Blended Wing Body Seaplane System
Final Report

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COLLEGE OF ENGINEERING
Craig M. Berge
Engineering
Design Program

THE NEW NOSE COMPANY, INC.

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1.0	First Draft of Final Report	May 6, 2025	

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The New Nose Company, Inc.

1.0 Introduction

This report presents the culmination of our two-semester preliminary design study of a Blended Wing Body Seaplane—an innovative concept that merges aerodynamic efficiency with waterborne operational capability. As the first known design of its kind, our project explores the viability, performance, and integration challenges of combining a BWB airframe with marine flotation. The report details our design methodology, including sizing, modeling, and verification procedures, and presents the final results. Subsequent sections cover system descriptions, performance analyses, verification data, budget breakdown, and lessons learned to provide a comprehensive overview of the design process and outcomes.

1.1 Final Report Introduction

Our goal is to develop a preliminary design for an amphibious, blended wing body (BWB) aircraft tailored for offshore missions, including deploying divers, submersibles, maritime surveillance, and search and rescue operations. The New Nose Company aims to address the limitations of current aircraft, which often lack the necessary range, amphibious capability, or efficiency for these tasks. By integrating a BWB configuration with an integral catamaran hull, this design offers improved aerodynamic efficiency, stability, and payload capacity. The objective is to compile initial sizing information to define aircraft dimensions while achieving a high lift-to-drag ratio. CFD and wind tunnel testing will validate performance, and design studies will refine a feasible, low-cost solution for versatile offshore operations. Each team member will contribute by focusing on structural layout, airframe design, hull layout, SOLIDWORKS modeling, stability and control, and CFD analysis. This report provides a structured overview, including the project description, system verification plan, design documentation, wind tunnel testing, and computational fluid dynamics analysis, offering a comprehensive foundation for future development.

1.2 Project Description

This study investigates the aerodynamic characteristics of two configurations of a Blended Wing Body (BWB) amphibious cargo seaplane: a baseline design and a variant equipped with catamaran-style floats. These configurations are intended for long-range offshore mission support. The goals of this project are to optimize the design to meet our performance requirements, to increase our coefficient of lift and decrease our coefficient of drag, to quantify the drag penalty introduced by the floats and to explore strategies for drag reduction and improved longitudinal stability. Experimental methods included Computational Fluid Dynamics (CFD) simulations and low-speed wind tunnel testing using a force balance and 3D-printed models. Aerodynamic performance was evaluated over a range of angles of attack at constant Reynolds numbers, yielding key metrics such as lift, drag, pitching moment coefficients, and lift-to-drag ratios. The results highlight the aerodynamic penalties of the float configuration and reveal opportunities for reducing drag while enhancing lift and stability through design refinements. These findings demonstrate the feasibility of optimizing the BWB seaplane concept for improved performance in future iterations.

1.2.1 Requirements

The requirements discussed here are set out to accomplish the required mission profile while meeting specific standards with similar flight performance capabilities as a C-130H aircraft. With a targeted range of 1000 nautical miles and a max payload of 40,000 lbs. The cruising speed is set for 300 knots at an altitude of 10,000 ft with a max speed of 330 knots at a ceiling of 20,000 ft. Take-off and landing speed of 85 knots with distances meeting FAR 25 standards. Takeoff distance on land and water of 3,250 ft and 3,100 ft with landing distance on land and water of 2,700 ft and 2,800 ft. Lastly, the sea level rate of climb must achieve FAR 25 standards with a rate of climb of 2,500 feet per minute.

1.2.2 MVP 1 Description

The MVP1 was designed to test three different float types that will be incorporated into our MVP2. The floats are designed to displace water when landing which subsequently provides buoyancy for the aircraft. The three different float types were constructed with a similar front, however, the aft ends are what sets them apart. Float Type I was constructed with an aft end that converges back to a sharp point. Float Type II's aft is terminated to a flat end. Lastly, Float Type III is designed with a curved aft. The front of each float is designed with the idea of guiding the water out and around the float while reducing the splashing effects of water onto the aircraft. The three designs were tested in similar conditions to identify which float type would produce the least amount of drag during flight.

1.2.3 MVP 2 Description

MVP2 was designed to compare the drag penalties between our control BWB seaplane and our experimental BWB seaplane. The experimental BWB seaplane includes our selected Floats which have been integrated into the underside of the model. The control model uses the same body and wings without floats. Float Type I being the most desirable design was used in MVP2. With the two designed models, wind tunnel and computational fluid dynamic (CFD) testing were performed at various angles of attack with constant dynamic pressure. The results from both tests were compared to test the accuracy of CFD.

1.2.4 Use Cases

The data obtained in this project will help guide the design of the BWB seaplane to meet the requirements. The BWB seaplane will be used for land-to-water flights, supporting offshore cargo delivery. The groundbreaking design of the blended wing body aircraft is used to reduce a major source of drag generated by the fuselage, by forming it into an airfoil shape. This allows for greater lift generation with and reduction in drag. Ultimately increasing the aircraft's range while allowing for heavier cargo capacity.

2.0 System Description and Block Diagram

Our goal is to develop a preliminary design for an amphibious, blended wing body (BWB) aircraft capable of versatile offshore operations, including loading and unloading payloads both on land and at sea, deploying divers, and conducting search and rescue missions over long-range capacities. Initial sizing information has been compiled to determine critical dimensions and achieve a high lift-to-drag ratio. CFD and wind tunnel testing have validated our preliminary designs and informed iterative improvements. Individual team members specialized in structural layout, airframe layout, hull layout, SOLIDWORKS modeling, stability and control, and computational fluid dynamics analysis. These collaborative efforts have transformed a highly conceptual design into a feasible model that aligns with regulatory constraints.

