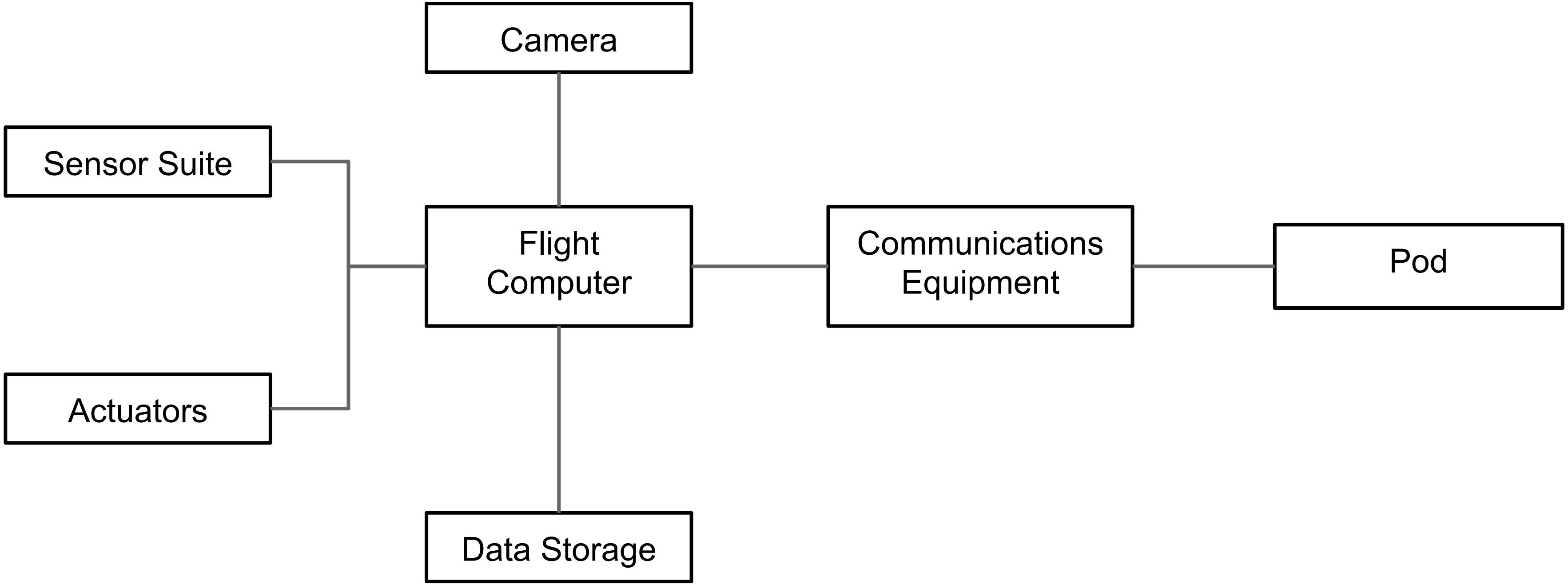
Concept of Operation - Return



GNC5

Nicholas Lima

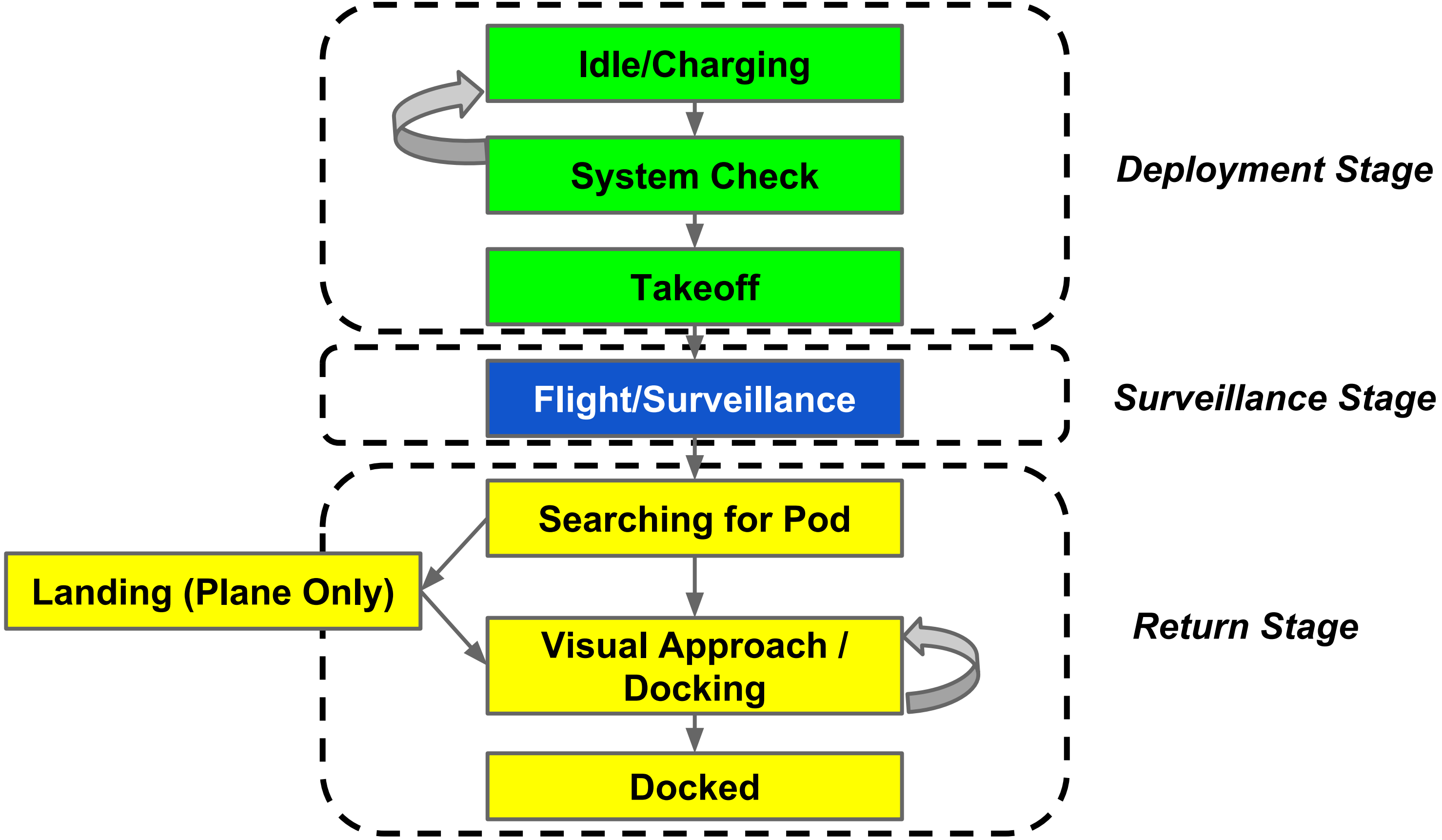
Integrated Systems Overview



GNC6

Nicholas Lima

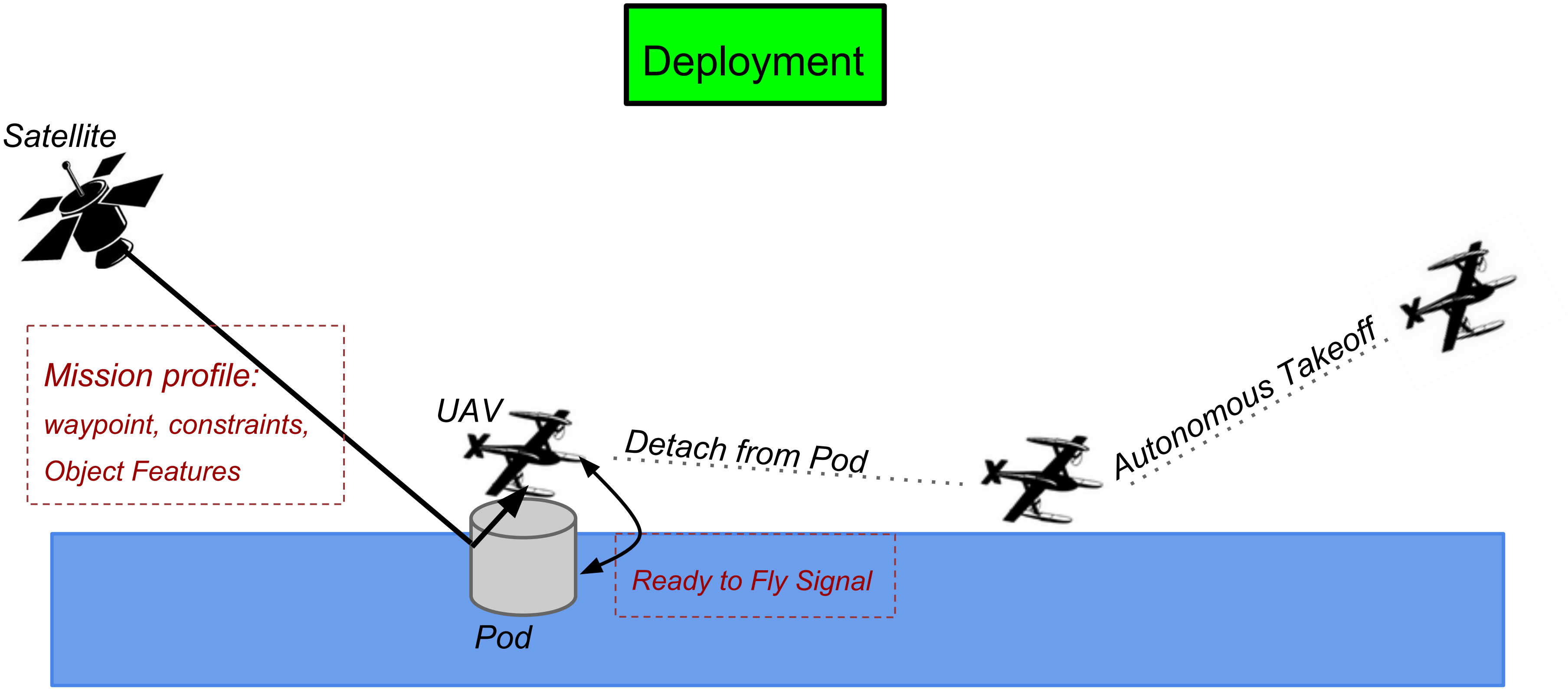
Modes of Operation: 3 Stages



GNC7

Shanelle Clarke

Modes of Operation - Deployment



Shanelle Clarke

UAV plans path using Mission Profile Data

Mission Profile

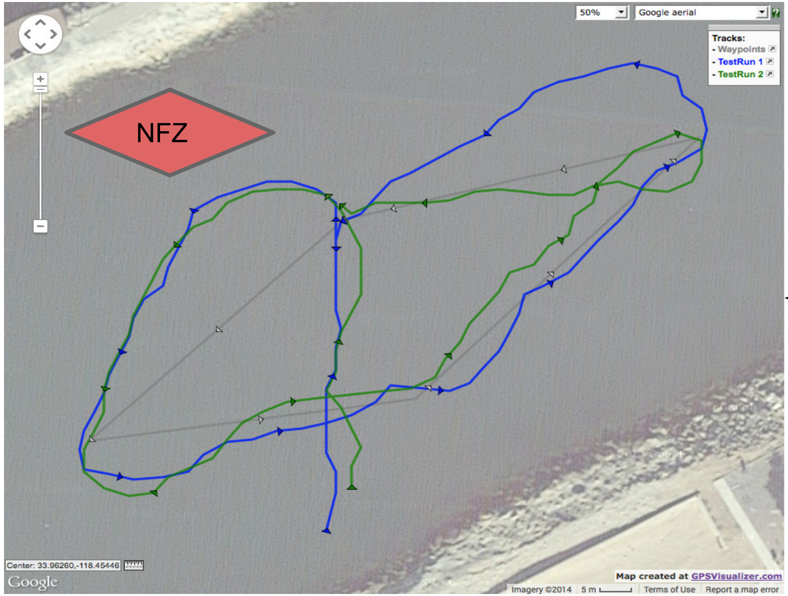
Waypoints (GPS coordinates, altitude)

Constraints (No-fly zones, weather conditions)

Object Features (color range, size,shape, specific images)

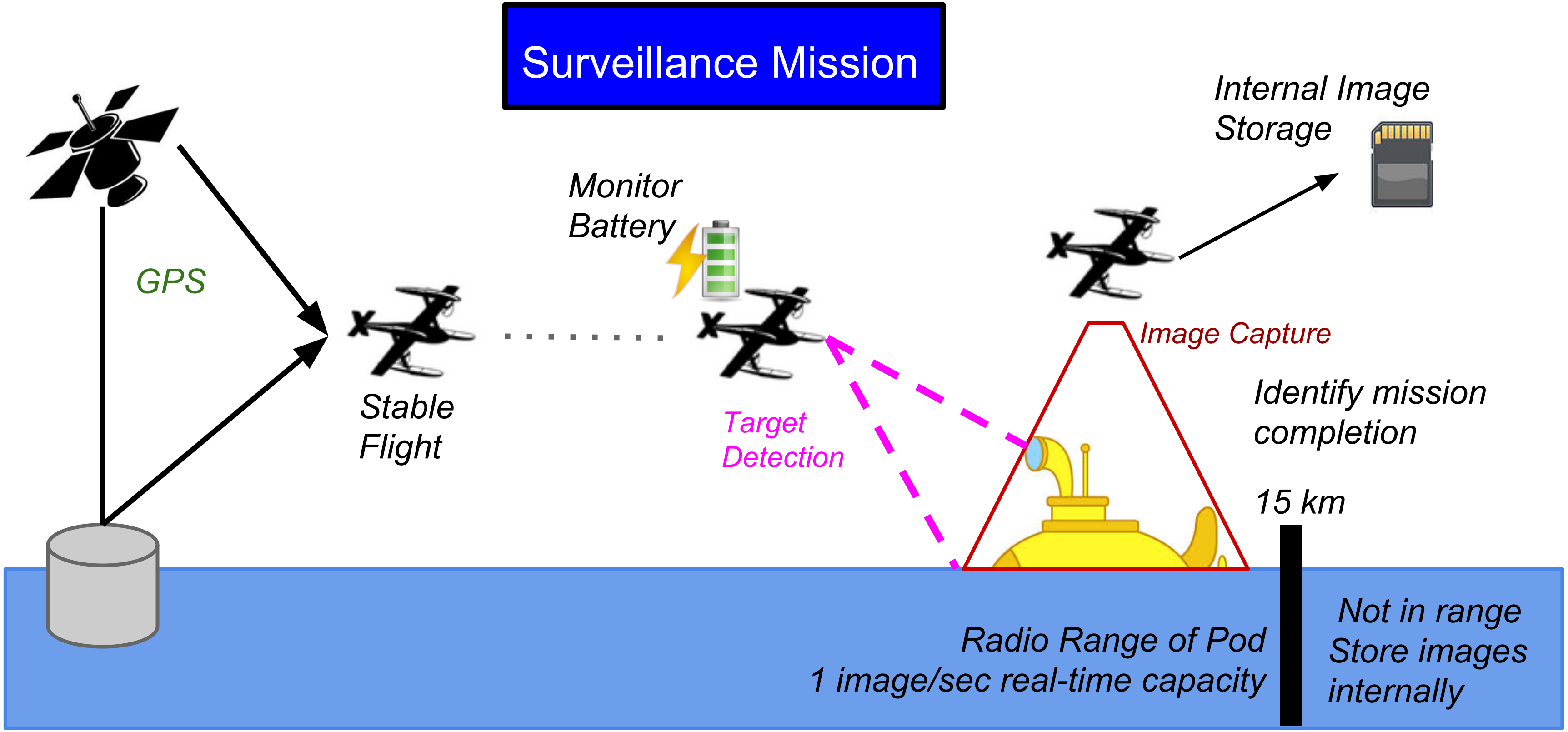
Mission Epoch and Terminus

Path Planning Algorithm



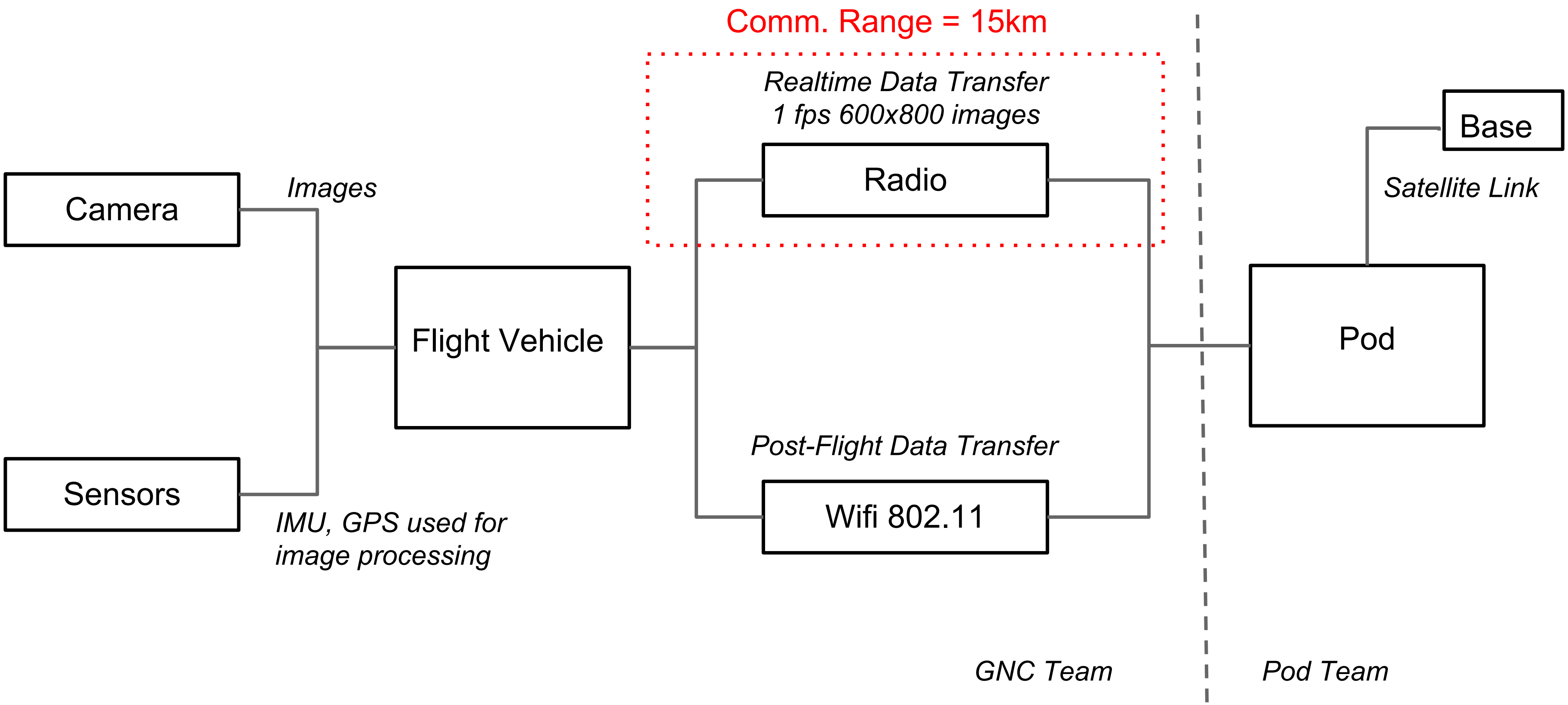
Shanelle Clarke

Modes of Operation - Surveillance



Shanelle Clarke

Surveillance Data Path



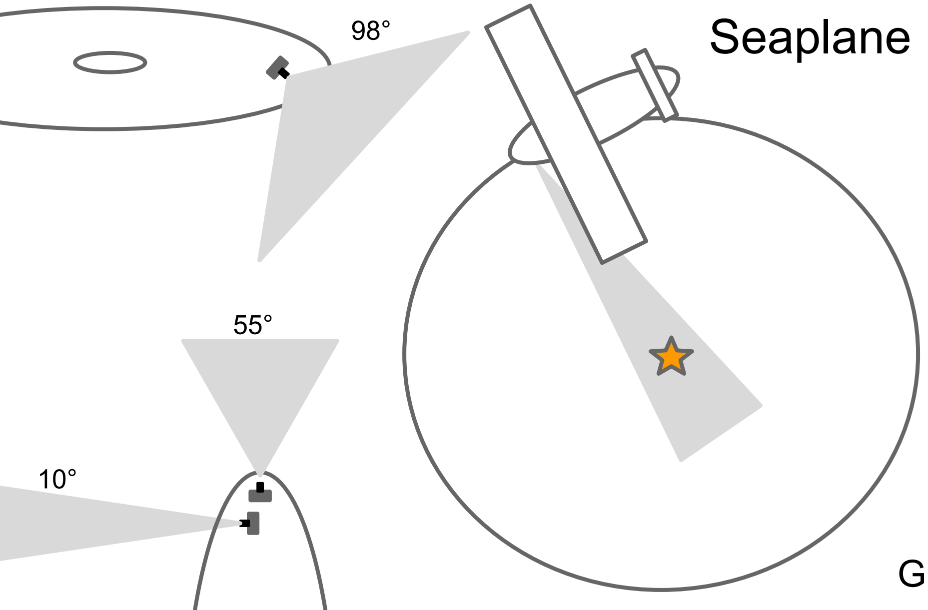
GNC11

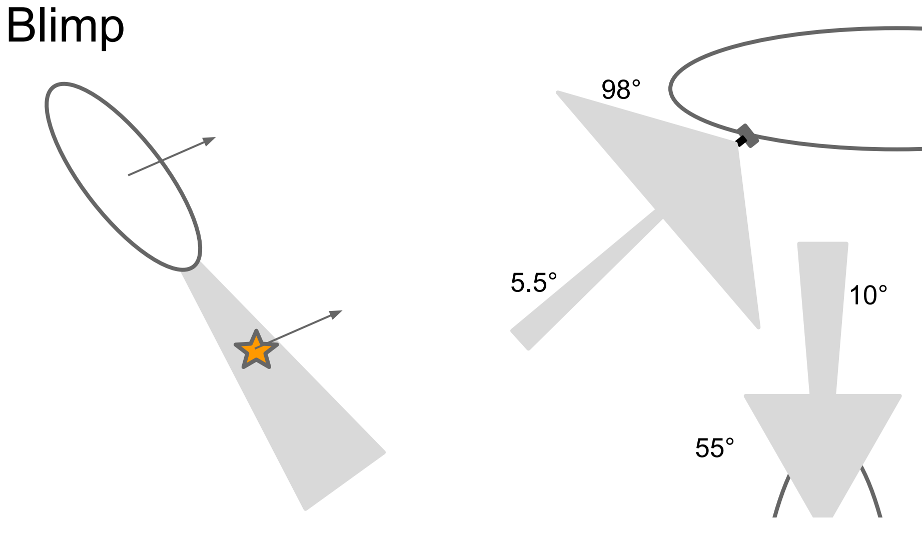
Shanelle Clarke

Camera Placement

1 camera for detailed view 10°x5.5° (Pi cam + 4x lens)

1 camera for wide view search 98°x55° (Pi noIR + 0.4x lens)





Shanelle Clarke

Target Identification

Image Acquisition

↓

Image Evaluation

↓

Features Extraction

↓

Features Matching

↓

Displacement Estimation

↓

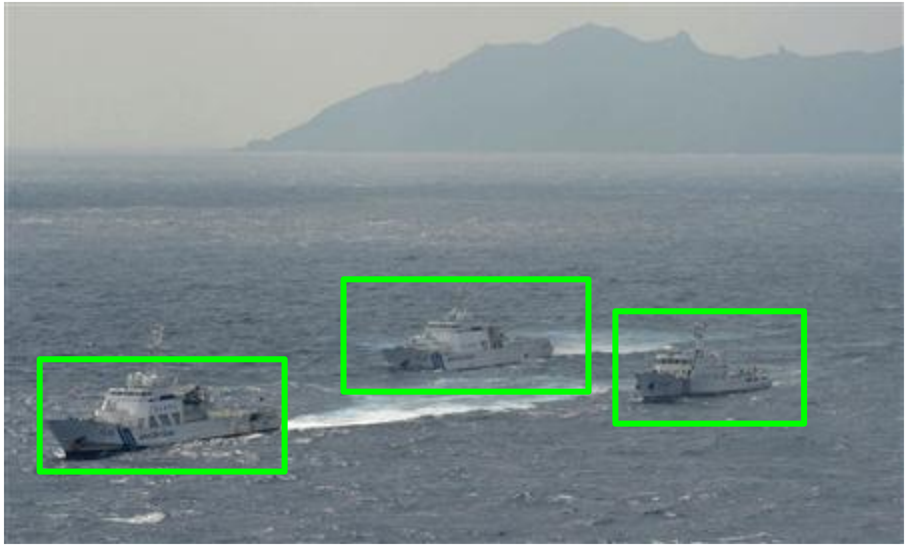
Features Matching

↓

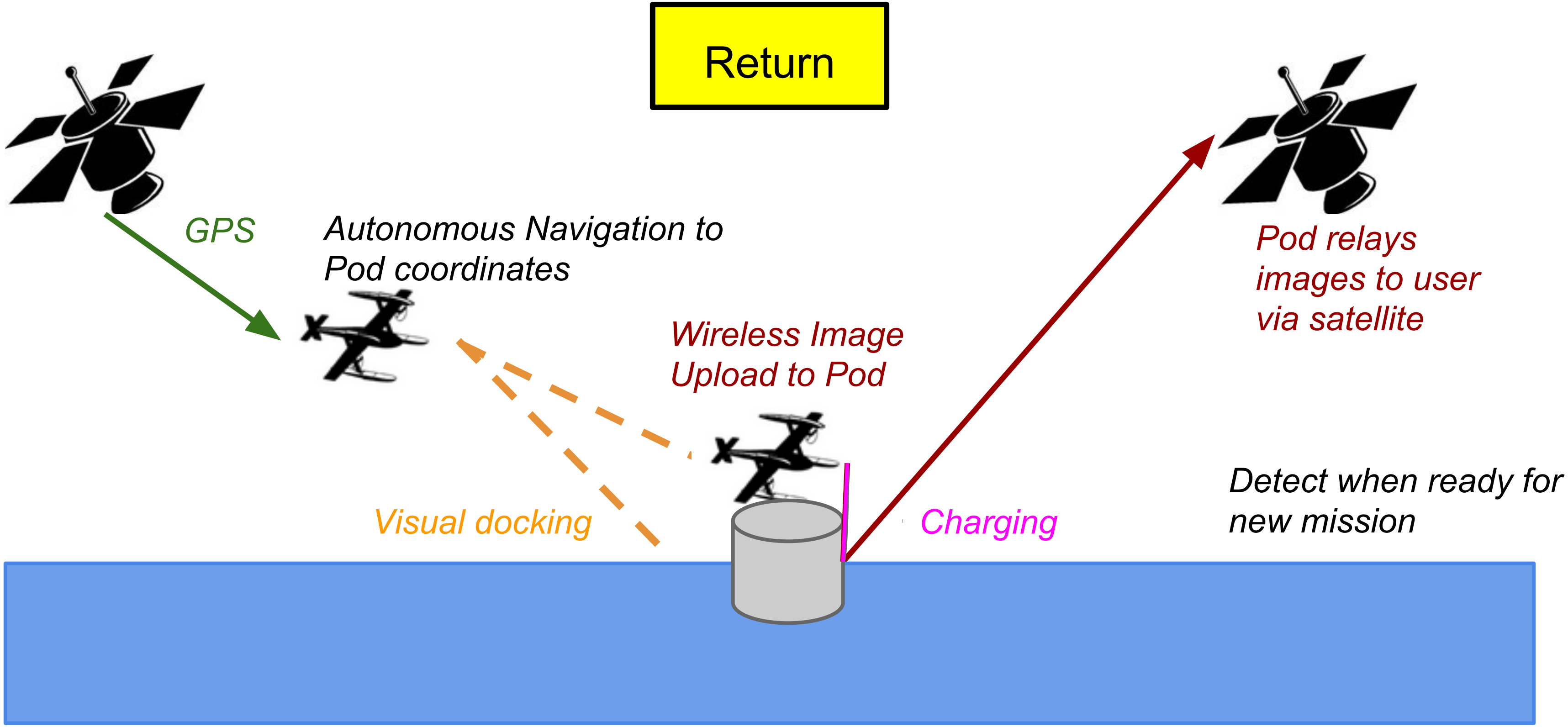
Target Tracking
(minimum target tracking time unless indicated by base)

