Team Inspiration

Marine Technology Society

22 April 2021

Our RoboSub Journey

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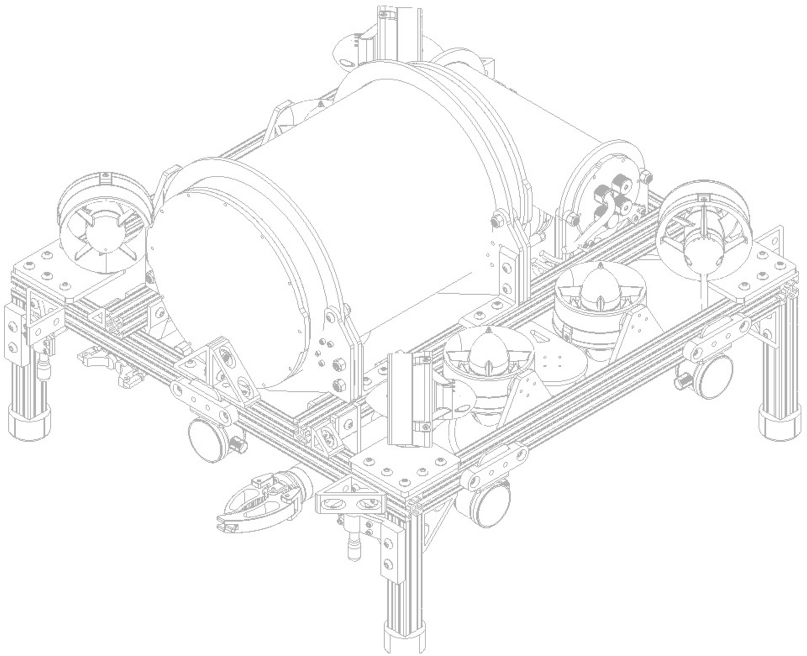
marine technology SOCIETY

Opportunity runs deep™

Team Inspiration

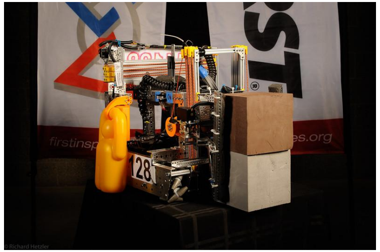
Agenda

- About Team Inspiration
    - Team History
- About RoboSub
    - Virtual Competition
    - Competition Results
    - Our Robot
    - Systems engineering
- Details of our system
    - 3D Models
    - PCB
    - Navigation
    - Testing and simulation
- Acknowledgements and Keynotes
- Questions



Team Inspiration History

2011 - FIRST Lego League (FLL)



2020 - RoboSub Champion
12 middle/high schoolers

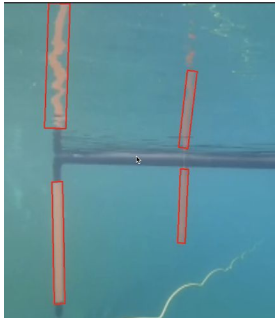
Systems engineering is the basis of our robotics journey

RoboSub Info and Venue

"RoboSub is an international student competition. Student teams from around the world design and build robotic submarines, otherwise known as Autonomous Underwater Vehicles (AUV). The behaviors demonstrated by these experimental AUVs mimics those of real-world systems, currently deployed around the world for underwater exploration, seafloor mapping, and sonar localization, amongst many others."

- RoboSub official website

2019 images



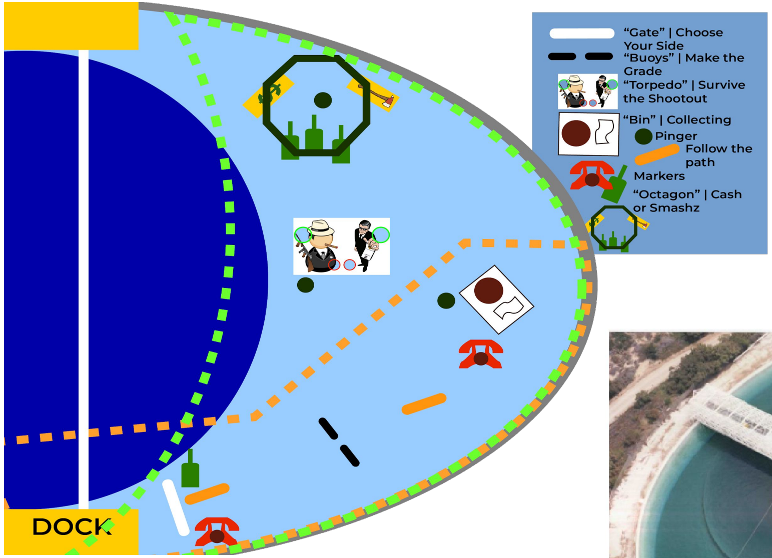
2021 is the 24th annual RoboSub competition

2020 Virtual Competition Criteria

Technical Paper
- Under 5 pages
- Should showcase the maturity of the system and team

Team Video
- Under 15 min
- Replacement for the onsite judging presentation

Team Website
- Should supplement the video and technical paper



Criteria drive our team objectives

Competition Results

Overall Standings

1st Place:	*Team Inspiration*
2nd Place:	Si Se Puede Foundation & Arizona State University
3rd Place:	Tecnológico de Monterrey
4th Place:	San Diego State University
5th Place:	Carnegie Mellon University

Video Standings

1st Place:	Tecnológico de Monterrey
2nd Place:	*Team Inspiration*
3rd Place:	Indian Institute of Technology Bombay
4th Place:	Si Se Puede Foundation & Arizona State University

Technical Design Report Standings

1st Place:	*Team Inspiration*
2nd Place:	California Institute of Technology
3rd Place:	Si Se Puede Foundation & Arizona State University
4th Place:	Duke University

Website Standings

1st Place:	*Team Inspiration*
2nd Place:	Si Se Puede Foundation & Arizona State University
3rd Place:	Amador Valley High School
4th Place:	Tecnológico de Monterrey

33 TEAMS

- Ain Shams University
- Amador Valley High School
- Arizona State University
- Beaver Country Day School
- California Institute of Technology
- California State University, Los Angeles
- Carnegie Mellon University
- Duke University
- École de Technologie Supérieure
- Federal University of Rio de Janeiro
- Georgia Institute of Technology
- Gonzaga University
- Indian Institute of Technology Bombay
- Kasetsart University
- Kennesaw State University
- National University of Singapore
- North Carolina State University
- Oregon Institute of Technology
- Robotics Association at Embry-Riddle
- San Diego City College
- San Diego State University
- Si Se Puede Foundation & Arizona State University
- Team Inspiration
- Tecnológico de Monterrey
- Texas A&M University
- The Ohio State University
- University of Alberta
- University of California at Riverside
- University of California, San Diego
- University of Colorado at Boulder
- University of Colorado at Boulder
- Vortex NTNU
- Wrocław University of Science and Technology

Being requirement-driven enabled us to win

What Made Our Team Excel

- Focus on the competition guidelines
- Competitor analysis and research
- Hard work and dedication
- Communication
- Iteration and parallel prototyping
- Trade studies
- Attention to detail
- Rigor in documentation
- Utilizing mentors and vendors
- Team work
- Availability
- Solution oriented

