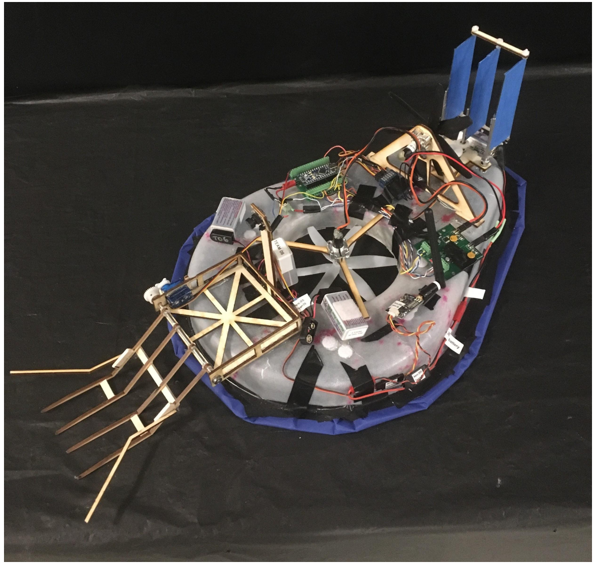
Team 6's Titan Hovercraft

December 1, 2018



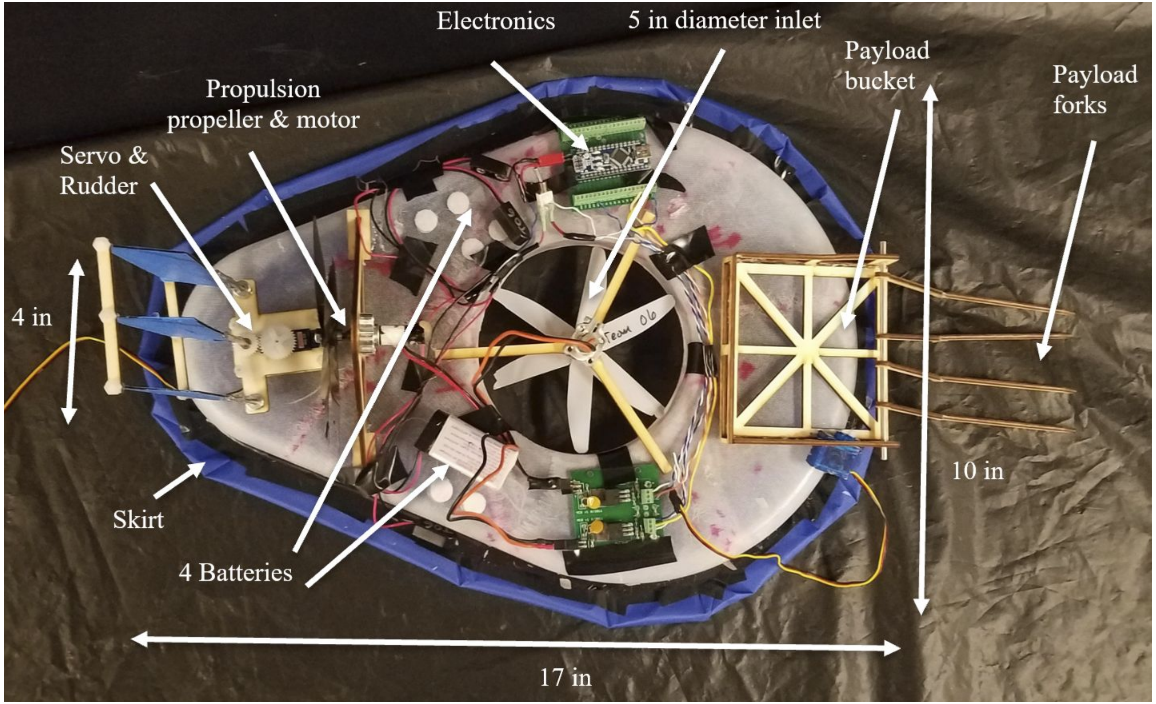
Adolfo Apolloni
Jacob Crouch
Reid Pringle
Drake Rundell
Matthew Winterstein

Introduction

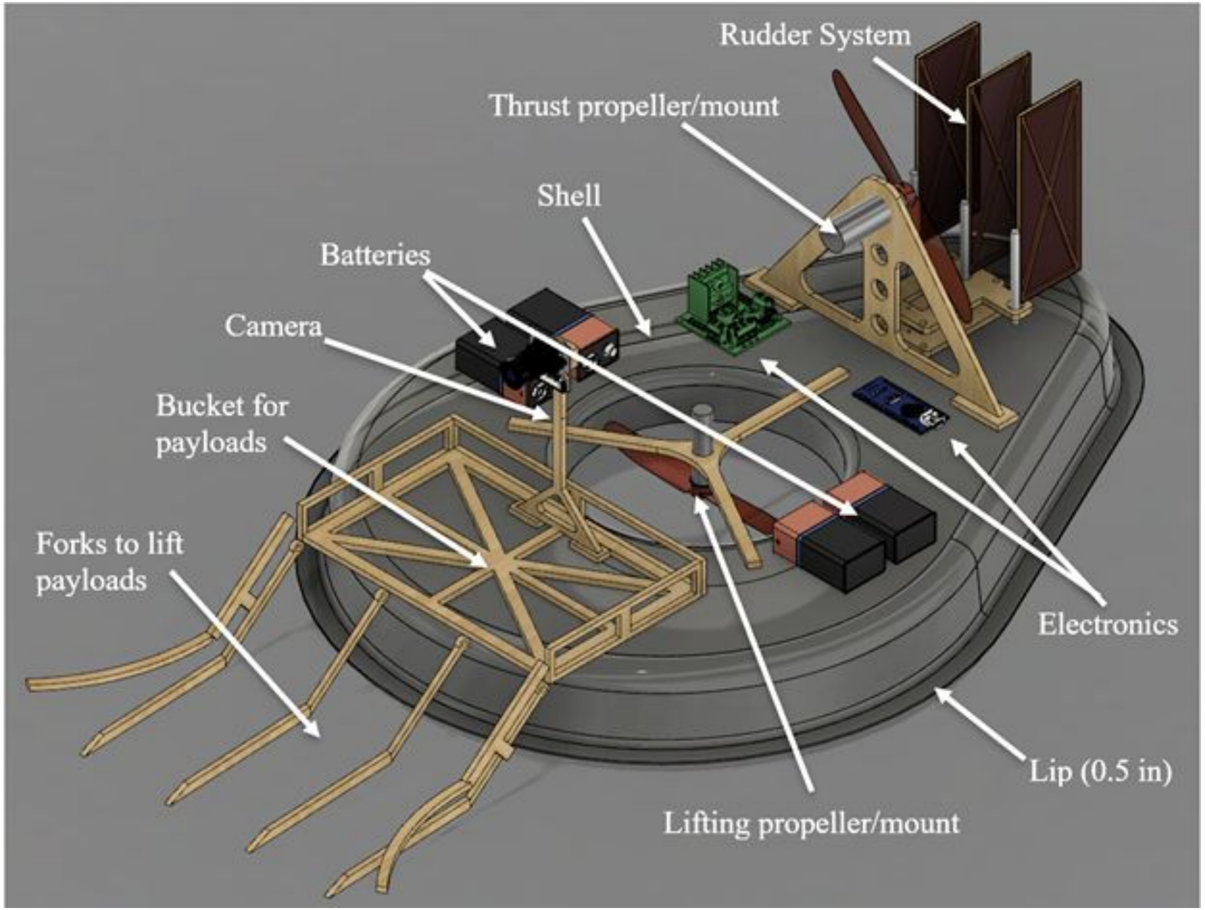
- **Problem:** NASA needs an autonomous surface skimming vehicle to survey a body in the solar system
- **Task:** Our team is tasked with creating a hovercraft to study this body under certain requirements
    - System mass under 1 kg
    - Maximum of 2 motors and eight 9V batteries
    - Electronics system with identifying LED's and a single power switch
    - Maximum size of 56x56x23 cm^3 or ~22x22x9 in^3
    - Deliver payloads of up to 50 grams while remotely and autonomously controlled
    - Survive surface and atmospheric obstacles while competing against other crafts
- **Purpose:** We are presenting how and why we have created our current hovercraft and its adaptations to the Titan environment