while in range

User Verification

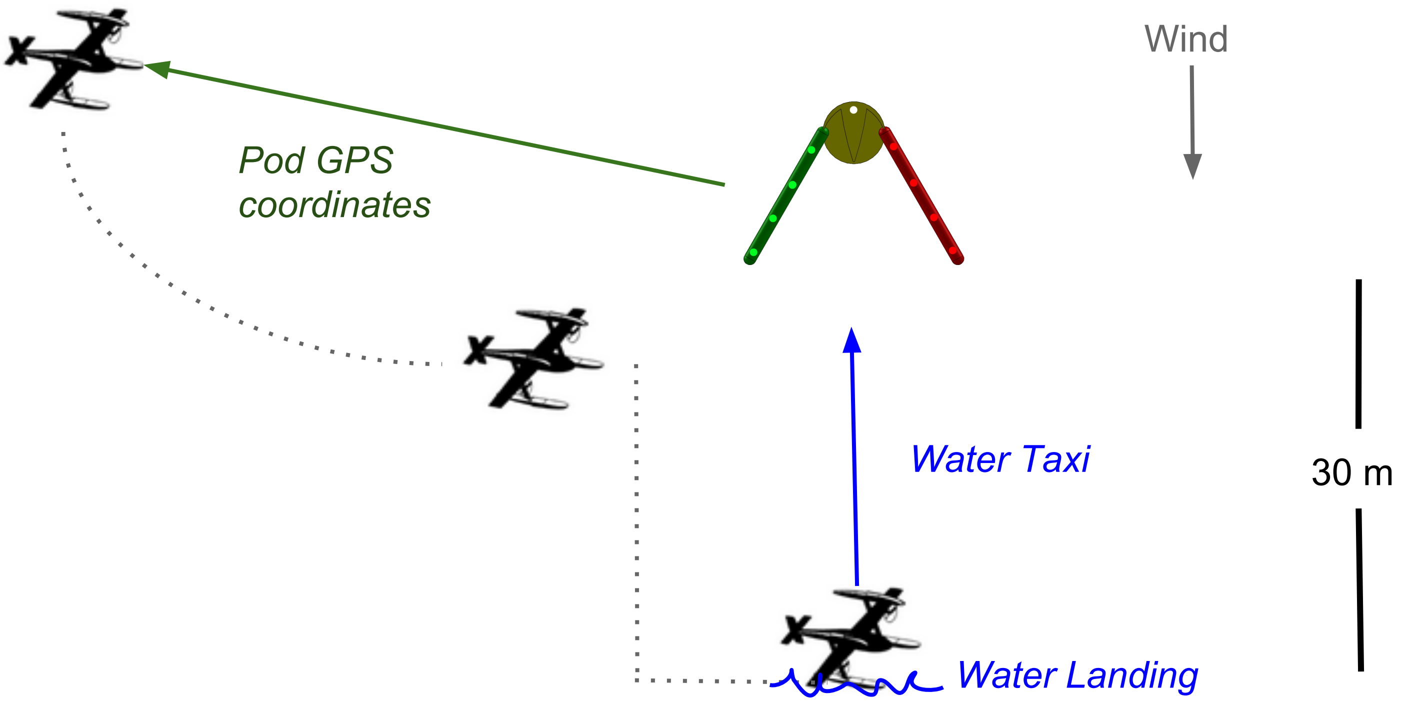


Modes of Operation - Return



Shanelle Clarke

Seaplane Docking Initiation



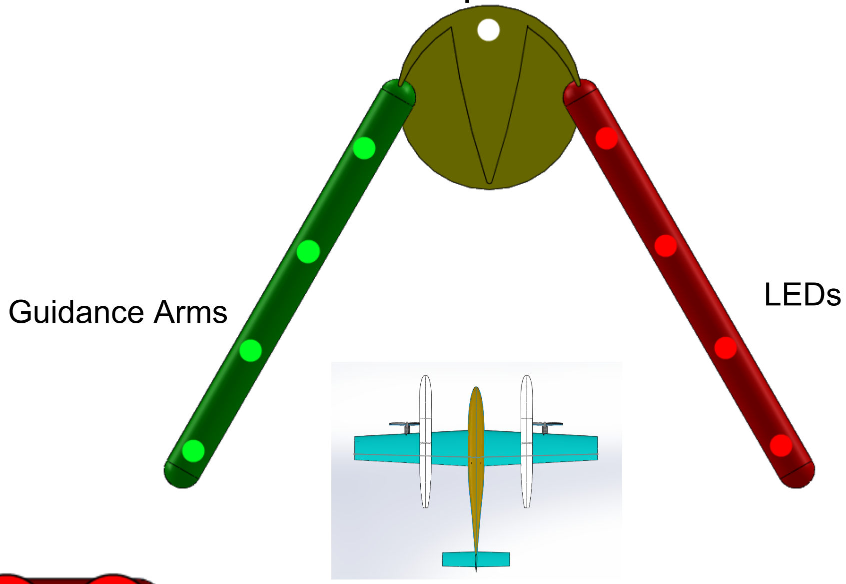
GNC15

Seaplane Docking Control

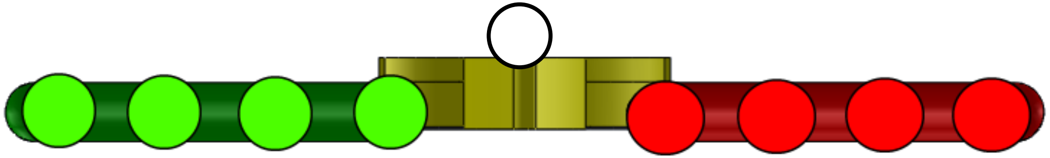
PID control

- IMU and visual input
- Image processing to identify beacons

Top View



Camera View



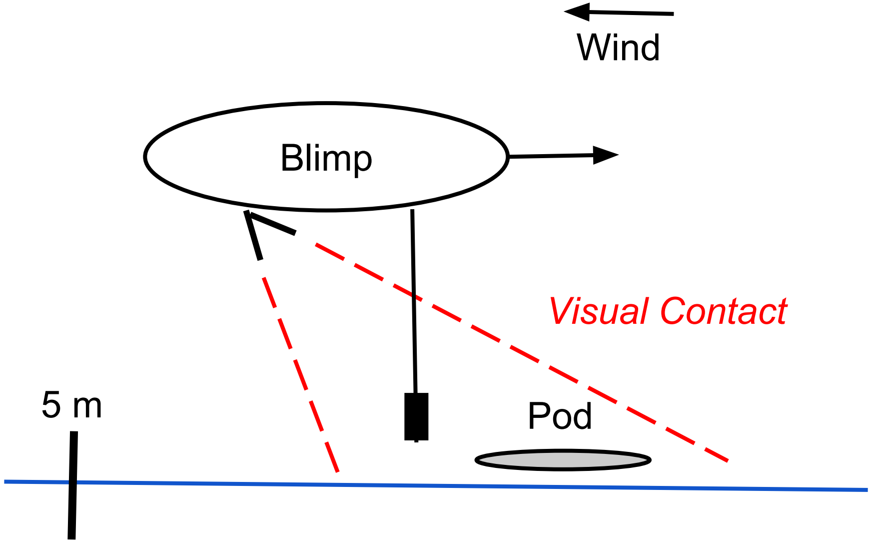
Arshia Surti

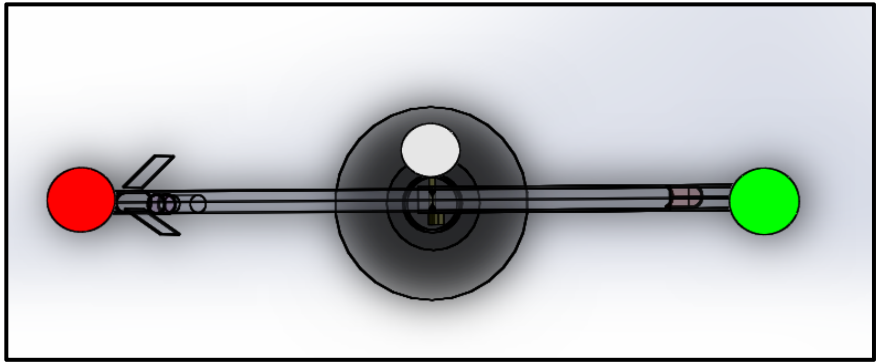
Seaplane-Dock Disengagement

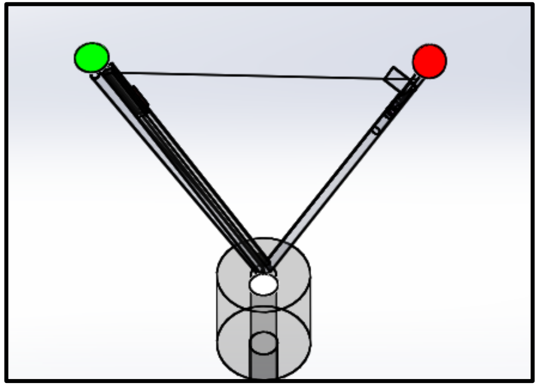
1. Pod sends new mission to seaplane
2. Seaplane confirms “Ready to Fly”
3. Seaplane tells pod to disengage
4. Pod turns off electromagnets and submerges
5. Seaplane takes off and begins mission

Messages between pod and seaplane sent over 900MHz radio

Blimp Docking Control







Side and top view of pod

Arshia Surti

Blimp-Dock Disengagement

1. Pod sends new mission to blimp
2. Blimp confirms “Ready to Fly”
3. Blimp tells pod to disengage
4. Blimp descends to release hook from finish line
5. Blimp flies away from dock (in opposite direction from initial capture) and begins mission

Messages between pod and blimp sent over 900MHz radio

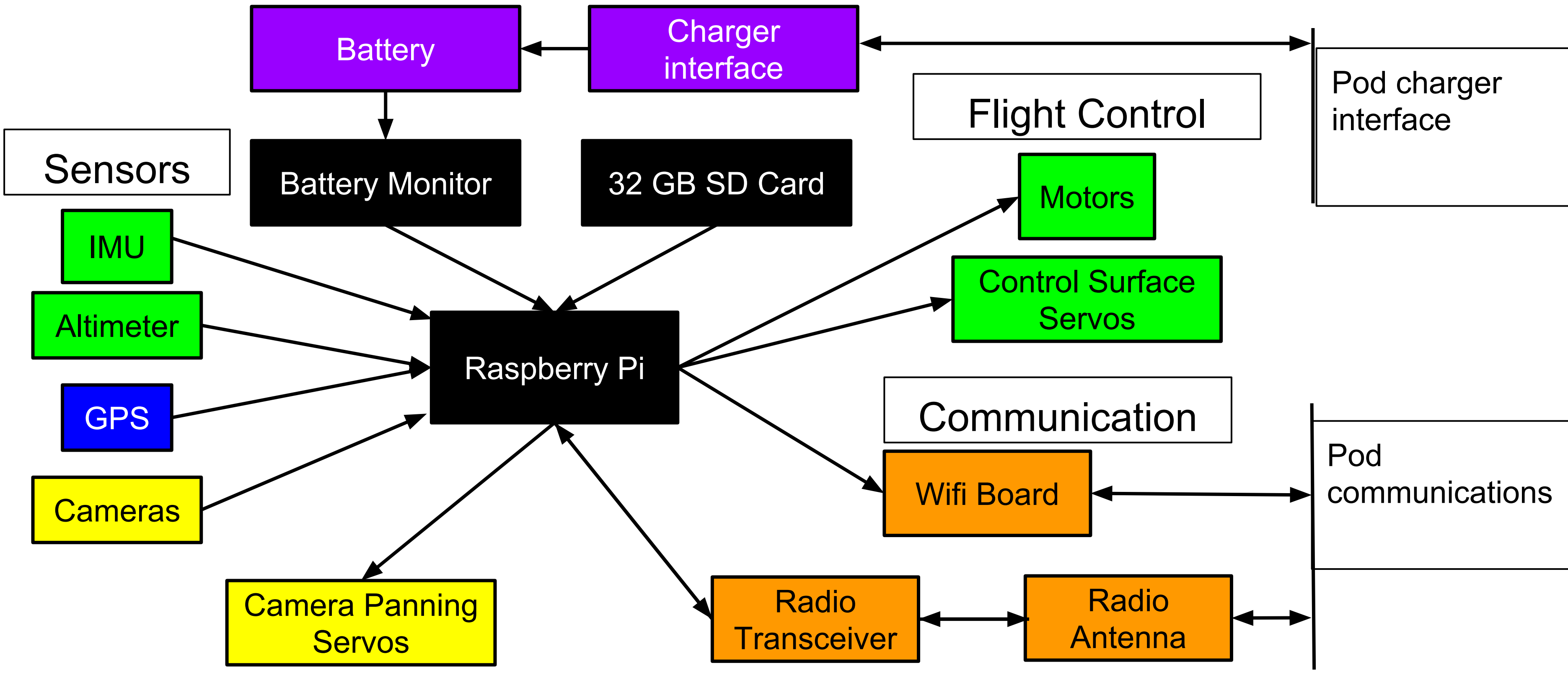
Arshia Surti

Hardware Functional Allocation

System	Function	Allocated components
Communications	Exchange data with pod	Antennas, transceivers
Flight Computer	Process images, store data, decide actions, manage other components	Microcontroller, SD card, battery monitor
Charging Interface	Provides charging connection with pod	Plug, pulley controller*
Navigation	Determines location and waypoints	GPS receiver
Guidance and Control	Controls vehicle trajectory	IMU, actuators, altimeter, pressure sensors*
Surveillance	Provides video feed	Cameras, panning servo

*Blimp only

Hardware Architecture Overview

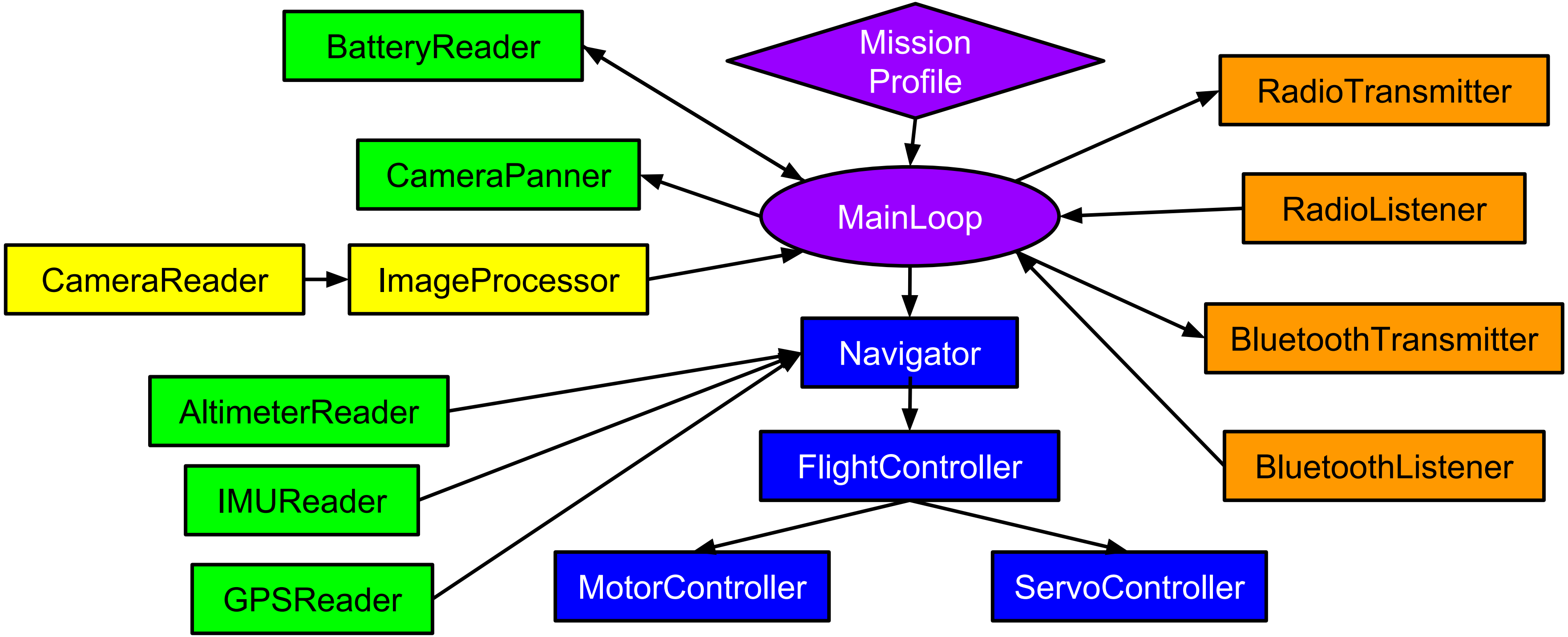


Guilherme Venturelli

Software Overview

Software	Function	Source
Mission planner	Decides actions, creates flight plan, integration, implements modes of operations	Custom
Image processor	Compression, correction, feature recognition	OpenCV ViSP
Autopilot	Guides and control aircraft	Ardupilot Navio
Comms. manager	Interfaces communications with antenna	Hardware-specific provided
Data acquisition	Interface data acquisition with sensors	Hardware-specific provided

Software Node Map



Guilherme Venturelli

GNC Mass Breakdown

Components	Mass/g	
	Blimp	SeaPlane
Raspberry Pi B+	45	
ArduIMU	6	
EM-411 GPS	17	
Pi NoIR	3	
PiCam	3	
Camera Servo	9	
Wireless Adapter	22	
9XTend Radio Transceiver	18	
LMH6518 Signal Amplifier	1	
SF10/C Altimeter	35	
LM3420 Battery Monitor	1	
Wiring	15	15
Radio Antenna	45	45
Pressure Sensors	6	N/A
Subtotal	226	220
Margin (20%)	45	44
Total	**271**	**264**

Janelle Mansfield

GNC Power Breakdown

Components	Power/W	
	Blimp	Seaplane
Raspberry Pi B+	1	
ArduIMU	0.2	
EM-411 GPS	0.4	
Pi NoIR	0.2	
PiCam	0.2	
Camera Servo	1	
Wireless adapter	4 peak, ~0 idle	
9XTend Radio Transceiver	1	
LMH6518 Signal Amplifier	1.1	
SF10/C Altimeter	0.005	
LM3420 Battery Monitor	0.001	
Pressure Sensors	0.002	N/A
Subtotal	5.108	5.106
Margin (20%)	1.02	1.02
Total	**6.13**	**6.13**

Janelle Mansfield

GNC Risks and Mitigation

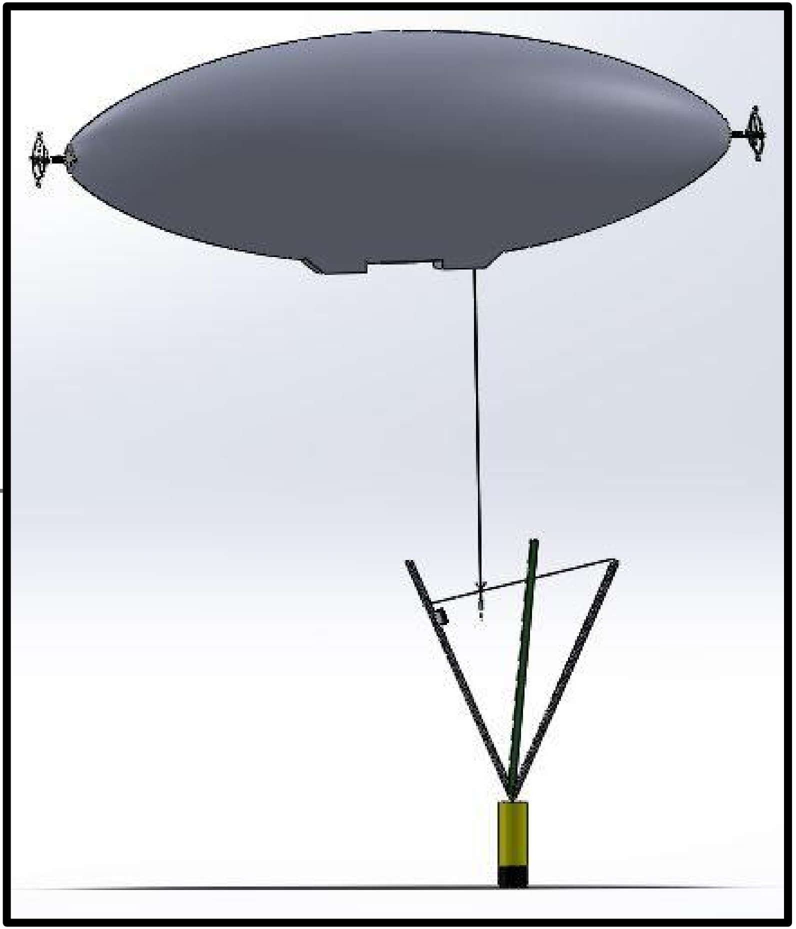
Risks	Mitigation
Development of custom mission planner software	Start research and development early. Contract out to software companies if necessary.
Development of custom dynamic models of flight vehicle	Begin dynamic modeling now with calculations from vehicle teams. Perform wind tunnel testing.
Insufficient Processing Power of Raspberry Pi	Early testing, buy additional RAM version, second Raspberry Pi, or different flight computer.

Janelle Mansfield

Blimp Design

Fully Autonomous & Tetherable
Aerial Sea Surveillance Blimp

Matt Cole
Kevin Sabo
Karly McLaughlin
Matt Connelly
Jacobi Vaughn
Lyndsy Muri
Bridget McCoy
Nate Colgan
Omar Trujillo
Nathan Miller
Candice Kaplan



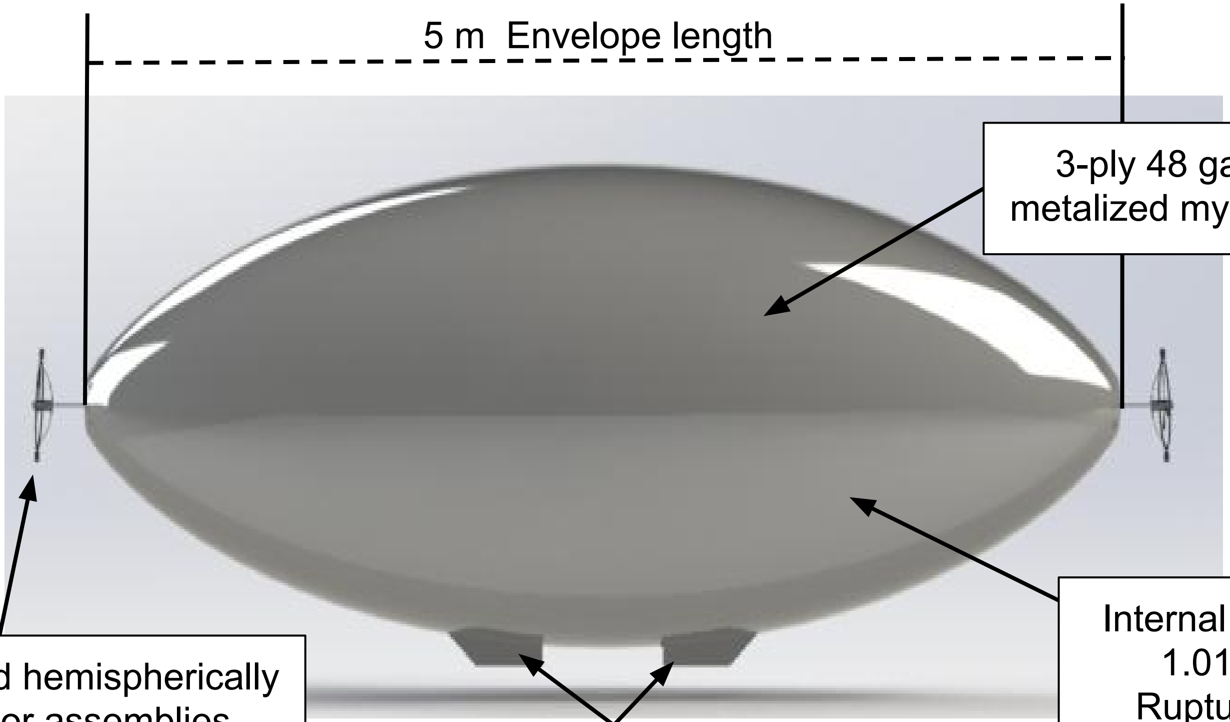
Symmetric, Surface Launched Helium Blimp

<u>Mission</u>:
Distance:
45 nm

Speed:
30 knots

Altitude:
1000 ft.
(2500 ft. max)

Time:
1.5 hours



3-ply 48 gauge
metalized mylar skin

Total Mass:
6635 g

Custom-designed hemispherically
gimballed motor assemblies

Internal pressure range:
1.01 to 1.10 atm
Rupture at 1.13 atm

Split Gondola: power system,
payload, docking system

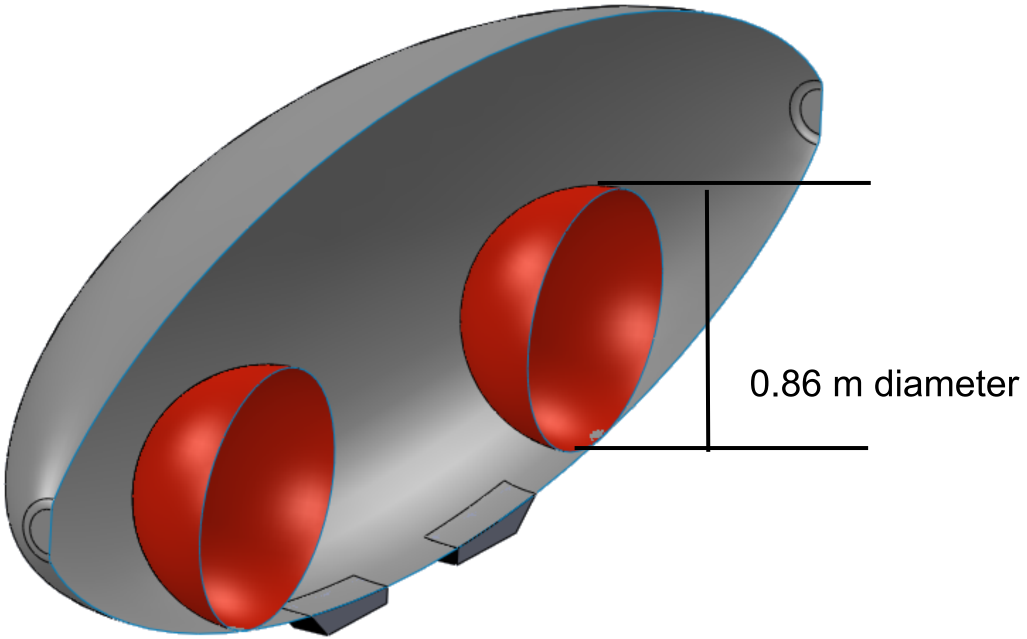
Lyndsy Muri

Blimp Cross-Section Showing Ballonets

Internal air ballonets control internal pressure (1.01 to 1.10 atm)

Coupled with internal pressure sensor and two air compressors

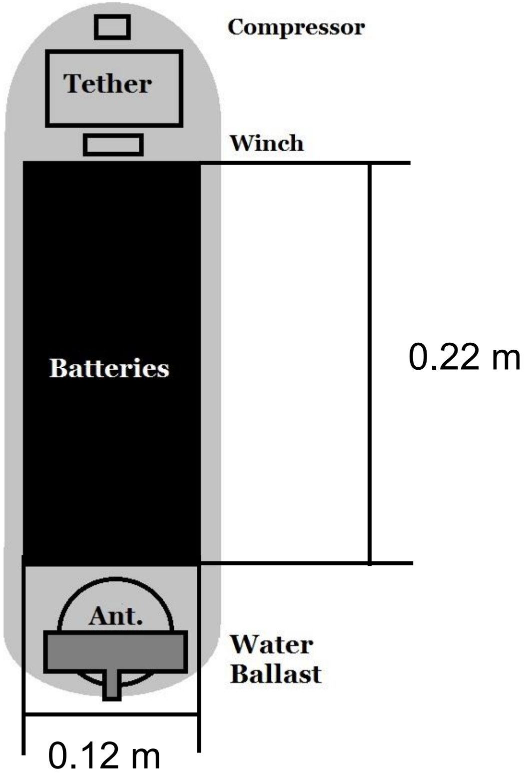
- Provide pitch control
- Keeps skin taut



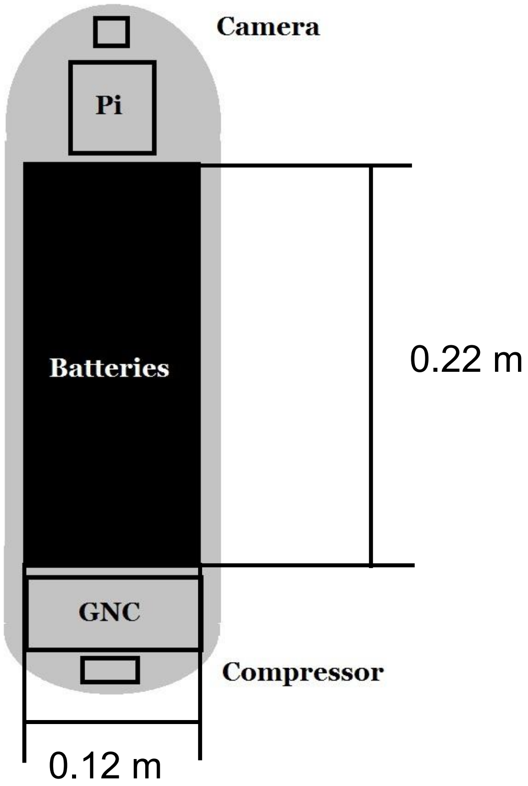
Lyndsy Muri

Gondolas house power components and payload

Fore Gondola:



Aft Gondola:



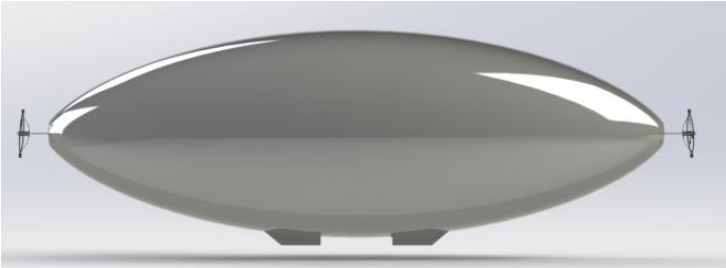
Lyndsy Muri

Blimp design provides advantages over other UAVs

- Minimal contact with water
  - Charging connection in air
  - No need for landing or take-off
  - Avoids waves
- Endurance (wind dependant)
  - No stall speed: missions can potentially be 1.5-50+ hours
  - Lower speed = less drag = longer range (potentially >150 NM) B5

Lyndsy Muri

Blimp symmetric geometry provides both control and stability



-Fore motor location maximizes controllability during docking while minimizing weight

-Given large amount of control power, fins become unnecessary weight

-Two gondolas structurally superior to one large one.

-Aft motor location dictated by aerodynamics (BLI).