Attributes	Weight	Dual Enclosure		Single Long Hull (8in)		Box Enclosure		Current Configuration (Short 6in)		Dual Hull Connected	
	1 - 5	Rank 1 - 5	weighted	Rank 1 - 5	weighted	Rank 1 - 5	weighted	Rank 1 - 5	weighted	Rank 1 - 5	weighted
Capacity	4	4	16	4	16	4	16	2	8	5	20
Water displacement(size)	0	2	0	2	0	3	0	4	0	4	0
Min Ports?	10	1	10	1	10	1	10	0	0	1	10
Ports	3	5	15	2	6	3	9	1	3	4	12
Cost	3	3	9	4	12	1	3	5	15	1	3
Ease of Maintenance(ease to open up and debug sensors etc.)	4	3	12	2	8	5	20	3	12	5	20
Ease of Fabrication (if we can make it in the garage with the tools we have)	5	4	20	4	20	1	5	5	25	1	5
Convience (what we can do now)	3	2	6	4	12	5	15	5	15	3	9
Room for expansion	4	4	16	3	12	3	12	1	4	3	12
Total Points		28	104	26	96	26	90	26	82	27	91
More points = Better											

Team Inspiration 1

The Design of Team Inspiration's 2020 AUVs

Colin Szeto (team lead), Ashiria Goel (deputy), Ashika Palacharla, Aditya Mavalankar, Shruti Natala, Raina Shapur, Pahel Srivastava, Mabel Szeto, Noah Tang, Rishi Veerepalli, and Eesh Vij

Abstract—Team Inspiration focuseds on perpetually learning and improving., andWe set out to improve our sub's navigation and expand our mission capability. Our second year team of 12 middle and high schoolers designed our 2 AUVs for the 2020 RoboSub competition, Græy and Orange (our AUV from last year modified to fit this year's challenge). Through designing Græy, we learned how to use Robot Operating System, ~~design Printed Circuit Boards~~, hydrophones, —simulation, and machine learning, ~~hydrophones~~, and Solidworks, and design Printed Circuit Boards. After the onset of the global pandemic, our team learned effective virtual collaboration and remote

I. Competition Strategy

hydrophones to our previous vision and sonar sensors.

We enhanced our image recognition by specifically working on determining the position

of the image in relation to the AUV; and image identification/recognition. CV is used to identify

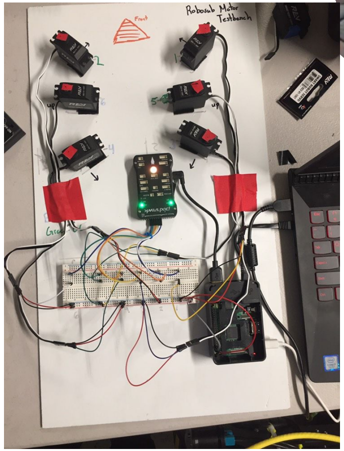
¶

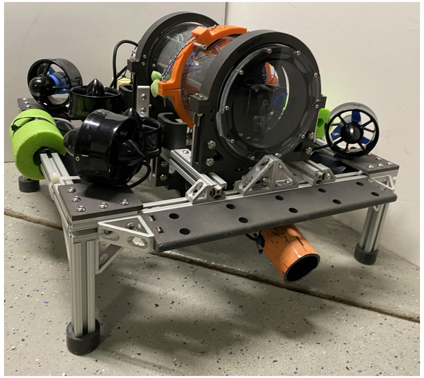
the buoys; and differentiate whether the tasks correspond to the G-man or Bootlegger. Hydrophones are used to locate the pingers that mark the torpedoes and surfacing tasks. A DVL is used to navigate to each task. This way Græy can get close enough to the tasks so the shorter ...ed sensors like the sonar and CV can take ... to assist Græy with accomplishing the ...sions. We implemented fail-safes into the ...gram for redundancy.

We ~~used~~ emulated Orange's simplicitye and ...lular construction ~~to~~ when ~~design~~designing ...y. The design allows easy expansion by simply increasing the cylinder length and

Because we are solution oriented COVID is not a blocker

RoboSub Progression





From sea perch to blue rov to orange

Systems Engineering “V” is an Enabler

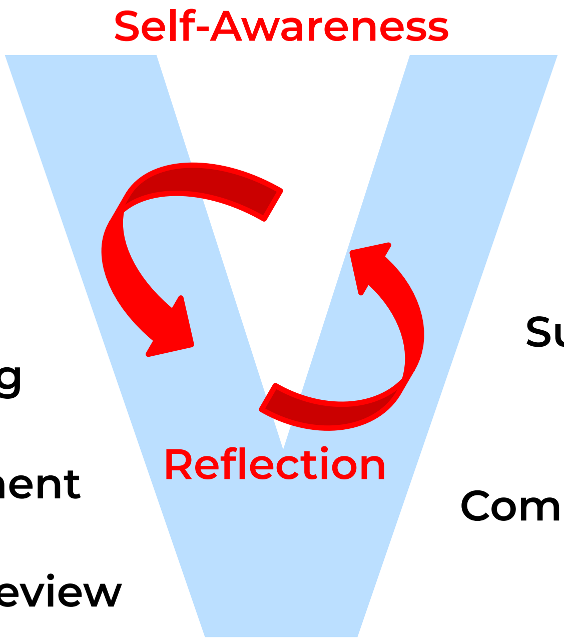
Competitor Research, Industry Survey

Mission Exploration

Planning

Requirement Development

Design Review



Modular & Parallel Development

System Testing

Subsystem Testing

Component Testing

Best practice with focus on reflection and self-awareness

Competitors Research & Industry Survey

- Learn from competitors
  - Survey RoboSub teams from last five years
  - Identify equipment usage
  - Identify lessons learned
  - Ask for advice
  - Study their subs
  - Learn from industry professionals
  - Systems engineering process proven at TRW, NASA JPL, Northrop Grumman
  - Marine industry products
  - Interview professional from Scripps Institute of Oceanography

Learn from the experts

Planning

- Draft schedule at Kick-Off – schedule focus
- Develop schedule backward from goal with contingency
- Long lead material procurement – RoboSub components
- Rapid prototype – weekly increments
- Parallel and modular development
- Early testing – start from the beginning
- Multiple decision milestones

Week	Agenda
16-Mar	Kick off – RoboSub team research
23-Mar	RoboSub team research – refine requirements – assign role
30-Mar	Identify/procure long lead items – Select computer – prioritize requirements
6-Apr	Connect benchtop vehicle – test component
13-Apr	Identify all equipment
20-Apr	program remote control
27-Apr	put together simple underwater vehicle – first prototype
4-May	Experiment first prototype in water
11-May	Progam autonomous
18-May	Experiment with IMU and depth sensor
25-May	Experiment with computer vision
1-Jun	Draft technical paper
8-Jun	Review draft – Experiment with second prototype
15-Jun	Final technical paper
22-Jun	Submit technical paper
29-Jun	Experiment sonar
6-Jul	Experiment with final vehicle
13-Jul	Data correlation with vision input Pre-qualification
20-Jul	Refine autonomous programming
27-Jul	Pack robot for competition
Jul 29 - Aug 4	Competition at NIWC PAC TRANSDEC