Summary

- Craft designed within mass, power, and size constraints
  - Shell length: 17 in
  - System mass: 561 g
  - System power: 31 W
  - Max. Speed: 5.68 ft/s
- Unique features:
  - Aerodynamic teardrop shape (Cd = 0.42)
  - Multiple payload capacity
  - Skirt for obstacle clearance
  - Minimum number of signal lights
- Multiple successful test flights



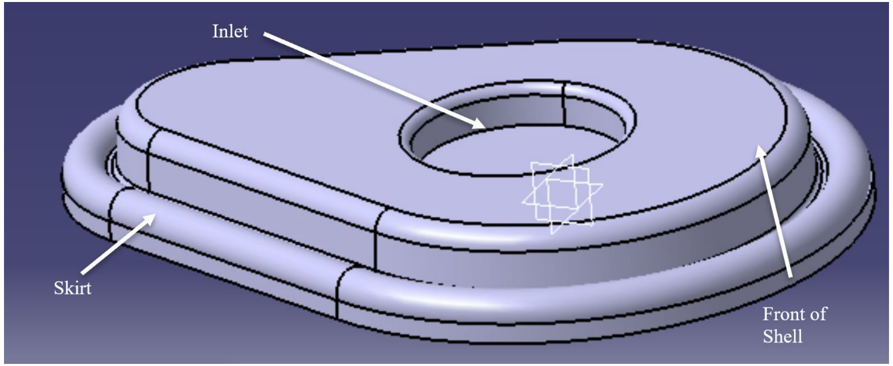
Overall Design

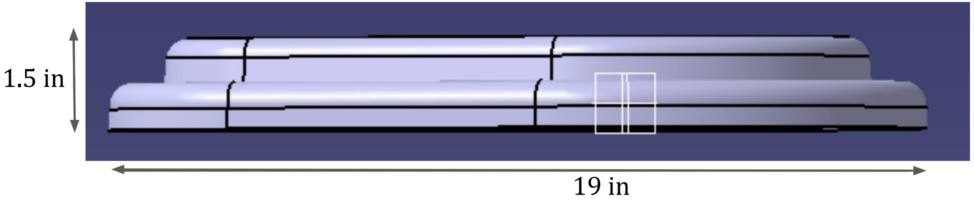


Note: dimensioned diagram of shell provided on a later slide (overall shell length is 17 in)

Shell Design

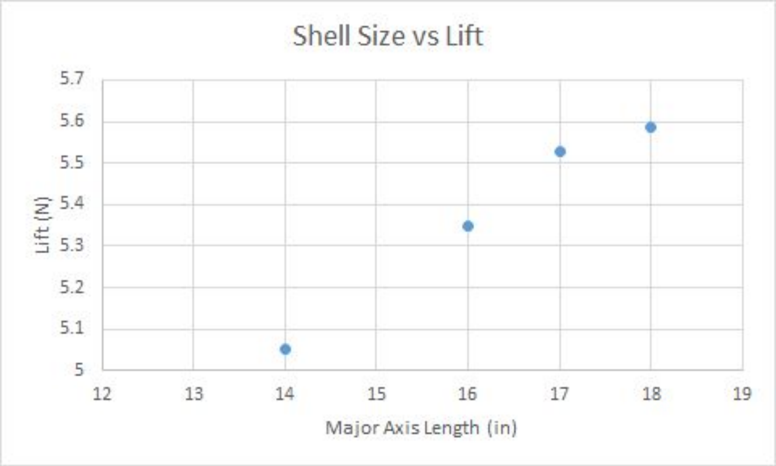
- Shape designed for external aerodynamics
    - Teardrop with low drag coefficient (Cd of 0.42)
    - Short (1.5 in tall) to minimize frontal area
- Vertical inlet for maximum downward velocity
- Externally mounted electronics
- Plenum skirt for obstacle clearance and increased lift
- Shell mass: 69.5 g

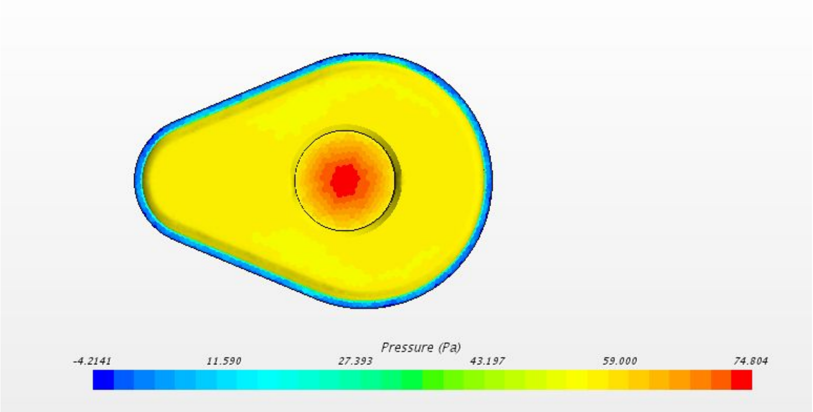




Internal Shell Simulation Results

- Simulation characteristics determined from airpuck results
  - Gap: 0.067 in
  - Inlet Velocity: 1.2 m/s
  - Scaled shell size to generate at least 5.5 N of lift (determined by mass budget)
  - Total hovercraft mass is ~560 grams
  - Chose a 17in long shell - simulates 5.54 N of lift