The innovative BWB seaplane developed by The New Nose Company addresses significant gaps in current offshore mission capabilities by combining a blended wing body configuration with an integral catamaran hull, enhancing aerodynamic efficiency, stability, and payload capacity. This groundbreaking design offers substantial benefits across multiple contexts:

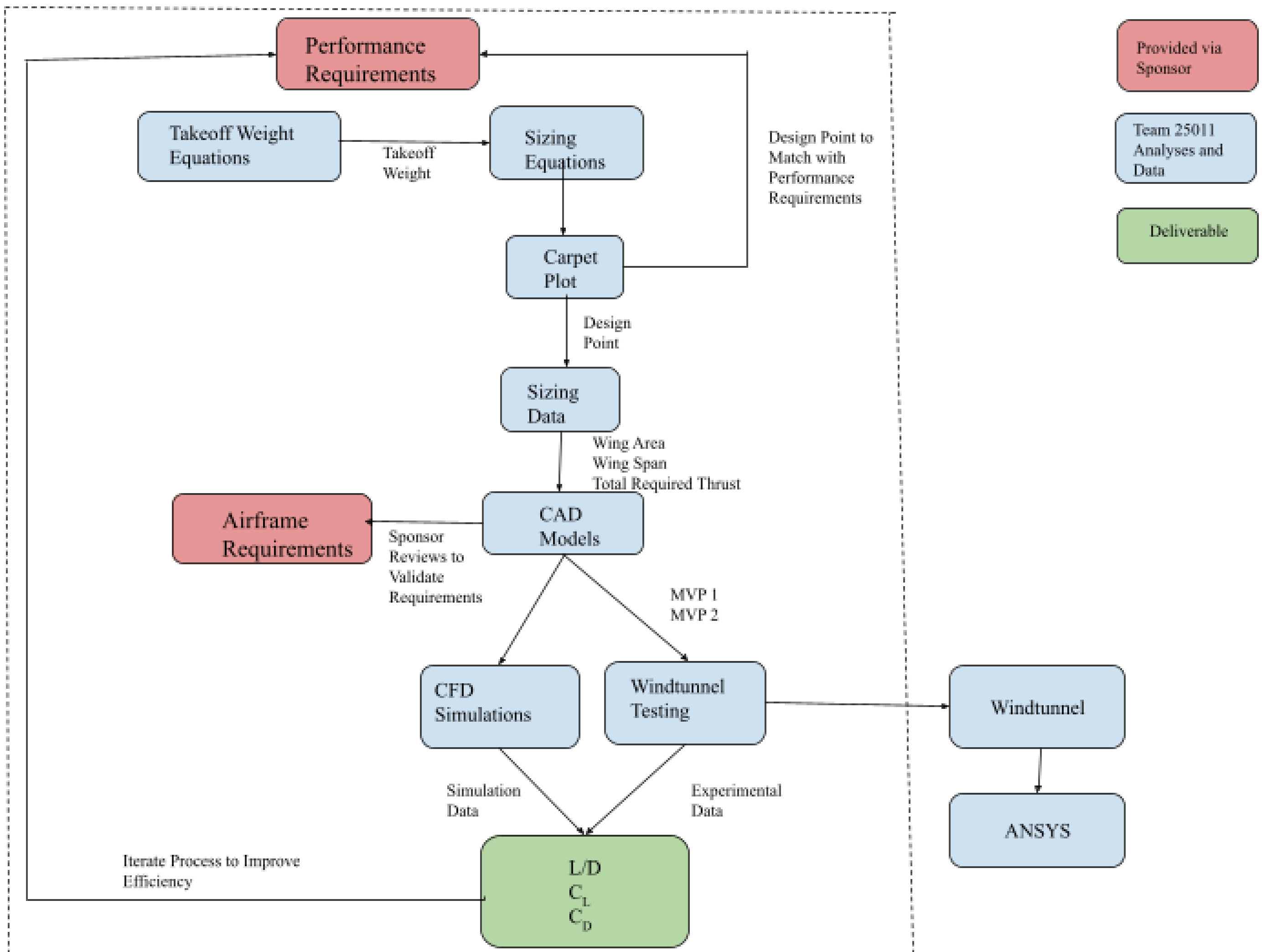
- Global Context: The extended operational range and amphibious capabilities significantly broaden global maritime mission possibilities. Enhanced efficiency facilitates sustained operations in remote and offshore regions, promoting international collaboration in search and rescue, surveillance, and humanitarian aid efforts.
- Cultural Context: By enabling versatile offshore missions, this system supports cultural exchange and cooperation, particularly in maritime communities dependent on reliable offshore transport. The integration of this seaplane into diverse operational environments can foster greater cultural understanding and international cooperation.
- Social Context: The aircraft significantly improves capabilities in critical social functions such as disaster response, medical evacuation, and maritime rescue operations. Its ability to operate efficiently in remote and challenging environments enhances public safety and

response times during crises, thereby positively impacting community resilience and social welfare.

- Environmental Context: The BWB configuration reduces aerodynamic drag significantly compared to traditional aircraft designs, resulting in improved fuel efficiency and reduced emissions. The incorporation of efficient float designs further minimizes drag, contributing positively to environmental sustainability by lowering the ecological footprint of extensive maritime and coastal operations.
- Economic Context: Economically, the BWB seaplane is designed to be cost-effective through enhanced fuel efficiency, reduced maintenance requirements due to fewer moving parts, and increased payload capabilities. These factors make it economically advantageous for commercial operators and governments by reducing operational costs and extending service life, thus providing a compelling value proposition.