-Calculated drag coefficient: CDA = 0.093 m^2 (Re = 5E6), CD = 0.086 (Re = 5E6)

Lyndsy Muri

Blimp can complete both missions:

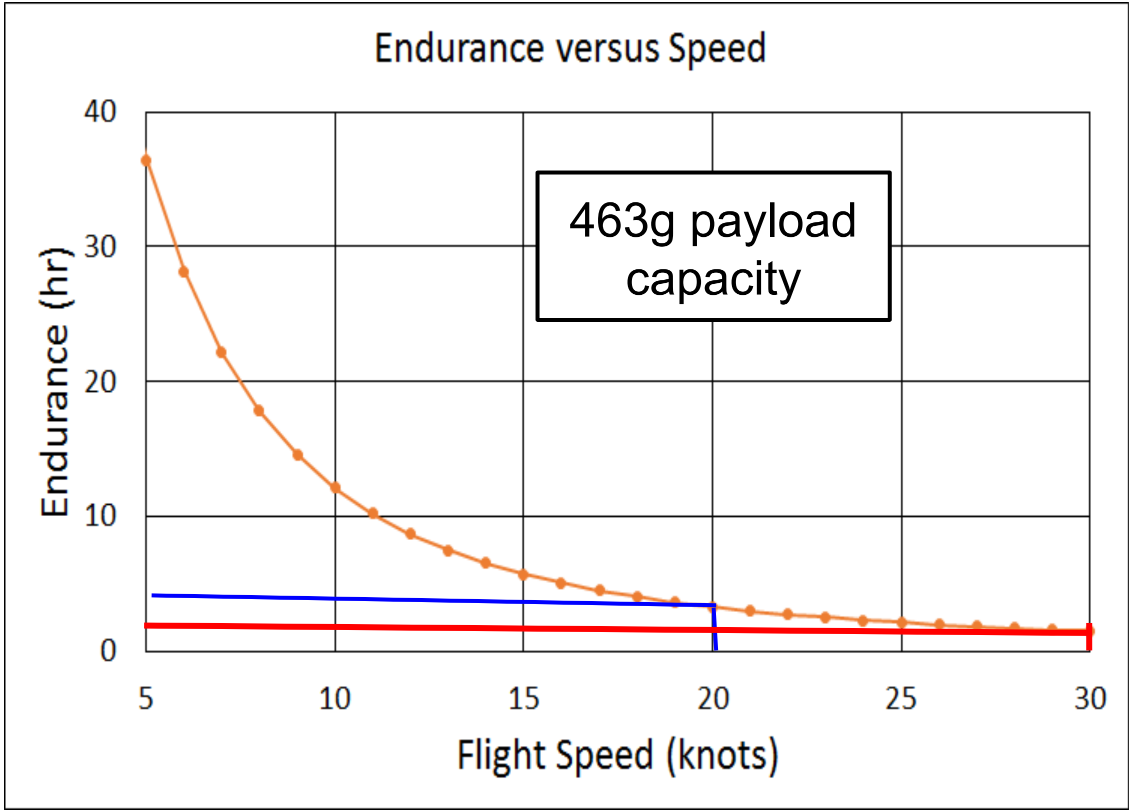
-Range mission: 30 kts, 1.5 hr

-Endurance mission:

20 kts, 2 hr, 1000ft altitude

-Range mission harder to accomplish due to high speed

- Designed to satisfy range mission requirements
- Exceeds endurance mission requirements



Lyndsy Muri

Range mission dictates blimp design and performance metrics

Range: 45 nm at full thrust

Top Speed: 30 knots

Mission Duration: 1.5 hours (at peak operational speeds)

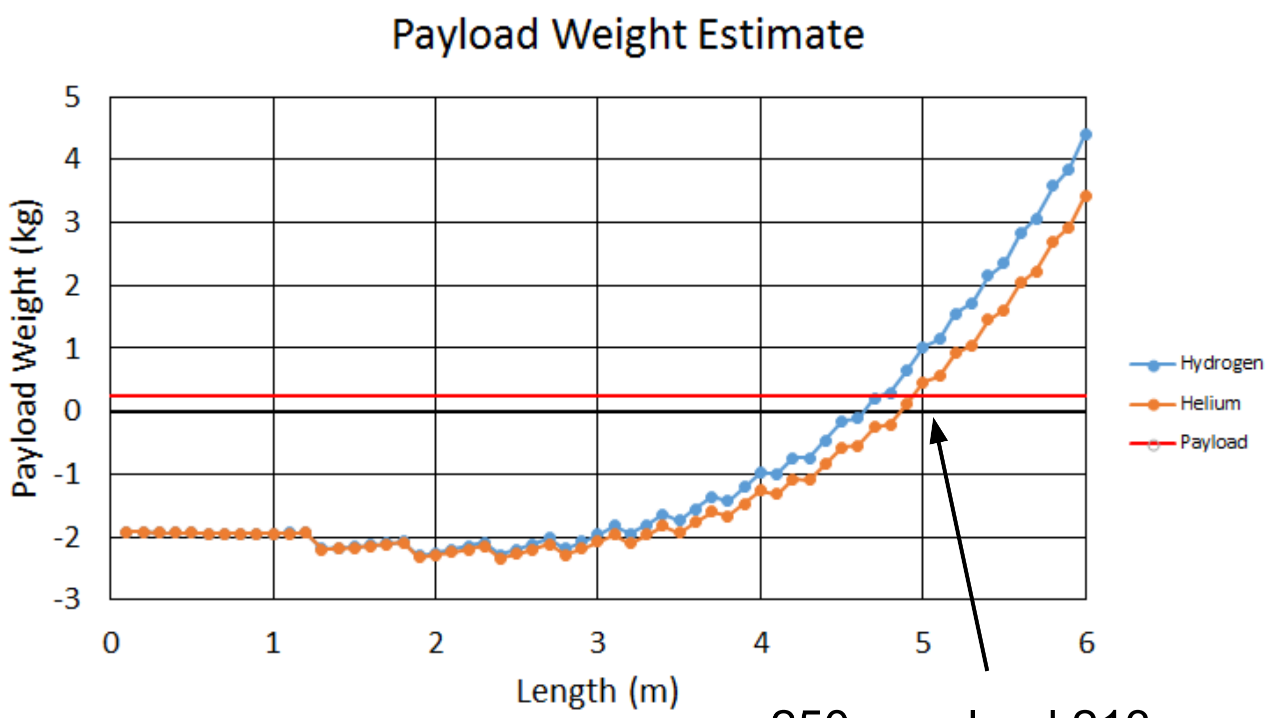
Charging: 10 A at 22.2V

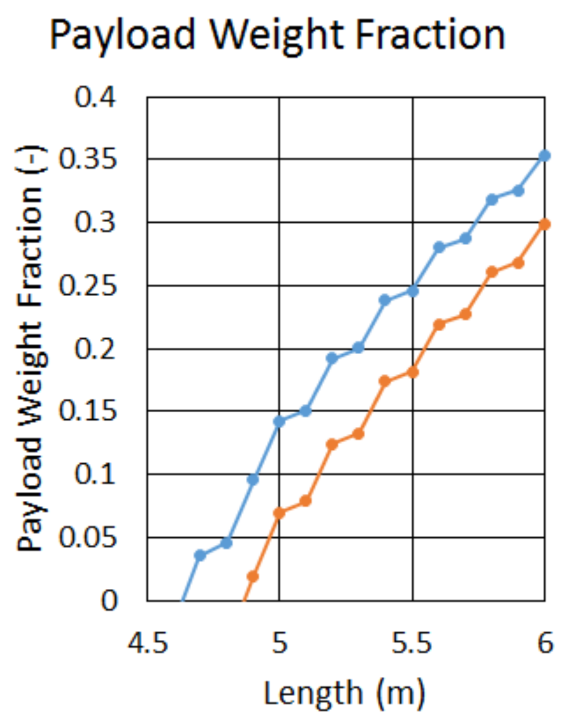
Charge Time: 3.25 hours

Mass Summary	
Structure	1434
Power	4738
Payload	250
Margin	213
Total (g)	6635

Lyndsy Muri

Best Performance at 5m, using Helium





250g payload 213g margin for 5m length

Jacobi Vaughn

Mass Budget (grams)

Skin	1025	Battery (12)	3192	GNC	200
Ballonet (2)	78	Wiring	231	GNC Margin	50
Gondola (2)	200	Motor (2)	286	Blimp Margin	213
Nose Cone (2)	30	Prop (2)	50		
Compressor (2)	46	Mount (2)	200		
Water Ballast	55	ESC (2)	100		
		Rate Gyro(2)	20		
		Docking	659		
Structural (g): 1434		**Power (g): 4738**		**Payload(g): 463**	
TOTAL MASS (g) 6635					

Wet Mate	500
Hook	25
Tether	95
Spool	30
Servo	9
Docking Breakdown (g): 659	

Jacobi Vaughn

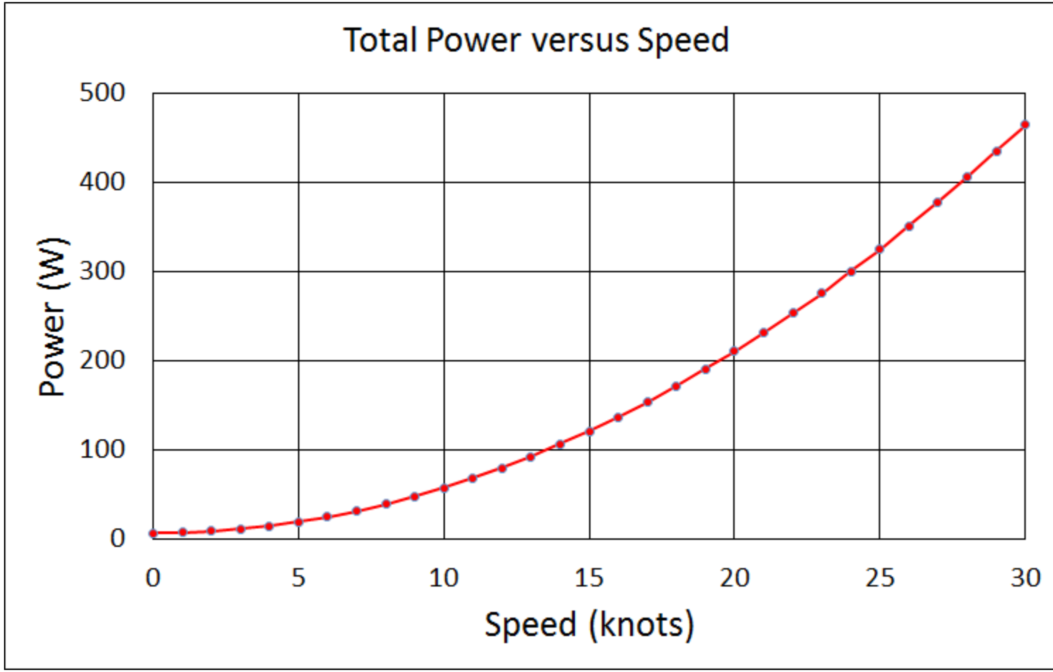
Power Budget

Total Energy: 694 W hr

Dictated by design point (range mission)

Fill or Empty Ballonets: 100 J

GNC: 6.25 W continuous

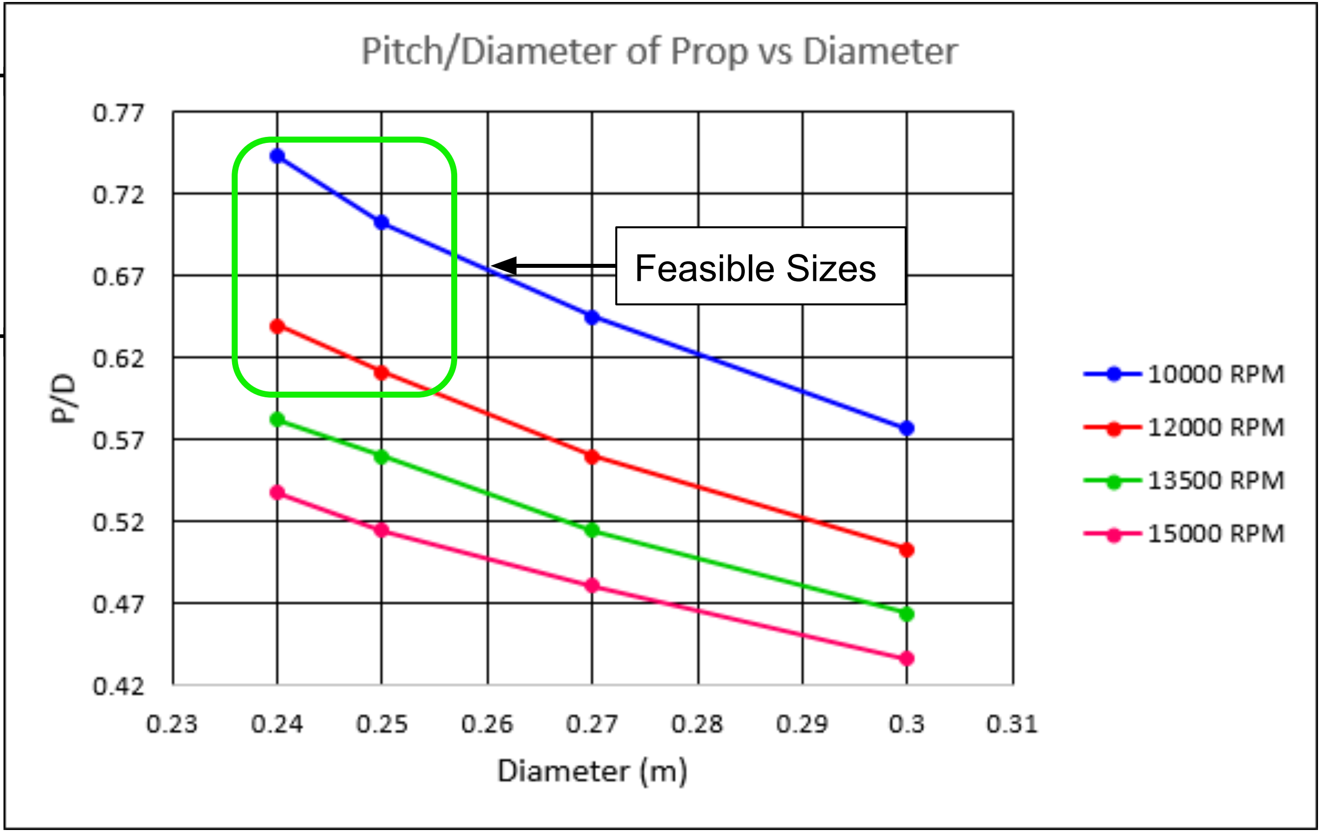


Jacobi Vaughn

Propellor Sizing for Efficiency and Power

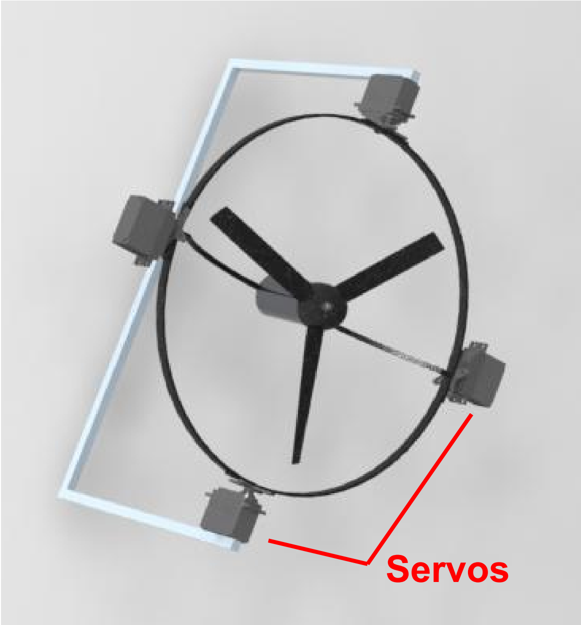
- 2-blade 10x6 sport prop
  - ~53% efficiency
- 3-blade 10x6 sport prop
  - ~54% efficiency

P/D = □*tan(□$^{0}_{tip}$)



Jacobi Vaughn

Motor assembly provides a full hemisphere of directionality



- Two pairs of servos work in tandem to provide quick response to control input.
- Carbon fiber construction is light and rigid
- Considering custom stainless steel bearings

Low RPM Motor for high propellor efficiency

- Hacker Brushless Motor
  - 104 grams
  - rated for up to 450 Watts
  - 800kv (rpm/V)
  - 15V ~ 12,000 RPM
  - 85% efficiency

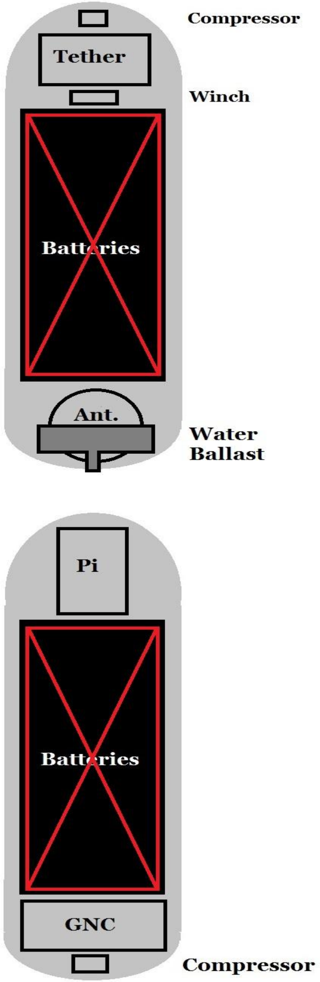
Jacobi Vaughn

Battery Pack: High Specific Energy

Tenergy Li-Ion 18650, 6 cell

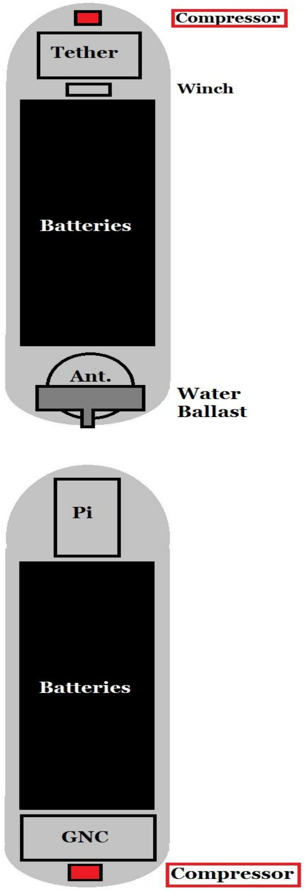
- 7.4V, 7.8 Ahr, 266g
- 7 A max discharge
- 3 A max charge
- 4.25” x 2.85” x 0.79”

<u>Quantity: 12</u>



Jacobi Vaughn

Ballonet Compressor



Schwarzer Precision SP 100 EC

Mass: 15.5g

3V, 100mA

70 sec fill/empty time

One in each gondola with tubing to nearest ballonet

Quantity: 2

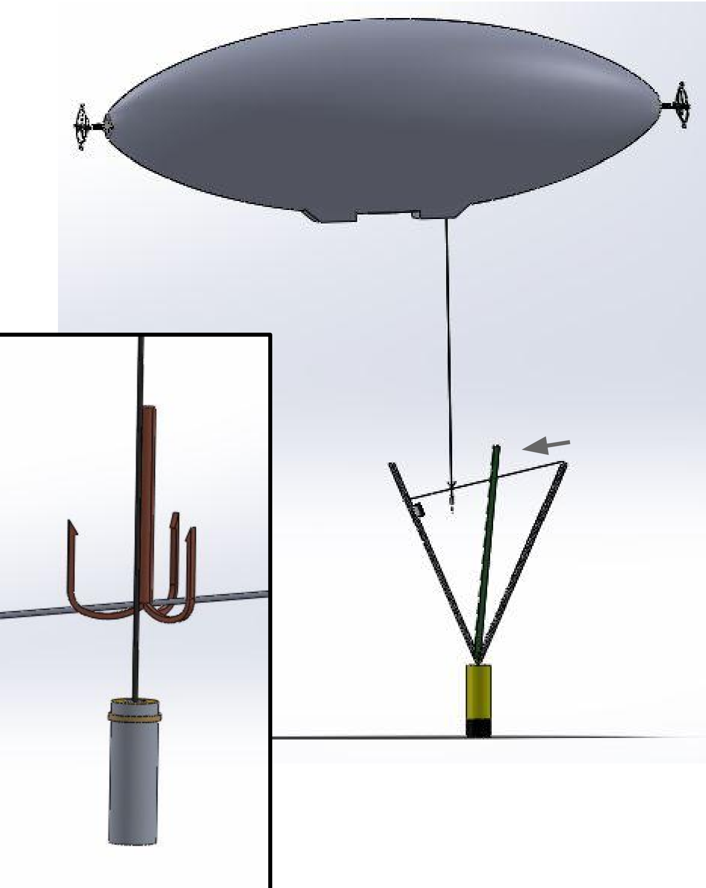
Jacobi Vaughn

Control overview

	Motors	Ballonets	Passive
Pitch	X	X	
Roll			X
Yaw	X		
Vertical	X	X	
Forward	X		

Jacobi Vaughn

Docking: The hook catches the pod's "finish line"

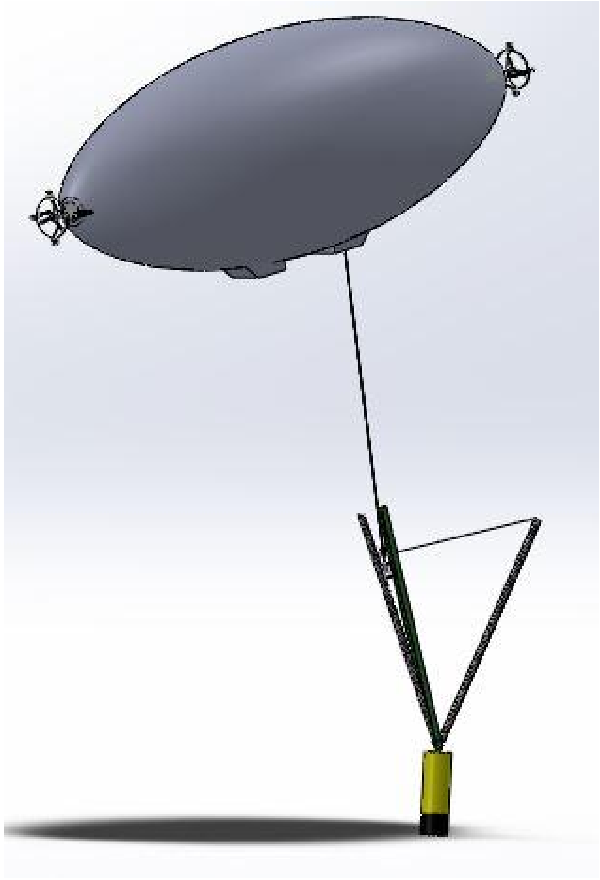


Tether is unwound from front gondola

Blimp flies over "finish line", hook catches the line

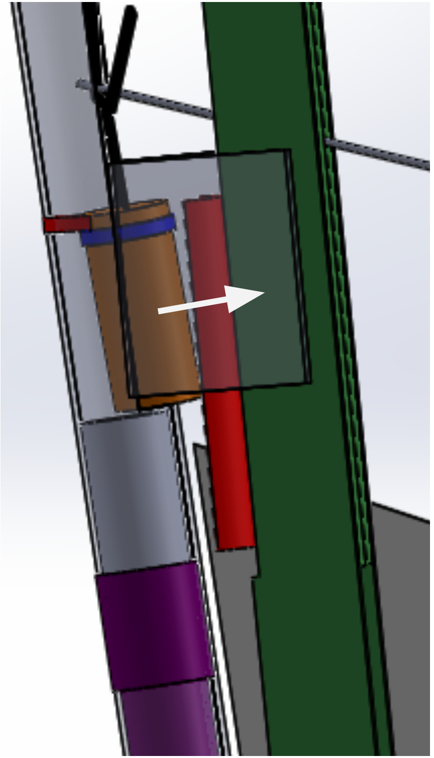
Moving arm pushes tether into charging port

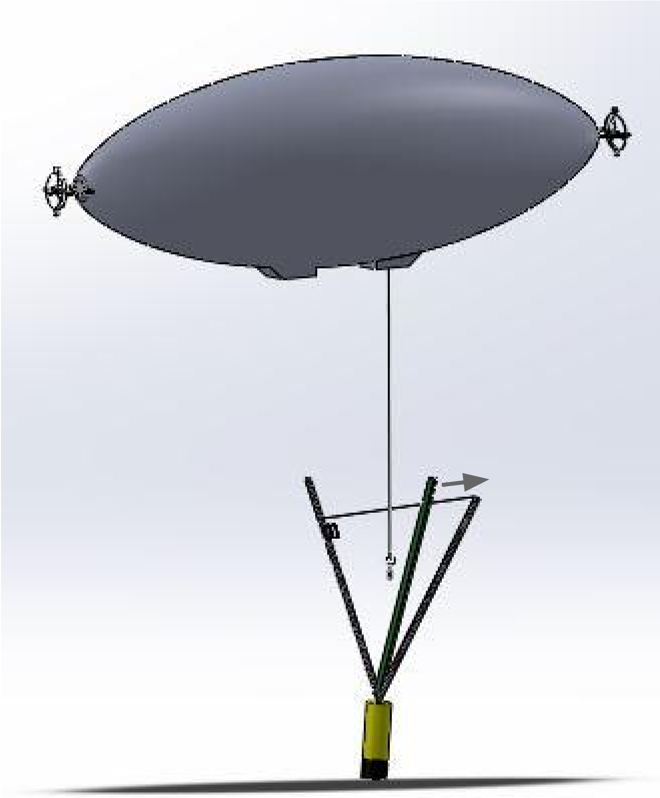
Once secured for charging, blimp floats above pod



Karly McLaughlin

Done charging, the blimp disengages the hook





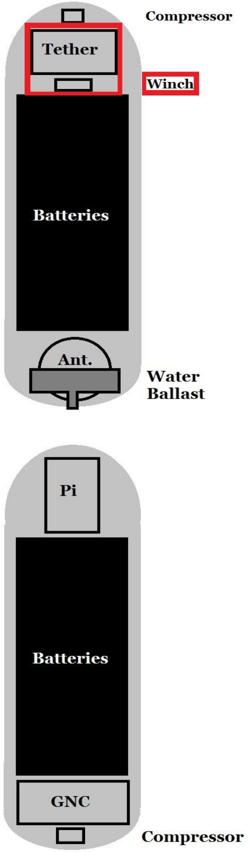
Charging complete, arm repositions hook away from port using magnets

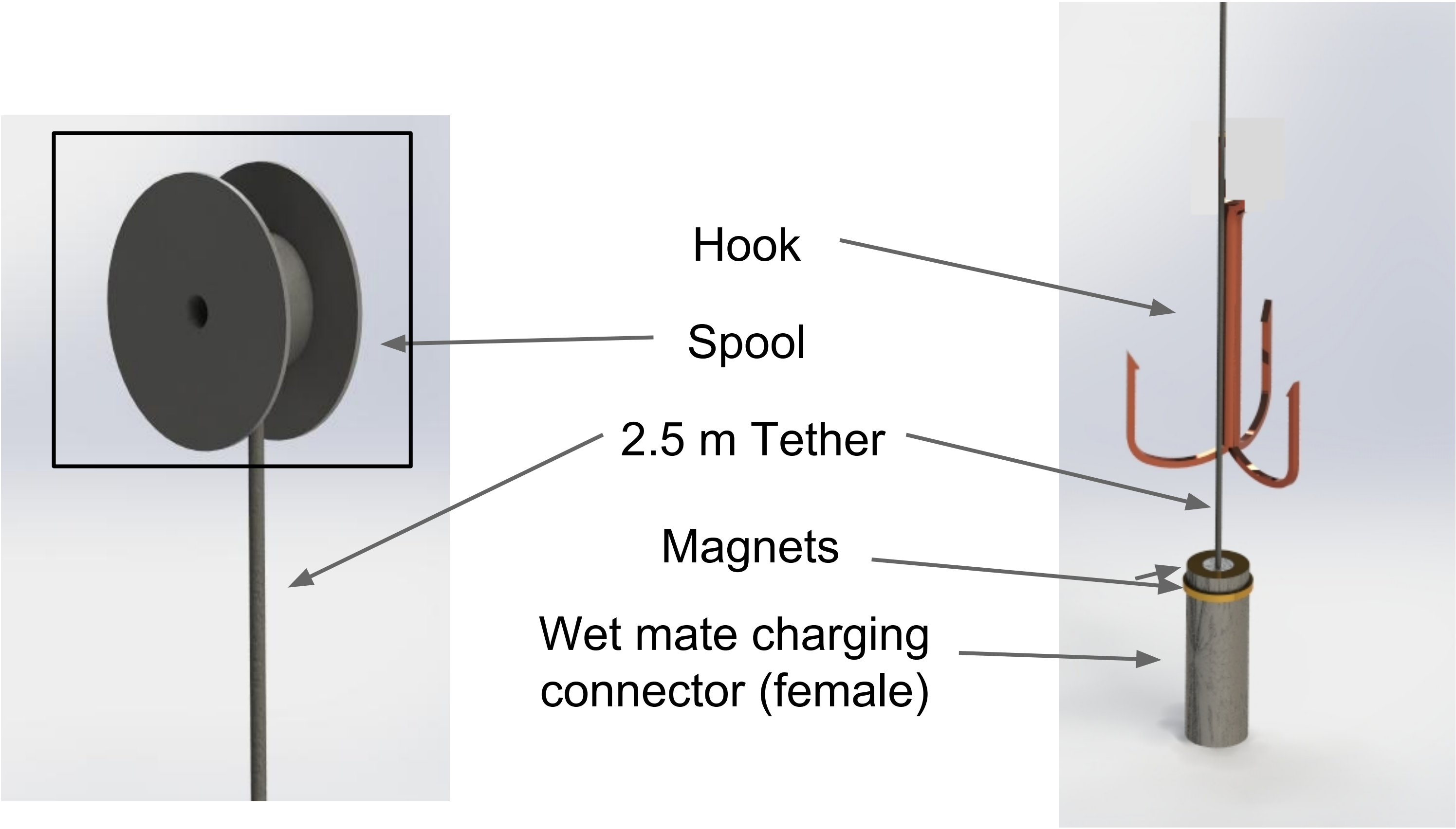
Magnets disengage

Blimp descends, releasing hook

Karly McLaughlin

Docking mechanism: tether, hook, and charger



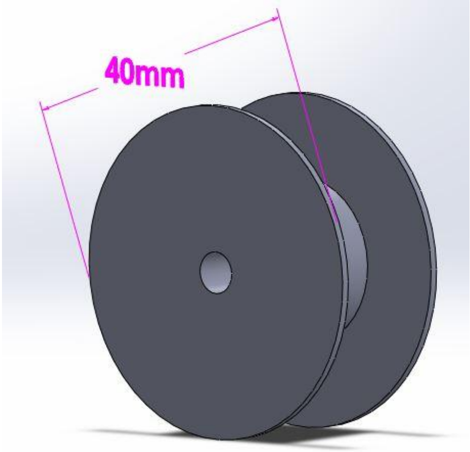


B20

Karly McLaughlin

Tether components are small and lightweight

- Tether: 2 18-gauge coated copper wires (for 10A charging current)
- Hook: 14/0 treble hook
- Spool: lightweight plastic



Karly McLaughlin

Blimp Risks

Probability					
5			A		
4		G			
3		E	D		
2			C	F	
1					B
	1	2	3	4	5

Impact

ID	Risks
A	Leakage of helium
B	Rupture of envelope
C	Weather concerns and mission specific extenuating circumstances
D	Docking Error: misses finish line, fails to detach
E	Loss of radio contact with pod
F	Batteries may not be the quality advertised or explode (overcharge)
G	Control algorithms not developed for gimbaling system

Lyndsy Muri

Blimp Risks (cont.)

ID	Risks	Mitigation	Probability	Impact	Risk
A	Leakage of helium	Mylar layered for inestimable lifespan dependent on manufacturing quality	5	3	15
B	Rupture of envelope	Operations take this risk into account	1	5	5
C	Weather concerns and mission specific extenuating circumstances	Potential weather conditions and extenuating circumstances are incorporated into the risk assessment	2	3	6
D	Docking error	Our controls and tether system are optimized for charging ease	2	3	6

Lyndsy Muri

Blimp Risks (cont.)