Plan with flexibility and contingency

Requirement Development

- Understand systems requirements
  - Flow down to mechanical, software, test, operation
- Understand interface
  - HW-HW, SW-SW, HW-SW, user
- Prioritize requirements

30%	Team capability
25%	Schedule
20%	Cost
10%	Risk
15%	Performance
100% Weighted	**Criteria**

Understand team capability is a major risk mitigation

Self-Awareness (2019)

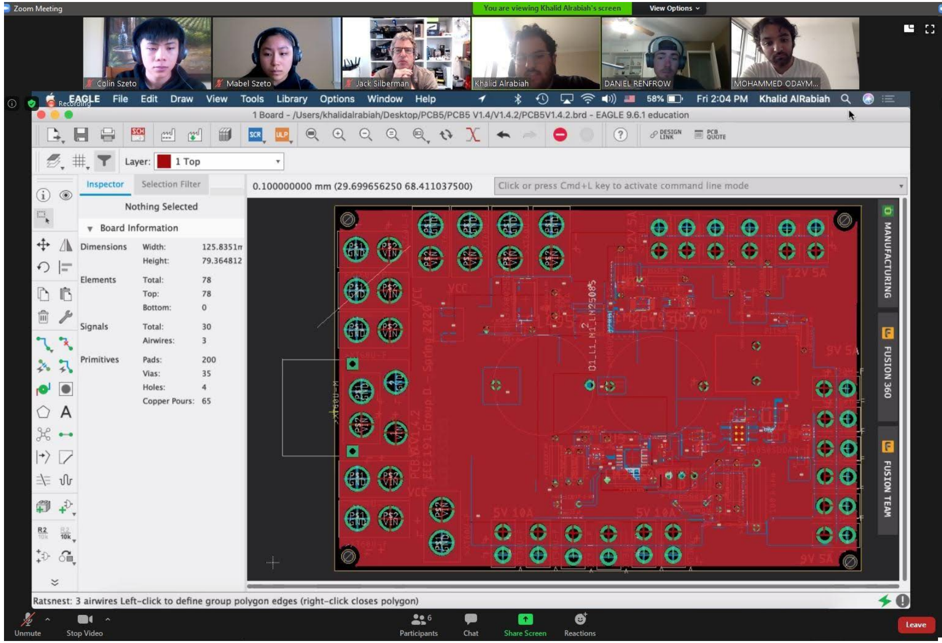
- Team members capabilities and resource
    - ~~Printed circuit card development (knowledge, resource & schedule)~~
    - ~~FPGA (knowledge, resource & schedule)~~
    - ~~Artificial Intelligent (knowledge & schedule)~~
    - ~~Neural network (knowledge & schedule)~~
    - ~~Machine milling part (cost)~~
    - ~~Complex sensors (cost & complexity)~~
    - General robotics knowledge
    - Integration
    - Programming
    - Garage lab and pool
    - Systems engineering
    - Teamwork
    - Dedication
    - Passion and drive
    - Mentors

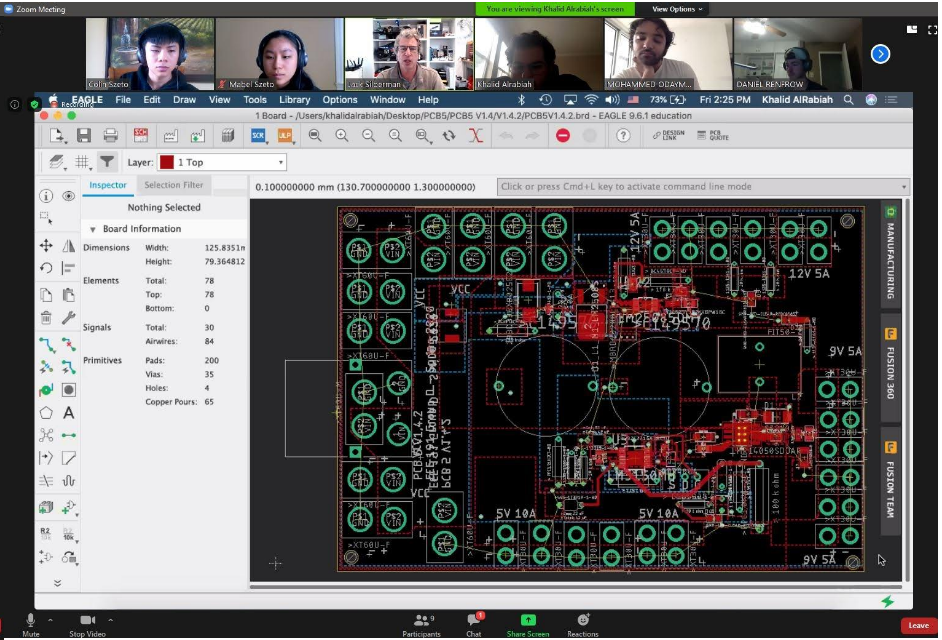
Aware of limitation – prioritize and seek help

RoboSub Motion Conceptualization

Visualizing the movement and communication to others

External Collaboration





Digital development enabled us to collaborate remotely. Surprisingly, we had more collaboration with professionals due to COVID-19.

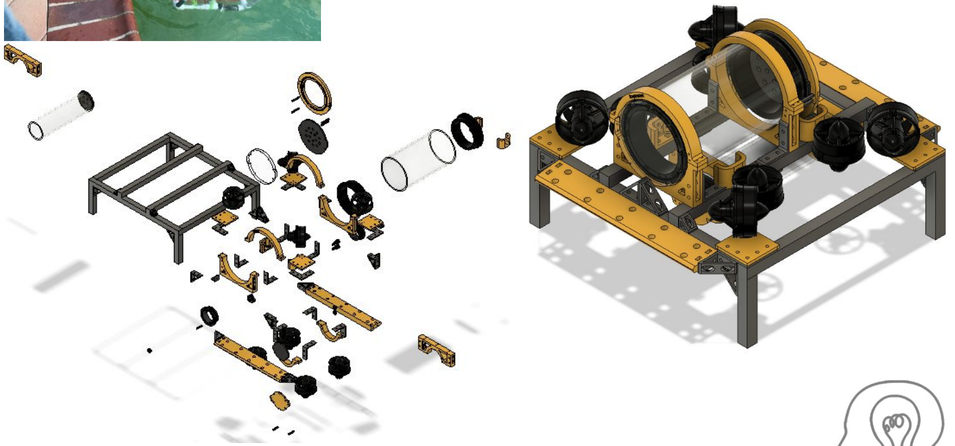
Design Review

- Design review is critical to align the team direction and awareness
- Trade study allows better decision making
- Rapid prototyping allows concept validation
- Weekly status review provides valuable feedback