In conclusion, by conducting thorough design studies, propulsion integration, and rigorous validation through CFD and wind tunnel simulations, this project has outlined a practical, cost-effective solution tailored to versatile offshore missions. This innovative design stands to significantly influence global maritime mission capabilities, offering meaningful advancements across global, cultural, social, environmental, and economic domains.

2.1 System Block Diagram



3.0 Technical Data Package

3.1 System Verification Plan

Interface Requirements	Method	Limit/ Reference	Measured/ Ref. Value	Notes
The system shall utilize a conventional mechanical control system to ensure longitudinal stability	A	$\frac{dC_M}{d\alpha} < 0$	0.005 (w/o floats) 0.0043 (floats)	A negative value of coefficient of moment with respect to AoA indicates a restoring moment with respect to AoA in the event of a perturbation

Environmental Requirements	Method	Limit/ Reference	Measured/ Ref. Value	Notes
Performance requirements shall be met at: ISA Sea Level +15 ◦C	A	Standard Atmospheric Parameters at Sea Level Standard Atmospheric Parameters at Sea Level +15 ◦C.	p = 101325 Pa ρ = 1.225 kg/m³ a = 340.3 m/s μ = 1.81E-5 Pa·s p = 101325 Pa ρ = 1.164 kg/m³ a = 350 m/s μ = 1.89E-5	Sizing calculations consider the appropriate parameters such as density, dynamic viscosity, and pressure.

			Pa·s	

Customer Constraints	Method	Limit/ Reference	Measured/ Ref. Value	Notes
The system shall utilize a BWB configuration	D	Drawing B0001	Drawing B0001	
The system shall utilize a catamaran hull configuration	D	Drawing H0003	Drawing H0003	
The system shall consist of a maximum of a 3 person crew	A	CS Carpet Plot	660 lbs total Includes passenger weight and personal cargo	Sizing calculations account for a crew of 3.
The system shall be capable of loading and unloading M-6 sized payload pallets	I	40L x 10W x 9H ft payload bay	40L x 10W x 9H ft payload bay	
The general airframe configuration must accommodate a 15° nose up attitude on takeoff from the water	I	Drawing B0001	Drawing B0001	

The system shall comply with FAA FAR 25 standards	A	CS Carpet Plot	CS Carpet Plot	Accounted for in the sizing calculations and design point choice

Performance Requirements	**Method**	**Limit/ Reference**	**Measured/ Ref. Value**	**Notes**
The system shall have a potential range of greater than or equal to 1000 naut miles	A	≥ 1000 nautical miles Takeoff Weight - Jet	1000 nautical miles	Each performance requirement is accounted for in the sizing calculations and selection of the design point according to the carpet plot.
The system must be capable of holding a payload weight of at least 40,000 lbs	A	40,000 lbs Takeoff Weight - Jet	40,000 lbs	
The system shall be capable of achieving a maximum speed of at least 330 kts at 20,000 ft	A	≥ 330 kts Takeoff Weight - Jet	2 Jet Engines produce sufficient lift to reach this cruise speed	
The system must be capable of achieving a cruise speed of at least 300 kts at 10,000 ft	A	≥ 300 kts	300 kts	

The system shall have a stall speed of less than or equal to 85 kts	A	≤ 85 kts	37.2 kts	
The system shall meet the requirements of FAR 25.111, 25.119, & 25.121 for single engine rate of climb	A	Jan Roskam-Airplane Design Volume 2	TBD	
The system shall comply with FAR 25 with regards to takeoff distance	A	≤ 3250 ft CS Size Matching - Jet	3250 ft	
The system shall comply with FAR 25 with regards to landing distance	A	≤ 2700 ft CS Size Matching - Jet	2700 ft	

Customer Testing Requirements	**Method**	**Limit/ Reference**	**Measured/ Ref. Value**	**Notes**
The system shall provide modeling for CFD and wind tunnel testing for specific flight conditions	T	Test Condition 1 Cruise	ISA +15 $^\circ$C T = 10.19 °C H_P = 10,000 ft v = 300 kts M = 0.457 AoA Range = -8° to 8°	The term "clean" refers to the status of configuration of the aircraft, namely having the landing gear and flaps retracted.

		Test Condition 2 Low Speed Clean	ISA +15 $^{\circ}C$ $T = 30\ ^{\circ}C$ $H_P = 0$ ft $v = 110$ kts $M = 0.162$ AoA Range = -8° to 15°	

3.2 Design Documentation

3.2.1 Indentured Drawing List

Part Number	Document
SC-002	F4421, W4412, H003 Seaplane
SC-001	F4421, W4412 Plane
4421	NACA 4421 Airfoil Schematic
4412	NACA 4412 Airfoil Schematic
WT-SC-001	1:180 Scale Wind Tunnel SC-001 Model
ATP-0002	Educational Wind Tunnel Acceptance Test Procedure
ATP-003	EWT CFD Acceptance Test Procedure
ATP-0003	EWT CFD Acceptance Test Procedure
WT-01	Wind Tunnel Mount Schematic
H003-002	Float Type III
H003-003	Float Type III
WT-SC-002	1:180 Scale Wind Tunnel SC-002 Model
ATP-0002	Wind Tunnel Acceptance Test Procedure
ATP-0003	CFD Acceptance Test Procedure

Part Number	Document
SC-003	FCS2-1812, W23012, T0012 Seaplane
H003-1 Rev. 3	Float Type III
ATP-003	CFD Acceptance Test Procedure
WT-SC-003	1:60 Scale Wind Tunnel SC-003 Model
ATP-004	ALSWT Acceptance Test Procedure
ATP-005	ALSWT CFD Acceptance Test Procedure
ATP-006	Test Conditions CFD Comparison Test Procedure
H002	Float Type II
H002-001	Float Type II
ATP-0001	Float Acceptance Test Procedure
H000	Float Sizing Schematic
H003	Float Type III
H003-001	Float Type III
H003-002	Float Type III
H003-003	Float Type III
ATP-0001	Float Acceptance Test Procedure
H000	Float Sizing Schematic

Document H000, Float Sizing Schematic, is excluded from this document to protect proprietary NNC data.

