1.4 Target Summary

1.4.1 Introduction

Targets and metrics are defined from the functions generated in the functional decomposition with specific attention to customer needs. Targets are specific quantifiable values the glider needs to be able to meet to be considered successful by the team. Metrics are how targets are measured. To develop these criteria, the base functions of the glider were benchmarked with existing gliders and combined with customer needs.

equation, $L = B * \cos(\xi)$ we can see the relation between the Lift L, net buoyancy B, and angle of attack ξ.

Drawing from the research paper mentioned above, the metric for regulating drag was also derived. At the same angle of attack of 5 degrees drag forces ranging from 8N to 28N were simulated with 20N as a high-fidelity value producing a drag coefficient of 3600. Note that for drag we would like to err on the lower side of this value unlike for lift (Tian, 2021).

To submerge the underwater glider, ballast tanks will be utilized that will increase the weight of the whole glider. The value for the metric is derived from the requirement that for the glider to submerge it must exceed the neutral buoyancy effect that would be experienced at the surface of the water. A small percentage of the total glider weight was selected to ensure descent to the target depth.

For the underwater glider to ascend, the ballast tanks will decrease the weight of the whole glider for its return to the surface. The selected value for the metric was 100% of the stored weight as this will allow the glider to return to the surface in a state of neutral buoyancy.

The metric for generation of forward thrust was derived from research performed by in the creation of a low-cost underwater glider for shallow conditions as well as the need for the underwater glider to maintain its own course and bearing while in the water. An effective horsepower in the range of .08 - .15 horsepower (Inprasetyoubudi, 2023) was selected based on the performed research and represents contribution of all components in moving the underwater glider to a given speed.

Table 2 lists out the functions of the underwater glider that were deemed to be mission critical for its success and their respective targets and metrics. Improvement direction is defined as follows: if the direction is upward, we aim for the target value or greater, but if it is

1.4.2 Targets, Metrics, Derivations

To create the targets, metrics, and derivations for the underwater glider several sources and logical ideation were considered. Prior research has been a key component of benchmarking. Articles used as part of this benchmarking are listed in references. Specific targets were provided by Boeing, these are considered critical targets as they are customer required targets.

1.4.3 Derivation of Metrics

The storage of data is a critical function of our glider. One of our key goals is observing the surrounding environment. Due to the difficulty of sending and receiving signals underwater, it is crucial that our glider possesses the ability to store the data it takes in until the end of its trip. The team plans to use a one-terabyte hard drive to store the data collected by the glider on each of its trips.

Storing power is necessary for the glider to function and perform its necessary tasks. Drawing on the research paper Optimal Lift-Drag Ratio of Underwater Gliders a metric was able to be derived to validate this function in energy consumption, joules, per meter (Tian, 2021). Simulations at a glider speed of 1 meter per second, our glider's goal speed, consumed an average of 150 J/m at glide angles ranging from -20 degrees to -30 degrees. Because the duration of our glider's trips has not been determined yet, we will measure the capacity in energy consumption, joules, per meter.

The lift of the glider will produce lateral motion, so it was important we derived this metric accurately. Using research paper Optimal Lift-Drag Ratio of Underwater Glider a lift force of 100N and lift coefficient of 4100, at an angle of attack at 5 degrees, was among the top ranges found (Tian, 2021). This allowed the glider to travel large distances efficiently. Using downward, we aim to be at or below the target. Table 3 is shortened for brevity, but the full table can be found in Appendix C: Target Catalog.

Table 2: Functions, Targets, and Metrics

#	**Function**	**Metric**	**Target**	**Improvement Direction**
1.	Store Power	Capacity	150 J/m	↑
2.	Store Data	Memory	1 TB	↓
3.	Endure Fatigue Stress	Cycles	1,000	↑
5.	Regulate Drag	Drag Coefficient	3600	=
6.	Control Lift	Lift Coefficient	4100	=
7.	Increase Buoyancy	Weight of water stored	5 - 10% of glider weight	↑
8.	Decrease Buoyancy	Weight of water stored	Expel 100% of stored weight	↓
9.	Withstand Pressure Difference	Water Pressure	0.6 MPa	↓
10.	Generate forward thrust	Effective Horsepower	0.08 - 0.15 HP	↑

1.4.4 Verification of Metrics

The main method used to test and validate our targets and metrics will be by constructing a glider prototype. This entails designing, fabricating, and launching the prototype with all sensors required to verify each metric. This will test the various components, control systems, and design ideas of the glider.