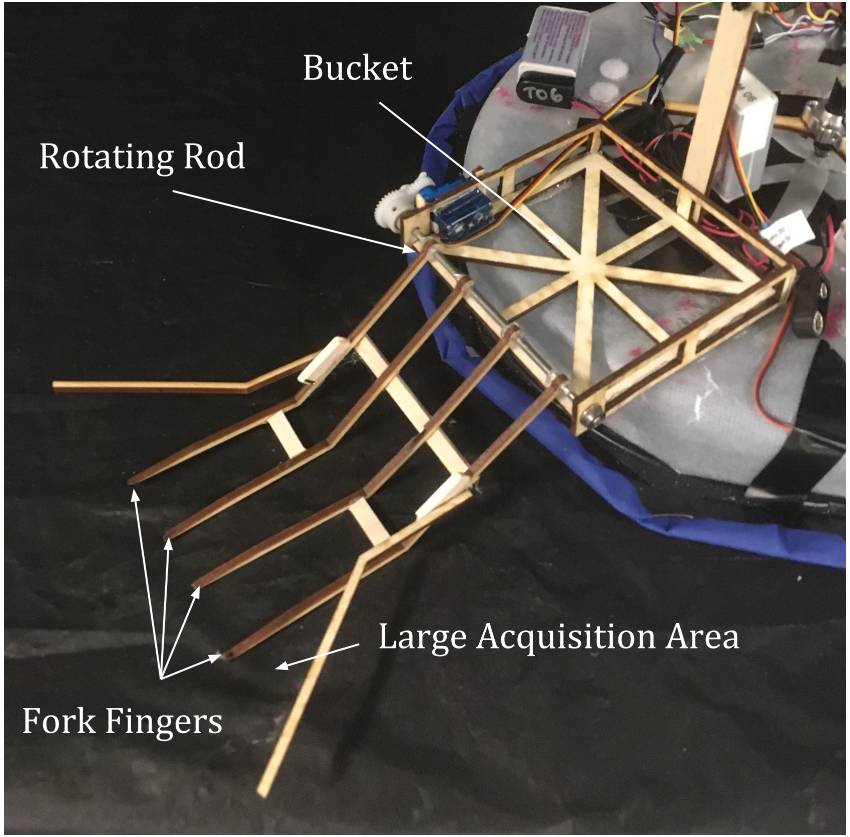




StarCCM simulation results showing pressure along bottom of shell

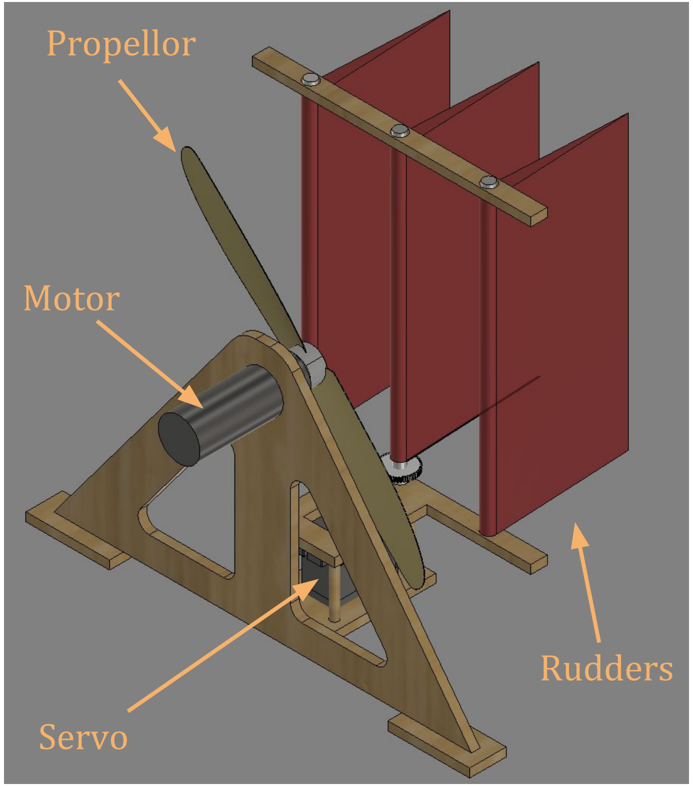
Payload Lifting Mechanism

- Bucket and fork design
  - Bucket can hold up to 2 payloads
  - Fork of thin wood pieces to minimize weight
  - 4 finger fork for large payload acquisition area
  - Single rotating rod
- Holds up to 3 payloads simultaneously
- Hope to deliver 8 payloads during competition time
- Camera on post can overlook payload retrieval
- Mechanism mass: 20 g