Review to solicit input and cross train

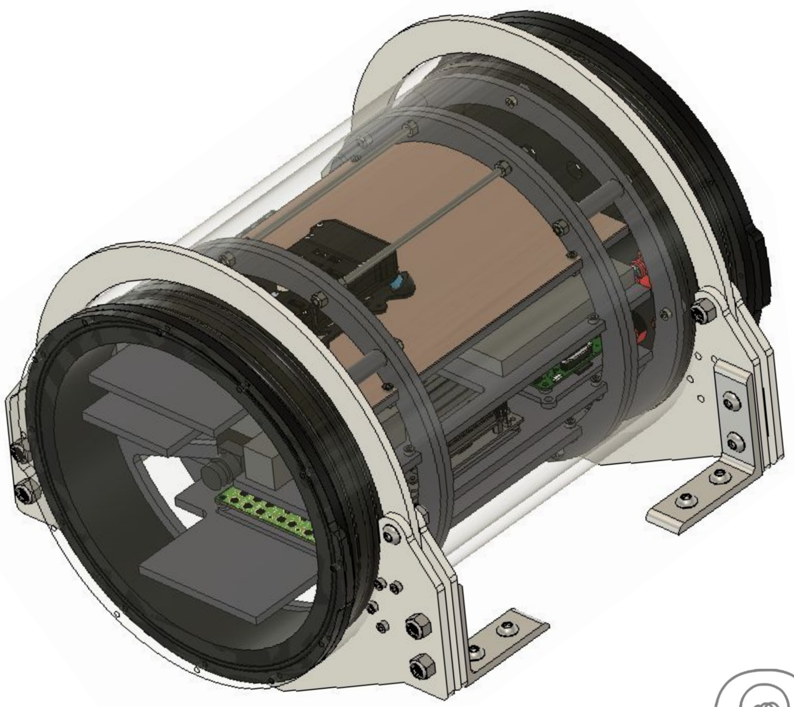
Parallel Prototyping

- Modular development allows team members to tackle multiple payload investigation simultaneously
- Parallel breadboard, simple vehicle, remote control vehicle testing allow timely design concept verification to identify development shortfall
  - Lessons learned are incorporated into the final vehicle development
- CAD and 3D printing allow quick modeling and testing of the design



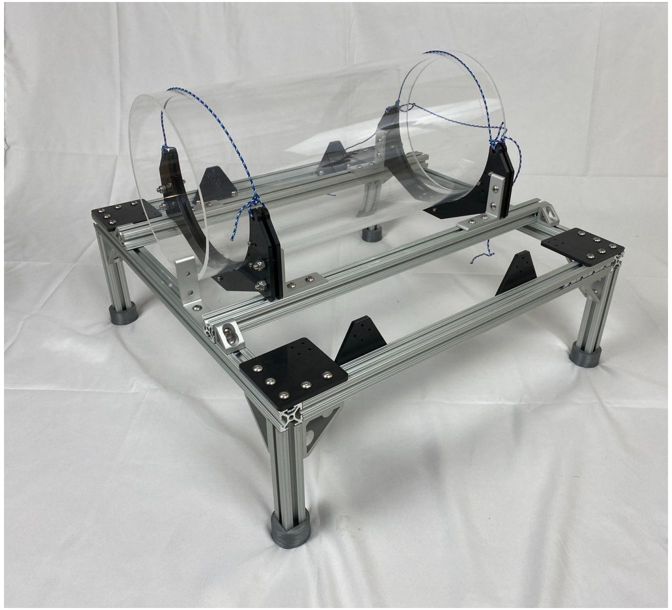
Modular and parallel development – amazing time multiplier

Parallel Prototyping



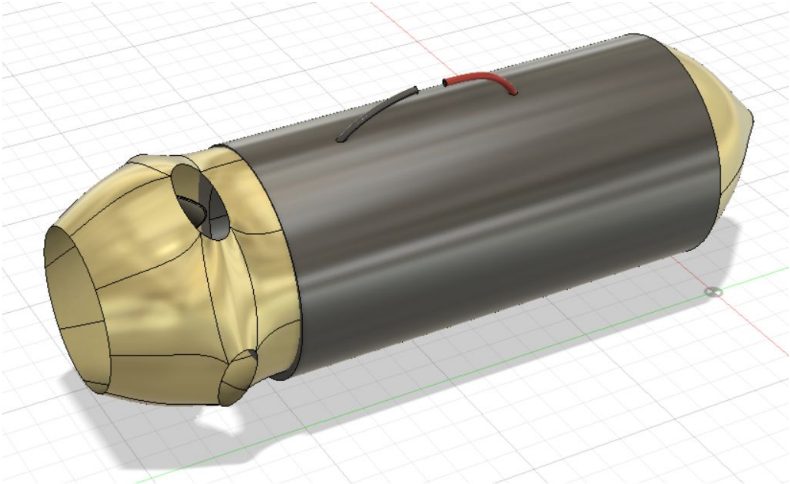
Independent team members' concepts

Electronics Enclosure



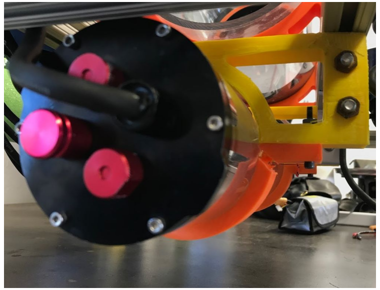
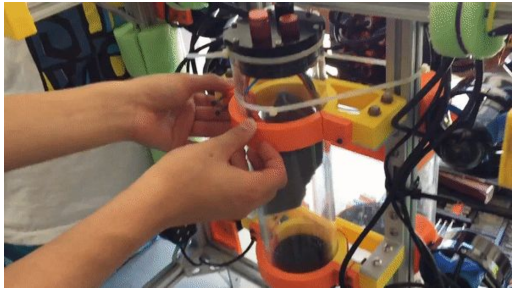
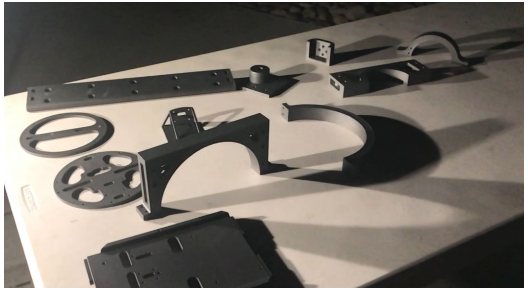
Planning for larger enclosure

Torpedos

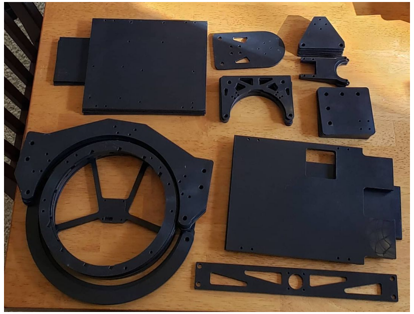
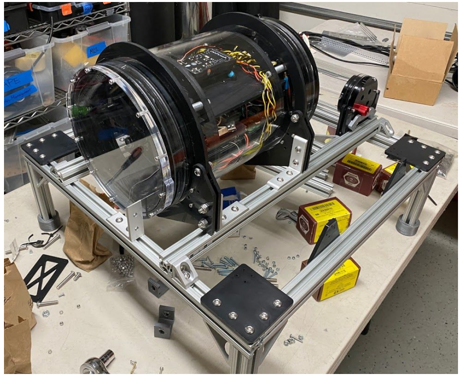