3.3 System Requirements Document

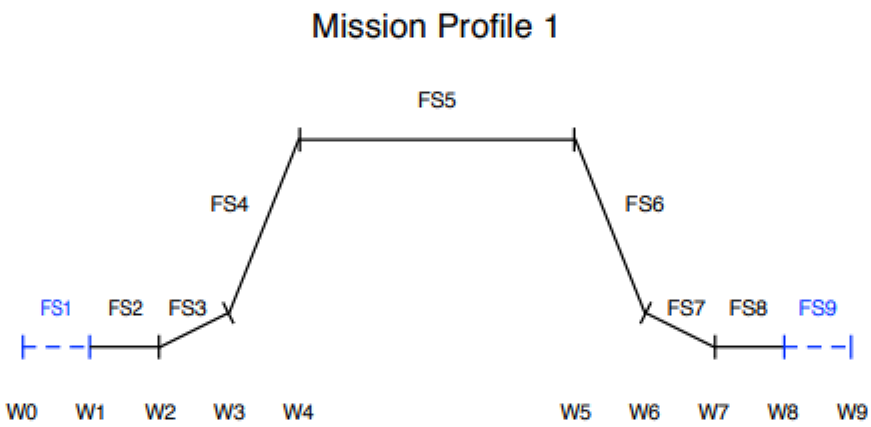
3.3.1 Applicable Documents

1. FAA FAR 25
2. FAA FAR 91
3. FAA FAR 135
4. Remote Area/Oceanic Ops (RNP-4)
5. Approach (RNP-1)

3.3.2 Requirements

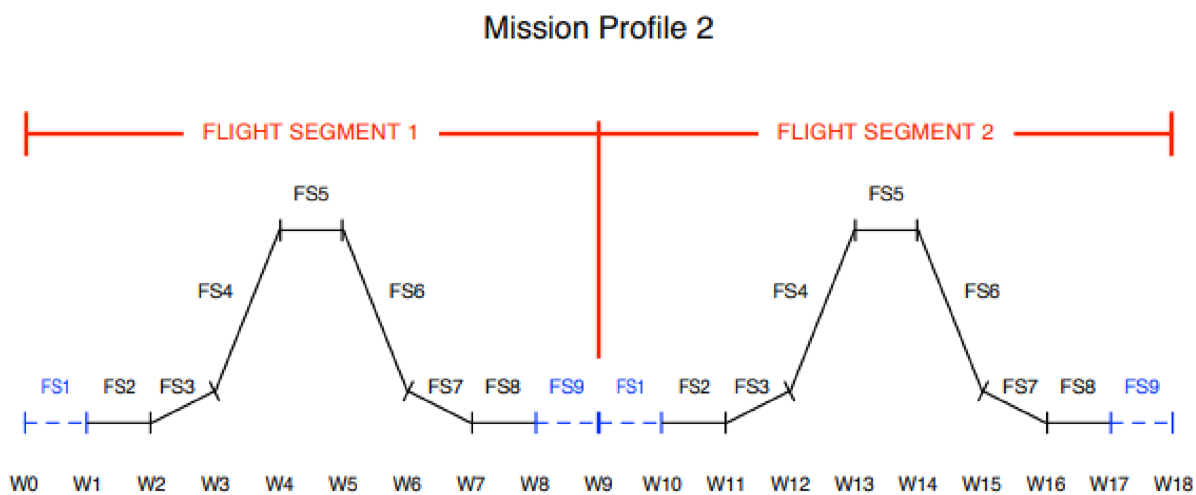
Requirements are dictated by the sponsor, NNC. Subject to change per sponsor direction.

3.3.2.1 Mission Profile 1



Flight Segments	FS Weight Fractions
FS1 = Engine Start & Warm-up	FS1 = W1 / W0
FS2 = Taxi	FS2 = W2 / W1
FS3 = Takeoff	FS3 = W3 / W2
FS4 = Climb	FS4 = W4 / W3
FS5 = Cruise	FS5 = W5 / W4
FS6 = Descent	FS6 = W6 / W5
FS7 = Landing	FS7 = W7 / W6
FS8 = Taxi	FS8 = W8 / W7
FS9 = Engine Shutdown	FS9 = W9 / W8

3.3.2.2 Mission Profile 2



3.3.2.3 Performance Requirements

Performance requirements shall be met at ISA SL / +15 deg.