ID	Risks	Mitigation	Probability	Impact	Risk
E	Loss of radio contact with pod	The blimp will go to the nearest known approximate location and attempt to find a new pod	3	2	6
F	Batteries may not be the quality advertised or explode	The charge of the batteries is monitored by the system and the charging has taken into account the risk of LiPo batteries	2	4	8
G	The unpredictable nature of wind may hamper controls	The control mechanisms allow for full range of motion from the control system	4	2	8

Lyndsy Muri

Gas leakage dominated by sealing imperfections

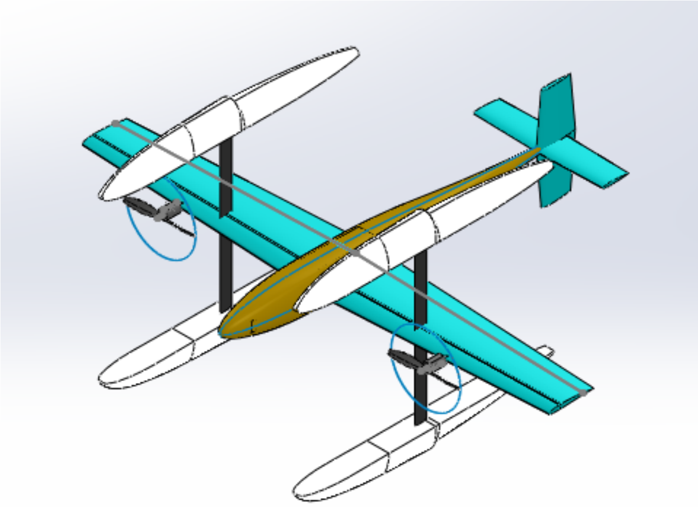
- Only considering skin effusion, Fermi estimation indicates a lifespan of O(10,000) days. (Exact calculations prohibitively difficult.)
- Thus, the lifespan is effectively dictated by sealing imperfections and manufacturing defects.
- Since these are impossible for us to model, **prototyping will be required to investigate this risk.**

Lyndsy Muri

Moving forward

- Structural tests on material samples and seals
- Communication with vendors about envelope manufacturing details and challenges
- Specific water ballast design
- Further research into seal gas leakage
- Firming specific gondola design
- Estimation of system dynamics

Lyndsy Muri



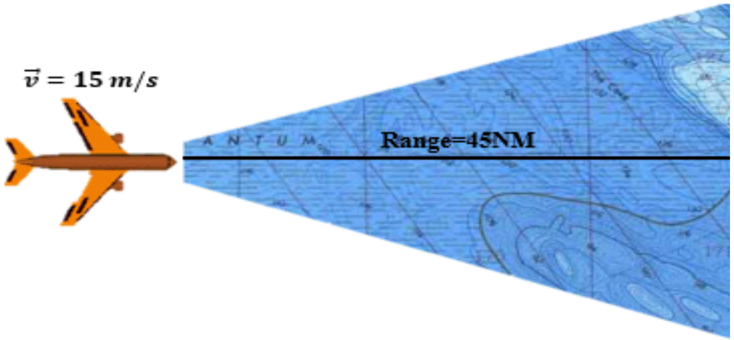
Airplane Design

Harris Chalat
Hayden Cornwell
Casey Denham
Ellen Liverpool
Devon Sklair
Gray Riley

Requirements and Design Drivers

Mission Requirements:

- Mission Time: 1.5 hr
- Average Speed: 15.4 m/s
- Aircraft is not disabled when inverted

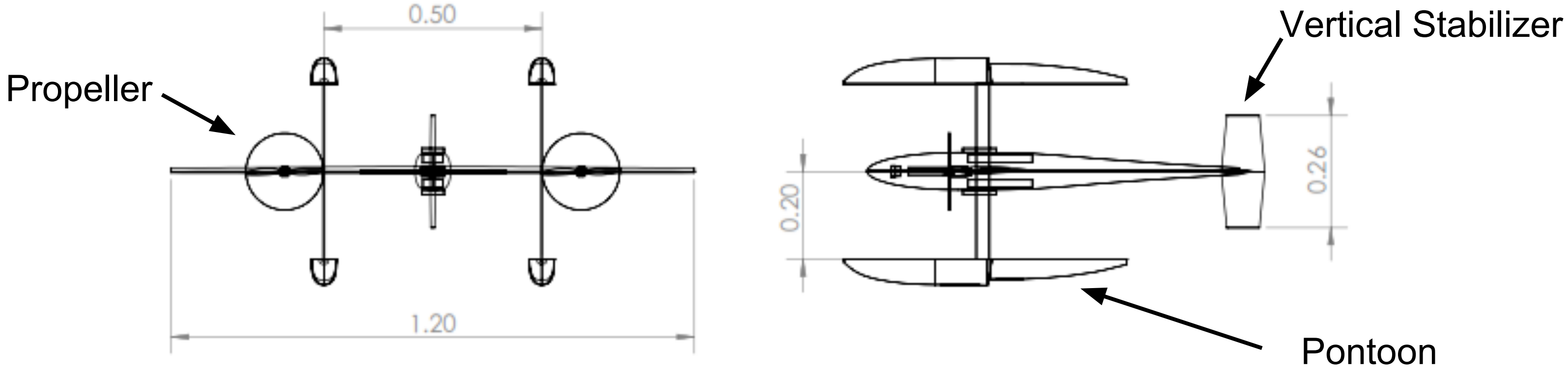


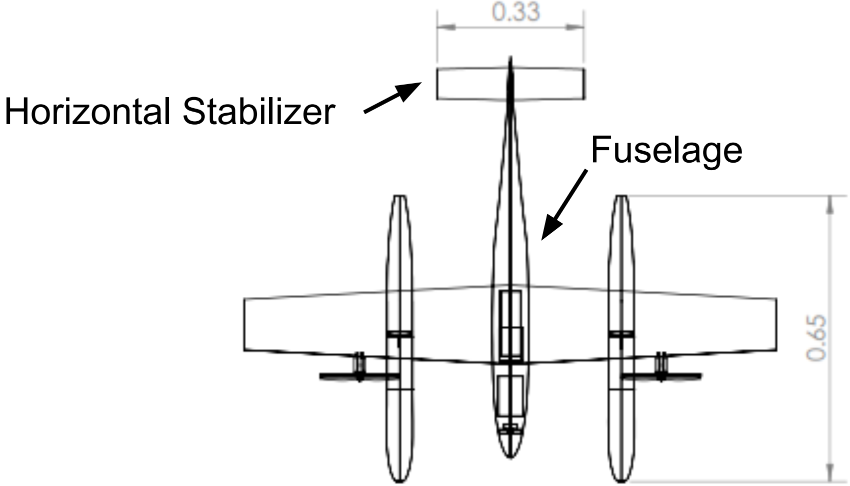
Design Drivers:

- Land, charge, and takeoff from inverted position
- Withstand hydro- and aerodynamic forces

Ellen Liverpool

3 View





Key Facts:

- Twin Engine
- Mid-wing
- Conventional fuselage
- Cruciform tail
- Semi-symmetric top and bottom

Ellen Liverpool

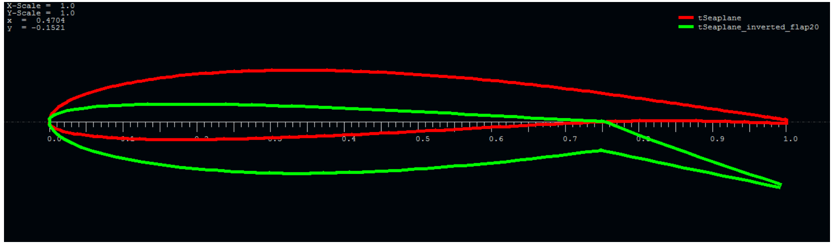
Airplane - Fast And Versatile

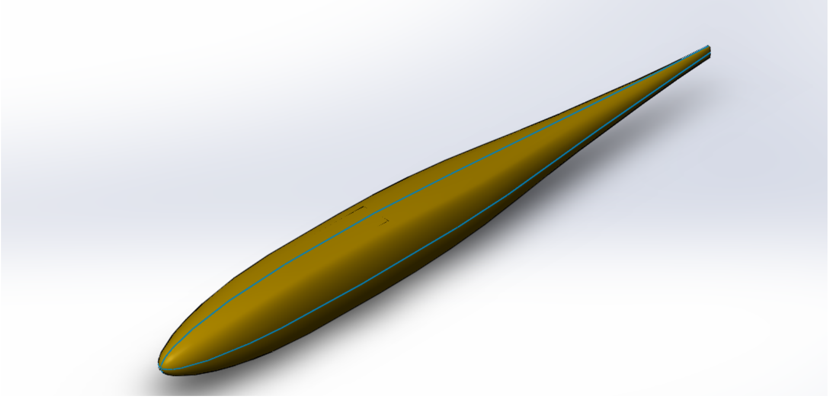
Benefit	Mission Relevance
Maneuverability	Can follow evasive targets and quickly move from area of interest to another
Speed	Allows UAV to sprint to emergency situations, giving operations ISR capabilities faster
Low power demand	Lower turnover rate when charging, spend less time away from the mission
Simple design and low cost	Cost of lost/broken UAVs is low, operator can use multiple UAVs without high financial risk

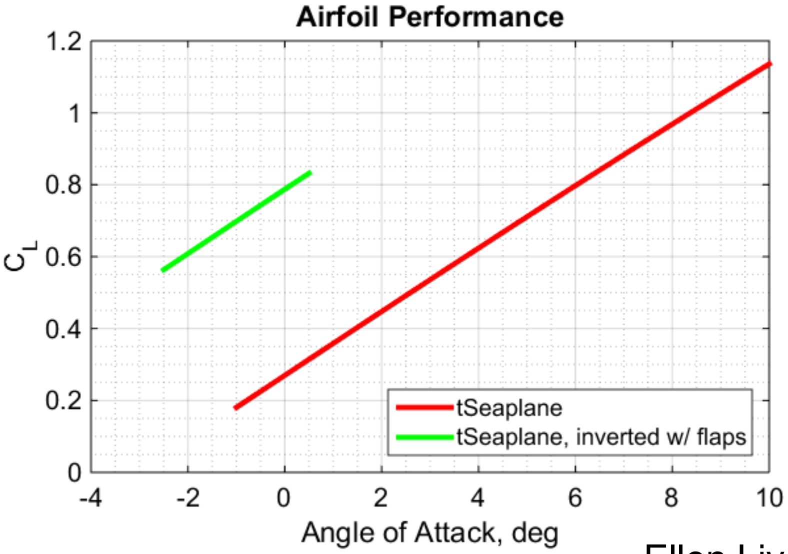
Ellen Liverpool

Aerodynamic Components

- **Custom Wing Airfoil**
- **Tail Airfoil**: NACA 0012
- **Low Drag Fuselage**



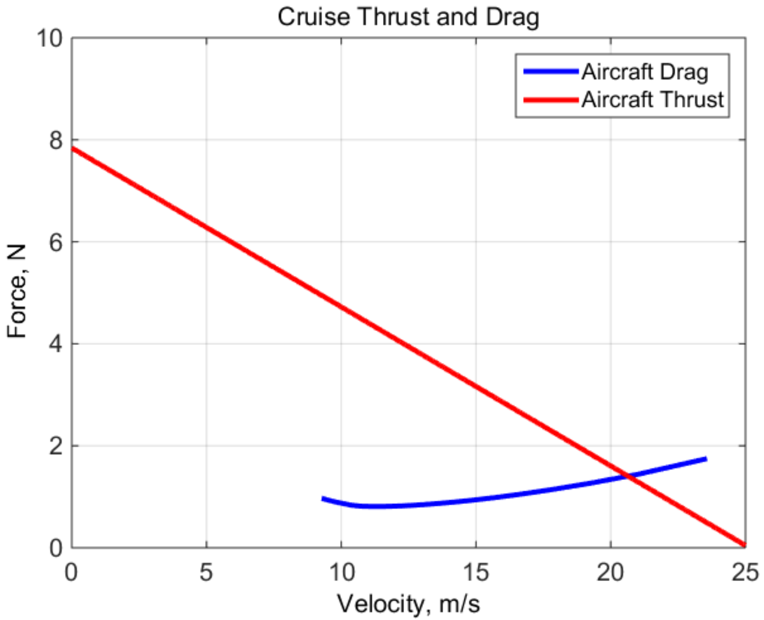




Ellen Liverpool

Aerodynamic Performance

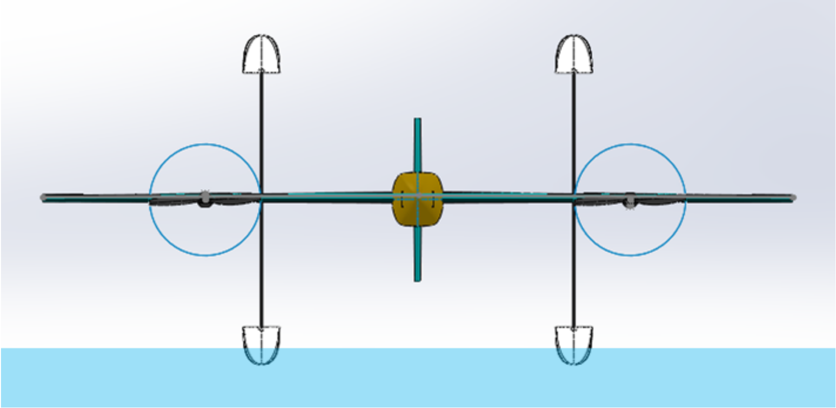
V_{stall}	8.2 m/s
$V_{maximum\ endurance}$	12.9 m/s
V_{max}	20.8 m/s
Estimated Range	93.0 km



Ellen Liverpool

Pontoon Selection

- Classic pontoon design
  - Reliable
  - Known performance
- Semi-symmetric design allows for inverted charging and takeoff

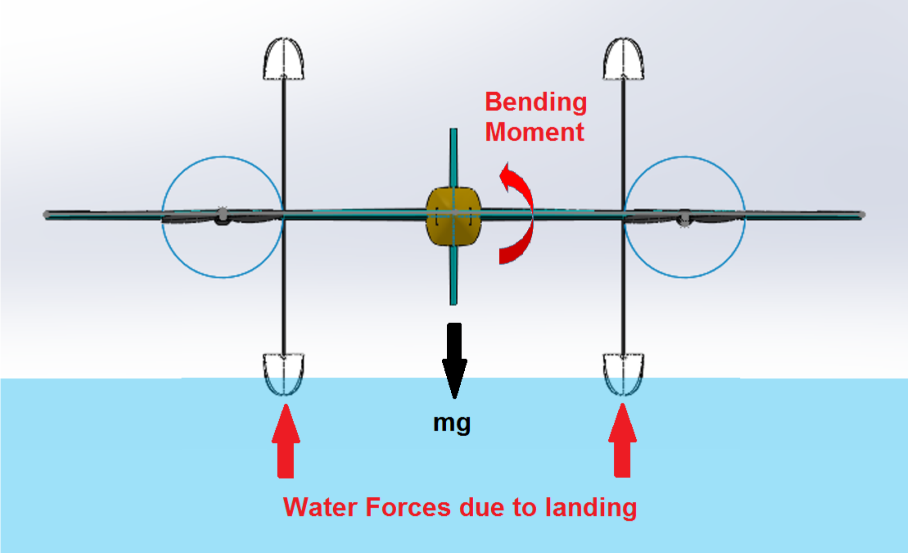


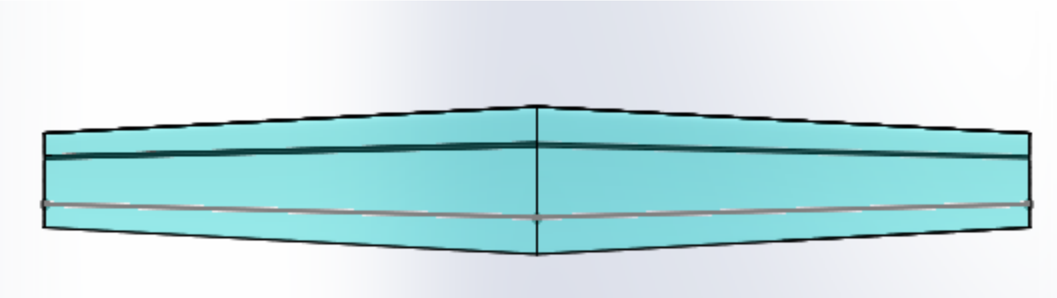
A7

Devon Sklair

Structural Components - Wing

- Wing spar sized for 15g landing
- Aircraft can withstand forces from outboard pontoons



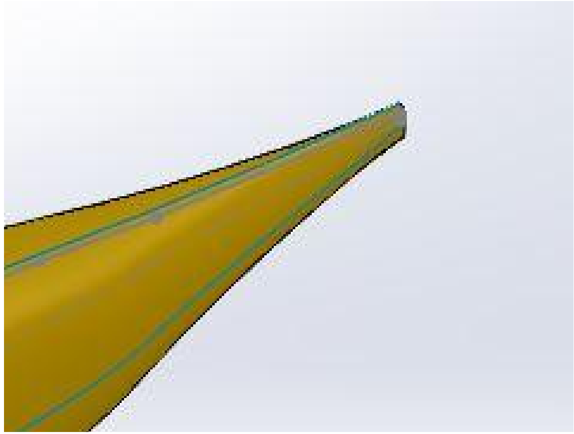


A8

Devon Sklair

Structural Components - Fuselage

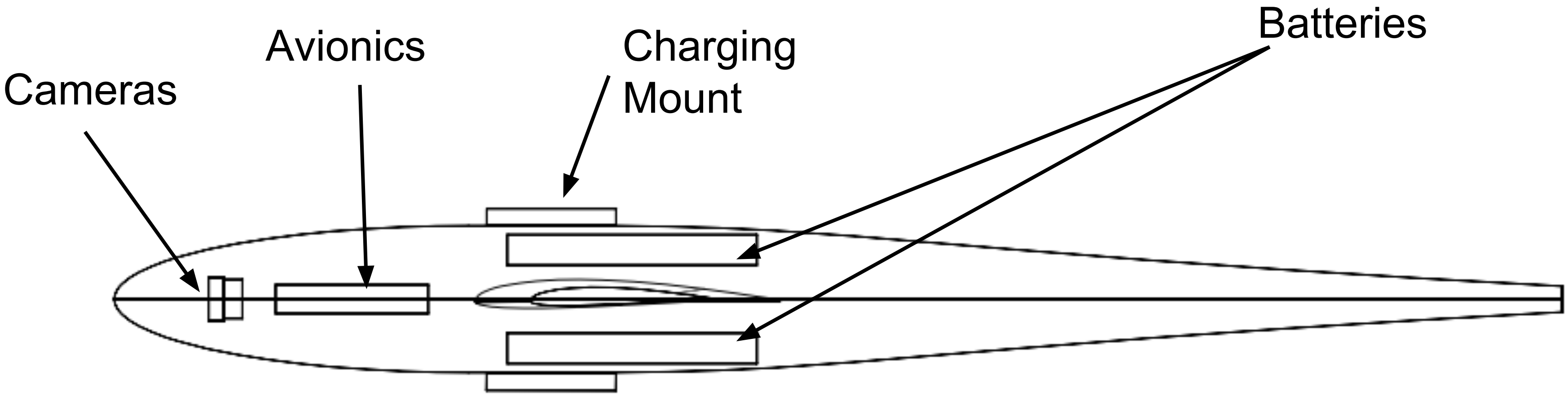
- Hollow molded composite or polyurethane foam
- Both materials can withstand loads, but with different benefits



Devon Sklair

GNC Package

- Camera, servos, batteries, and avionics are placed so that CG is located just aft of the batteries' centers
- CG of GNC package complements the CG of the airplane



Ellen Liverpool

High Level Power Breakdown

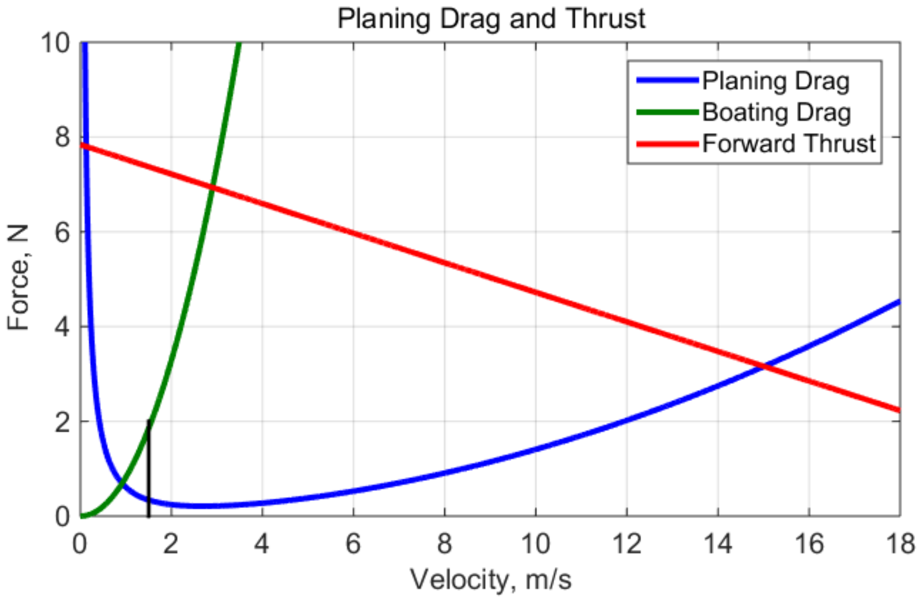
Component	Energy required (Wh)	Battery Mass (kg)
Cruise	53.4	0.356
GNC	11.9	0.079
Take-off	4.80	0.032
Emergency	5.20	0.035
Total	**75.3**	**0.502**

Assumptions: Range Mission of 15.4 m/s for 1.5 hours and emergency leniency for a second take off and 550 extra meters of Cruise/GNC

Harris Chalat

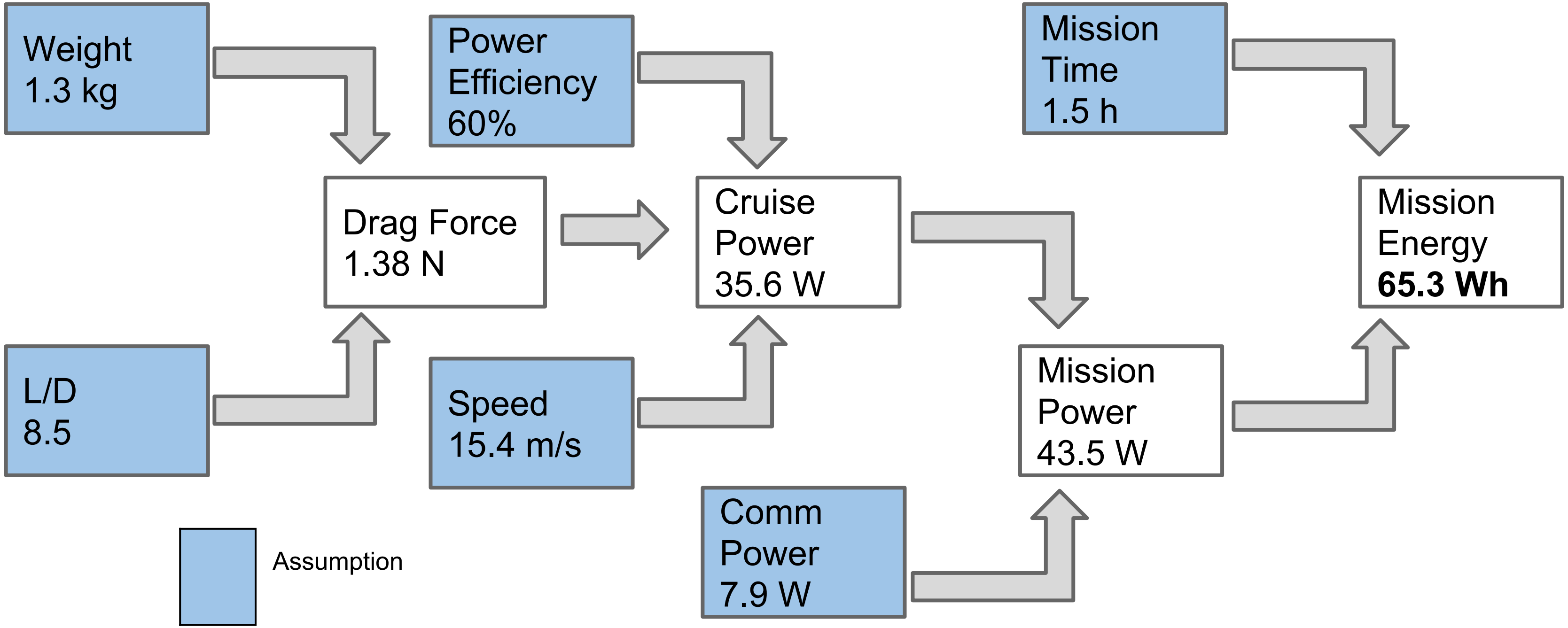
Motor design driven by takeoff while inverted

- Take-off Velocity
  - Normal: 8.4 m/s
  - Inverted: 12 m/s
- Planing Regime
  - V > 1.5 m/s
- Final Takeoff Drag
  - Normal: 1 N
  - Inverted: 2 N
- Takeoff time: 90 sec



Harris Chalat

Mission ops major determinant of total energy



These calculations are based off the Range Mission

Harris Chalat

Final Power System

- **Motor (2) :**
  - 31g
  - 1100Kv
  - Max Power: 190W
- **Propellor Size:** 7x5in
- **Battery (2):**
  - 3S (11.1V)
  - 253g
  - 3000mAh
  - 20C (30C burst)

Harris Chalat

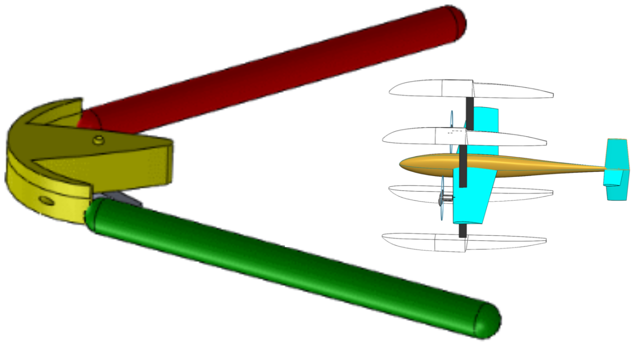
Mass Budget

	Mass [kg]	**Mass Fraction**
Payload	0.24	0.18
Powerplant	0.57	0.44
Airframe	0.49	0.38
Total	**1.3**	**1.0**

Harris Chalat

Docking with Wet Mate Charging

- Platform-V docking system
- Pontoons hug platform to align changing mechanism
- Platform makes contact with male connector on bottom of the fuselage.



Devon Sklair

Airplane Risks

Probability					
5					
4	A	C			
3			E		
2				D	
1				B	
	1	2	3	4	5

Impact

ID	Risk
A	Low Visibility on Water
B	Propeller Damage
C	Takeoff in Large Waves
D	Nose Down Stability
E	Docking Alignment Error

Devon Sklair

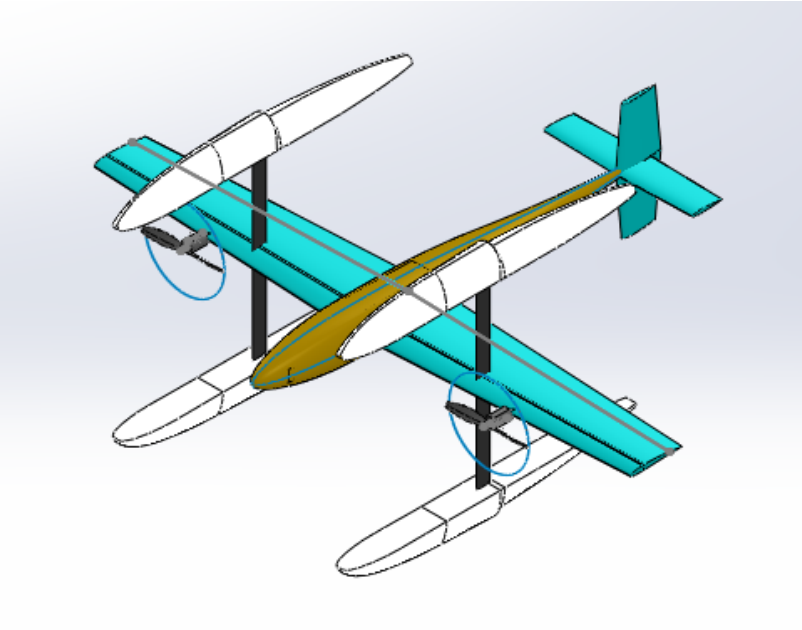
Risk Mitigation

ID	Risks	Mitigation	Probability	Impact	Risk
A	Low Visibility	Cameras are mounted high and are attached to servos that allow for some panning capability.	4	1	4
B	Propeller Damage	Docking V material will be chosen to reduce the risk of damage to the prop from impact.	1	5	5
C	Takeoff in Large Waves	Available thrust has a factor of safety above needed thrust to overcome planing drag.	4	2	8
D	Nose Down Stability	Looking into how to modify the design to make it passively unstable	2	4	8
E	Docking Alignment Error	Dock and airplane will be designed so that airplane is unlikely to become wedged between the platform and an arm of the V	3	3	9

Devon Sklair

Summary

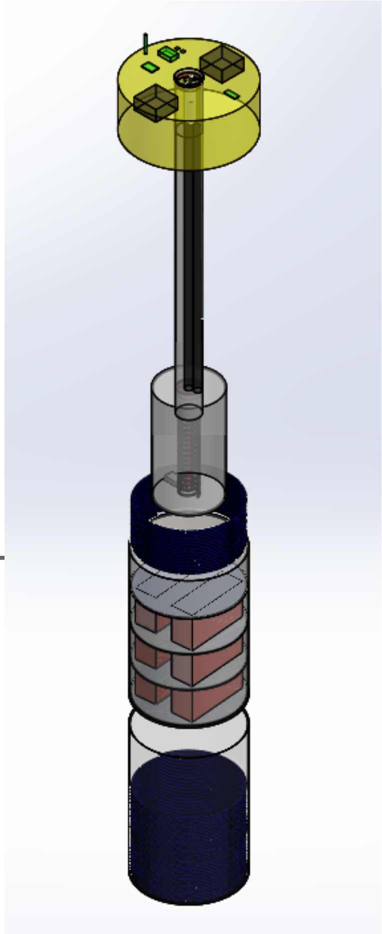
- Semi-Symmetric Seaplane
    - Wingspan: 1.2 m
    - Mass: 1.3 kg
    - Max Speed: 20.8 m/s
    - Max Range: 93 km
- Allows for inverted charging and takeoff
- Uses Platform-V docking system to ensure reliable docking



Devon Sklair

Pod Design

Javier Alvarez
Sarah Brennan
Jasmine Chan
Alex Chen
Thuan Doan
Kirstyn Hein
Rohun Kulkarni
Dacie Manion
Jaya Narain
Emma Nelson
Audrey Sedal
Manjinder Singh



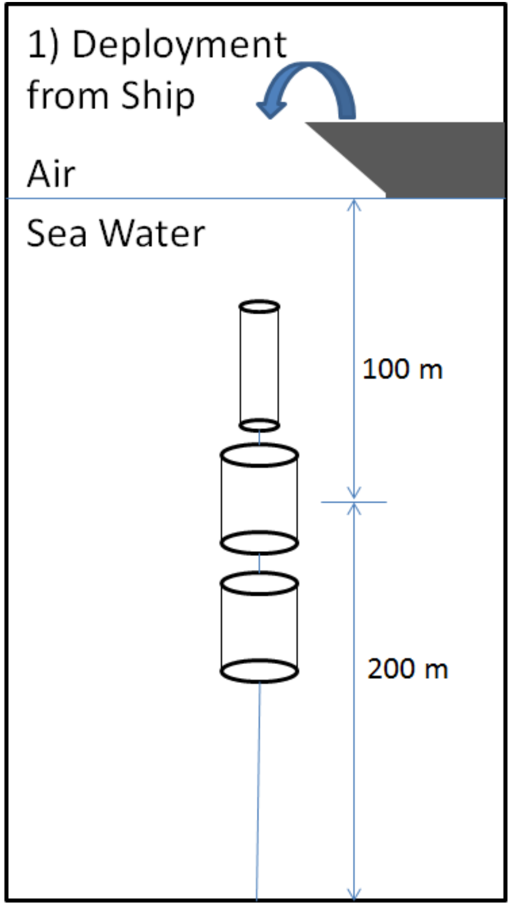
Javier Alvarez

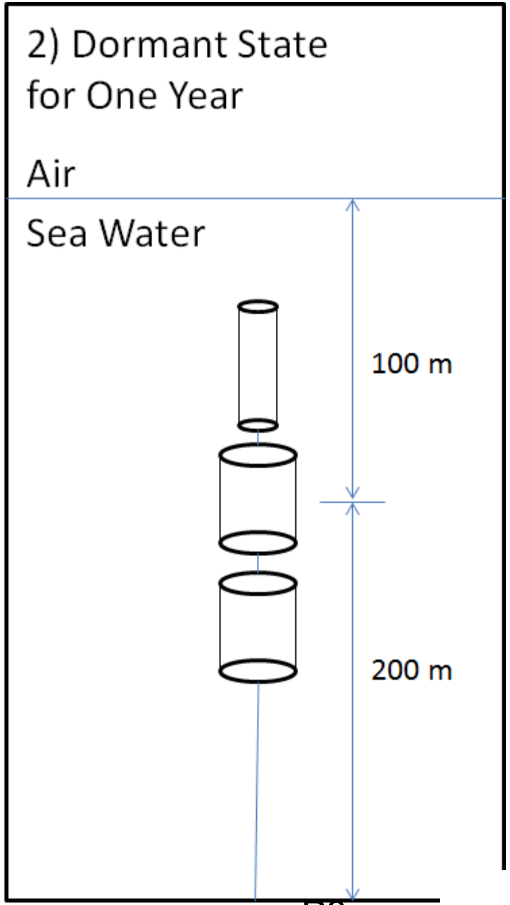
Engineering Requirements

Anchoring	Limits overall system drift to a 300m radius (long-term)
Power	Uses a Power source, stay idle for 1 year, and once activated, charge 0.271 MJ seaplane 37 times or 2.5MJ blimp 4 times
Communications	Uses GPS to prove ~5m accurate locational data and Wifi to transmit data at 720 Kbs or faster to the UAV
Docking	Includes docking mechanisms hydrodynamically compatible at sea state 3 to reliably mate to the plane and blimp