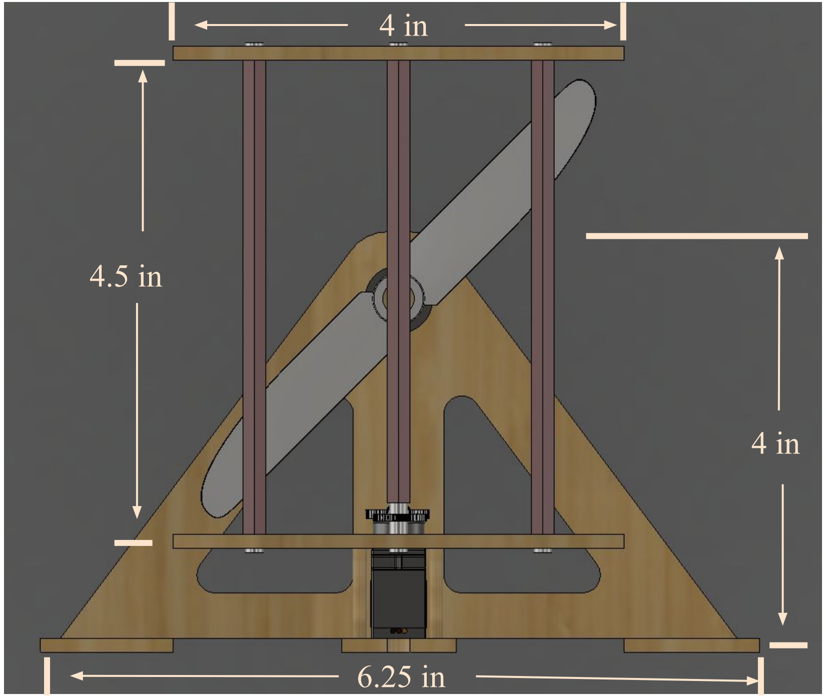


Propulsion System

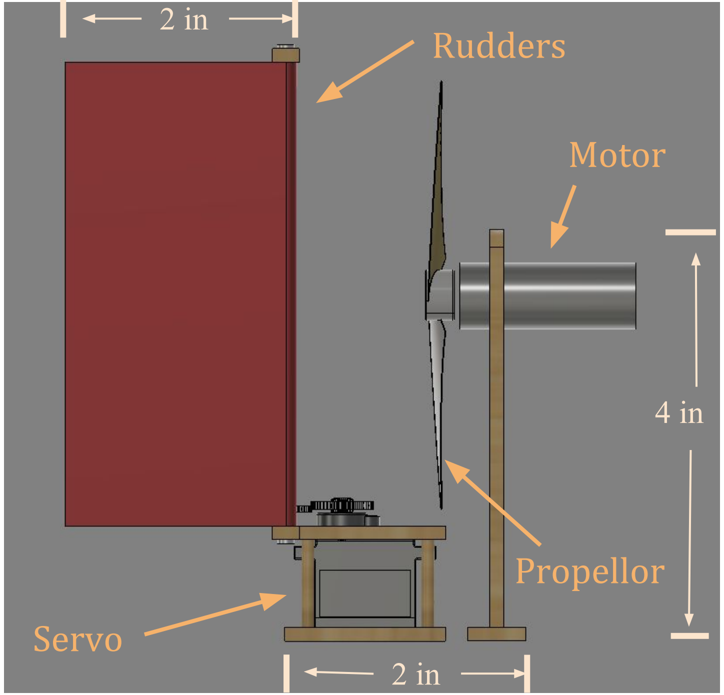
- Statically mounted fan
  - Minimizes torque by limiting rotating mass
  - Propeller applies pressure to rudders which are controlled by a servo
  - Capable of providing reliable steering
- Wood frame to minimize mass while being structurally sound
- Simplicity of assembly allows for easy modification of design
- Subsystem mass: 21g
- Subsystem power: 10.5 W



Propulsion System Design



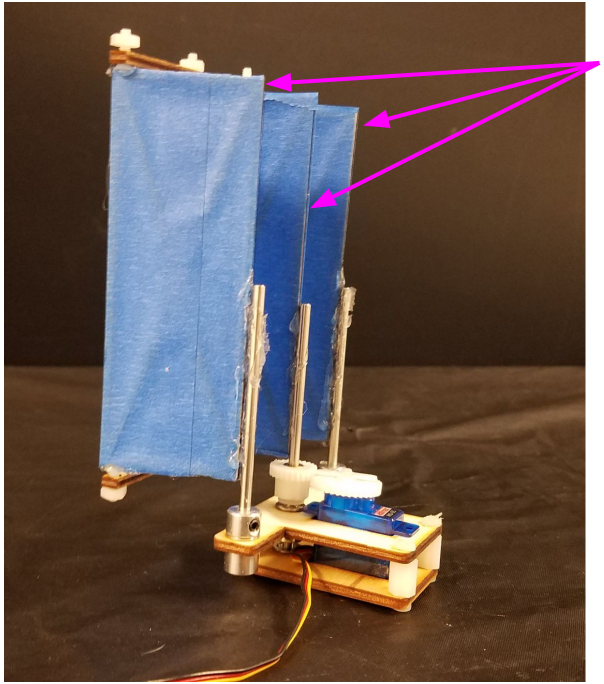
Back View



Side View

TEAM 6

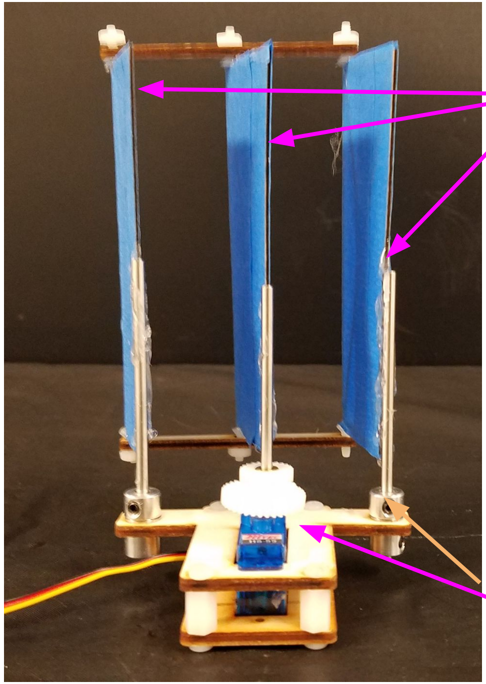
Rudder System Assembly



Rudders

Servo

Side View



Rudders

Servo

Front View

Power Budget

Item	Power (W)	Quantity	Total Power Supplied/Consumed (-) (W)
Servo	2.32	2	-4.64
Motor & Motor Control Board	8.8	2	-17.6
Arduino	0.72	1	-0.72
Camera	1.3	1	-1.3
Signal Lights	0.1	1	0.1
Total Power Consumption			**-24.4**
4 Battery Power Supply			**31.2**
Net Power			**6.8**

Mass Budget

- Total Mass of System: 560 grams
- Under 1 kg mass limit by 44%
- Under maximum generated lift (7.5 N) by 26%

Subsystem	Item	Mass (g)	Quantity	Total Mass (g)	Subsystem Total (g)
Shell/Lifting Fan	Shell	64.3	1	64.3	
	Lifting Fan Assy.	8	1	8	
	Propeller	2.4	2	4.8	
	Skirt	20.8	1	20.8	
					97.9
Rudder/Propulsion	Rudder Assy.	38.8	1	38.8	
	Rear Propeller Assy.	16.2	1	16.2	
	Propeller	2.4	2	4.8	
					59.8
Payload	Payload Acquisition Assy.	20	1	20	
	Payloads	50	2	100	
					120
Electronics	Camera Assy.	34.02	1	34.02	
	Signal Lights	5.32	1	5.32	
	Receiver	6.5	1	6.5	
	Arduino	31.3	1	31.3	
	Motor Control Board	17.5	1	17.5	
	Servo	8	2	16	
	Battery	26.4	4	105.6	
	Wiring	14.8	1	14.8	
	Motor	21.1	2	42.2	
					273.24
				Systems Total	**550.94**
Misc.	Glue/Tape	9.66	N/A	9.66	
				Overall Total	**560.6**

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					120

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Flight Test Trials

Test Type	Trial 1	Trial 2	Trial 3	Average
Straight Race (s)	39	51	32	40.7
Figure 8 Race (s)	32	39	29	33.3
Max Speed (ft/s)	5.53	5.36	5.68	5.5

Titan Environment

- Pressure: 1.45 atm
  - Higher pressure than Earth leads to more lift
- Temperature: 93.7 K
  - Very low temperature can lead to material freezing & fatigue/failure
- Atmosphere: 98.4% Nitrogen & 1.6% other gases
- Dense atmosphere and distance from sun leads to <1% sunlight at surface compared to Earth
- Rocky surface and potential methane precipitation