Requirement	**Parameter**
Range	>= 1000 nm
Max Payload	40,000 lbs
Max Speed @ 20,000 ft	>= 330 kts
Cruise Speed @ 10,000 ft	300 kts
Max Stall Speed (any config.)	<= 85 kts
Takeoff Speed	85 kts
Max Operating Altitude (Service Ceiling)	25,000 ft
Cruise Altitude	10,000 ft
Single Engine Ceiling	12,500 ft
Takeoff Distance - Field (FAR 25)	3,250 ft
Takeoff Distance - Water	3,100 ft

Landing Distance - Field (FAR 25)	2,700 ft
Landing Distance - Water	2,800 ft
Sea Level Rate of Climb	>= 2,500 fpm
Single Engine Rate of Climb	See FAR 25

3.3.2.4 Crew Requirements

Design must allow for a 3 persons crew consisting of a captain, first officer, and loadmaster. Minimum flight crew shall be 2 persons, consisting of a captain and a first officer.

3.3.2.5 Payload Requirements

Max payload capacity shall be 40,000 lbs.

3.3.2.6 Airframe Requirements

- BWB with integral catamaran hull airframe configuration
- Payload Bay shall be no less than (40 ft L x 10 ft W x 9 ft H)
- Cargo doors to load / unload M-6 sized payloads while on the water or land
- Diver egress / ingress hatch in the cargo compartment between the floats
- Landing gear for amphibious operations
- General airframe configuration must accommodate a 15 deg nose up attitude on takeoff from the water
- Movable leading edge high lift devices shall be avoided if possible

3.3.2.7 Certification Requirements

- Design compliance with FAA FAR 25
- Operations under FAR 91 & FAR 135
- Day/Night/IFR
- No certification for flight into known icing
- No certification for RVSM
- Remote Area/Oceanic Ops (RNP-4)
- RNP-1 Approach capability

3.3.2.8 Testing Requirements

CFD test cases shall be performed for the following flight conditions. Additional testing may be performed at the discretion of the sponsor or the engineering team.

3.3.2.8.1 Test Condition 1: Cruise

- ISA +15 degrees Celsius
- T = 10.19 degrees Celsius / 50.34 degrees Fahrenheit
- Altitude = 10,000 ft (Assume standard day)
- Velocity = 300 knots / Mach = 0.457
- Angle of Attack Range of -8 to +8 degrees.

Deliverables:

- Maximum L/D
    - CL vs AoA
    - CD vs AoA
    - CL vs CD
    - CD0 (CD @ CL = 0)
- Flowstream visualizations at max L/D

3.3.2.8.2 Test Condition 2: Low Speed, Clean

- ISA +15 degrees Celsius
- T = 30 degrees Celsius / 86 degrees Fahrenheit
- Altitude = 0 ft (Assume standard day)
- Velocity = 110 knots / Mach = 0.162
- Angle of Attack Range of -8 to +15 degrees.

Deliverables:

- Maximum L/D
    - CL vs AoA
    - CD vs AoA
    - CL vs CD
    - CD0 (CD @ CL = 0)
- Flowstream visualizations at max L/D

3.3.2.9.1 Structural Layout and Airframe Requirements

The BWB seaplane system shall follow FAA FAR 25.533 and FAR 25.527 regulations on structural layout. In the mentioned articles, the basic airframe layout is first designed for appropriate applications, and then the structural layout is designed for the critical point of the mission profile, where the seaplane must land on water. Loads are calculated through the floats that transfer to the BWB seaplane fuselage main frames:

- Water reaction load factor; $n_w = 1.39$ (25.527)
- Water reaction load on each float; $R_w = 97,647\ lbs$
- K1 vertical force profile on floats; $F_{max_{K1}} = 12,124\ lbs$ (25.533)
- K2 bottom force profile on floats; $F_{max_{K1}} = 22,086\ lbs$
- Loads through fuselage main frame members based on K1 profile from floats

Note: K1 and K2 profile are placed in section 4.2.2

3.3.3 Verification Requirements

System Requirements	Subsystems					
	Airframe	Wings	Hull	Engine	Tail	Sensors
1.1 Stability (A): Longitudinal, directional, and roll stability	1. A (Derived): Pitch, roll, yaw moment contributions shall be calculated.	2. A (Direct): shall provide pitch and roll stability. 3. A (Direct): shall provide pitch and roll stability.	3. A (Derive) Shall withstand hydrodynamic forces	1-5. A (Derived): Provide enough thrust > 39 kN to create stabilizing moments	1. A (Direct): shall provide directional stability. 2. A (Direct): shall provide directional stability.	
1.2 Crew operations (D): Pilot controls	3. D (Direct): shall house control systems, such as throttle and yoke.	2. D (Direct) Shall adjust flaps 3.D (Direct) Shall adjust ailerons			2. D (Direct) Shall adjust elevators and rudders	1. D (Direct): shall read and respond to sensor calculations
1.3 Cargo (D): Cargo load and unloading	4. D (Direct): shall open and close to allow access to cargo bay.					
1.4 Sensors (A): Record flow information during flight						1. A (Direct): shall record flight parameters.
2.1 Amphibious Capabilities (D): Water Landing	2. D (Derived): Shall land within 2,800 ft	2. D (Direct): Shall produce maximum amount of lift before landing to reduce hull impact.	2. D (Direct): shall land on water with the ability to remain buoyant	1-5. D (Direct): Shall engage reverse thrusters for landing	1. D (Direct): Shall provide directional stability during landing in the case of crosswinds. 2. D (Direct): Shall provide directional stability during landing in the case of crosswinds.	
2.2 Amphibious Capabilities (D): Water Takeoff	2. D (Derived): shall takeoff within 3,100 ft	2. D (Direct): Shall produce sufficient amount of lift to reduce take-off distance.	2. D (Direct): shall take off with a maximum weight of 141000lbs and maintain bouyancy	1-5. D (Direct): Shall provide enough thrust for take-off		
2.3 Amphibious Capabilities (D): Ground landing	2. D (Direct) Shall land on a runway with a landing gear capable of withstanding impact	2. D (Direct): Shall produce maximum amount of lift before landing to reduce landing distance.		1-5. D (Direct): Shall engage reverse thrusters for landing	1. D (Direct): Shall provide directional stability during landing in the case of crosswinds. 2. D (Direct): Shall provide directional stability during landing in the case of crosswinds.	
2.4 Amphibious Capabilities (D): Ground takeoff	2. D (Direct) Shall take off with a maximum weight of 141000lbs	2. D (Direct): Shall produce sufficient amount of lift to reduce take-off distance.		1-5. D (Direct): Shall provide enough thrust for take-off		
2.5 Deploy landing gears (D)	2. D (Direct): shall be capable of extending down.					
2.6 Retract landing gears (D)	2. D (Direct): shall be capable of retracting up.					
3.1 Standards Compliance (D): FAA FAR 25	D (Direct): Made of structurally sound material	D (Direct): Made of structurally sound material	D (Direct): Made of structurally sound material	4. D (Derived) V(cruise) =< .8*V(dive)	D (Direct): Made of structurally sound material	

