Critical Targets and Metrics:

Function:	Metric:	Target:
Control Airflow	Increased lift-to-drag ratio	Increase by 10%
Combats Aerodynamic Load	Remain below failure strength during operation	Using a safety factor, the hardtop has no failure during all operating conditions.
Support Needed Weight	Remain below failure strength during service and maintenance	Using a safety factor, support the weight of a 200 lb. serviceperson.
Resist Plastic Deformation	Remain within elastic region Stress Induced (sigma = P/A)	Shear stress < Ultimate Tensile stress < Ultimate Max Stress Induced (when considering whole hardtop area): 153 Pascals or 0.022 psi Max Stress Induced (when considering rough area of service person (2ft x 2ft area): 4788 Pascals or 0.694 psi
Regulate Deflection Under Load	Deflection	Support needed force/mass without failure Max deflection 0.25”

Derivation of Targets/Metrics

We determined the critical targets and metrics through our functions determined previously. These critical targets and metrics are the most important to ensure we can satisfy our customer's needs. Ensuring that the lift-to-drag ratio is increased was a direct request from Intrepid. The ability to withstand all forces is also crucial to ensure that the hardtop can be implemented. We also determined non-critical targets and metrics that are listed in the appendix of this evidence manual. These non-critical targets and metrics are required in order to ensure the new hard top works with the 409 Valor, allowing for success of the design.

How Targets and Metrics Were Determined:

For the “Control Air flow” function, the metric was determined since the new design must be improved compared to the current hardtop. Through calculations and modeling of a similar NACA airfoil we determined that the target for this function would be an increase in lift-to-drag ratio of 10%. We will adjust this value as we research more. We must also consider channel flow between the vessel and the hardtop during these calculations.

The function “Combats Aerodynamic Load” has its metric defined by taking into consideration the safety of the individuals in the boat since the hard top must not fail during operation. This includes a factor of safety of 2, according to Intrepid.

The metric for “Support Needed Weight” was derived by knowing that a service person will have to operate while being on the hardtop, leading to the testing method with the respective factor of safety of 2 to avoid failure. The weight of the service person as well as necessary equipment for maintenance and equipment already attached to the hardtop for operation.

For “Resist Plastic Deformation”, we calculated values for the area of the current hardtop and for the load generated from the service person plus a factor of safety of two. To calculate the stress over the correct amount of hardtop area, we considered a 2-foot by 2-foot section to be representative of the amount of area that the service person’s load would be distributed over, and consequently generated stress values by using the expression shown above in the targets and metrics table. Given the calculated stress values, we can ensure that the new design will not fail, as the calculated stress does not come close to reaching the yield stress of the current materials. Even when considering extraneous load sources like the service person’s tools or the radar equipment that will be mounted on the hardtop, the stresses generated stay below the limits.

We derived the metric for “Regulate Deflection Under Load” to be measuring the stress values with apparatuses, the values for stresses and the required resistances were provided by Intrepid. We chose 0.25” for the deflection value because this is the manufacturing tolerance used by Intrepid.

Discussion of Measurement:

Most of the resources needed to test and validate the above targets will be mathematically oriented. This means that we will need to reference textbooks, class notes, and other educational information to find relationships for the many parameters we are testing and validating. For withstanding the weight of a service person while accounting for the safety factor, we will need to conduct force analysis using free body diagrams as well as test the current and prospective materials for their respective engineering characteristics. For the increased lift-to-drag ratio target, we will need to find a relationship for lift against the hardtop, modeled as a NACA airfoil, to get a number for the current hardtop. We can validate the target of increased lift-to-drag ratio once these numbers are calculated and changes are made.

Method of Validation:

Various testing procedure will be used for the targets and metrics listed above. We will compare the current hardtop used and find a NACA airfoil with a similar profile and improve on it in order to increase the lift-to-drag ratio (sometimes called the aerodynamic or L/D ratio) generated by the hardtop. Using the same profile, analysis will be performed using equations learned in aerodynamics to ensure the new hardtop can withstand the loads encountered during operation. Further, we will perform analysis on the materials selected to ensure that the hardtop can support the weight of the service person performing maintenance. The hardtop needs to resist plastic deformation and we will perform deflection calculations to ensure the hardtop has the proper rigidity.