Javier Alvarez

Pod Deployment & Dormant State





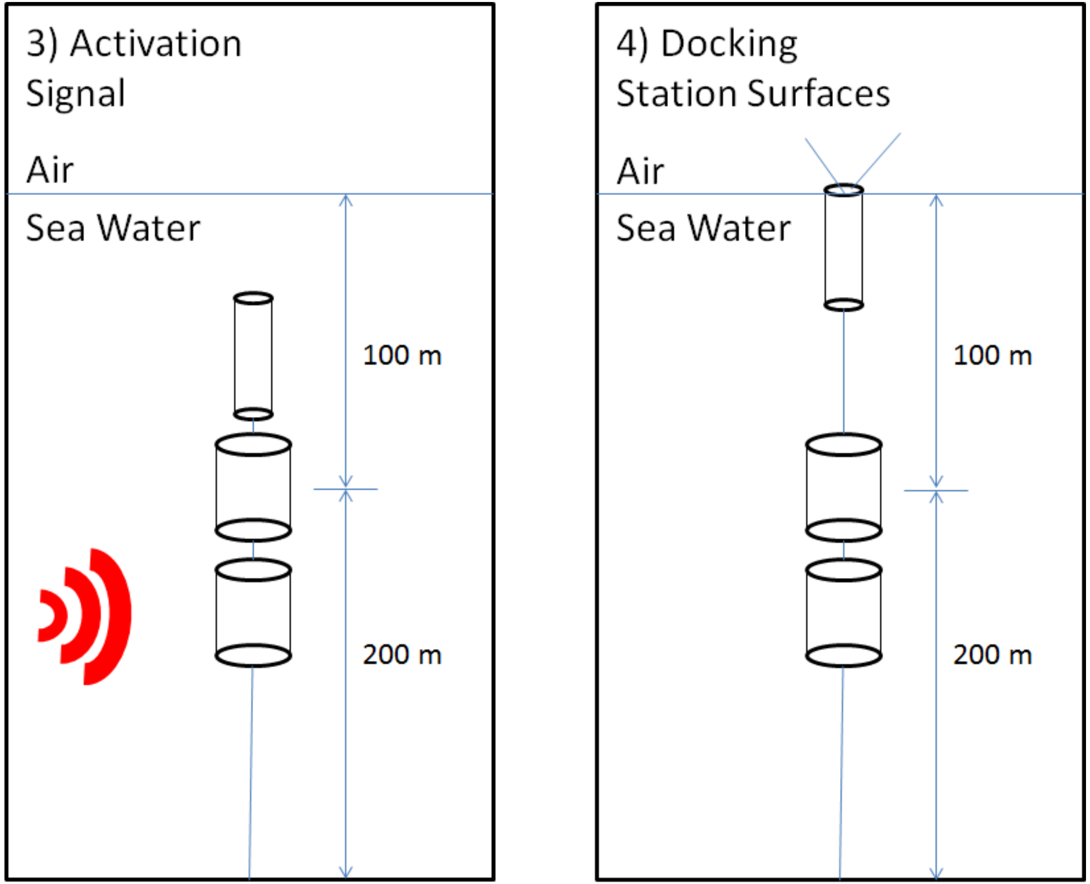
Modular system deploys sections

Anchors to seafloor, up to 305m depth

System awaits activation before deploying dock

Javier Alvarez

Pod Activation & Docking Deployment

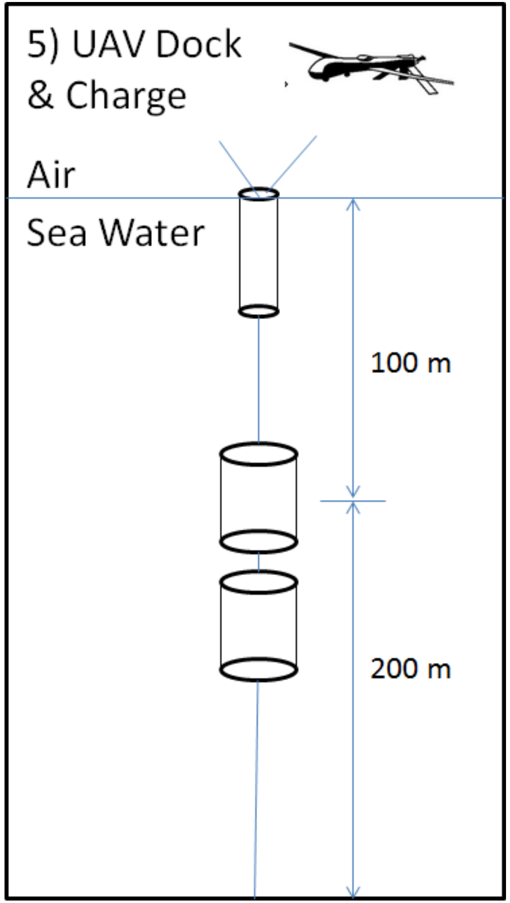


Pod receives activation beacon while at 100m

Docking station is released from pod and surfaces

Javier Alvarez

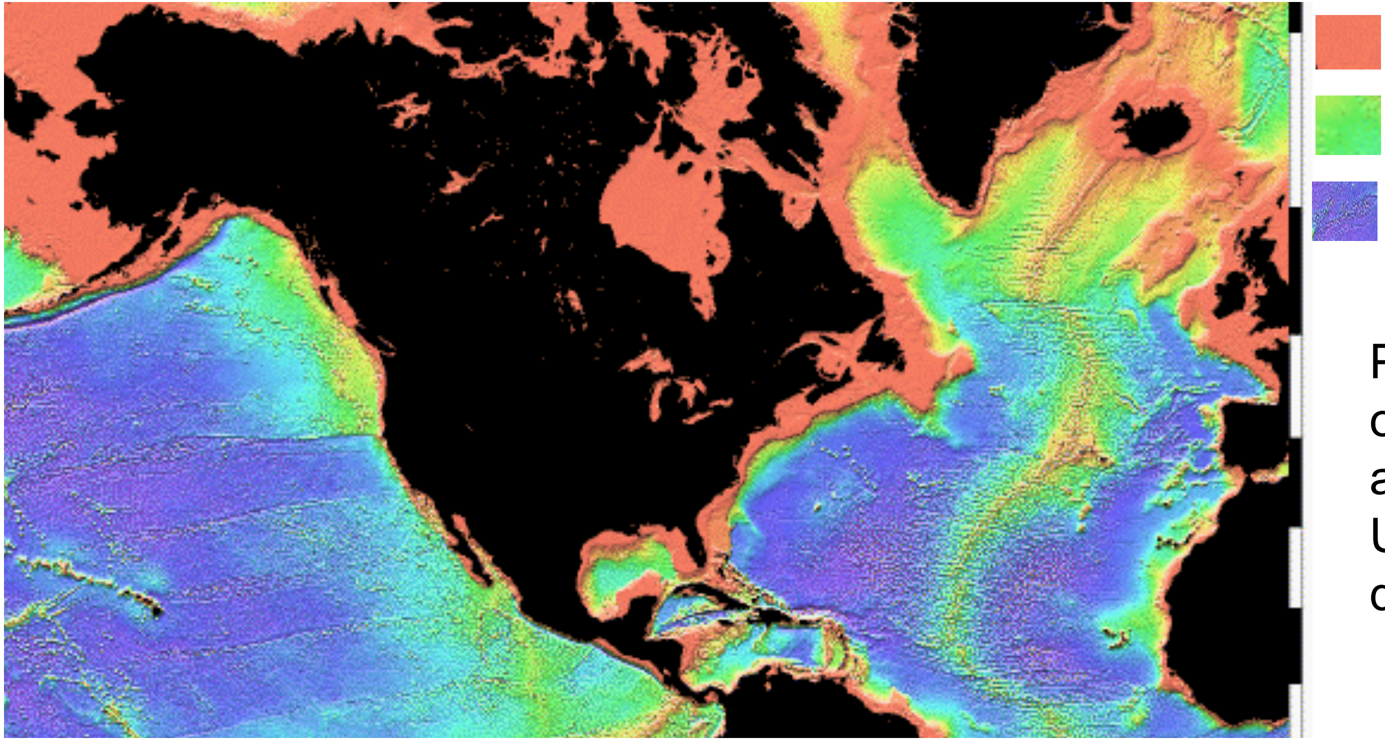
Mission Completion



Docking station interfaces with UAVs at surface

Remainder of pod sections remain at 100 m during this state to reduce biofouling and surface current drag

Operational Area



60m-300m

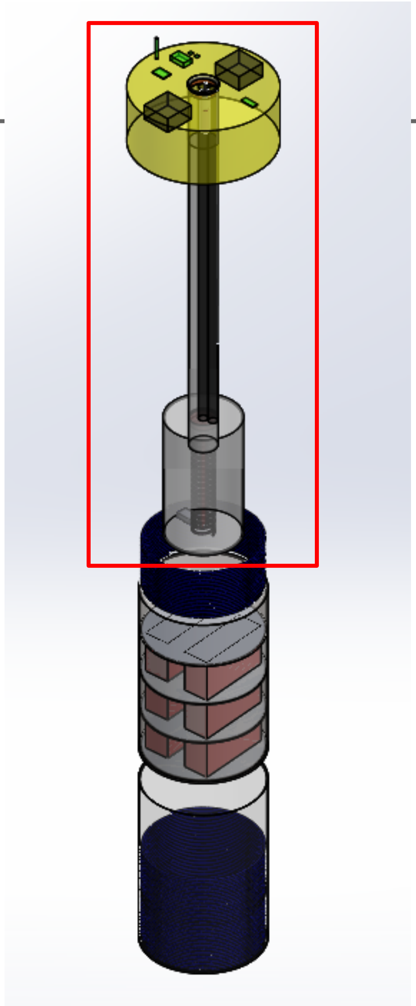
300m-2000m

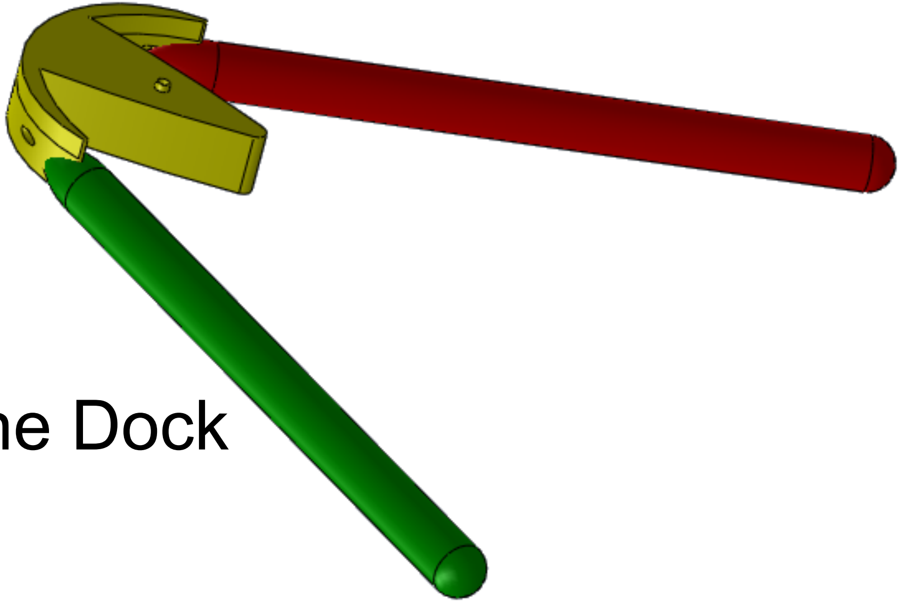
2000m-4000m

Pod operational area:
Up to 305m depth (**red**)

Javier Alvarez

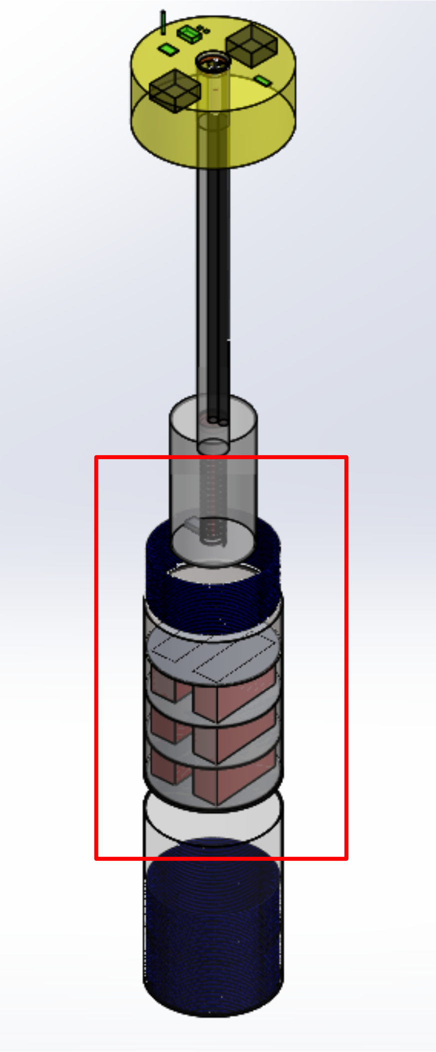
Pod Chain - Docks

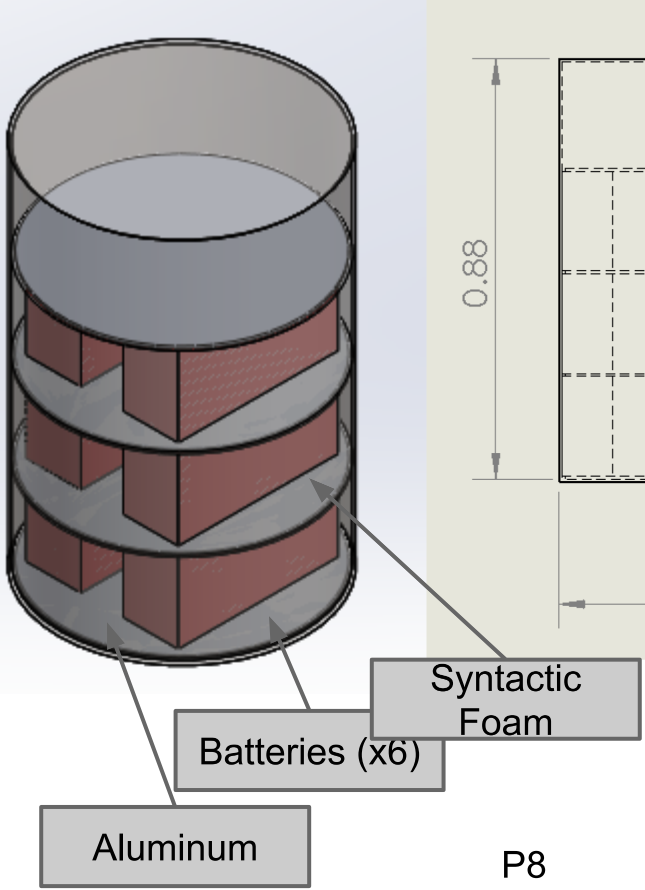


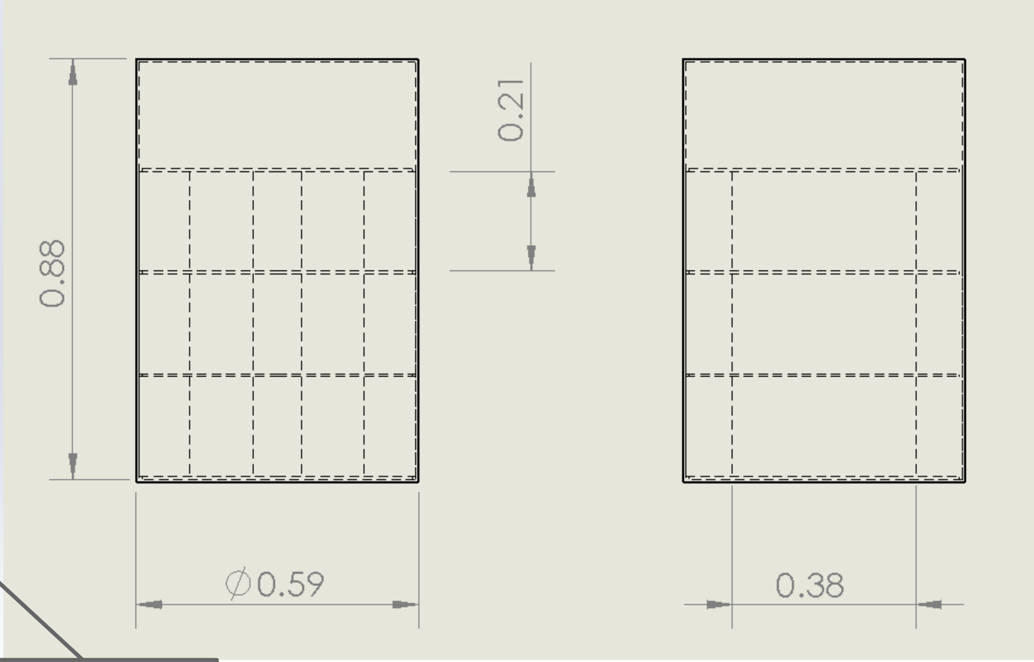


Javier Alvarez

Pod Chain - Battery Pod

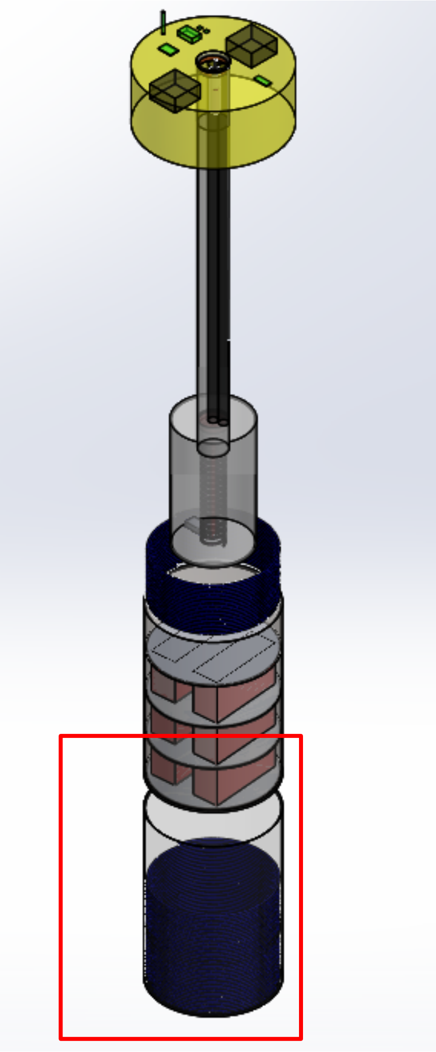


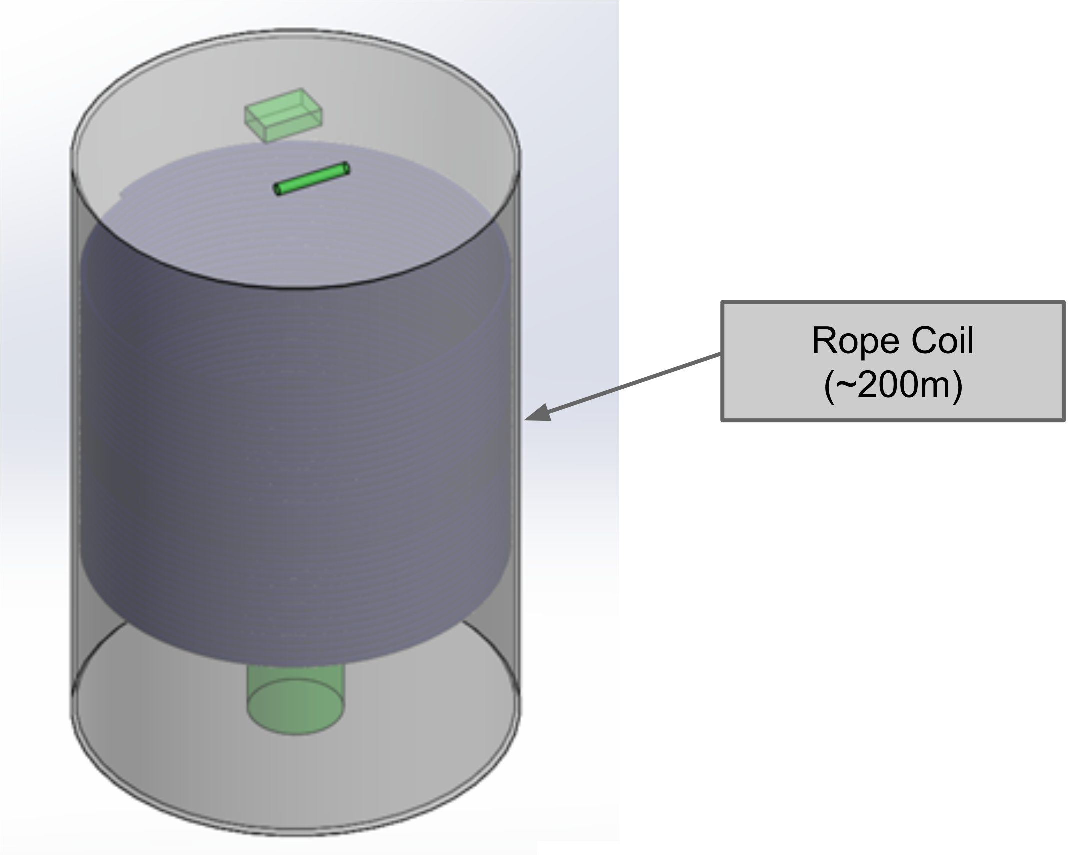




Javier Alvarez

Pod Chain - Anchor Pod

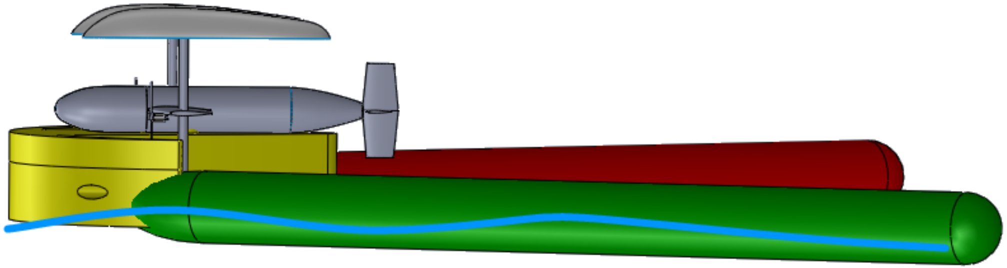




P9

Docking

Seaplane Dock Requirements

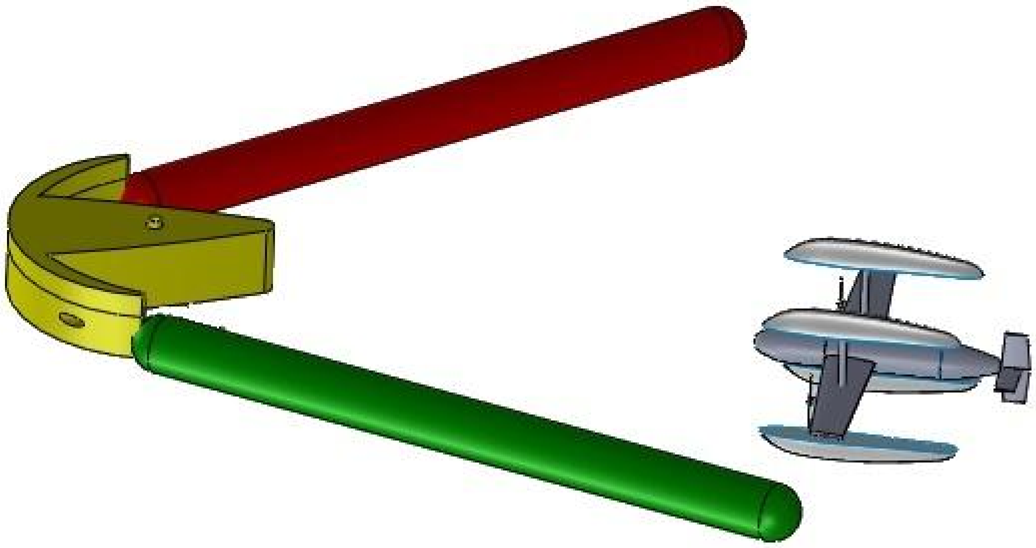


Provide power to seaplane on the surface of the ocean

Create a platform for physical and electrical connection

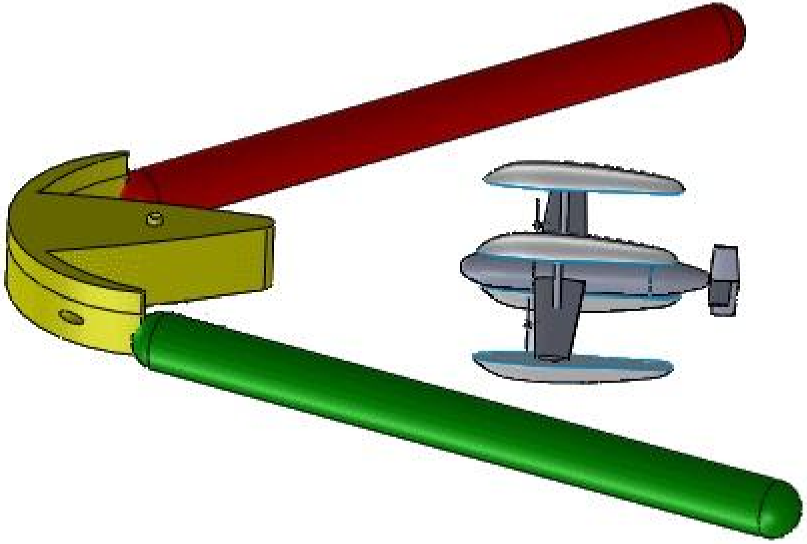
Jasmine Chan

Docking Process - Taxi



1. GPS signal received
2. Plane taxi using GPS > LED beacon
3. Pontoon guidance to charging station
4. Magnetic alignment via cone (detected by hall effect sensor)
5. Linear actuator connects wet mate
6. Plane Charges
7. Linear actuator demates and plane backs up

Docking Process - Alignment



1. GPS signal received
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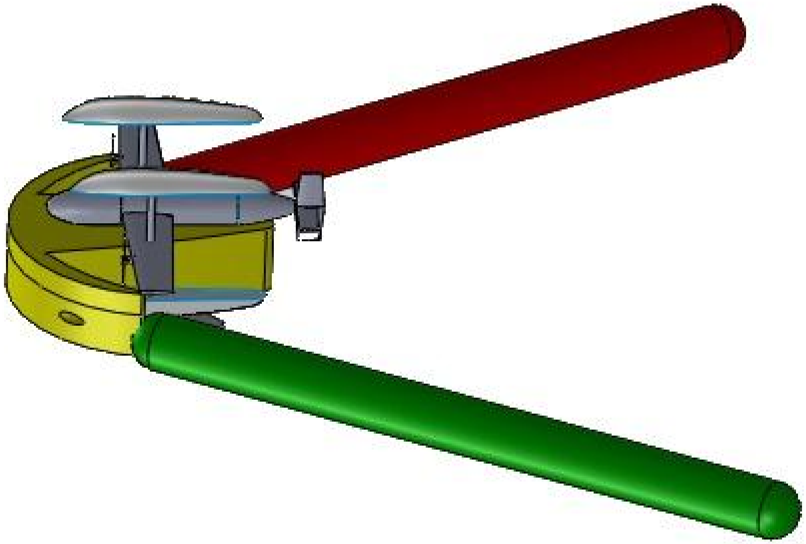
3. Pontoon guidance to charging station
4. Magnetic alignment via cone (detected by hall effect sensor)
5. Linear actuator connects wet mate
6. Plane Charges
7. Linear actuator demates and plane backs up

Jasmine Chan

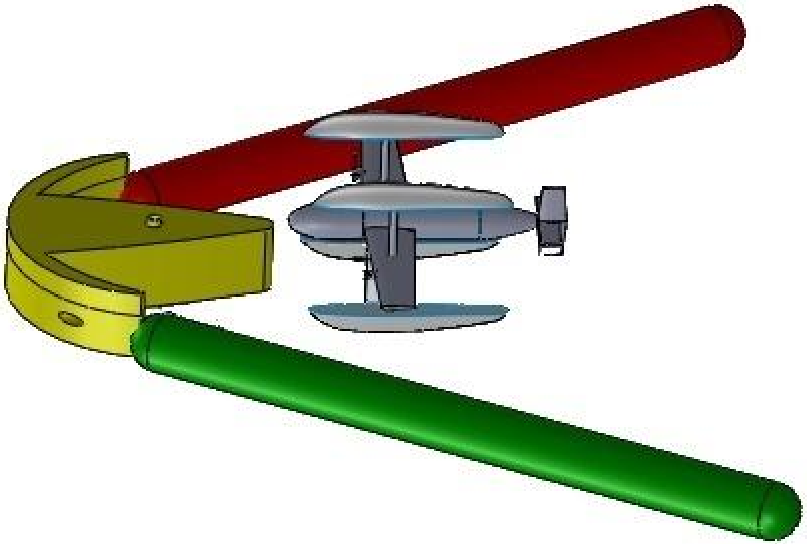
Docking Process - Connection



1. GPS signal received
2. Plane taxi using GPS > LED beacon
3. Pontoon guidance to charging station
4. Magnetic alignment via cone (detected by hall effect sensor)
5. Linear actuator connects wet mate
6. Plane Charges
7. Linear actuator demates and plane backs up

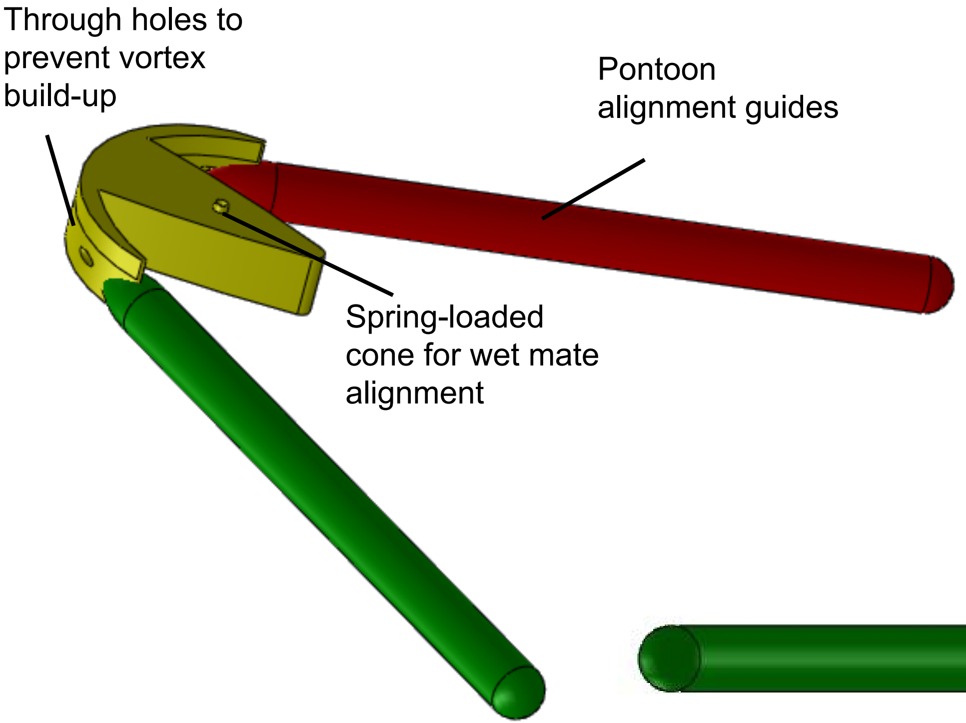
Jasmine Chan

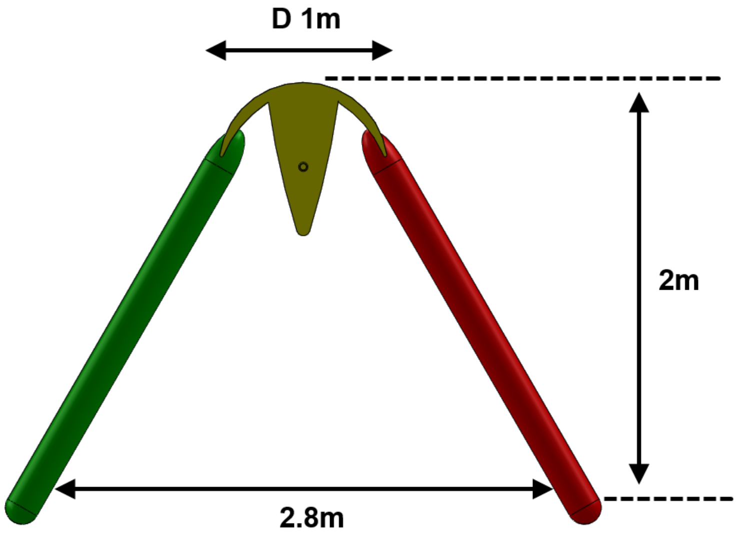
Docking Process - Demate

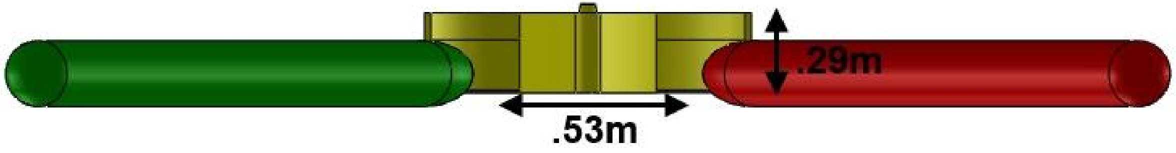


1. GPS signal received
2. Plane taxi using GPS > LED beacon
3. Pontoon guidance to charging station
4. Magnetic alignment via cone (detected by hall effect sensor)
5. Linear actuator connects wet mate
6. Plane Charges
7. Linear actuator demates and plane backs up

