SIEMENS Unmanned Autonomous Submarine Team

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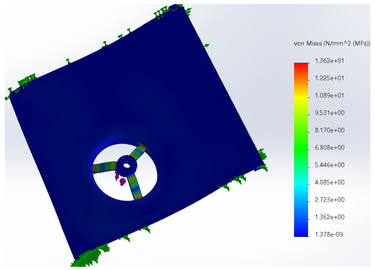
Executive Summary

Challenge/Objective: Underwater exploration is too dangerous for human exploration. A safer alternative is necessary.

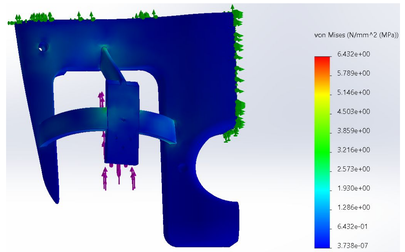
Design Solution: A fully autonomous submarine that features:

- Object tracking capabilities
- Efficient underwater navigation (5 DOF)
- Optimized energy usage for extended operations.

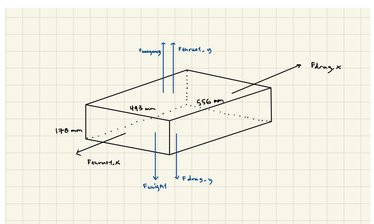
Chassis and Thrust Analysis



Von Mises front vertical motor bracket (7.5 kg force)



Von Mises lateral motor bracket (7.5 kg force)



$\Sigma F_x = F_{thrust} - F_d = 0 \qquad F_d = \frac{1}{2}\rho C_d v^2 A \quad F_{thrust} = ?$

$Frontal\ Area = 493\ mm\ x\ 173\ mm = 0.087754\ m^2$
$\rho = 1000\ kg/m^3 \quad C_d = 1.0\ (for\ rectangular\ prism)$
$v = 1.2\ m/s$
$Solving\ for\ thrust$
$\Sigma F_x = F_{thrust} - \frac{1}{2}(1000)(1)(1.1)^2(0.087754) = 0$
$F_{thrust} = 6.44\ kgf$
$Given\ two\ propellers,\ each\ will\ need\ 3.22\ kgf\ for\ max\ speed\ of\ 1.2\ m/s$

Propeller Thrust Analysis

$\Sigma F_y = F_{thrust} + F_{buoyancy} - F_d - F_{weight} = 0$
$V_{displaced} = V_{shell} + V_{enclosed}$
$V_{shell} = \frac{m}{\rho} = \frac{3.8\ kg}{1250\ kg/m^3} = 0.00304\ m^3$
$V_{enclosed} = \frac{\pi}{4}(0.127)^2(0.2032) = 0.002584\ m^3$
$V_{displaced} = 0.00304 + 0.002584 = 0.005624 m^3$
$\rho = 1000\ kg/m^3 \qquad g = 9.81\ m/s^2$
$F_{buoyancy} = \rho g V_{displaced} = (1000)(9.81)(0.005624) = 55.17\ N$

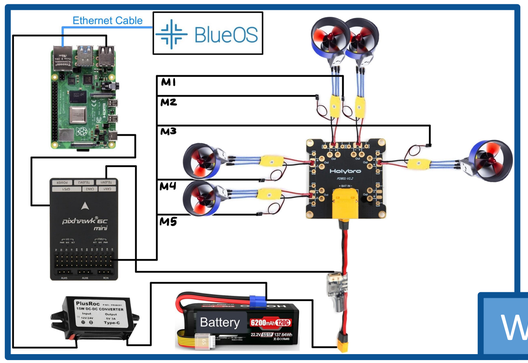
$F_{weight} = mg$
$Sub\ Mass = 4\ kg\ (shell) + 2.48\ kg\ (propellers) + 0.834\ kg\ (batteries)$
$Sub\ Mass = 7.314\ kg$
$F_{weight} = 7.314(9.81) = 71.75\ N$

$\Sigma F_y = F_{thrust} + F_{buoyancy} - F_d - F_{weight} = 0$
$Assuming\ zero\ velocity:\ F_d = 0$
$Solving\ for\ F_{thrust} = F_{weight} - F_{buoyancy} = 71.75 - 55.127 = 16.623\ N$
$For\ one\ of\ three\ vertical\ thrusters:\ F_{thrust} = 3mg = 5.541\ N$

$m = \frac{5.541}{3g} = 0.565\ kg\ of\ thrust\ required$

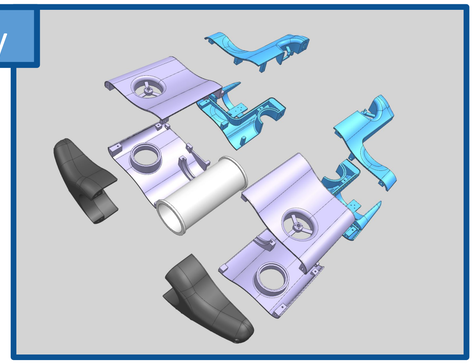
Hardware Performance

Power Efficiency	v= 1.2 m/s								
	Thrust (kg)	Voltage range	Current draw	Electrical Power Draw (MIN)	Electrical Power Draw (MAX)	Mechanical Power (MIN) @ 1.2 m/s	Mechanical Power (MAX) @ 1.2 m/s	Min Efficiency	Max Efficiency
Amazon 2.4 kg IPX8 Underwater Thruster Nuhikap	2.5 kg	24 V	11.7	N/A	280.8	N/A	36.8	N/A	13.10
U5 Brushless Thruster (Underwater thrusters)	2.18 - 6.72 kg	12 -24 V	15 - 33 A	180	792	32.1	98.9	17.82	12.49



Wiring Diagram

CAD Assembly

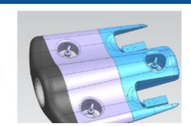


Design Parameters

Parameters	Specifications
Max Depth	1.5 m
Endurance	10 minute operating time
Speed	1.2 m/s max speed
Navigation	INS
Communication	Tethered
Power Source	On board 6s Lipo battery 6200 mAh
Weight	7.3 kg

System Communication

BlueOS



Autonomation: camera -> BlueOS -> program -> x/y coordinates -> error from center of frame -> movement commands -> pixhawk -> submarine

Future Improvements

- Fine tuned propulsion control
- Integrated software for tetherless design
- Improved waterproofing design for ease of use

Acknowledgements

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