In order to test lift-to-drag ratio increase, we will find an airfoil with similar properties to the current hardtop and calculate current lift generated for comparison. The coefficient of lift can be increased because density, speed and area should all be kept constant during our experiment. A higher coefficient of lift can be completed from changing airfoil characteristics. This testing will also require testing drag because that is another aspect of lift-to-drag ratio. We must also ensure we avoid flow separation during operation to avoid detrimental air effects.

Calculating the coefficient of drag and the area of the hardtop will be important. The area of the hardtop that encounters air flow will need to be kept to a minimum to achieve the most efficiency. If less area is encountered, the overall force due to drag will be lower. This can be achieved by optimizing the angle of attack that the hardtop is oriented in during the regular usage of the boat or under acceleration or constant speed conditions, so it may be more beneficial to keep the drag coefficient and area exposed to wind to a minimum rather than increase coefficient of lift. Increasing the coefficient of lift may help the vessel to stand out of the water, however, it may also increase the overall drag due to the increased area of the hardtop exposed to wind and may cause the boat to accelerate at a slower rate or lower stability at higher speeds. Values must be calculated to validate whether increasing lift or decreasing drag will be more beneficial for the boat running performance. Overall, we must find the highest lift-to-drag ratio that is achievable for the hardtop.

Further, testing whether it fails during regular operation, we will need to perform analysis of the aerodynamic forces and moments on the hardtop. This should be performed at the highest velocity currently achievable by the vessel to make sure it can handle the most extreme conditions. The lift, drag, axial and normal forces will all need to be calculated and these forces will be carried forward to find moment about the leading edge and quarter chord length. Similarly, calculating failure during service and maintenance requires analysis of forces and moments on the most extreme parts of the hardtop and making sure that the materials are well below failure during this process. For testing deflection, we will assume a small distributed load of the force calculated previously, whether weight of service person or forces during operation, and use deflection equations to calculate the theoretical deflection on the hardtop.

Summary

The table below shows a summary of all the critical targets our project is expected to hit. A complete catalog of targets, metrics and functions is in the appendix for more detail. These targets are the most critical to this project. The first target is necessary to ensure our design improves on the aerodynamics of the hardtop. The second is to ensure that it does not fail during normal operation. The third ensures that maintenance workers can safely perform their jobs when required to stand on the hardtop. The fourth target ensures that the hardtop has a similar lifecycle to the boat and the last one ensures that the hardtop does not deform.

Increase lift-to drag ratio by 10%	Using a safety factor, the hardtop has no failure during all operating conditions	Using a safety factor and an estimated service person's weight of 200lbs, the hardtop will not fail	Shear stress < Ultimate Tensile stress < Ultimate Max Stress Induced: 4788 Pascals or 0.694 psi	Support needed force/mass without failure Max deflection 0.25"

Targets and Metrics:

Function:	Metric:	Target:
Control Airflow	Increased lift-to-drag ratio	Increase by 10%
Combats Aerodynamic Load	Remain below failure strength during operation	Using a safety factor, the hardtop has no failure during all operating conditions.
Support Needed Weight	Remain below failure strength during service and maintenance	Using a safety factor, support the weight of a 200 lb. serviceperson.
Resist Plastic Deformation	Remain within elastic region Stress Induced (sigma = P/A)	Shear stress < Ultimate Tensile stress < Ultimate Max Stress Induced (when considering whole hardtop area): 153 Pascals or 0.022 psi

		Max Stress Induced (when considering rough area of service person (2ft x 2ft area): 4788 Pascals or 0.694 psi
Regulate Deflection Under Load	Deflection	Support needed force/mass without failure Max deflection 0.25”
Length	Analyze current length vs new design length	Retain current hardtop length value (15.25 feet)
Width	Analyze current width vs new design width	Retain current width (8.25 feet)
Mass	Analyze current mass vs new design mass	Less mass than current hardtop