Seaplane Dock Geometry







Dock Mass: 30 kg

Hydrodynamically stable (COG < COB) and positively buoyant

Jasmine Chan

SEACON Wet Mate Connectors

Features:

Underwater mateable

Rotationally symmetric

Direct electrical connection

Risks:

Mating force - 13-26N

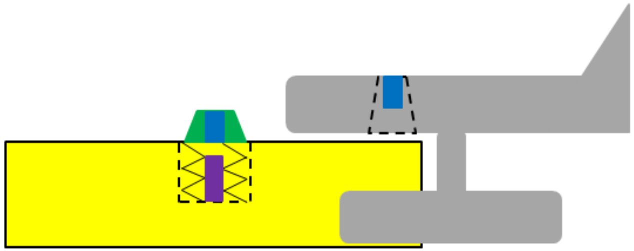
Weight - 0.5kg per connector

CM2001 - 10 Amps

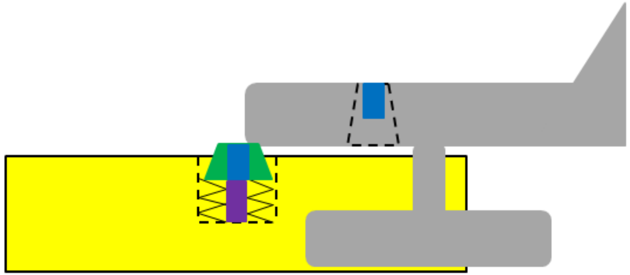
Jasmine Chan

Seaplane Wet Mate Connector Alignment

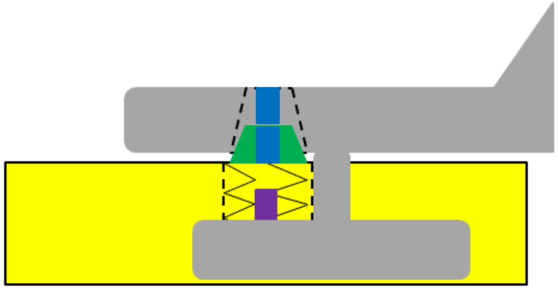
1. Pontoons guided onto docking station



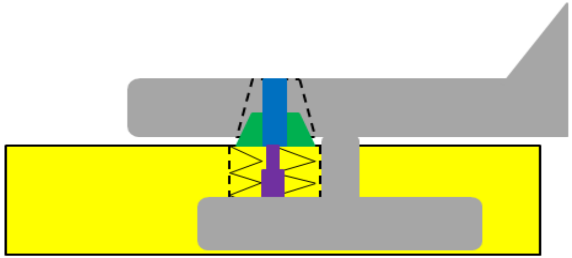
2. Vehicle nose engages spring loaded cone



3. Cone fits into plane cavity



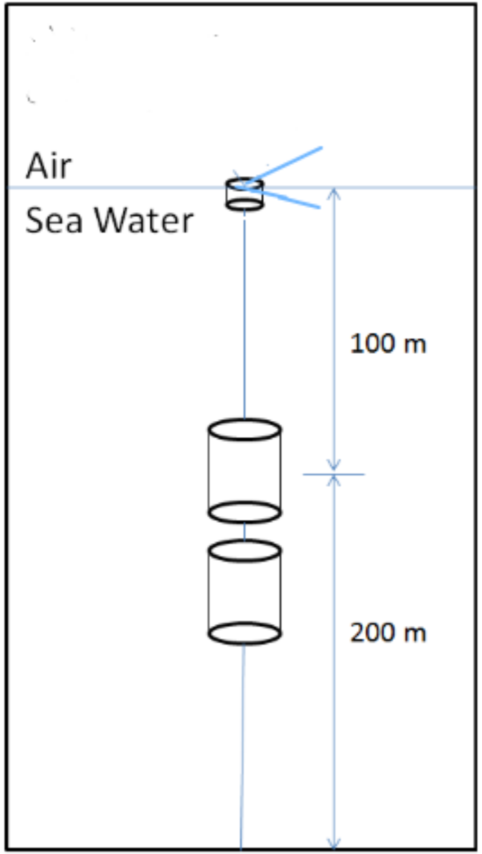
4. Linear actuator makes connection



Jasmine Chan

Seaplane Dock Storage and Deployment

- Stored in top module of pod system
- Positively buoyant docking module floats to surface
- Dock is released and arms are inflated



Jasmine Chan

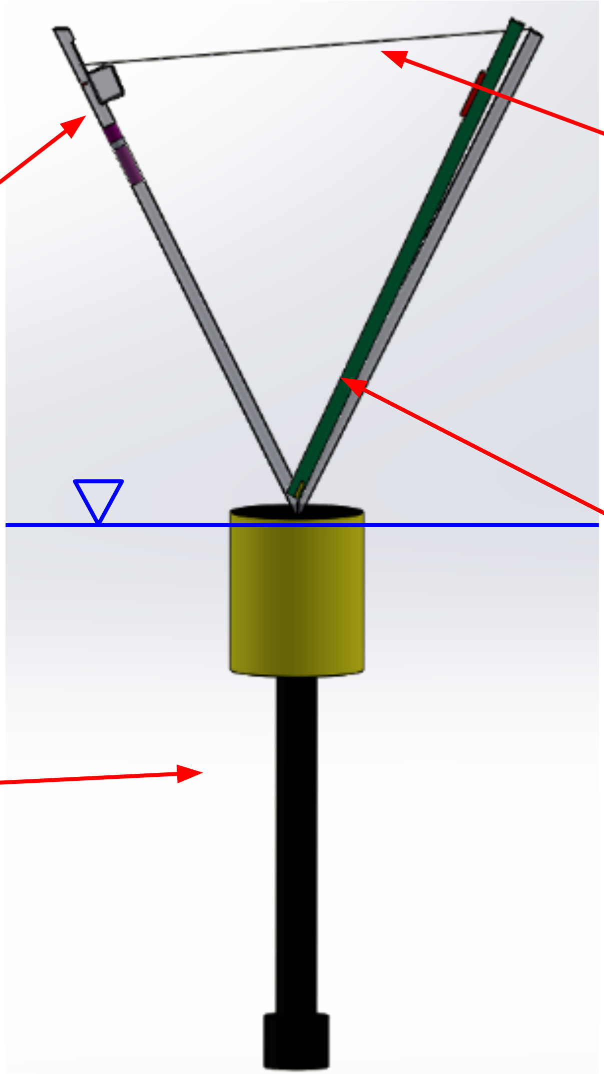
Seaplane Dock Risks and Mitigation

Risk	Mitigation
Wet mate connector weight	In contact with connector company to look for custom products
Chop creates uncertain environment for dock and plane	V- based mechanical guidance system allows for a wider range of control error
Wave forces when plane is docked due to uncoupled motion between plane and dock	Minimize mass of dock to closely couple motion

Jasmine Chan

Blimp Dock

Wet mate receptacle for charging



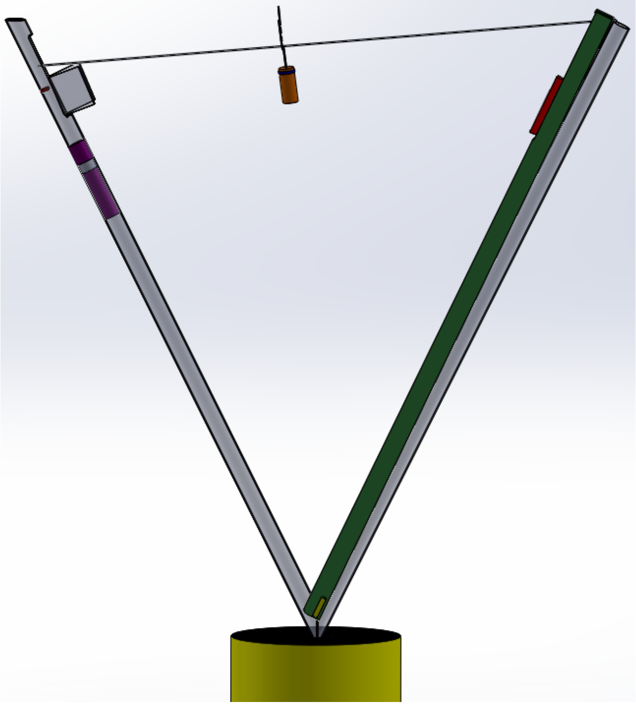
Finish line for initial connection

Moving arm to direct blimp tether

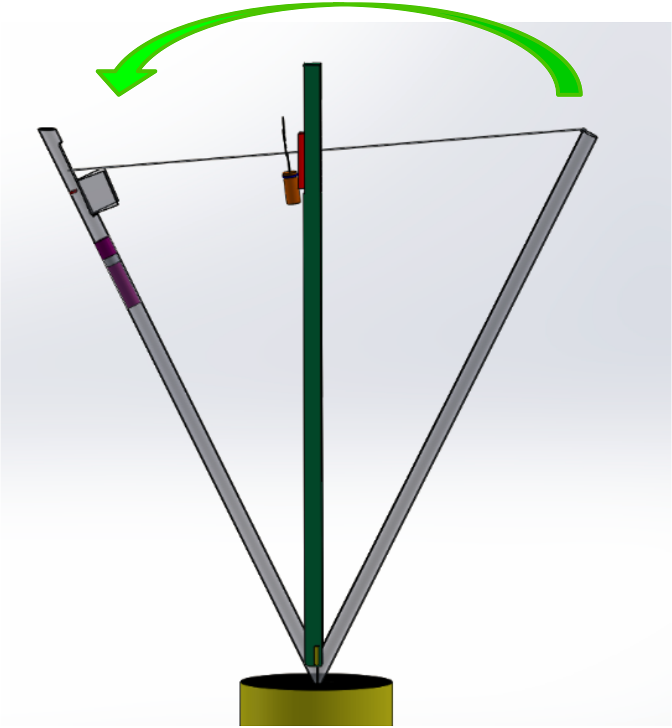
Spar buoy for stability

Jasmine Chan

Docking Process - Initial Connection



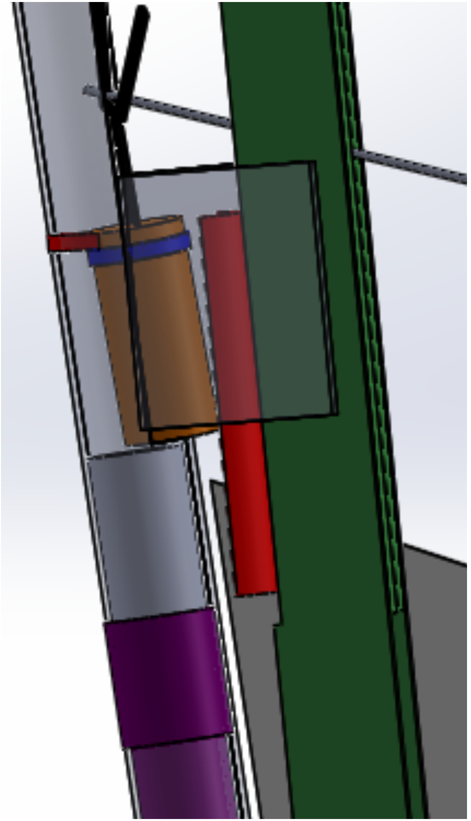
Blimp hooks on; provides enough tension to remain connected



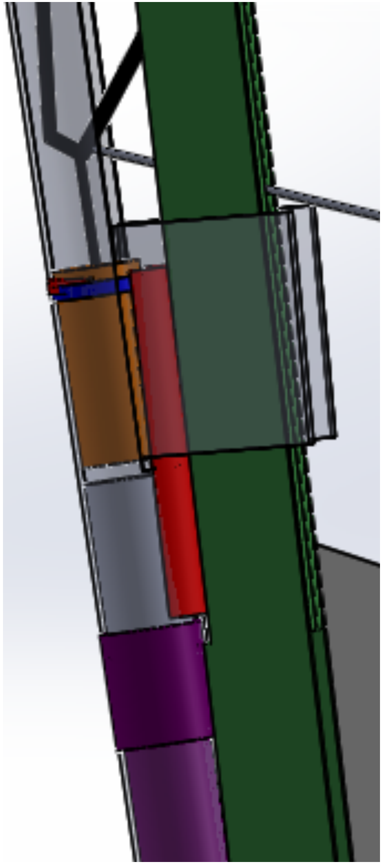
Push arm rotates across; tether is pushed to end

Jasmine Chan

Docking Process - Wet Mate Alignment



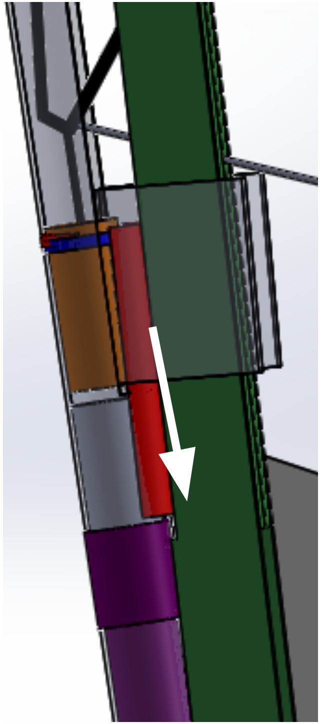
Tether funneled into end, magnetically locks in place



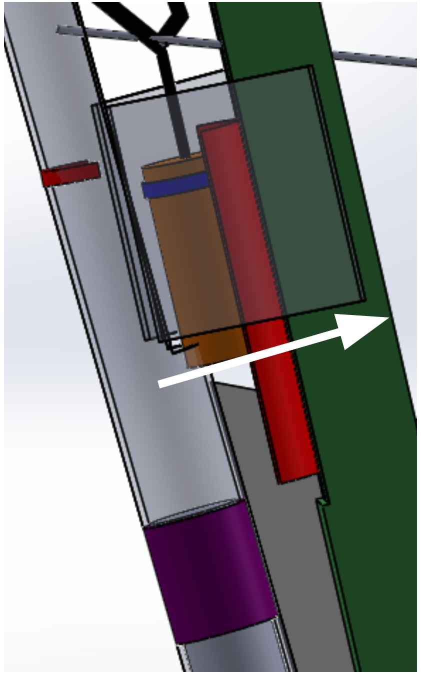
Linear actuator pushes male wet-mate into female

Jasmine Chan

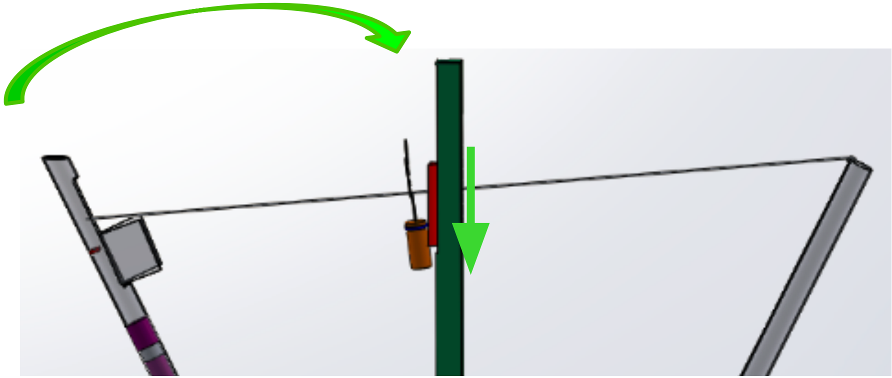
Docking Process - De-Mating



Linear actuator retracts male wet-mate



Arm guides tether out



Without tension, tether falls; blimp flies free

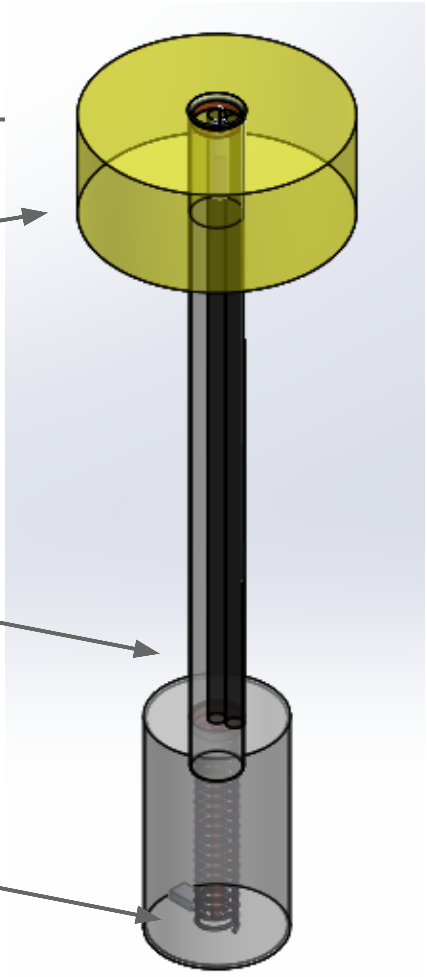
Jasmine Chan

Storage and Deployment

Buoy to allow dock system to rise

Housing for arms to prevent biofouling when submerged

Spring and piston for deployment at the surface



Jasmine Chan

Docking Comparisons

	Seaplane Dock	**Blimp Dock**
Stability in Random Environment	Dock follows the waves	Dock stable in roll and pitch (spar buoy design)
Deployment	Passive mechanism (buoyancy)	Active mechanism (piston)
Mating Orientation	Mechanical guidance system	Wet mate oriented initially via gravity

Jasmine Chan

Anchoring/Depth

Anchoring System

Anchor type: Mushroom Anchor (75kg)

- Scope ratio 2:1
- Horizontal holding force ~ 2x anchor weight
- Drift radius = anchor depth
- Amsteel blue rope (3mm)
  - Tension safety factor of 2

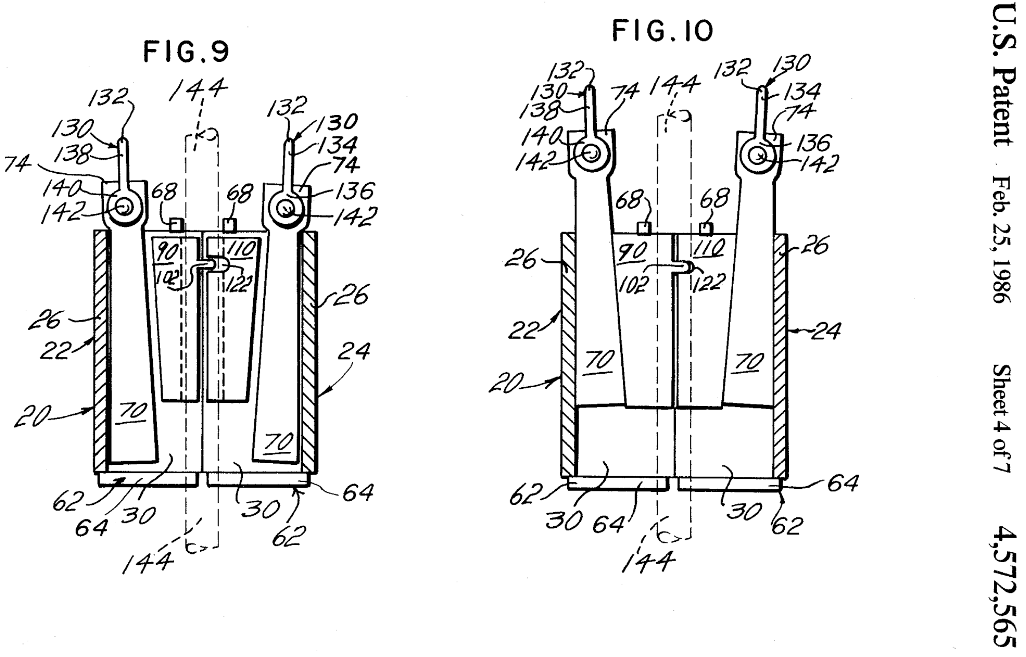
Actuated rope-clamping mechanism to control release of anchor

Manjinder Singh

Rope Stopper

Key characteristics:

- Clamp-style stopper to avoid line tangling
- Rough urethane coating for increased friction



Mitigating Biofouling

- Without mitigation, 100% of exposed surface may be fouled in 2 weeks at the surface
  - Increases dock drag
  - Harmful to underwater actuators

- Copper-based antifouling paint around casing for battery pod and viable areas on dock

- Effective for a minimum of 1 year

Manjinder Singh

Power

Power-Overview

- ➔ Power Requirement
- ➔ Battery Selection
- ➔ UAV Charging Method
- ➔ Power Management

Power requirements

State	Energy Requirement (Whr)	Assumptions
Idle	2800	• Dormant for 1 year • Module to receive activation signal
Charging Capabilities		
Active (Plane)	6200	• Results in 37 full charges assuming range mission
Active (Blimp)	6200	• Results in 4 full charges assuming range mission.

NB: Includes inefficiencies

See appendix for calculation details

Rohun Kulkarni

Bluefin LiPo Battery

Features	● Built-in safety control ● Wet mate compatible ● Fully submersible
Specific energy	105Whr/kg (1500Whr/battery)
Mass	14kg
Operating Temperature	-20-48 ℃
Monthly discharge	<2%
Dimension	15.1x5.2x8.2in