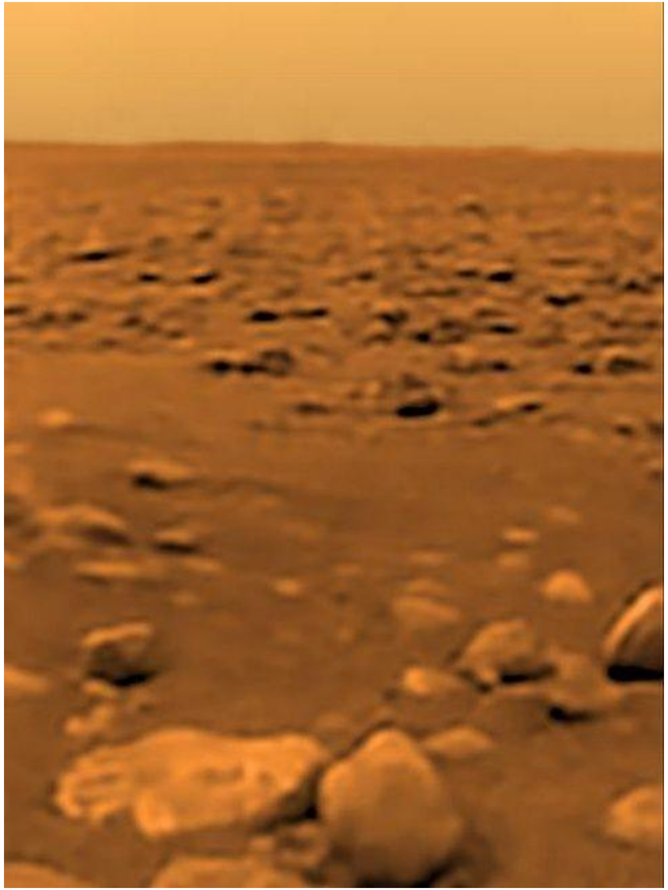


Image from NASA's Huygen's mission

Titan Design Modification

- RTG base station to recharge batteries
  - Eliminates mass on hovercraft
- Insulation and heating from battery cycling prevents battery freezing
- Magnesium shell and electronics cover
  - Prevents resin failure at extreme temperature
  - New shell weight of ~50 g vs 65 g prototype
  - Allows for added insulation mass
- Flat landing and exploration site
  - An obstacle avoidance program could be implemented

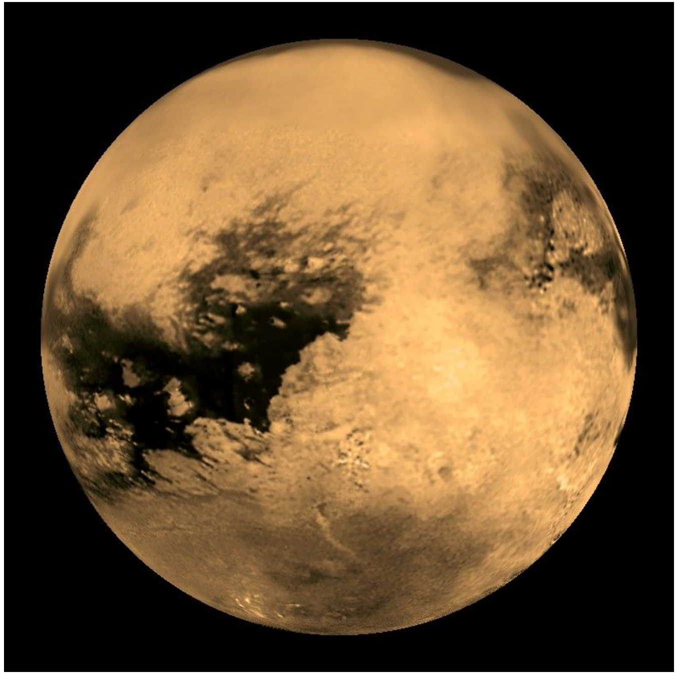
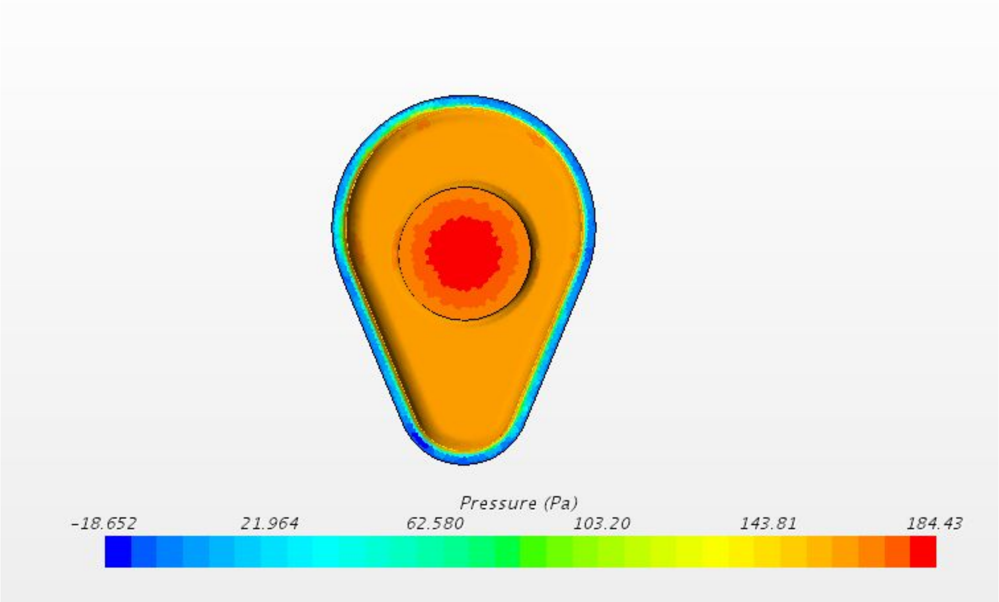


Image from sos.noaa.gov

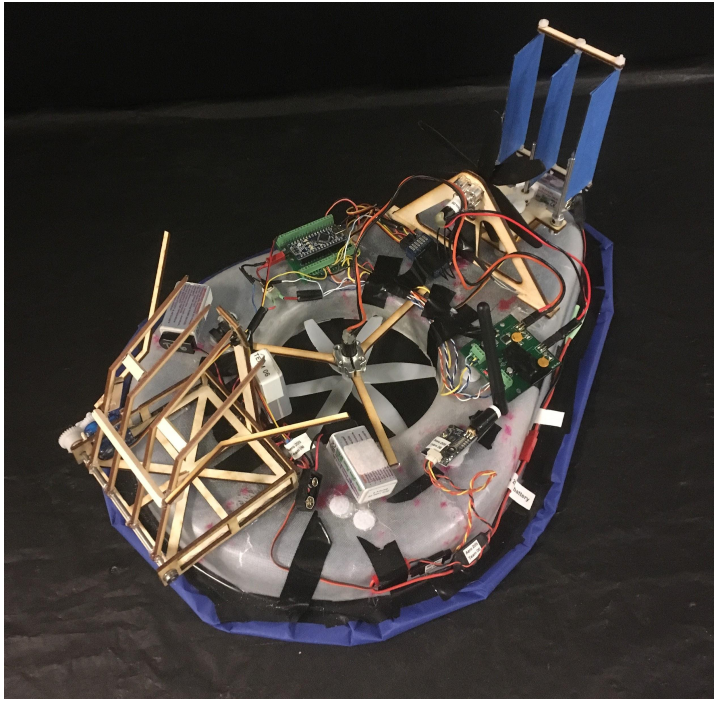
Titan Atmosphere Simulation Results

- Simulation run at 1.45 atm, and 95 K
- Same inlet velocities as before (1.25 m/s)
- Total Lift: 9.52 N
  - Higher lift than prototype
  - Allows for greater system mass