Independent team members' concepts

Material Evolution

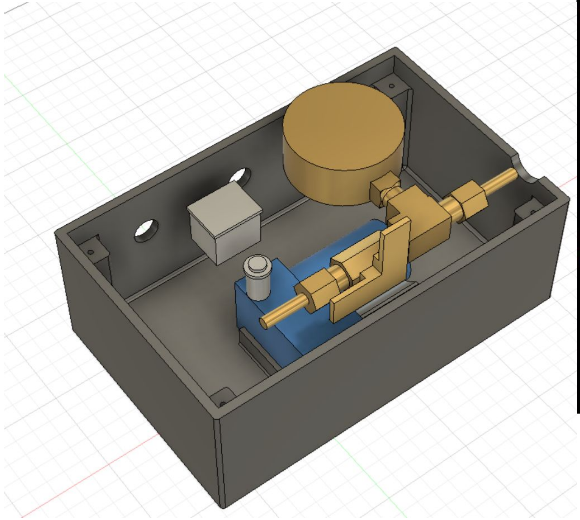




FORECAST 3D
MFG USA

From simple to advanced materials

Vacuum Pump



Currently no good solution to determine if watertight

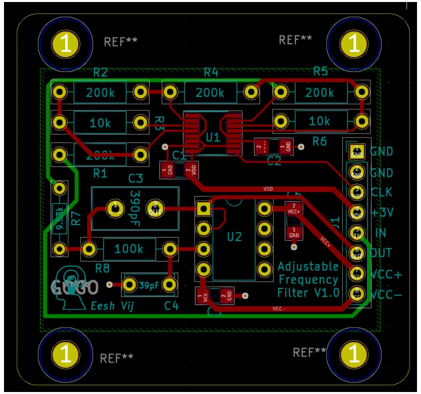
Using Wet Connectors

How would you suggest to integrate?

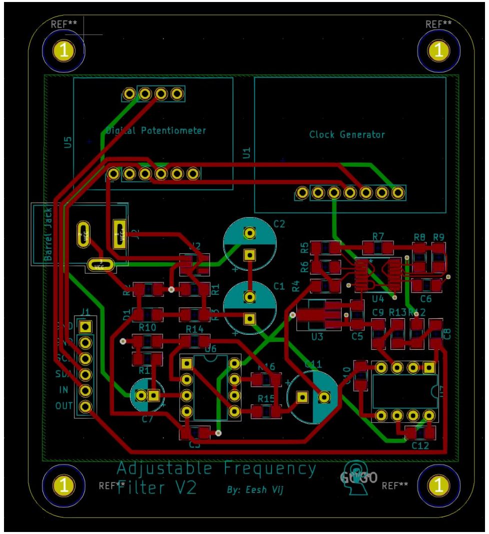
Hydrophones

- Three hydrophones used around Græy in the vertices of the largest possible equilateral triangle that fit in our design
- Sampling at 200 kHz at a 12-bit resolution allowing for precise signal processing
- The signal processing takes place on single custom designed PCB which offloads the amplification, noise isolation, and frequency selection to a hardware based solution, freeing resources on the processor.
- The algorithm takes into account the Differences in the Time of Arrivals (DTOA) of each signal to calculate the approximate heading of the pinger.