3.3.4 Verification Matrix

The Verification Matrix below represents the methods by which the BWBSS will be verified for each system level requirement. The verification methods are Test (T), Analysis (A), Demonstrate (D), and Inspection (I).

Group 1

Interface Requirements	**Verification Method**			
	T	**A**	**D**	**I**
The system shall provide longitudinal stability		X		
The system shall perform crew operations			X	
The system shall load and unload cargo			X	
The system shall record flow information during flight		X		

Group 2

Environmental Requirements	**Verification Method**			
	T	**A**	**D**	**I**
The system shall land on water			X	
The system shall takeoff from water			X	
The system shall land on land			X	
The system shall takeoff from land			X	
The system shall deploy landing gears			X	
The system shall retract landing gears			X	
The system shall be able to operate nominally under intense weather conditions	X			

Group 3

Standard Requirements	Verification Method			
	T	**A**	**D**	**I**
The system shall comply with FAA FAR 25	X			
The system shall comply with FAA FAR 91	X			
The system shall comply with FAA FAR 135	X			

Group 4

Performance Requirements	Verification Method			
	T	**A**	**D**	**I**
The system must meet RNP-4 (Remote Area and Oceanic Operations) capabilities.	X			
The system must meet RNP-1 (Approach) capabilities.	X			

3.3.5 Verification Progress

Interface Requirements	Method	Limit/Reference	Measured/Ref. Value	Pass/Fail	Notes
The system shall utilize a conventional mechanical control system to ensure longitudinal stability	A	$\frac{\delta C_M}{\delta \alpha}$	SeaCat 1: 0.005 (w/o floats) 0.0043 (floats) SeaCat 2: 0.0526	Fails in current iteration	A negative value of coefficient of moment with respect to AoA indicates a restoring moment with respect to AoA in the event of a perturbation Longitudinal stability issues may be accounted for by utilizing a fly-by-wire system

Environmental Requirements	Method	Limit/Reference	Measured/Ref. Value	Pass/Fail	Notes

Performance requirements shall be met at: ISA Sea Level +15 ∘C	A	Standard Atmospheric Parameters at Sea Level Standard Atmospheric Parameters at Sea Level +15 ∘C.	p = 101325 Pa ρ = 1.225 kg/m^3 a = 340.3 m/s μ = 1.81E-5 Pa·s p = 101325 Pa ρ = 1.164 kg/m^3 a = 350 m/s μ = 1.89E-5 Pa·s	Pass	Sizing calculations consider the appropriate parameters such as density, dynamic viscosity, and pressure.

Customer Constraints	Method	Limit/Reference	Measured/ Ref. Value	Pass/Fail	Notes
The system shall utilize a BWB configuration	D	Drawing B0001	Drawing B0001	Pass	
The system shall utilize a catamaran hull configuration	D	Drawing H0003	Drawing H0003	Pass	
The system shall consist of a maximum of a 3 person crew	A	CS Carpet Plot	660 lbs total Includes passenger weight and personal cargo	Pass	Sizing calculations account for a crew of 3.
The system shall be capable of loading and	I	40L x 10W x 9H ft payload bay	40L x 10W x 9H ft payload bay	Pass	

unloading M-6 sized payload pallets					
The general airframe configuration must accommodate a 15° nose up attitude on takeoff from the water	I	Drawing B0003	Drawing B0003	Pass	
The system shall comply with FAA FAR 25 standards	A	CS Carpet Plot	CS Carpet Plot	Pass	Accounted for in the sizing calculations and design point choice

Performance Requirements	Method	Limit/Reference	Measured/ Ref. Value	Pass/Fail	Notes
The system shall have a potential range of greater than or equal to 1000 naut miles	A	≥ 1000 nautical miles Takeoff Weight - Jet	1000 nautical miles	Pass	Each performance requirement is accounted for in the sizing calculations and selection of the design point according to the carpet plot.
The system must be capable of holding a payload weight of at least 40,000 lbs	A	40,000 lbs Takeoff Weight - Jet	40,000 lbs	Pass	