Conclusion

- Craft designed within mass, power, and size constraints
  - Maximum rigid length is 17 in
  - 4 batteries supply 31.2 W
  - 550 gram system mass (with two payloads)
  - Tested lift generation of 7.5 N
- Unique features of hovercraft gives competitive edge
  - Teardrop shape and low profile for external aerodynamics provides speed of 5.5 ft/s
  - Multiple forks for large payload acquisition area
  - Capable of carrying multiple payloads
- Designed adaptations to Titan
  - RTG base station for battery charging
  - Higher lift with a lighter magnesium shell



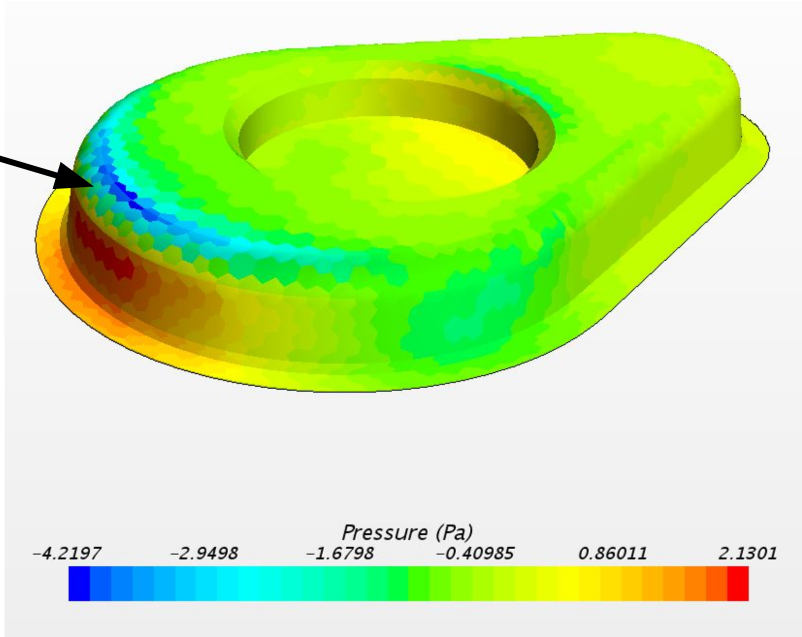
Thank You & Any Questions

Management Plans and Tasking

- Software Development:
  - Lead: Adolfo Apolloni
  - Secondary: Drake Rundell
- Shell Design and Layup
  - Leads: Reid Pringle & Jacob Crouch
  - Secondary: Adolfo Apolloni
- Mechanism fabrication and system integration
  - Lead: Jacob Crouch
  - Secondary: All others
- Mechanism Design
  - Leads: Drake Rundell & Matthew Winterstein
- Presentations & Deadlines
  - Lead: Adolfo Apolloni
  - Secondary: Matthew Winterstein

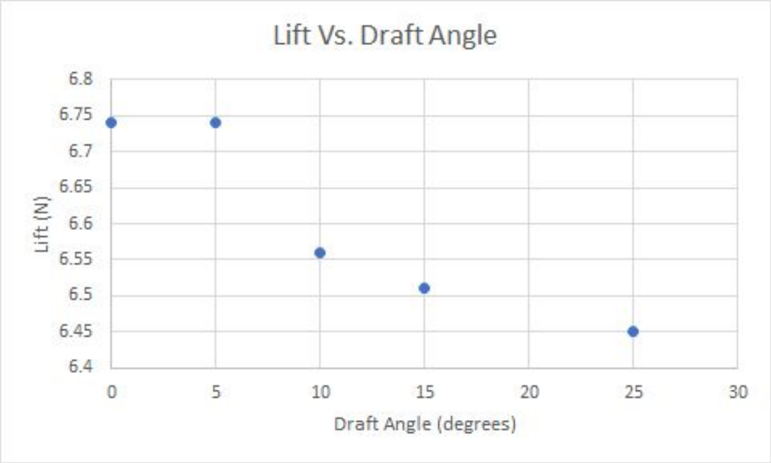
External Flow Simulation Results

- Simulated with a freestream velocity of 2 m/s
- Drag Coefficient of our shell: 0.4215
  - Drag Coefficient of circular shell: 0.5097
- For the size of our shell, drag is 0.0085 N
  - Generate 0.0294 N of Lift
- Negative pressures along leading edge of shell
  - Could pull the front upwards while in motion



Draft Angle and Height Simulation Results

Note: Simulation run with 0.05 in gap, 1.0 m/s inlet velocity and 5 degree draft angle



Note: Simulation run with 0.05 in gap and 1.0 m/s inlet velocity

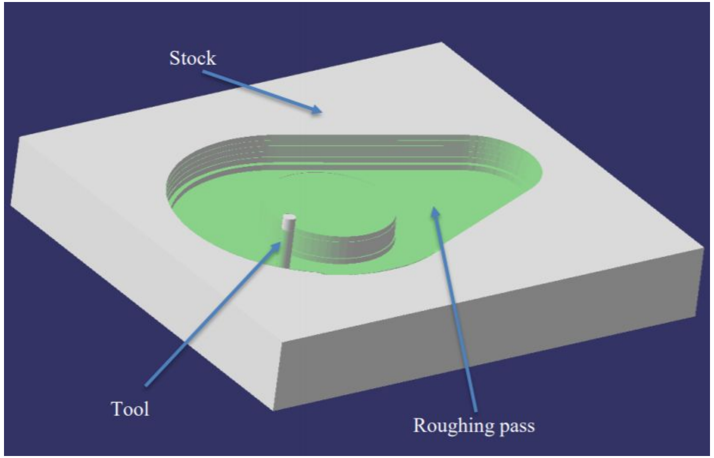
- Using a low draft angle (5 degrees vs. 25) yields 5% lift increase
- Height has an insignificant effect on Lift (<0.5% variation)
    - Thus a short (1.5 in tall) hovercraft shell was selected to reduce drag

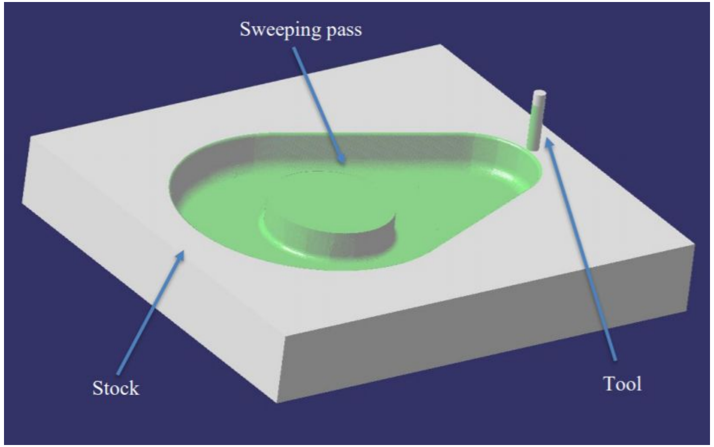
Programming

- Full code is not completed yet
- Arduino must:
  - Control two electric motors (Propulsion and Lifting)
  - Control two servos (Payload Mechanism and Rudder)
  - Receive input from radio controlled receiver
  - Illuminate three solid state LED's (Green, Red, White)
  - Flash one yellow LED when lifting motor is on
- Data filtering will be used to improve performance of programming