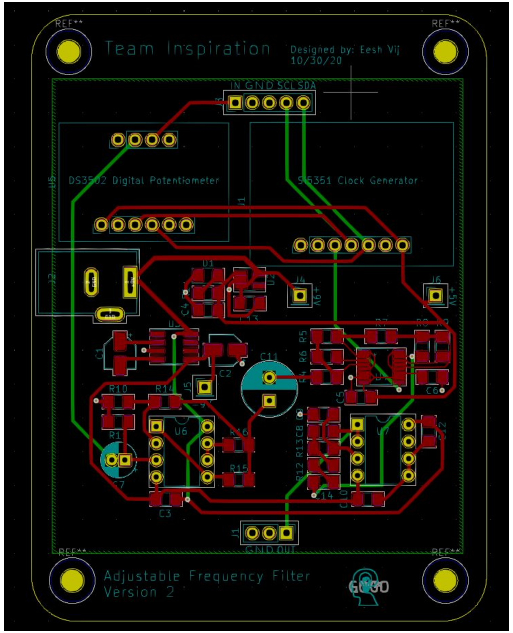
PCB Designs for Hydrophones



V1



V2



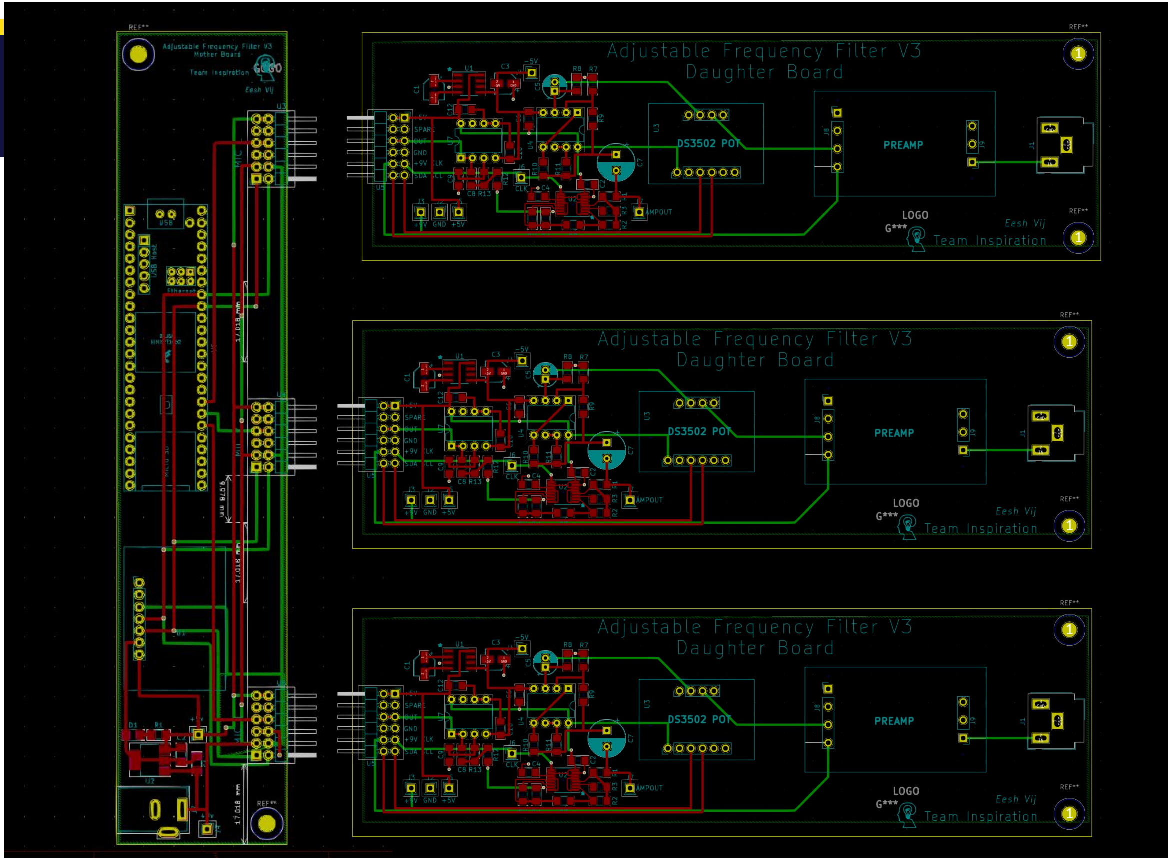
V2.1

Everything is developed in iterations

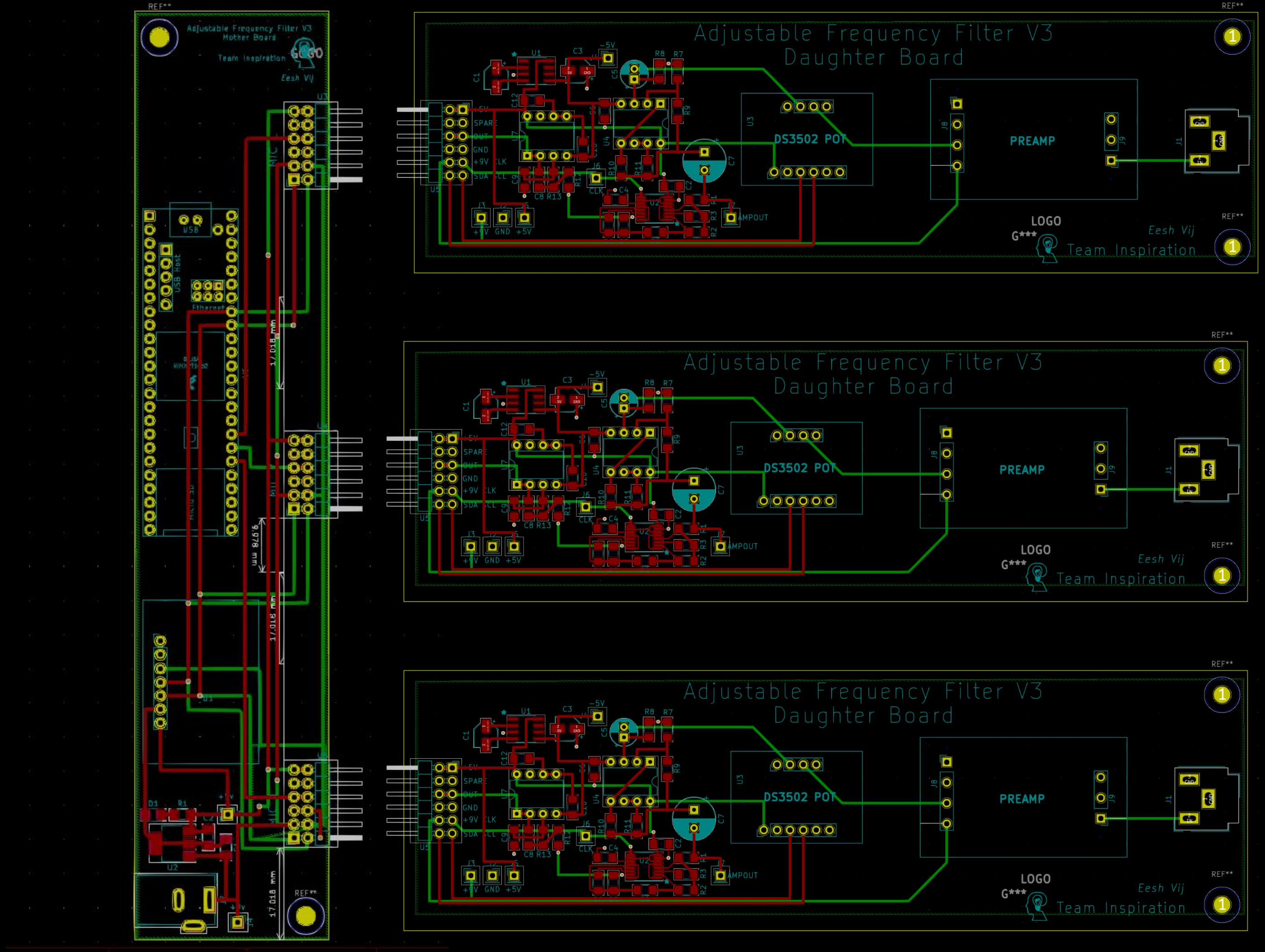
PCB Designs

V3

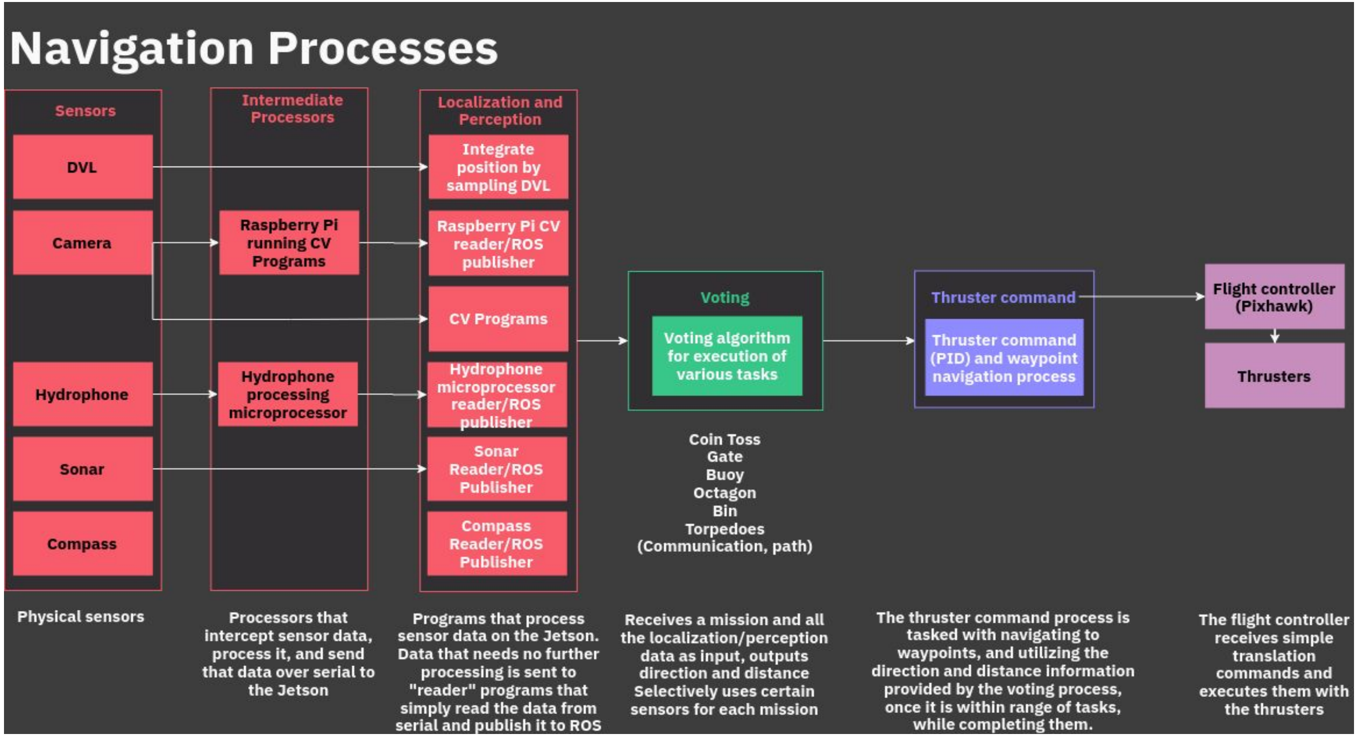
- Low-Cost
- Maintainable
- Ease of use
- Future Expandability