The system shall be capable of achieving a maximum speed of at least 330 kts at 20,000 ft	A	$\geq$ 330 kts Takeoff Weight - Jet	2 Jet Engines produce sufficient lift to reach this cruise speed	Pass	
The system must be capable of achieving a cruise speed of at least 300 kts at 10,000 ft	A	$\geq$ 300 kts	300 kts	Pass	
The system shall have a stall speed of less than or equal to 85 kts	A	$\leq$ 85 kts	37.2 kts	Pass	
The system shall meet the requirements of FAR 25.111, 25.119, & 25.121 for single engine rate of climb	A	Jan Roskam- Airplane Design Volume 2	TBD	Pass	
The system shall comply with FAR 25 with regards to takeoff distance	A	$\leq$ 3250 ft CS Size Matching - Jet	3250 ft	Pass	
The system shall comply with FAR 25	A	$\leq$ 2700 ft CS Size Matching -	2700 ft	Pass	

with regards to landing distance		Jet			

Customer Testing Requirements	Method	Limit/Reference	Measured/Ref. Value	Pass/Fail	Notes
The system shall provide modeling for CFD and wind tunnel testing for specific flight conditions	T	Test Condition 1 Cruise	ISA +15 $_{\circ}$C T = 10.19 °C H_P = 10,000 ft v = 300 kts M = 0.457 AoA Range = -8$_{\circ}$ to 8$_{\circ}$	Pass	The term “clean” refers to the status of configuration of the aircraft, namely having the landing gear retracted.
		Test Condition 2 Low Speed Clean	ISA +15 $_{\circ}$C T = 30 $_{\circ}$C H_P = 0 ft v = 110 kts M = 0.162 AoA Range = -8$_{\circ}$ to 15$_{\circ}$	Pass	

3.4 Verification Documentation

Datasheets containing test data are located in the appendix.

3.4.1 ATP-0001 Float Acceptance Test Procedure

3.4.1.1 Introduction

A design of experiments is to be conducted on the floats to determine which trailing edge geometry would create the least amount of drag. This procedure explains how to conduct the fluid simulation on the float designs and how to analyze the results. Testing will be performed using SOLIDWORKS Fluid Simulation. The tests will generate a report of aerodynamic forces and moments acting upon the models. Once completed, the drag forces can be directly compared so that the model that induces the least drag can be used on the Seaplane.

3.4.1.2 Reference Documents

Blended Wing Body Seaplane System Requirements Document, 10/15/24, rev. 2

3.4.1.3 Required test equipment

Description	Model Number	Accuracy
N/A	N/A	N/A

3.4.1.4 Table of Tests

Test #	Test	Requirement
1	Forces and Moments about C.G.	Coefficient of Lift Coefficient of Drag Coefficient of Moment

3.4.1.5 Procedure

1. Open the model in SOLIDWORKS.
2. Enable SW Fluid Simulation.
3. Use the built-in Fluid Wizard to establish the computational domain and set the flow parameters. Use Test Condition 1 (cruise).
4. Insert force and moment goals to output aerodynamic forces.
5. Record the drag force experienced by the model.
6. Repeat steps 1-5 for all float designs.

3.4.1.6 Support Requirements

All simulations should be conducted using SOLIDWORKS 2023 Fluid Simulation or later.

3.4.2 ATP-0002 Educational Wind Tunnel Acceptance Test Procedure

3.4.2.1 Introduction

Since the project demands a preliminary design for the BWBSS, all subassembly components are combined in Wind Tunnel Testing. This procedure explains the testing done for wind tunnel testing performed on the entire blended wing body seaplane system. Testing will be conducted at the University of Arizona Educational Wind Tunnel Room. This test will generate a report of the aerodynamic forces and moments acting upon the model. Once completed, we can analyze the drag profile of the model, as well as make assumptions about the full-scale model's range and performance.

3.4.2.2 Reference Documents

Blended Wing Body Seaplane System Requirements Document, 10/15/24, rev. 2
AME 401 Subsonic Experiment 1, Test Section and Hot Wire Calibration Post-lab Memo, 9/12/2024

3.42.3 Required test equipment

Description	Model Number	Accuracy
Educational Wind Tunnel	Ni-DAC	>99% (Calibrated)
3D Printed Seaplane Model	1000-9000-1	N/A

3.4.2.4 Table of Tests

Test #	Test	Requirement
1	Forces and Moments about C.G.	Coefficient of Lift Coefficient of Drag Coefficient of Moment

3.4.2.5 Procedure

1. Attach our model to the wind tunnel's balance that will record forces and moments on the model
2. Ensure the wind tunnel is on and the LabVIEW codes are operational.
3. Plug in the USB drive and create a folder for Experiment 5.
4. Calculate the dynamic pressure needed to achieve 105,000 Reynolds Number. Ensure to adjust for tunnel calibrations.
5. Set the angle of attack to 0° and press 'Zero Angle' on LabVIEW.
6. Set the angle of attack to -10°.
7. Select 'Tare Balance' on LabView to zero the forces on the balance

8. Set the fan power to correlate to the appropriate dynamic pressure. This will run the tunnel.
9. To take a measurement, press ‘Take Data’.
10. Save the data by pressing ‘Save Data’. This records the normal force, axial force and pitching moment.
11. Repeat steps 7-10, increasing the angle of attack by 2° each time until an angle of attack of 20° is reached.
12. Transfer all data to USB when complete, and eject the USB.
13. Turn off the wind tunnel.

3.4.2.6 Support Requirements

Wind tunnel time for the Educational Wind Tunnel is provided by the University of Arizona. At least 2 (two) engineers must be present when the wind tunnel is enabled.

3.4.3 ATP-0003 Educational Wind Tunnel CFD Acceptance Test Procedure

3.4.3.1 Introduction

CFD testing shall be performed in conjunction with wind tunnel testing so as to aid in validating the results of one another. CFD allows for exact specifications and testing conditions to be met, and will be performed on each model a total of two times: once exclusively with the floats, and a second time with the floats connected to the rest of the BWBSS. The flexibility of CFD is a major advantage which allows for specific testing environments to be realized.