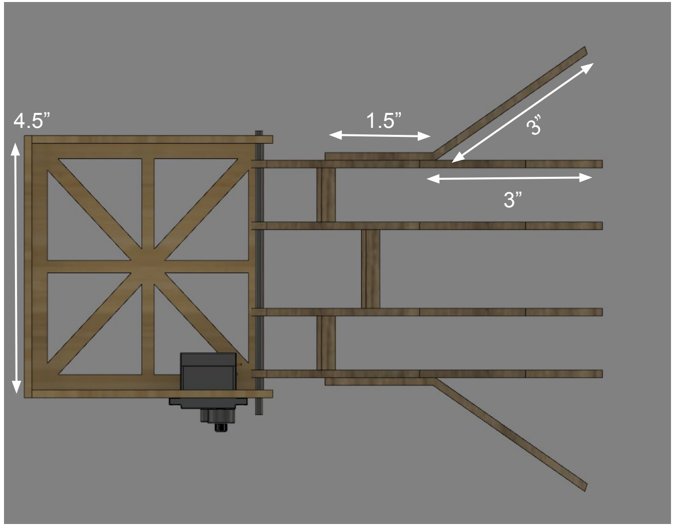
Shell Manufacturing

- CNC router was used to cut out shell from a 19.75” x 17.75” wax block
- To ease in the release of the shell from the mold and decrease the cracking of the mold we used Vaseline