Everything is developed in iterations


Adjustable Frequency Filter V3
Mother Board
Team Inspiration
Eesh Vij
Adjustable Frequency Filter V3
Daughter Board
DS3502 POT
PREAMP
LOGO
Eesh Vij
Team Inspiration
AMPOUT
+5V
SPARE
OUT
GND
+9V
CLK
SDA
SCL
-5V
USB
USB Host
Ethernet
17.018 mm
9.978 mm

Navigation Software Architecture



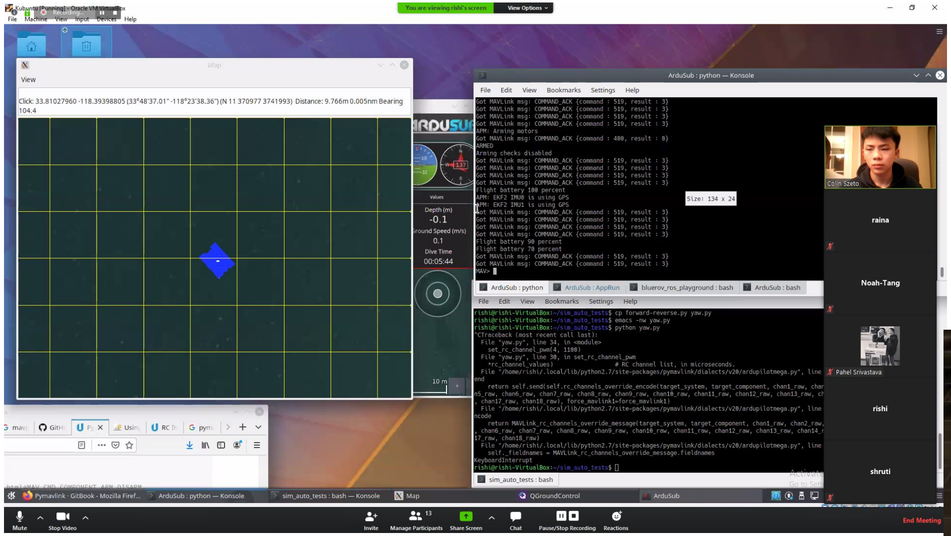
Localization/perception programs interpret data from hardware, and produce information about env. or location

Sensor fusion program combines localization programs' data to produce estimate of location and env.

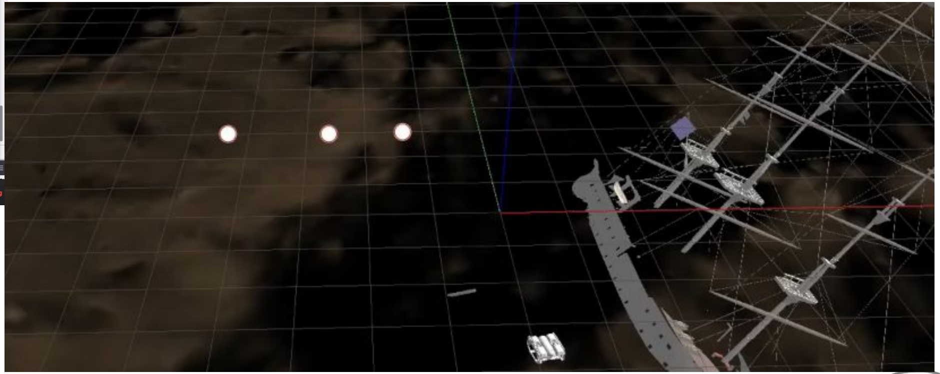
Sent to thruster cmd process which controls motors based on information provided by the sensor fusion program

Clear Architecture and Flow Diagrams

Virtual Simulation



A software in the loop (SITL) 6DoF simulation that simulates our flight controller runs in an Ubuntu virtual machine. SITL is linked with Gazebo to provide a 3D model/visualization. Gazebo also provides information like coordinates/heading which we can use to verify simulation results. We model sensor inputs using the position and velocity information Gazebo gives us.



Utilizing Gazebo and ArduSub software-in-the-loop simulation in place of in-water testing

Testing, Testing, and More Testing

Breadboard testing starts in the second week is key to shorten the development life cycle

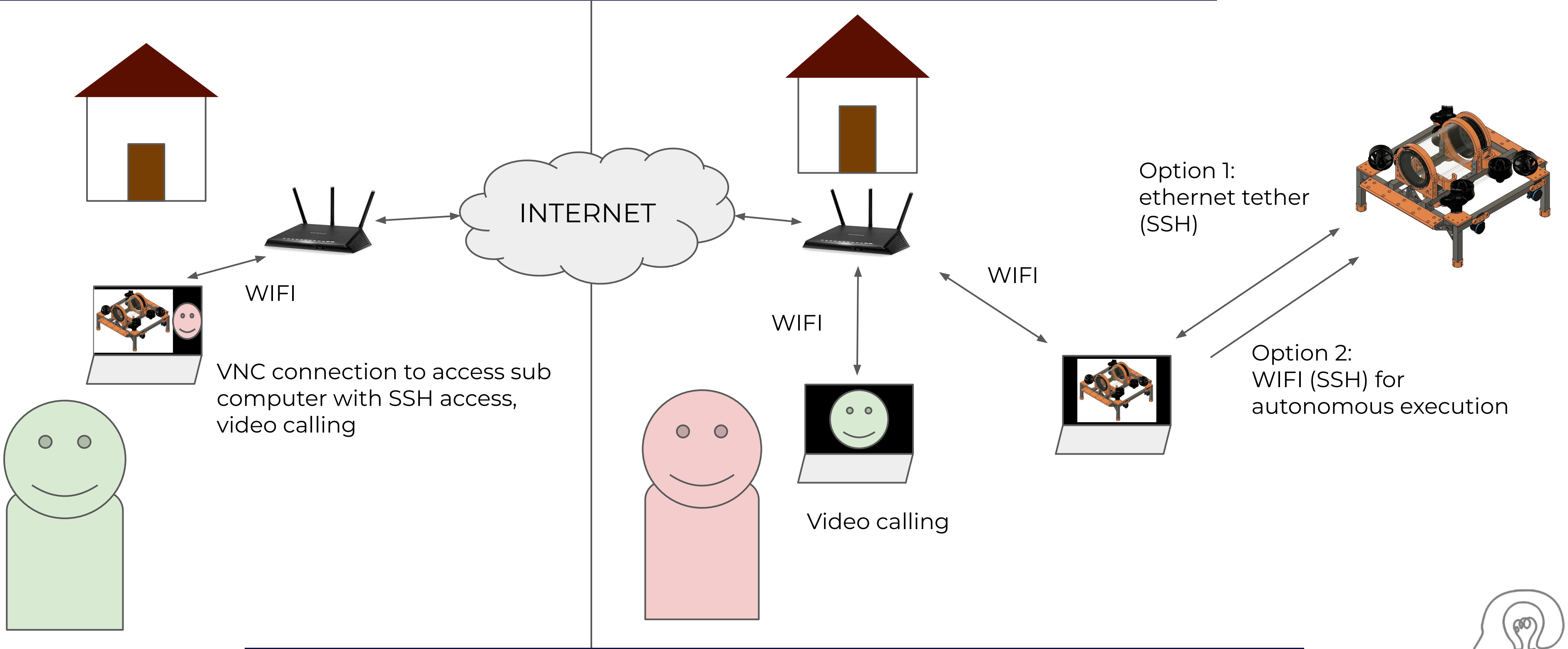
Remote-control vehicle testing allows observation to incorporate features into the final design