Set constraint:
Fit in 55 Gallon drum→
6 Batteries

Rohun Kulkarni

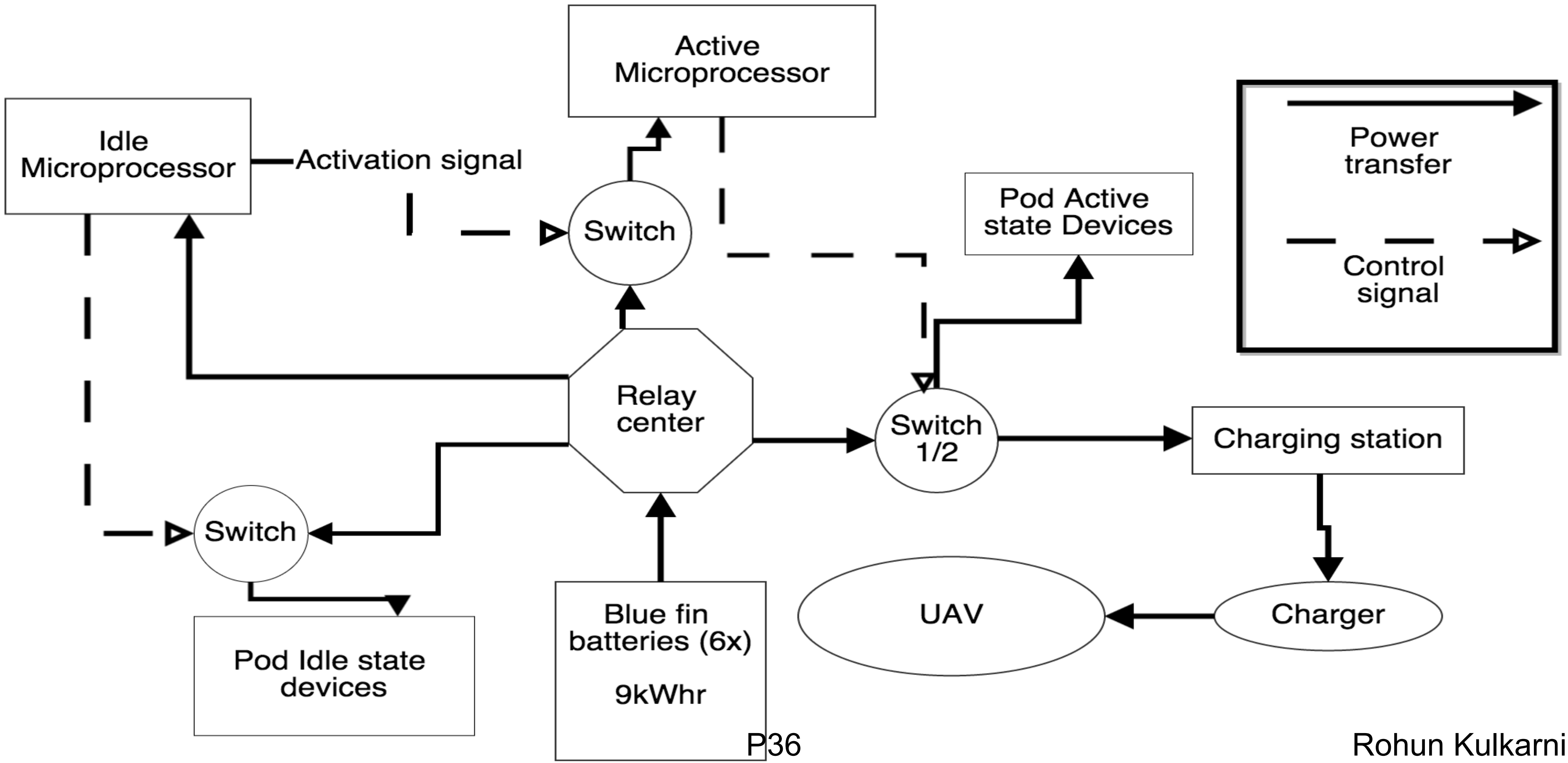
Wet mate charging times

10A, at given UAV Voltage

UAV	Charge Voltage (V)	Charge Time
Seaplane	11.1	40 min
Blimp	7.4	10 hours

*Wet mate nominal operating current

Power Management

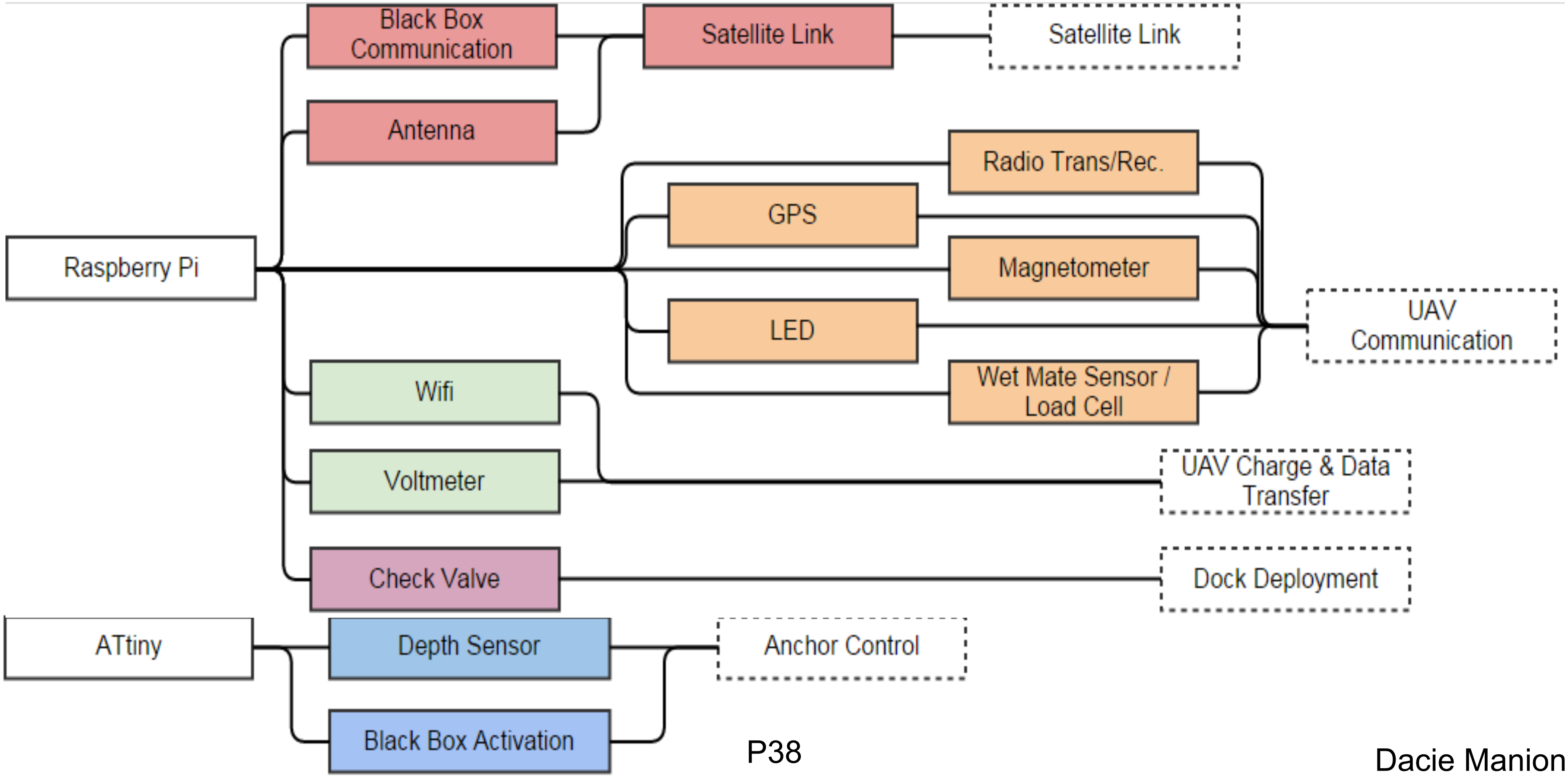


Rohun Kulkarni

Controls/ Communications

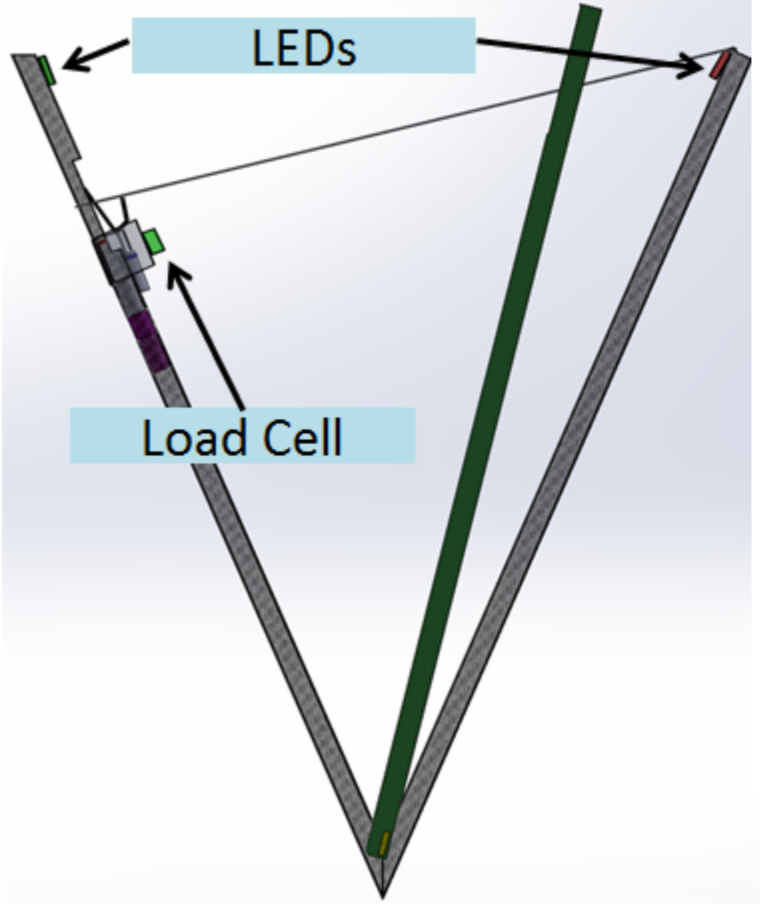
Dacie Manion

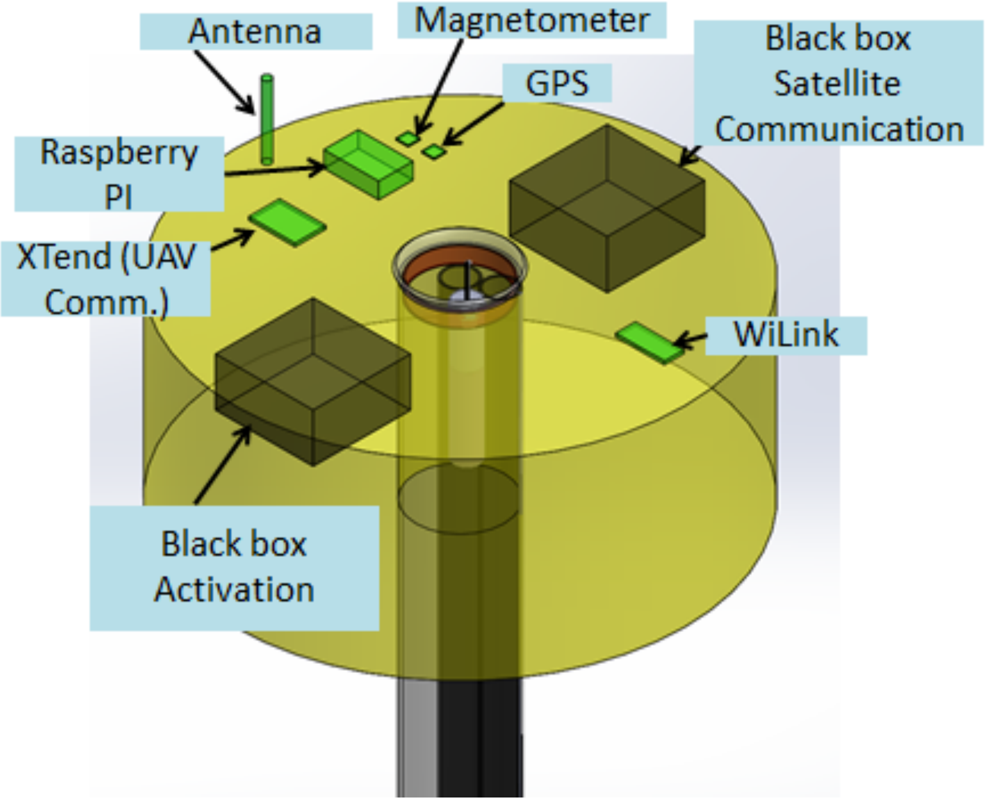
Overview



Dacie Manion

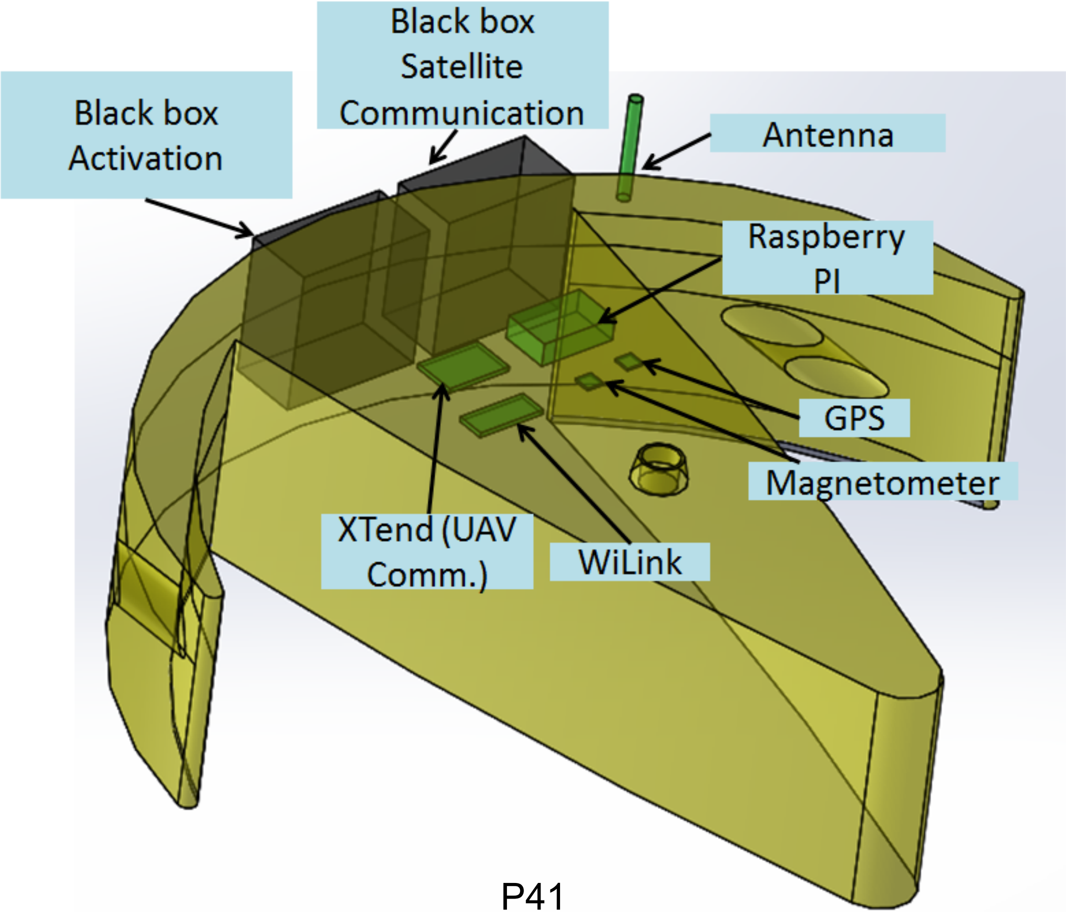
Blimp Docking Sensor Overview





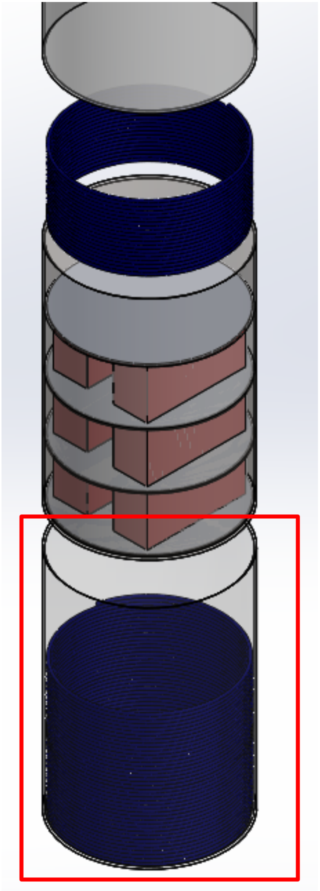
Dacie Manion

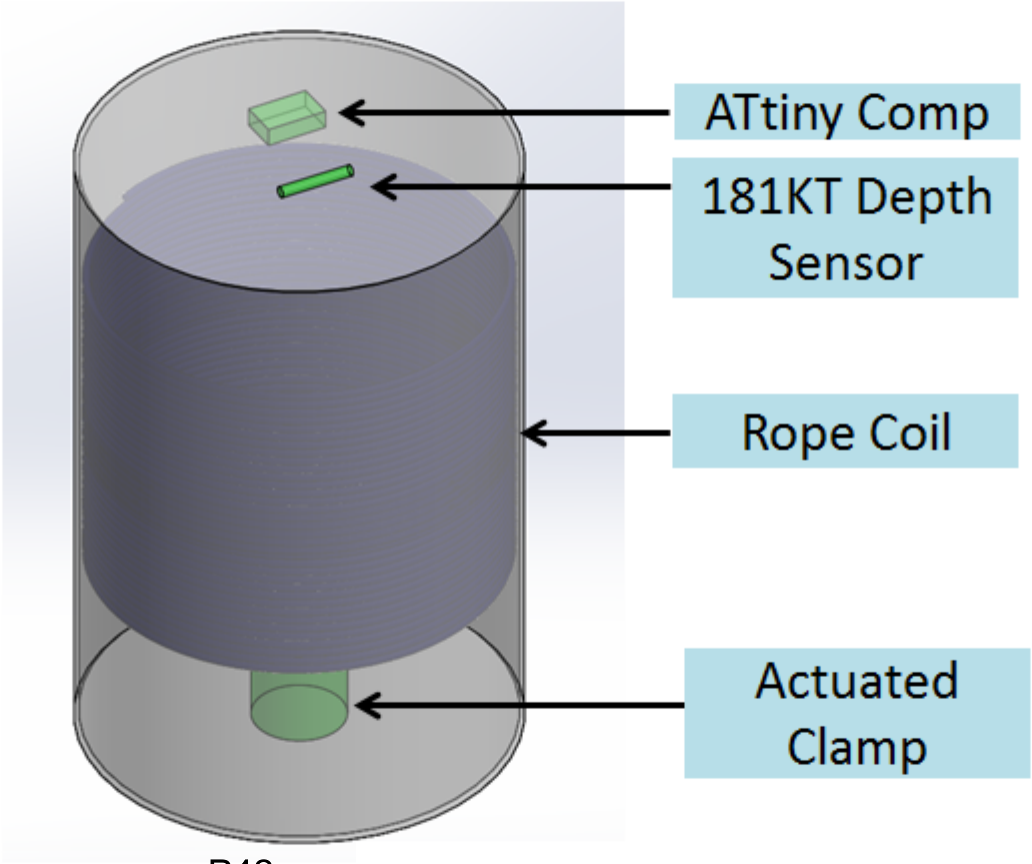
Seaplane Docking Sensor Overview



Dacie Manion

Anchor System Overview





Dacie Manion

Pod Design Summary

Dacie Manion

Pod Design Features

- Is **fully autonomous** after deployment
- Idles dormant for **one year**; upon activation, docking components surface
- **Modular system** allows for customization
- Provides power for **37 seaplane missions or 4 blimp missions**
  - Charges UAV with **LiPo battery** source via **wet-mate** to maximize efficiency
- Contains **separate** docking mechanisms for blimp and seaplane

Dacie Manion

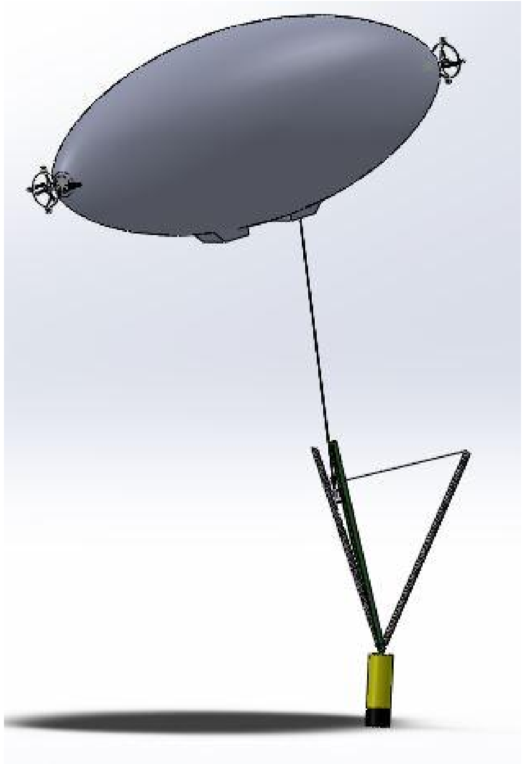
General Conclusions

System Benefits Summary

- Autonomous system for maritime surveillance
- Pod operational up to 305 m depth
- Able to withstand sea state 3 conditions
- Pod designed as modular system of 55 gallon drums
- Pod idle state up to 1 year
- Pod active state supports:
  - Up to 37 missions/recharges of the seaplane
  - Up to 4 missions/recharges of the blimp
- Both UAVs capable of both mission profiles, optimized for range mission

Blimp Features

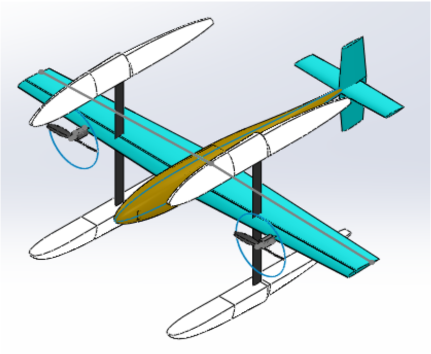
Design Feature	Extension to Mission
Adjustable endurance	Can continue mission for extended time and distance
Ability to remain stationary in air	Simple mission operations and higher energy efficiency
Does not come in contact with the water	Eliminates many complications from docking

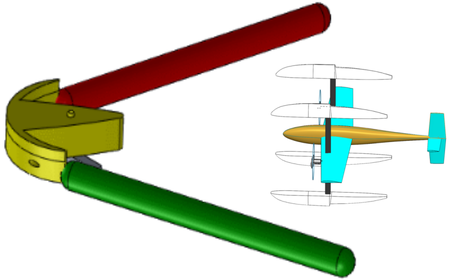


Nathan Miller

Seaplane Features

Design Feature	Extension to Mission
High maximum velocity	Can reach area of operation in shorter period
Low power demand	Fast recharge time for quick turnaround between missions
Design experience, simple design	Cheap and easy to build, lower economic risk





Nathan Miller

System Operational Risks and Mitigation

Risk	Mitigation
Blimp leakage	Prototyping to increase confidence in estimates
Raspberry Pi computing power	Evaluate other computers
Availability of commercial control software	Research current commercial capability and consider possible outsource if necessary
Biofouling on pod	Use copper coating when feasible

System Operational Risks and Mitigation

Risk	Mitigation
Wet mate connector mass	Continue research for unique lightweight wet mate connector
Forces on seaplane dock	Minimize mass to improve motion coupling
Detaching from blimp dock tether	Design hook such that CG allows easier detachment

Nathan Miller

Appendix

Docking Appendix

V-Guidance Motivation - Motion at Sea State 3

Sea kayaker moving at Sea State 3 with stationary mounted camera

D1

Blimp Docking Materials

Carbon fiber arms

- No corrosion; strong

Amsteel rope (3mm)

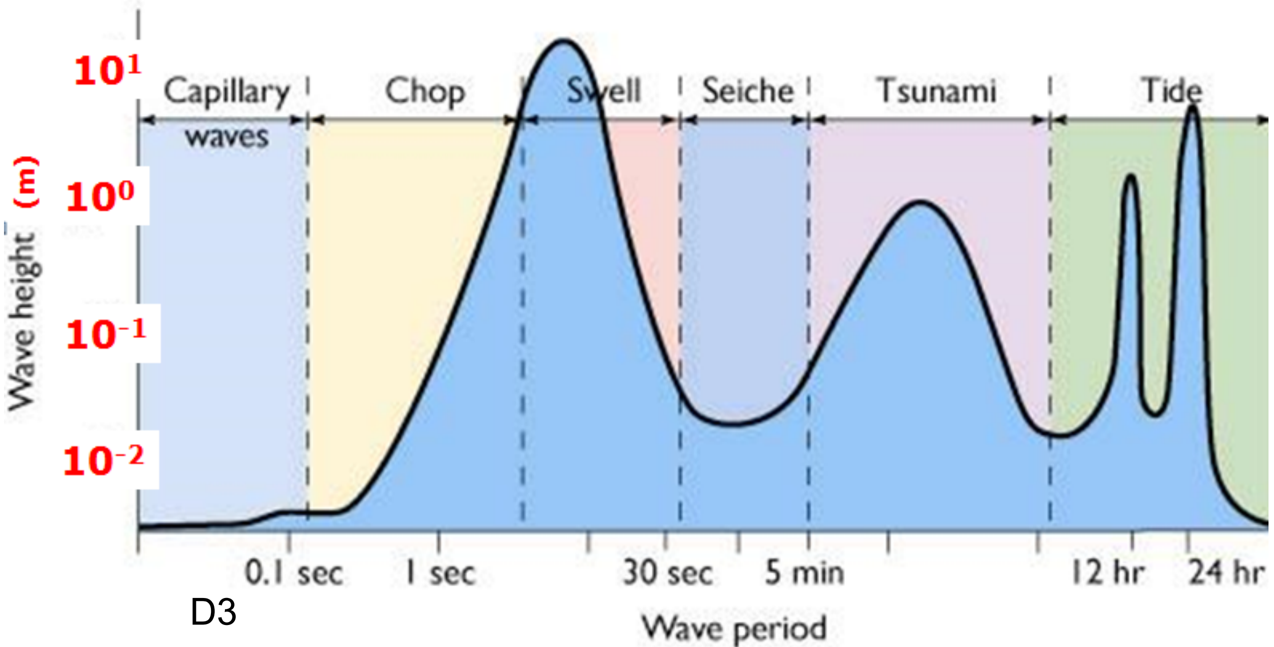
- No stretch; strong

Megatorque Motor from NSK

- Require at least 20 N*m of torque to rotate the arm

V-Guidance Motivation - Wave Dynamics

- Chop is random and dominates when docking
- Chop operates at much higher frequencies and from centimeters to swell amplitude

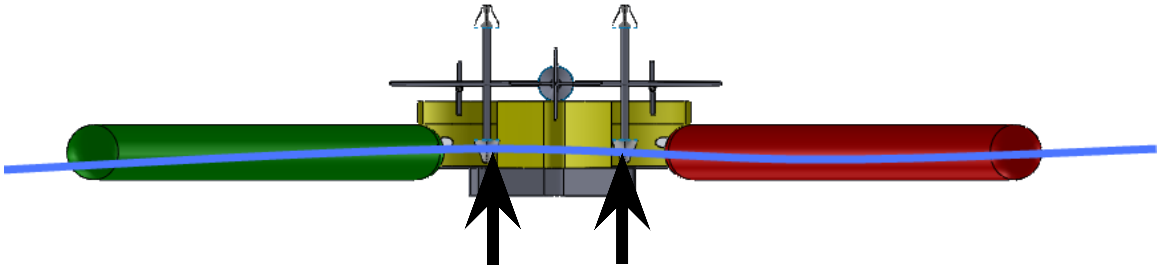


D3

Wave Forces During Docking

Estimated Vertical Heave Force (upper bound): F_{wave} = 300 N

Model: Plane is a fixed structure in water



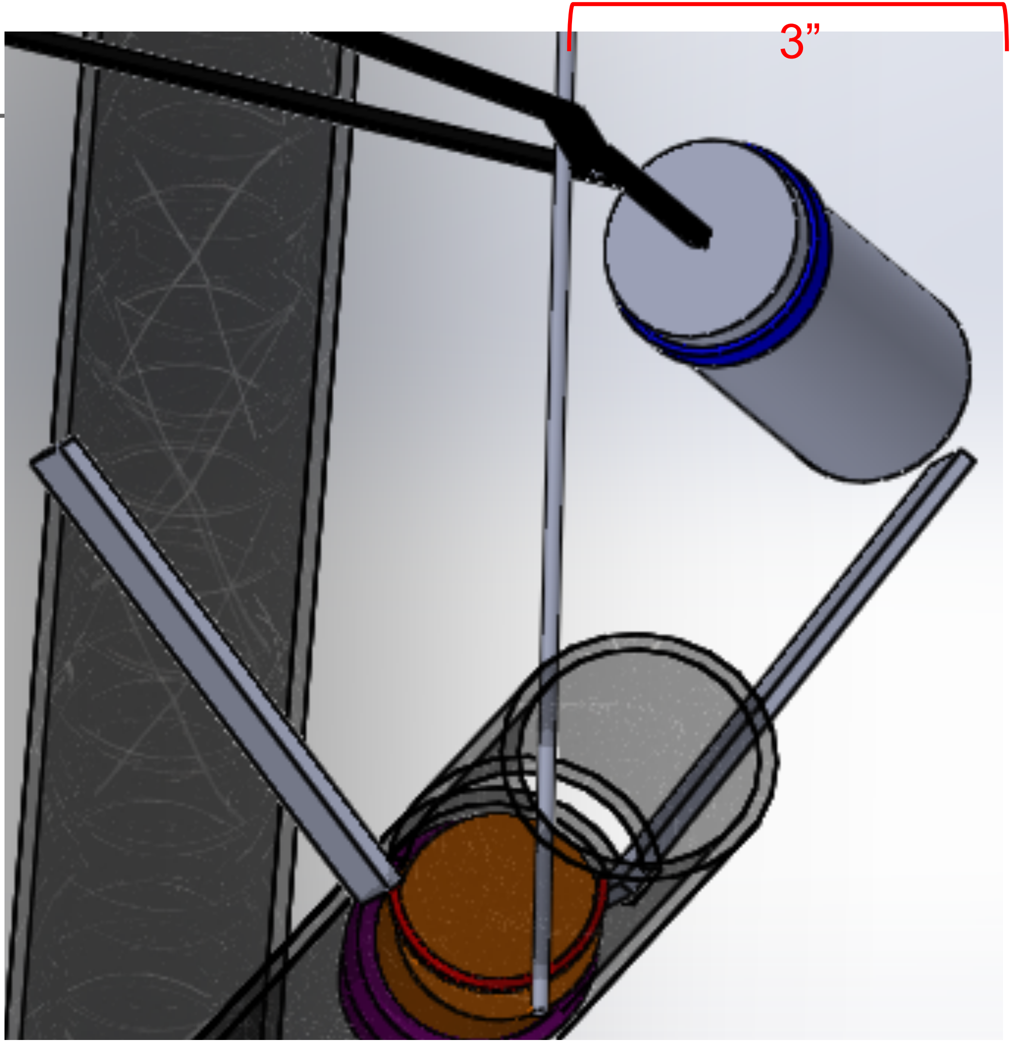
F_{wave} = 300 N

Risk Mitigation Options

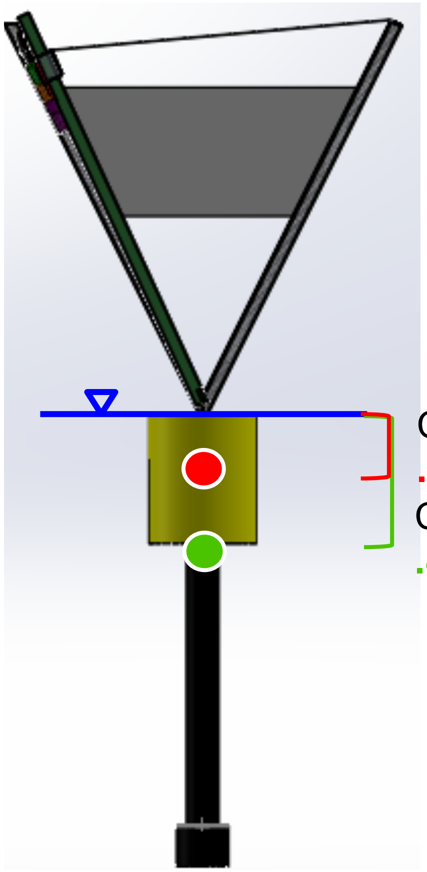
- Lift plane such that pontoons rest above water surface
- Compliant connection between plane and dock during charging

Blimp Docking

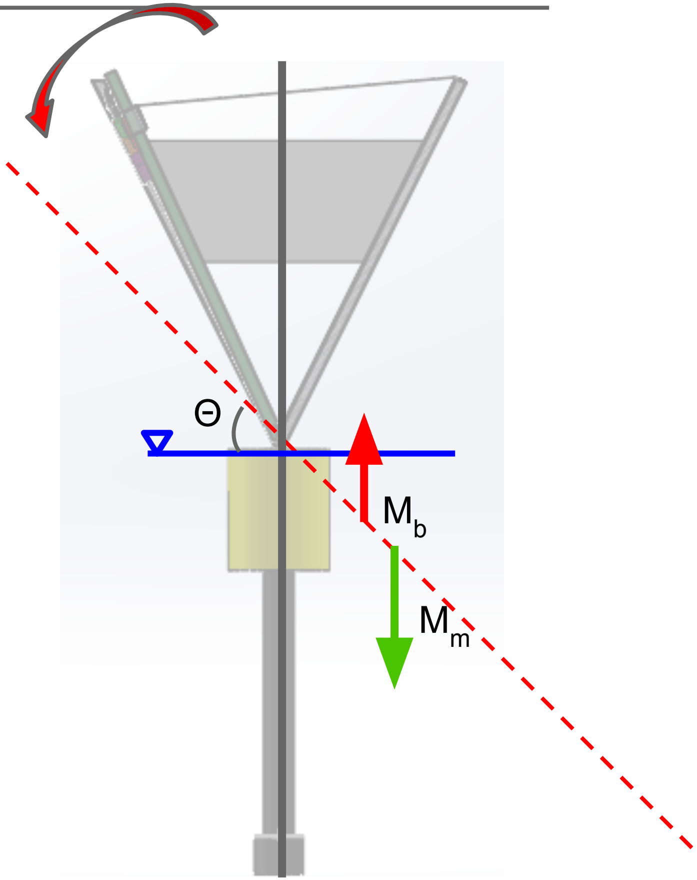
- assuming max 60deg angle either direction: max horizontal displacement 3”



Blimp Dock Stability



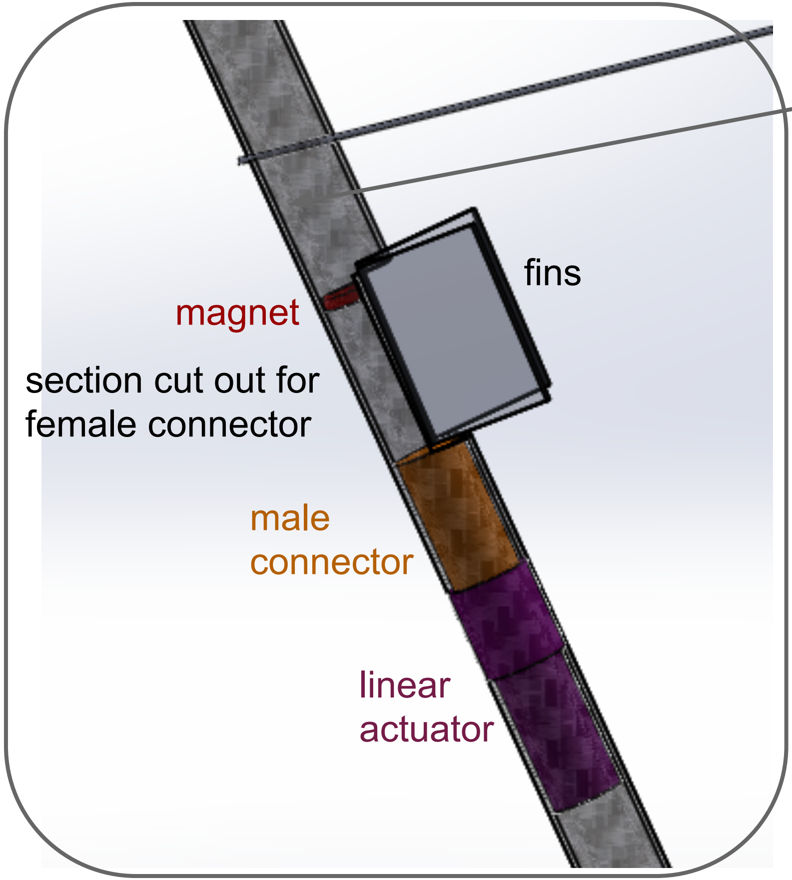
Center of buoyancy:
.35m below waterlevel
Center of mass:
.80m below waterlevel

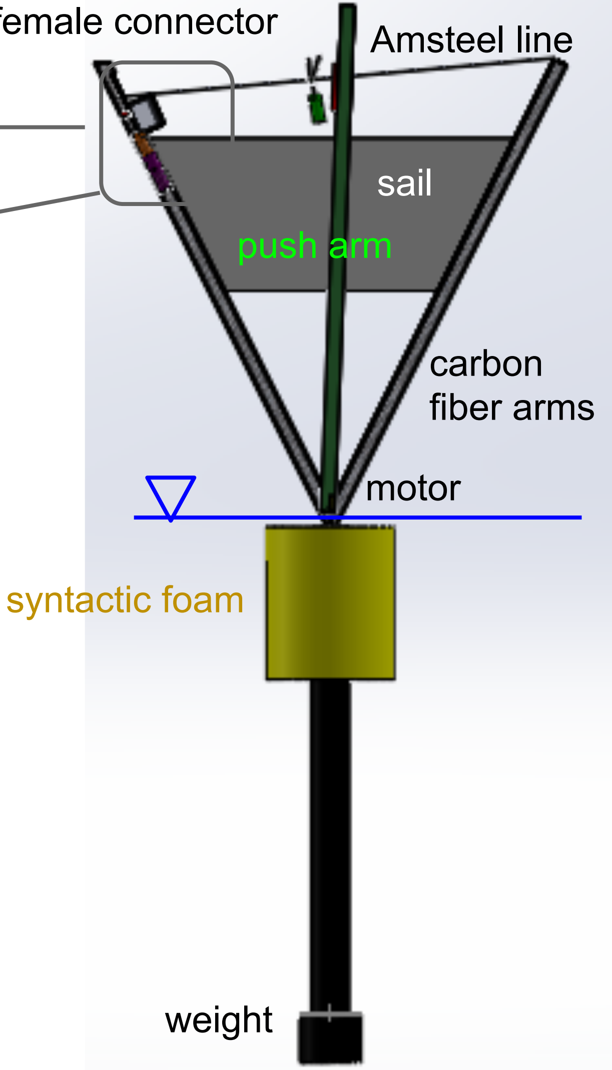


D6

System withstands a very high angle Θ

Blimp Docking

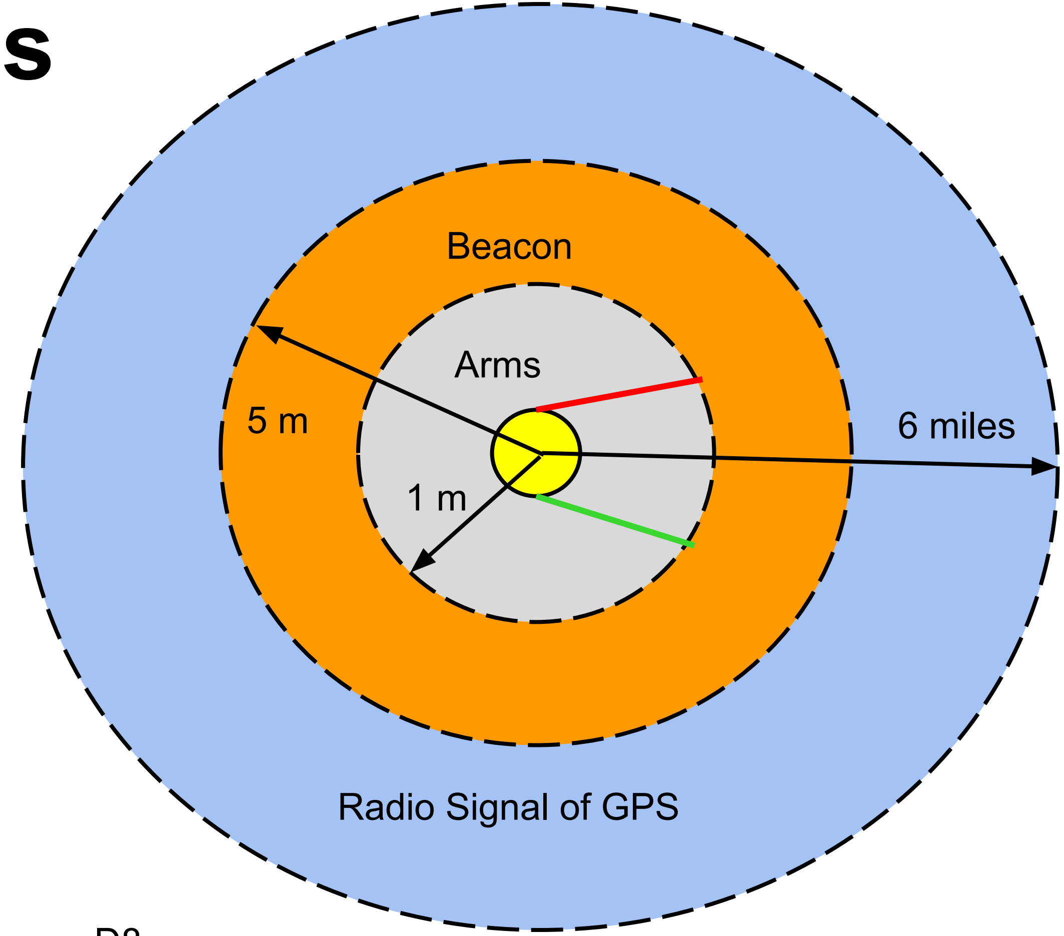




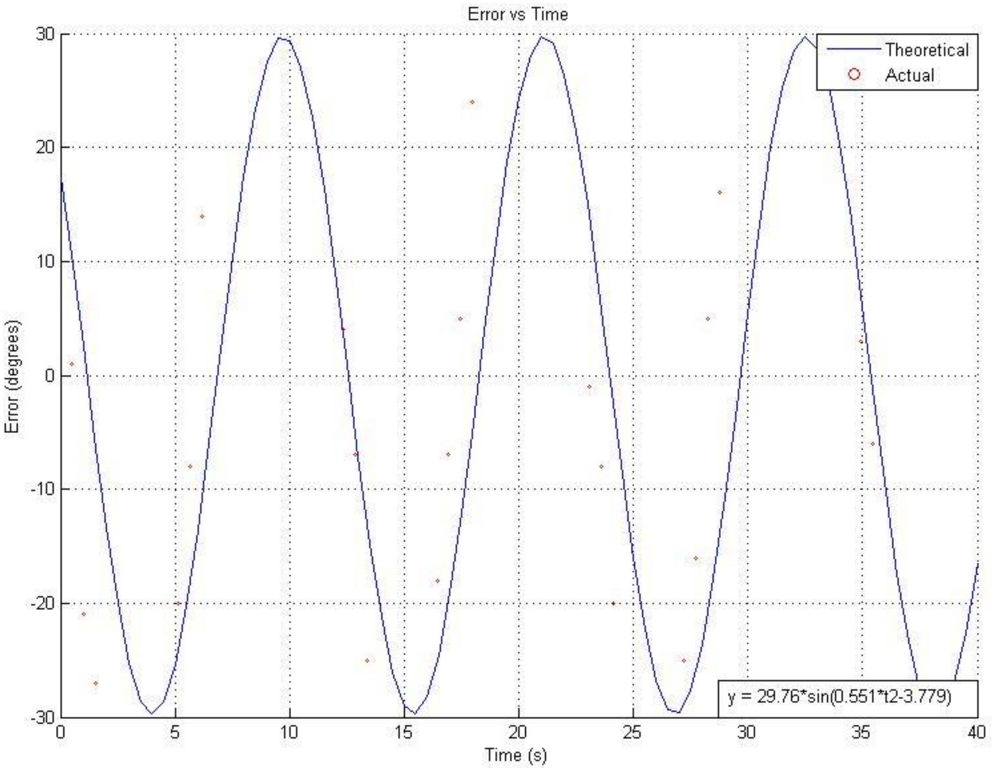
Navigation Rings

Locationing using:

- GPS
- LED Beacons
- Arms

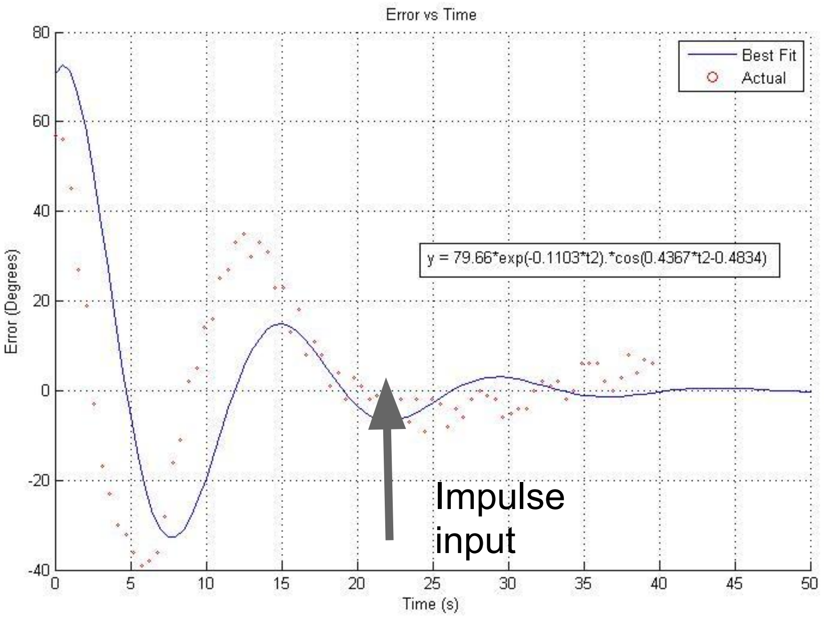


Software Error



Heading error tracking a stationary object in flat water using openCV algorithms and Raspberry Pi processor

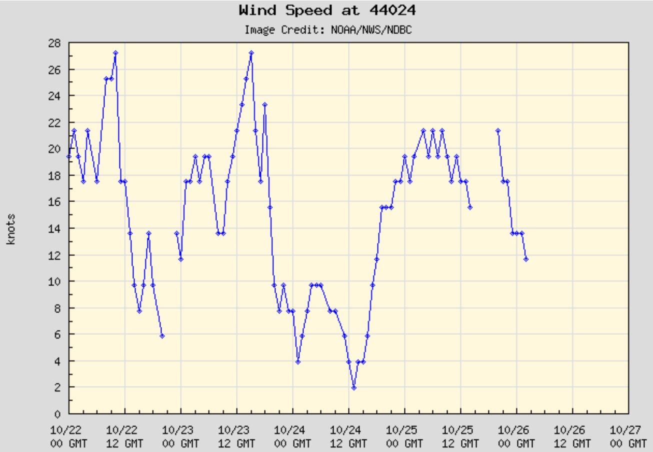
PID Control

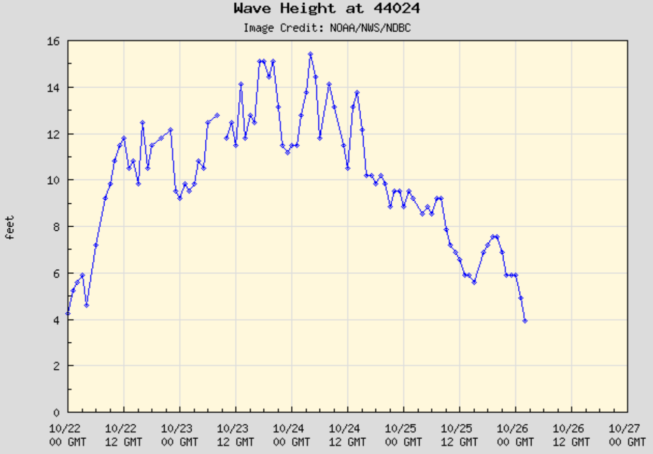


Error vs Time
Best Fit
Actual
y = 79.66*exp(-0.1103*t2).*cos(0.4367*t2-0.4834)
Error (Degrees)
Time (s)
80
60
40
20
0
-20
-40
0
5
10
15
20
25
30
35
40
45
50
Impulse input

Navigating in Uncertain Environment

- Difficult to navigate to navigate on the water with:
  - Changing wind speed, direction, and gusts
  - Changing wave amplitude and direction
- Surface craft navigation error in calm water
  - 0.45m with GPS (Small boat)
  - 0.7m with sonar (Kayak)

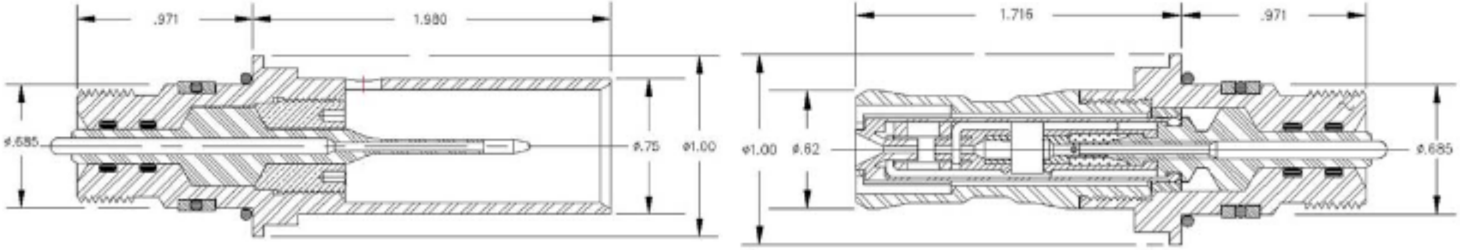




Wet Mate Connector Specs

Seacon CM2001

- Single Pin connector
- Wet MAte Force: 3-6lbs
- Max Diameter: 1”
- Stroke Length ~ 1.7”



D12

Heave Forces on the Plane

Heave Force a function of added mass and wetted area

$$F_z \cong (m+a)\ddot{\xi} + \rho g A_w \xi$$

For worst case scenario of sea state 3 plane can expects to see 350N (35kg)

While the plane is fixed on the dock, can neglect added mass

Seaplane Dynamics on the Water

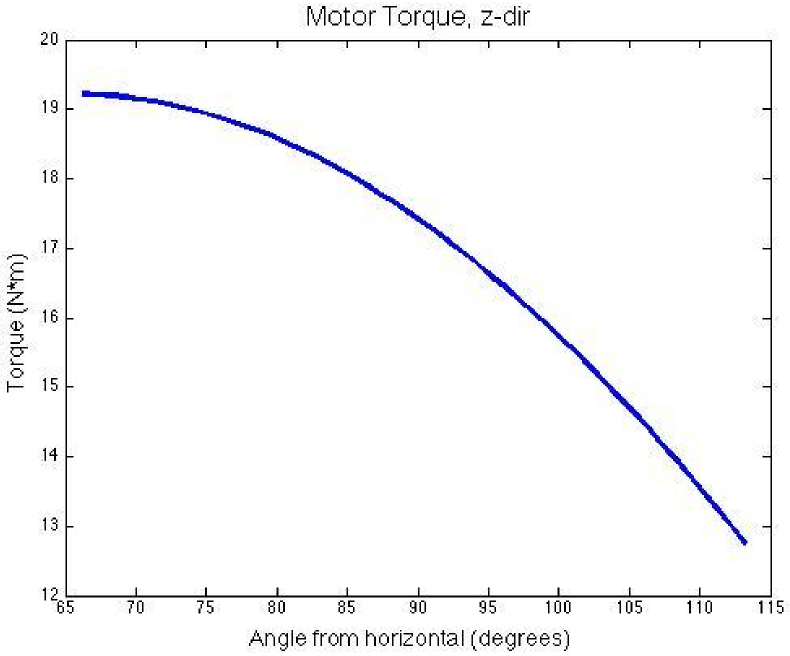
-Dominated by drift forces

$$m\ddot{\vec{x}} = -\tau_{h20} \cdot \dot{\vec{x}} + b \cdot \vec{u}_{h2o} + \tau_{wind} \cdot \vec{u}_{wind}$$

-Lacks control in the lateral direction

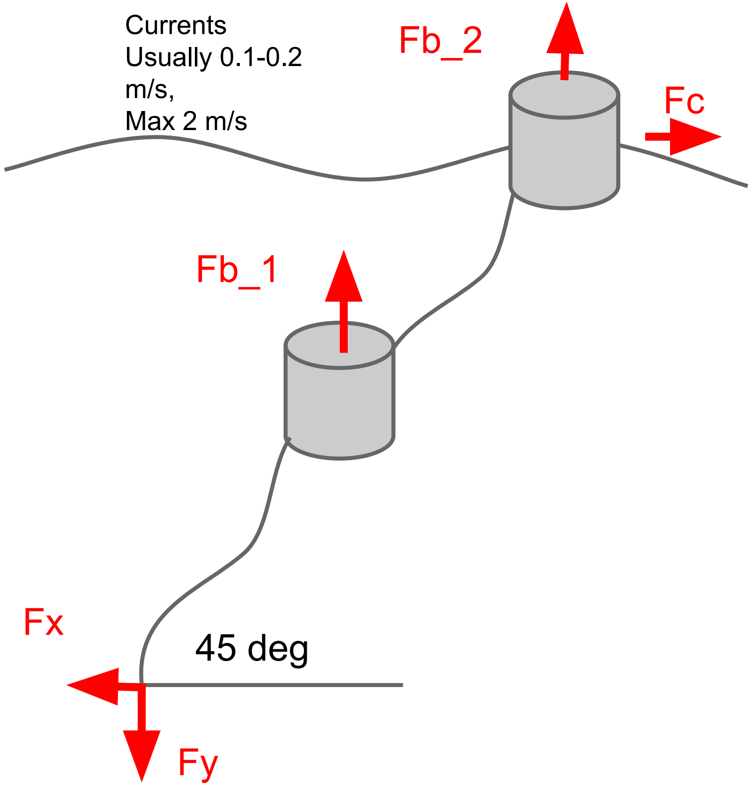
-Weathervanes with the wind

Blimp Dock Arm Torque



Includes gravitational force and drag force from submerged portion of arm.

Appendix: Anchor Force Breakdown



Fc	$0.5pv^2Ac_d$	300N
Fb	pVg	Fb_1 = 360N, Fb_2 = 300N
Fy	mg	750N
Fx	2*mg	1475N
F_total	$sqrt(Fy^2+Fx^2)$	1650N

Pod Controls/Communications Appendix

Pod System Sensors

Items	Sensor	Justification
Pod activation	Black box	Classified technology
Computing system	Raspberry Pi	Compatibility
GPS	Copernicus II	Broadcast location
Depth sensor	181KT	Pod depth; range, accuracy

Communication Sensors

Items	Sensor	Justification
UAV communication	XTend 900 Module	Compatibility
Antenna	LSR IP67	Compatibility, Waterproof
UAV data transfer	WiLink 8	Compatibility
Satellite link	Black box (transceiver and antenna)	Support in system design

Docking Sensors

Items	Sensor	Justification
Docking LED	LPD8806 RGB Color Strip	UAV navigation; brightness, color customization
Magnetometer	MAG3110	Pod orientation
Load cell	LCM703-5	Blimp hook attachment
Check valve		Pressure in inflatable section of plane dock

Appendix: Computing System

Rasberry Pi

- Code Compatibility with UAVs
- Data Processing and Transfer
- USB and I/O Compatible
- 3.25 Watt

Appendix: Depth Sensor

Depth Sensor (Model 181KT)

- Operate at up to 700m depth
- +/- 0.02% accuracy
- Anti fouling pressure port
- Average power draw 0.018W

Appendix: Depth Sensor

- Depth: 0 to 700m
- Dimensions: 1.52cm diameter, 10.16cm long
- Power Requirement: 9V, 0.002A
- Temperature Range: -2°C to +45°C
- Weight: 0.11kg
- used for underwater towed array applications

Appendix: UAV Communication

Digi XTend 900Mhz Module

- 40 mile range with high gain antenna
- 115.2kbps
- 1W power draw

Appendix: Pod GPS

Trimble Copernicus II Module

- 132 mW typical draw
- Serial or DIP Interface
- 1Hz update rate

Appendix: LSR IP67 High Gain Antenna

- Waterproof linear-vertical dipole antenna
- Frequency: 902-928MHz
- Mass: 29g
- 204mm x 13mm (OD)
- Operating temperature: -40C to +85C
- +2dBi / 50 Ohms impedance

Appendix: UAV Data Transfer

Transfer wirelessly during charging

Wifi transceiver (2.4GHz):

- Wifi 802.11: 80Mbps - 100Mbps
- For 100MB file, max transfer time: ~5 min.
- Transfer range: ~100m

Appendix: MAG310 Magnetometer

- 1.95 V to 3.6 V supply voltage
- 2 mm x 2 mm x 0.85 mm, 0.4 mm pitch, 10-pin package
- Output Data Rates (ODR) up to 80 Hz
- Power Requirement: 0.00324 WHr
- Operation Temp: -40°C to +85°C

Appendix: LCM703-5 Load Cell

- Range: ±5N
- Operating Temp: -40°C to +82°C
- Dimensions: 38mm x 14mm x 19mm
- Voltage: max 15V

Appendix: MPX5999 Pressure Sensor

- Range: 0-1000kPa
- Accuracy: ±2.5% $V_{\text{Full Scale Span}}$
- Response Time: 1 ms
- Sensitivity: 4.5 mV/kPa
- Power Draw: 0.035 W; 0.003 WHr
- Operating Temp: -40°C to +125°C

Communications Reference Slide

1. Alnestig, Henrik. “On the Feasability of Low Cost Computer Vision.” <http://www.idt.mdh.se/utbildning/exjobb/files/TR1666.pdf>. 8/16/2014.
2. O’Connor, Rory. “Developing a multipcopter UAV platform to carry out research into autonomous behaviors, using onboard image processing techniques.” University of Western Australia. Perth, Australia, 2014.
3. Francois Pasteau, Vishnu Karakkat Narayanan, Marie Babel, Francois Chaumette. “A visual servoing approach for autonomous corridor following and doorway passing in a wheelchair.” Robotics and Autonomous Systems, Elsevier, 2014. <hal-01068163>
4. [PiCam and PiNoIR images] “PiNoIR what’s it for? Comparison of Raspberry PiCam and PiNoIR images”. <http://raspi.tv/2013/pinoir-whats-it-for-comparison-of-raspicam-and-pi-noir-output-in-daylight>

GNC Appendix

GNC Appendix A: Flight Computer

Raspberry Pi B+ Model

- 512 MB RAM, has been used as an autopilot platform and for visual servoing purposes [see reference slide in appendix]
- 40 pins, 4 USB ports, microUSB, microSD, camera port
- 4 mounting holes for stable mounting, lower power consumption than previous models

GNC Appendix B: Cameras

Raspberry Pi NoIR

- visible and infrared
- extend vehicle operability to night

Pi Noir Image

PiCam image

5MPixel sensor

2592 x 1944 pixel static images

1080p30, 720p60 and 640x480p60/90 video

Pi Noir image at night
(with IR illumination)

GNC Appendix C: Surveillance Data Trade Study

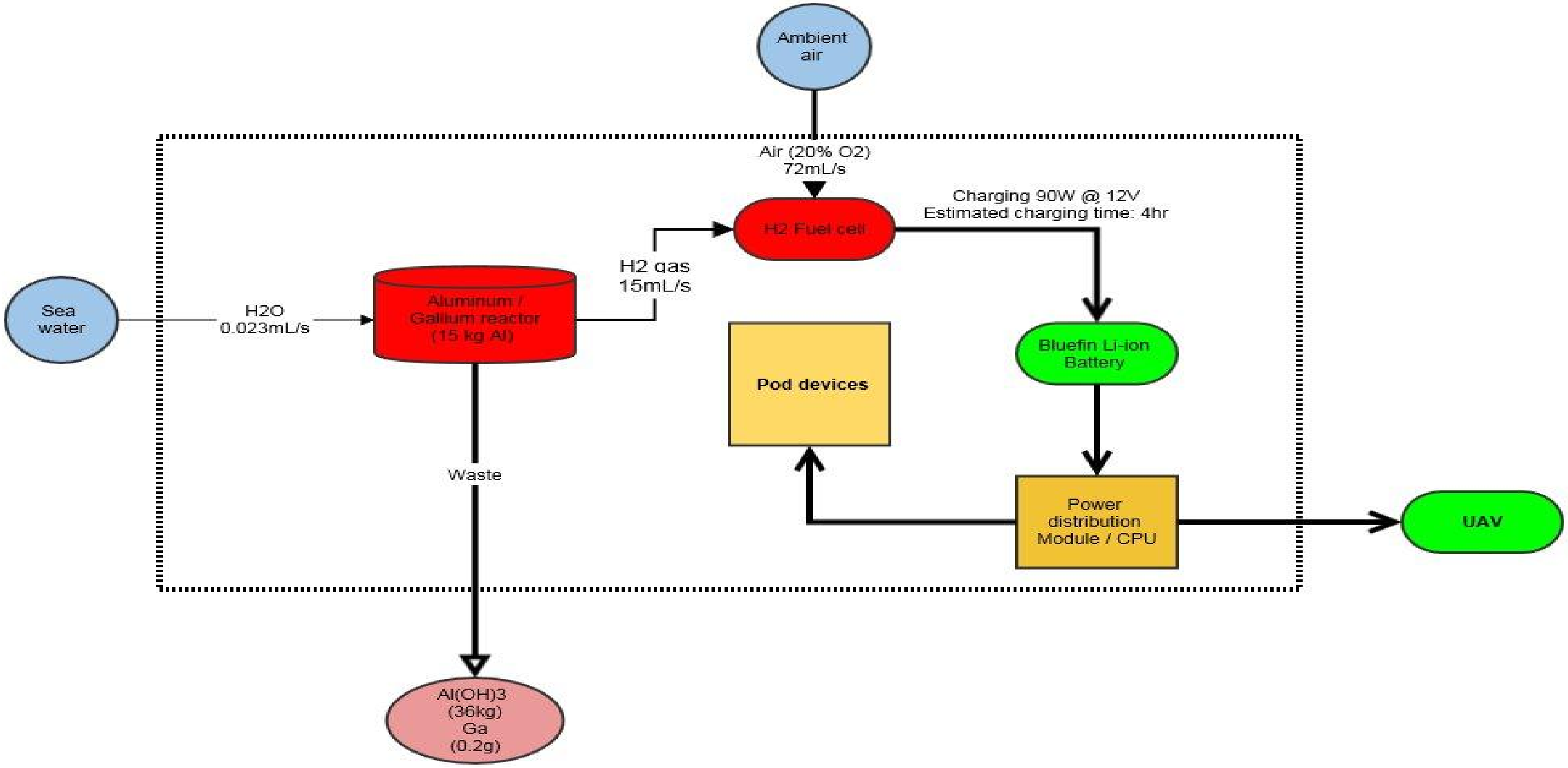
Image Size [pixels]	File size for 1 hour of data	Wifi upload time (100 Mpbs)
600x800	3.3 GB	4.5 minutes
800x1000	6.6 GB	9 minutes
1000x1600	10.2 GB	13.6 minutes
1200x1800	15.2 GB	21 minutes

Picam Field of View 410x275 ft
30 knots = 50 feet/sec
Assume 2 hrs data, 1 frame/sec
Charging time for plane is 1-2 hours, for blimp 6-7 hours

Janelle Mansfield

Pod Power Subsystem Appendix

Open system diagram



AIO Reactor Support system

In:	
Oxygen (5L/min)	12V Air Pump (35L/min)
Seawater	Hydra-cell Pumps
Out:	
Waste	Store
Excess heat	Cu Pipe out to SI

Appendix: Power Distribution

PYB30-U Series Convertor		• Best conversion efficiency (88 %) • input: 9~36 V • outputs: 5, 12 and -12 V
Severe Service Dual Vehicle Electrical Center		• Best Safety Features • customized circuit layout that includes fuses, relays, diodes, and circuit breakers

Appendix-Power requirements

Idle Requirements (1 year dormant)		
Payload	**Energy Requirement (Whr)**	**Assumptions**
Communications/ Controls	118	● Receives activation signal and turns on system. Active continuously for one year (timer chip unnecessary ● Low power consumption.
Depth Sensor	0.042	● Periodically take depth measurements every 1 hour

Reference

Appendix-Power requirements

Active Requirements (1 week)		
Payload	**Energy Requirement (Whr)**	**Assumptions**
Communications/ controls	639	• For communicating with Pod. Also includes sensors for docking. Active continuously for one week.
Docking/charging	4900	• Charging blimp for 6 hrs at 7.4V
Docking/charging	4900	• Charging plane for <1 hrs at 12V

Reference

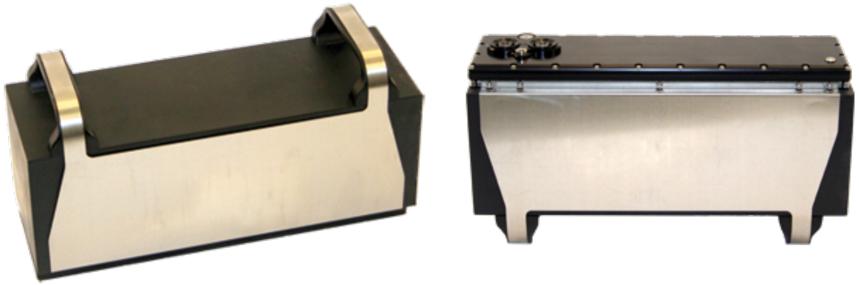
Appendix: Bluefin LiPo Spec

Dimension: 38.4 x 13.3 x 21 cm (10.72512L)

Weight: 14.3 kg

Depth Rating: 6,000 m

Discharge: 10 A nominal, 30A maximum



Appendix: System Efficiency

LiPo Discharge Efficiency: 97.5%

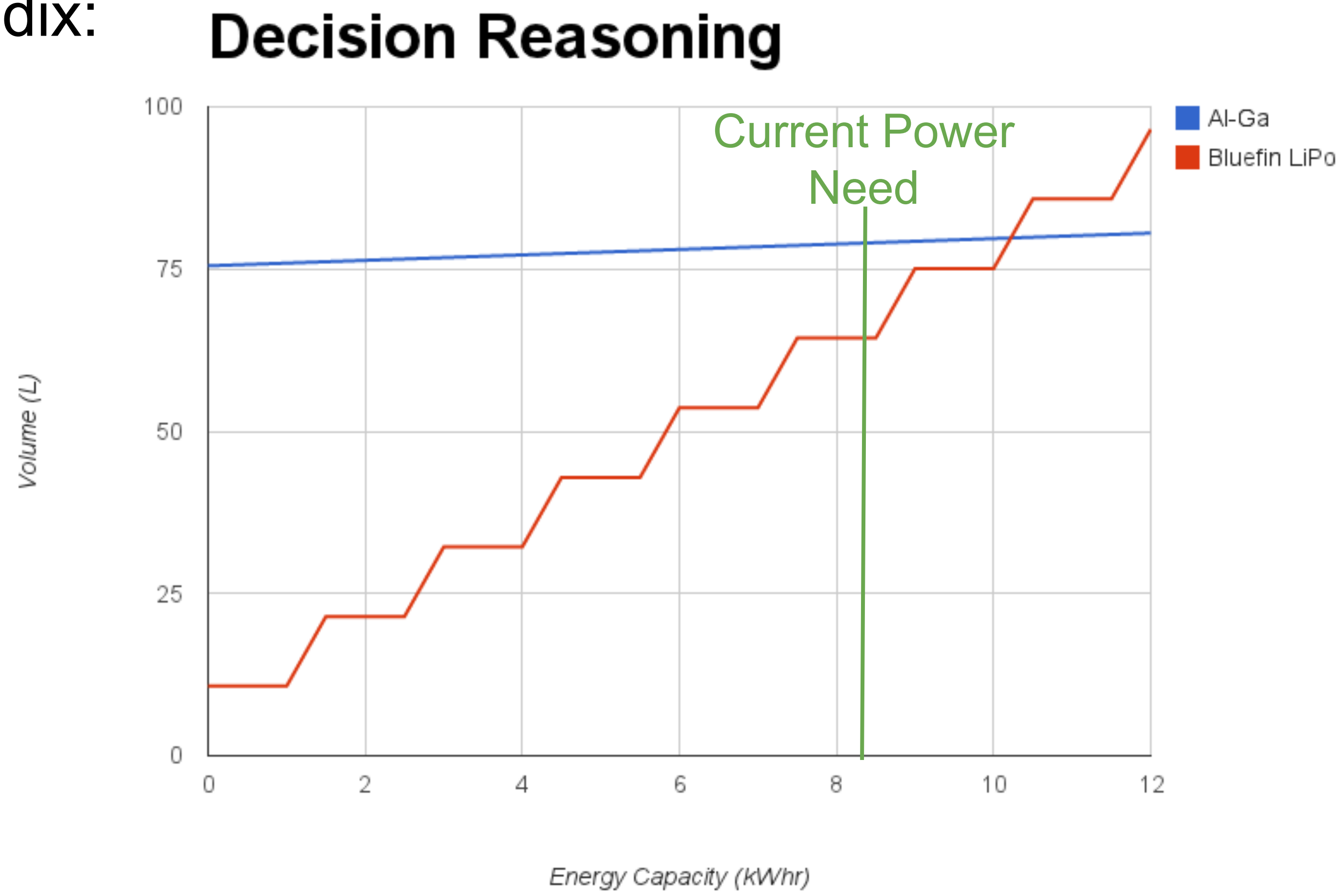
  12 months @ 2% monthly self-discharge.

Wire Transfer Efficiency: 98%

Voltage conversion Efficiency: 88%

Total Efficiency: 67.2%

Appendix:


Decision Reasoning
100
75
50
25
0
Volume (L)
0
2
4
6
8
10
12
Energy Capacity (kWhr)
Current Power Need
Al-Ga
Bluefin LiPo

Appendix: DC2-110 Series

- DC input from 9~36VDC
- Provides 4 outputs at 5 V and 12 V at 3 A max
- 5% voltage variability depending on load
- 88 % conversion efficiency

Appendix: Severe Service Dual Vehicle Electrical Center

- can withstand high vibration and moisture during operation
- customized circuit layout that includes fuses, relays, diodes, circuit breakers
- Maximum of 24 relays and/or 64 fuses
- 400A maximum rating
- 30A per output pin
- 100A per output connector

Pod System Risks

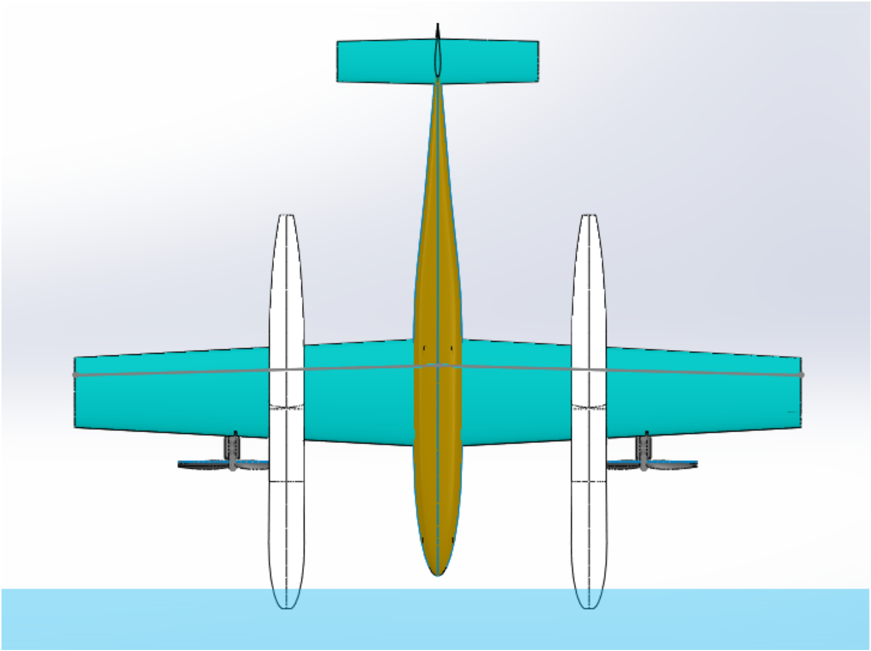
Risk	Mitigation
Wet Mate Connector Weight	Contact Seacon for consult and inquire for a unique connector
Activation Module Power Draw	Stronger estimates, and possibly independent energy source.
Idle State Self-discharge	Contact Bluefin for a low self-discharge version of their battery
Anchor Line Biofouling	Anti fouling paint coating, neglectable mass increase.

AC

Airplane Appendix

Buoyancy Stability

- Passively stable nose down
- Working on ways to change this dynamically
  - Longer, narrower pontoons



Devon Sklair

GNC Appendix

Data Options for Docked Upload

Picture Size [pixels]	Frames/Sec	Filesize	Wifi upload time, 100 Mbps
600x800	1	3.3 GB	4.5 minutes
1200x1800	1	15 GB	20 minutes
600x800	5	16.8 GB	22 minutes
1200x1800	5	75 GB	100 minutes

Calculated for 2 hours of data
Camera FOV is ~200x400 ft at 100 ft altitude
30 knots = 50 feet/sec