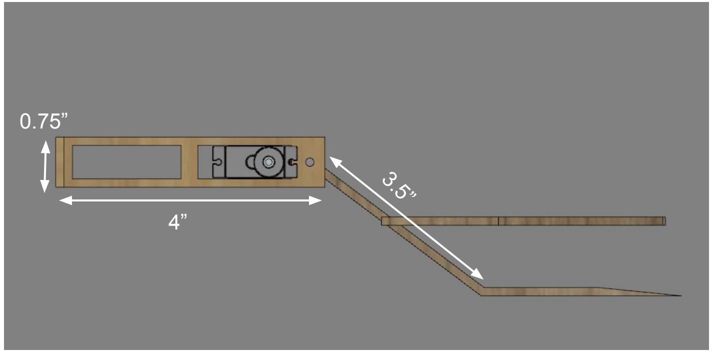




Payload Lifting Mechanism Design



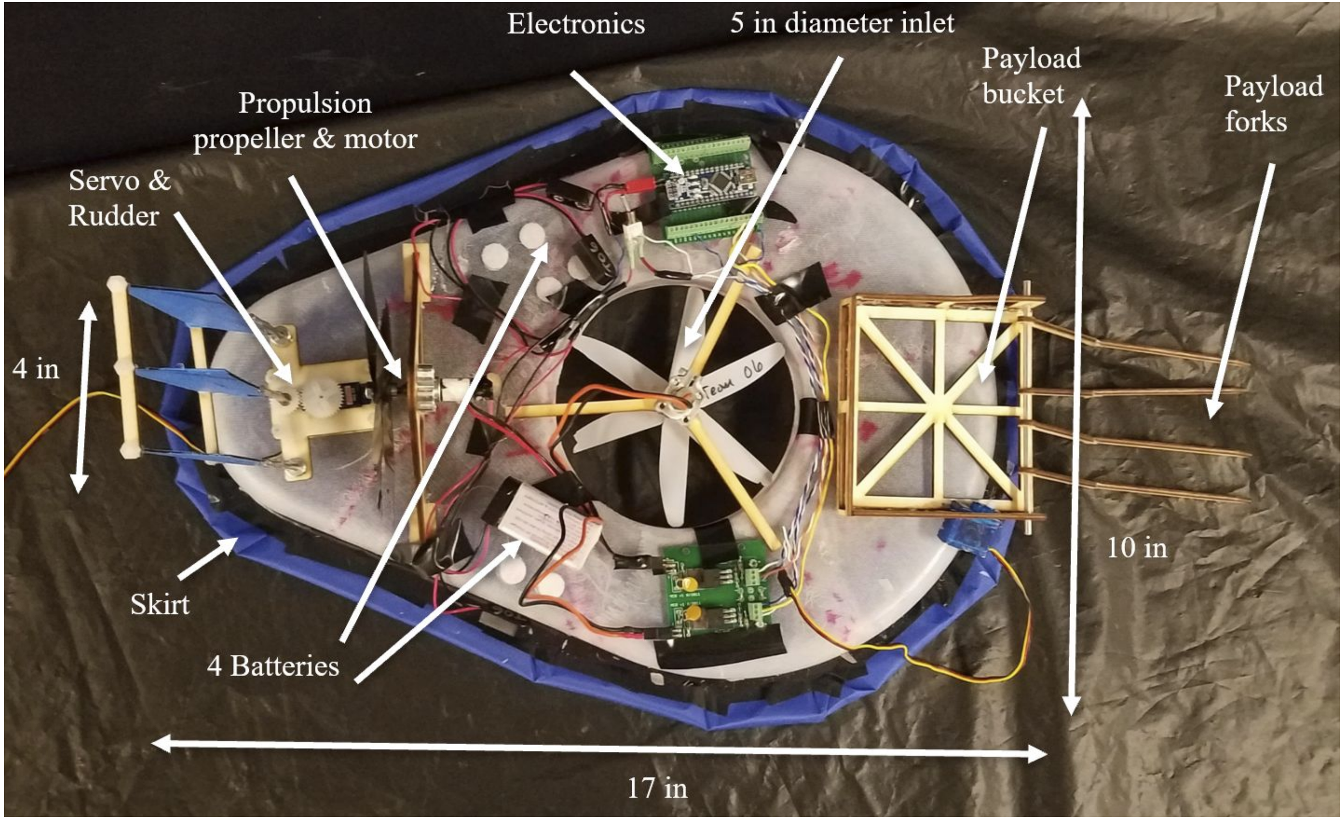
Top View



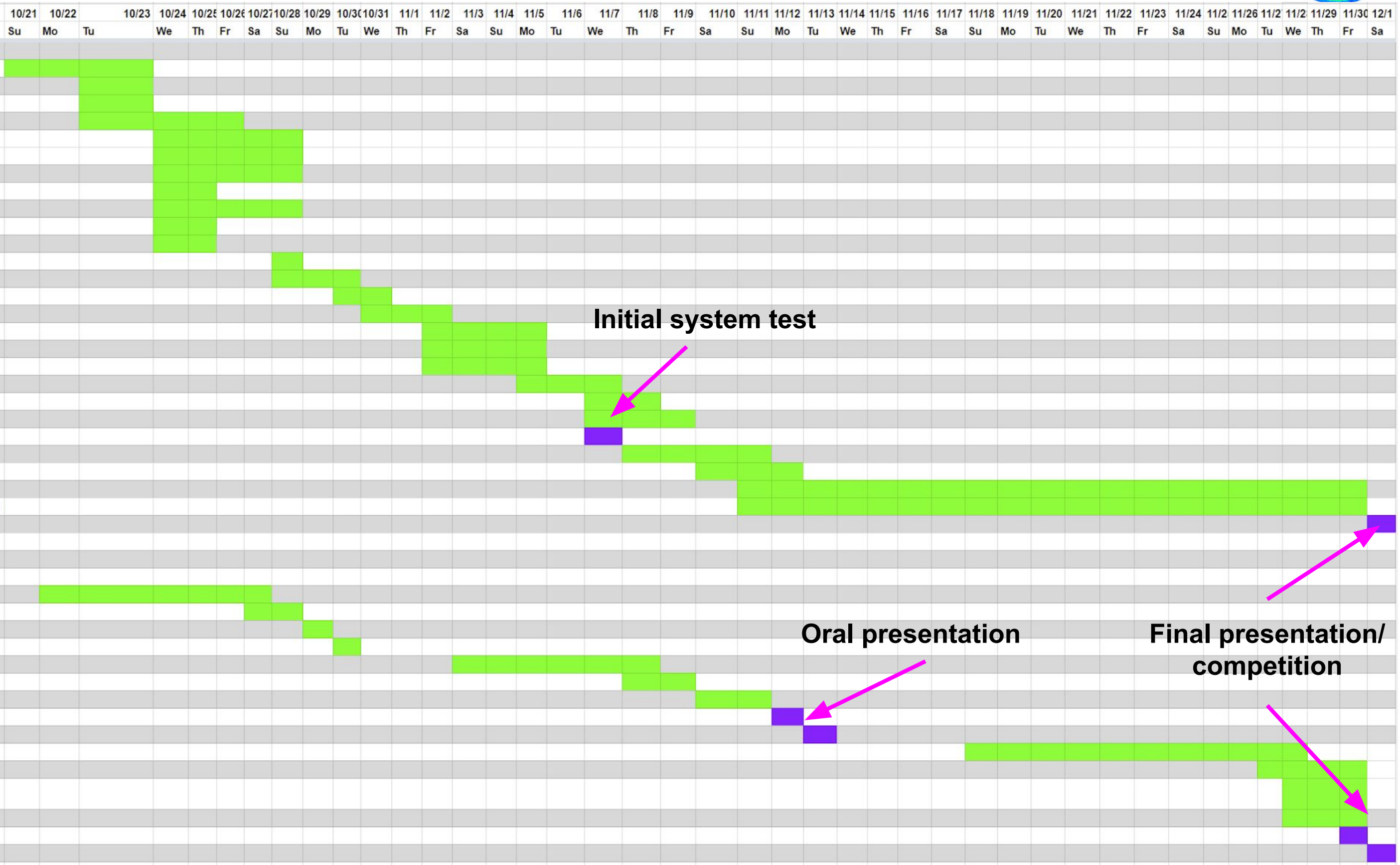
Side View

Hovercraft Prototype

- Tested lift with skirt: 7.5 N
  - Difference from simulation induced by smaller outlet gap (caused by skirt)
- Current overall craft mass: 410 grams
  - Not all systems have been integrated yet
- Currently capable of lifting and self-propelled flight



Schedule/Timeline



Task	Duration	Point Person
ROV Design and Build		
Overall System Brainstorming	3 Days	All Team Members
Compare notes and decide overall features	1 hour	Team
Select Shell Shape	30 minutes	Team
Model Shell Sizes and Determine Optimal Shell	4 hours	Reid
External Flow Simulation (Wind Tunnel)	3 hours	Jacob
CAD Lifting Mechanism	2.5 hours	Matthew
Design Propulsion Fan Mechanism	2.5 hours	Drake
Wireless Communication Code	1 hour	Adolfo
Determine Electronics Layout	1.5 hours	Adolfo
Make Power Budget	1 hour	Adolfo
Make Mass Budget	1.5 hours	Adolfo
Design Review Meeting	1 hour	Jacob
Finalize Subsystem Designs and integrate CAD	4 hours	All Team Members
Create Shell Mold	2 hours	Reid
Layup Shell	2 days	All Team Members
Laser Cut and Assemble Lifting Mechanism	2 hours	Matthew
Laser Cut and Assemble Propulsion Mechanism	3 hours	Drake
Install Fan On Shell	1.5 hours	Adolfo
Install Batteries and Electronics on Shell	1.5 hours	Drake
Install Plenum Skirt	1.5 hours	Jacob
Install Mechanisms	3 hours	Reid
Demo flight of hovercraft	1 hour	Matthew
Modify hovercraft per flight test	4 days	All Team Members
Test payload mechanisms	3 days	Matthew
Test Integrated Hovercraft	16 days	TBD Varies by Problem
Update Mechanisms per Tests	16 days	TBD Varies by Problem
Final Competition	N/A	All Team Memers
Reports and Presentations		
Draft Oral Design Presentation Slides	6 days	Adolfo - Lead
Review Oral Design Presentation Slides	2 days	Matthew
Practice Oral Design Presentation	1.5 hours	All Team Members
Oral Presentation Slides Due	Deadline	Adolfo
Draft Class Oral Presentation Slides	6 days	Reid
Review Class Oral Presentation Slides	2 days	Jacob
Practice Class Oral Presentation Slides	2.5 hours	Drake
Class Oral Presentation Slides Due	Deadline	Adolfo
Class Oral Presentation	Deadline	Adolfo
Draft Final Presentation Slides	10 days	Adolfo - Lead
Review Presentation Slides	4 days	Matthew
Review Final Presentation Slides with GSI and/or Washabaugh	1 hour	Drake
Practice Final Presentation Slides	4 hours	All Team Members
Final Presentation Slides Due	Deadline	Adolfo
Final Presentation	Deadline	Adolfo

Key: green = done blue = in progress red = not started purple = deadline

References

Introduction Solid Modeling and Computer Aided Manufacturing, *Aerospace 205 Lab Manuals,* Professor Peter Washabaugh, October 27, 2018.

Introduction To Simulation - Fluid Mechanics, *Aerospace 205 Lab Manuals,* Professor Peter Washabaugh, October 27, 2018.

Embedded Programming & Simple Sensors, *Aerospace 205 Lab Manuals,* Professor Peter Washabaugh, October 27, 2018.

Power Budgets, Components, Material Selection, Design, and a Camera, *Aerospace 205 Lab Manuals,* Professor Peter Washabaugh, October 27, 2018.

Schedule

- Fabrication & testing is currently on track
  - Electrical system is currently functional
  - Craft is capable of lifting and translational motion
  - All-non payload subsystems are fully assembled
- Expected entire system test by 11/15
- Meeting all targets on timeline/gantt chart