The power storage can be verified in the prototype by using test equipment to take readings of the voltage and current. These readings can then be used to calculate the power stored, at which point the expected power output can be compared with the actual power output of the battery.

Data storage capacity can be validated by using computer software to verify the integrity of the storage device. Scans can be completed to check the drive for potential errors that may arise.

Fatigue stress of the prototype can be verified through a combination of computer modeling and actual testing. Computer modeling will perform the calculations to show the stresses that the underwater glider will undergo, especially with repeated diving. This data can then be taken to account for the prototype which will be subjected to multiple dives to ensure that the physical model can withstand the stress of repeated submersion. Inspections will be done for any cracks or other physical deformities during this process.

The lift and drag coefficient can be calculated through modeling and then physically verified through measurements of flow conditions, such as pressure, density, and speed of fluid, when the glider is powered and moving within the water.

The measured experimental data will be compared to hand calculations and software generated data. Software's such as MATLAB and COMSOL will be used to calculate the glider kinematics and fluid dynamics over the glider surface respectively.

For testing glider lift three methods of verification will be used as it is one of the most important metrics. The lift of the glider will drive horizontal motion and propel the glider forward. Two methods will use computer generated values form MATLAB and COMSOL. MATLAB modeling the glider kinematics will display the path of the glider at various angles of attack and the lift can be derived from this motion. COMSOL uses advanced fluid dynamics calculations across the surface of the wings. And lastly experimentally, by tracking the glider's motion in the water real time data can be acquired on the lift generated. Another experimental method, Particle Image Velocimetry (PIV) could be used to experimentally verify lift and drag coefficients.

Testing the forward thrust of the glider can be tested and validated by measuring multiple parameters: the speed at which the glider moves underwater, the drag the glider experiences, and the force generated by the glider's propulsion. Speed can be measured via an accelerometer. Computer modeling can show the behavior of the glider when subjected to different conditions and can be confirmed through actual measurements of the speed at different depths. This speed comparison can then be measured against what is simulated for verification of results.

Increase and decrease of buoyancy can be examined through computer modeling. Computer models can show the different buoyancy forces that the glider will experience at various depths. If the sum of the glider and the stored weight in the ballast exceeds the buoyancy force in the computer model, then it can be inferred that the glider will be able submerged. These values can be confirmed in prototyping by measuring the weight of the glider when extra weight is stored and measuring the actual depth that the glider submerges to. Real time calculations can also be done by using accelerometer data to determine the rate at which the glider is moving up and down through the water column. For example, if the glider was not accelerating at all it would be considered neutrally buoyant.

Pressure constraints on the glider can be verified by confirming that the glider can withstand the difference in pressure when it submerges to a selected depth for a period, ascends back to the surface, and is checked to ensure that there are no physical deformities present on the vessel. Finite element analysis can also be performed as a preliminary check to ensure no components will deform.

To measure horsepower simple energy equations can be applied to the glider to determine the power output. The equation that will be used to calculate power output of the glider is $W = F \cdot d$ where W is work, F will be some resultant force, and d is the distance traversed by the glider. One horsepower is defined as $1\text{HP} = \frac{(1\text{lb})(\ 33{,}000\text{ft})}{1\ \text{minute}}$. Velocity could be measured via an accelerometer placed within the glider. Since the force on the system is a function of the acceleration and the mass is known, the accelerometer could be applied to this as well.

1.4.5 Non-Function Targets and Metrics

Some targets and metrics don’t necessarily pertain to the function of the glider but are important to specify. This includes the weight and the dimensions of the glider. These are essential to create simulations and specify characteristics of the glider.

The weight requirement should not be incredibly important for the glider since it will be essentially weightless in the water, but it should be able to be easily transported by humans.