Incremental testing allows rapid lessons learned

Early subsystem and system level testing allows us to improve the design and development weekly similar to the agile process

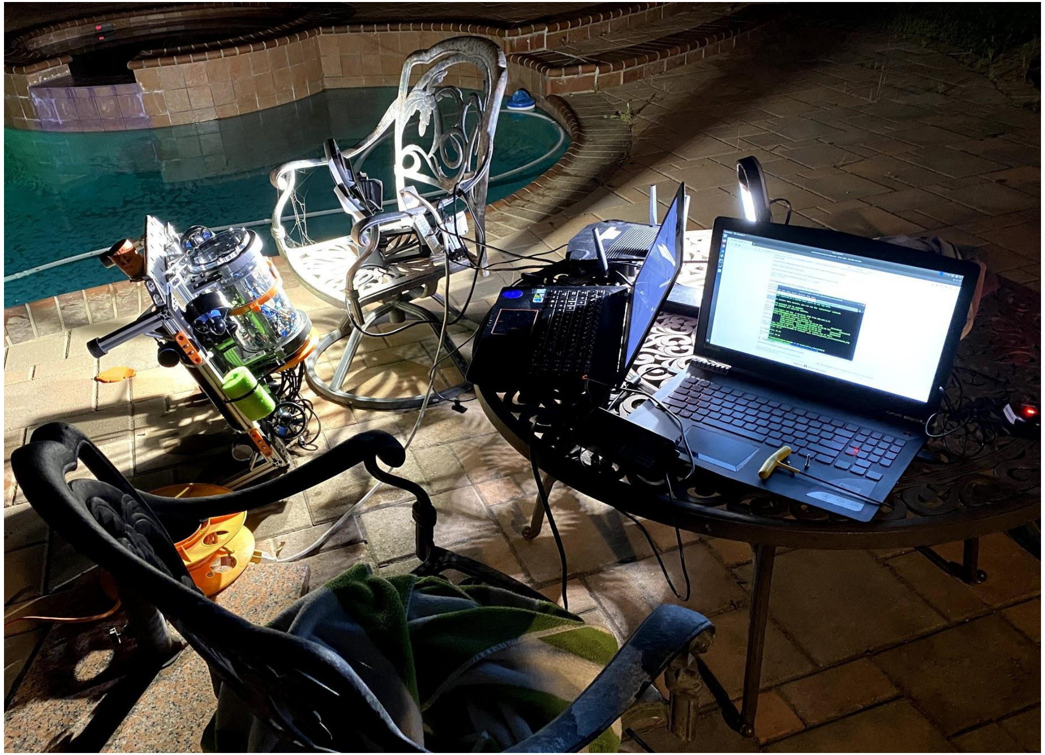
Test to understand and discover the limitation

Network of Online Testing



Remote configuration, control & operation

In-pool Testing



Remote testing with in-pool support

Keynotes

Know the mission – understand the problem to solve

Keep It Simple Silly

Passion

Reliability

Teach

Fail quickly

Teamwork

Systems thinking is applicable to any project and any level

Acknowledgement

- Team Inspiration Members
  - Ashiria Goel (Team Captain), Eesh Vij (Deputy Captain), Rishi Veerepalli (Deputy Captain), Aditya Mavalankar, Ashika Palacharla, Claire Zhao, Colin Szeto, Eric Silberman, Isabelle Gunawan, Mabel Szeto, Noah Tang, Pahel Srivastava, Raina Shapur, Shreyas Rangan, and Shruti Natala
- Lead coaches
  - Alex Szeto, Jack Silberman
- Mentors
  - Amit Goel, Brian Liu, Dave Warner, Eric Lo, Eugene Kim, Kenzo Tomitaka, Kris Chopper, Kunal Srivastava, Pamela Cosman, Pat McLaughlin, Phil Yao, Michael Arnstein, Valibabu Saladi, and Venkat Rangan
- Sponsors/supporters

Teamwork

Supports

Mentors

Sensors - beacon, FOG, hydrophone

Tooling - CNC, laser cutter, ...

Software - simulator, ...

Test equipment -

Funding - Travel

Questions?

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Email: 11128inspiration@gmail.com

ftc11128inspiration teaminspiration11128 Inspiration Robotics 11128

Græy

Navigation

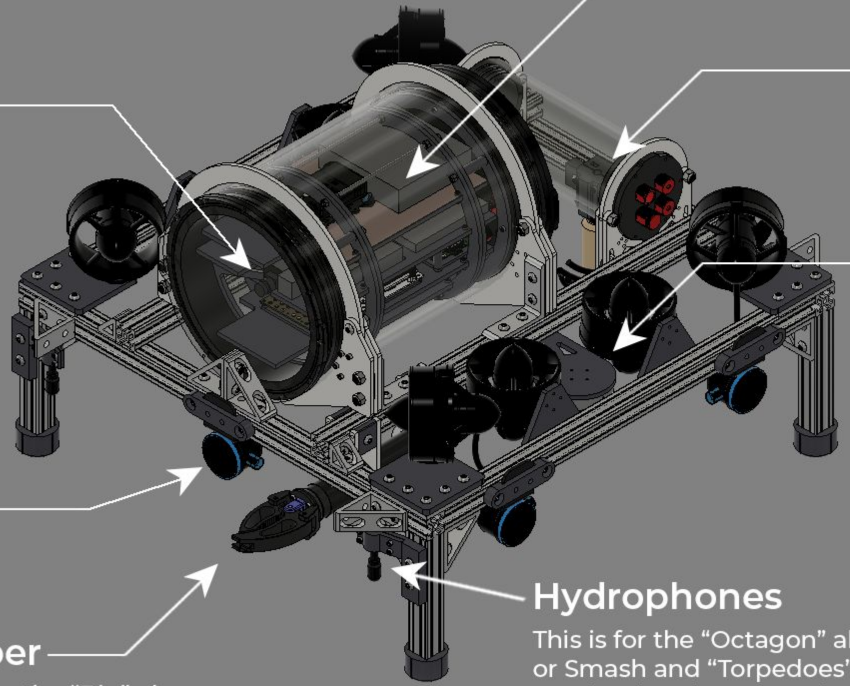
We used several sensor inputs and used ROS as our interprocess communication software to integrate the programs.

Computer Vision

This is for the “Gate” aka Choose Your Side, “Buoys” aka Make the Grade, “Bin” aka Collecting, “Torpedoes” aka Survive the Shootout, and “Octagon” aka Cash or Smash missions.

Modem

This is for the intersub comunication mission.



DVL

This is for navigating to every mission.

Sonar

This is for the “Buoys” aka Make the Grade and “Torpedoes” aka Survive the Shootout missions.

Gripper

This is for the “Bin” aka Collecting and “Octagon” aka Cash or Smash missions.

Hydrophones

This is for the “Octagon” aka Cash or Smash and “Torpedoes” aka Survive the Shootout missions.