3.4.3.2 Referenced Documents

Blended Wing Body Seaplane System Requirements Document, 10/15/24, rev. 2

3.4.3.3 Required test equipment

Description	Model Number	Accuracy
N/A	N/A	N/A

3.4.3.4 Table of Tests

Test #	Test	Requirement
1	Forces	Coefficient of Lift Coefficient of Drag Coefficient of Moment

3.4.3.5 Step by Step Procedure

1. Import the model into ANSYS SpaceClaim.
2. Verify that the model does not have any repairable features. Fix any issues detected by ANSYS, including missing faces, gaps, or other inconsistencies.
3. Establish a computational domain around the imported model.
4. Mesh the geometry using the ANSYS Watertight Geometry workflow. Establish a resolution adequate enough to simulate turbulent flow.
5. Set-up the simulation for either Test Condition 1 (cruise) or Test Condition 2 (low-speed, clean).
6. Create drag, lift, and moment monitors.
7. Run the simulation for a minimum of 300 iterations.
8. Repeat steps 5-7 for any desired angle of attack by changing the inlet velocity vector.
9. Move on to post processing once the runs are done.
10. Check on drag, lift, and moment monitors (graphs should appear).
11. Make the coefficients of lift and drag show up in the command window.
12. Graph all of them in excel and take average of the iterations starting from when they converge.
13. Plot your lift-to-drag ratio data.

3.4.3.6 Support Requirements

All simulations should be conducted using ANSYS 2024 R1 Fluent or later.

3.4.4 ATP-0004 Arizona Low-Speed Wind Tunnel Acceptance Test Procedure

3.4.4.1 Introduction

Wind tunnel testing is to be conducted on the second iteration of the BWBSS. This procedure explains the testing done for wind tunnel testing performed on a right-half wing model of the BWBSS, as required by the wind tunnel facility. The test will be conducted at the Arizona Low-Speed Wind Tunnel. This test will generate a report of the aerodynamic forces and moments acting upon the model. The performance and stability of the Seacat 3 BWBSS is to be analyzed and compared with the previously tested iterations.

3.4.4.2 Referenced Documents

Blended Wing Body Seaplane System Requirements Document, 10/15/24, rev. 2

3.4.4.3 Required test equipment

Description	Model Number	Accuracy
3D Printed Seaplane Model	SC-003	N/A

3.4.4.4 Table of Tests

Test #	Test	Requirement
1	Forces	Coefficient of Lift Coefficient of Drag Coefficient of Moment

3.4.4.5 Step by Step Procedure

1. Attach model to wind tunnel balance adaptor.
2. Mount model to side-wall balance.
3. Connect USB to the wind tunnel operation computer.
4. Set forces and moments measured by the balance to zero.
5. Set the angle of attack testing schedule to -10° to 10°.
6. Set up the document name and take tare data of the model, that is, the weight of the model when the wind tunnel is off.
7. Turn on the wind tunnel and set up the wind tunnel fan frequency to set the required airspeed.
8. Set up the document name and take aerodynamic forces and pitching moment data for the -10° to 10° angle of attack schedule.
9. Set the angle of attack testing schedule to -15° to 35° both with increments of 1°.
10. Perform steps 6 to 8 for the -15° to 35° angle of attack schedule.

11. Transfer all data to USB when all runs are complete and eject USB.
12. Turn off wind tunnel

3.4.4.6 Support Requirements

Wind tunnel time for the Arizona Low-Speed Wind Tunnel is provided by the University of Arizona. At least (one) trained engineer must be present when the wind tunnel is enabled.

3.4.5 ATP-0005 Arizona Low-Speed Wind Tunnel CFD Acceptance Test Procedure

3.4.5.1 Introduction

CFD testing shall be performed in conjunction with wind tunnel testing for CFD validation purposes, that is, comparing real-life results to simulations. CFD allows for exact specifications and testing conditions to be met, and will be performed on the Seacat 3 to match the conditions recorded during the Arizona Low-Speed Wind Tunnel test (refer to ATP-0004). The low-cost, quickness, and flexibility of CFD is a major advantage which allows for faster and more convenient testing iteration.

3.4.5.2 Referenced Documents

Blended Wing Body Seaplane System Requirements Document, 10/15/24, rev. 2

3.4.5.3 Required test equipment

Description	Model Number	Accuracy
N/A	N/A	N/A

3.4.5.4 Table of Tests

Test #	Test	Requirement
1	Forces	Coefficient of Lift Coefficient of Drag Coefficient of Moment

3.4.5.5 Step by Step Procedure

1. Measure the exact location of the center of gravity with the Evaluate Mass Properties feature.
2. Prepare the model by selecting all parts and selecting the Combine option from the Analysis Preparation tab.
3. Create a coordinate system with the center of gravity as a reference.
4. Rotate the model around the center of gravity to the desired angle of attack.
5. Use the Flow Simulation wizard tool to input flow condition parameters of wind tunnel test.
6. Establish a computational domain around the model.
7. Modify global mesh to the desired settings.
8. Establish global goals to X, Y, Z forces and torques with the coordinate system of step 3 as reference.
9. Press Run and select all cores to be used during the simulation.
10. After simulation is done, select insert Goal Plots in the results section.
11. Select X, Y, Z forces and torques, press show, and copy results to be stored.
12. Repeat steps 1-11 for all angles of attack.
13. Plot final results and compare with wind tunnel results.

3.4.5.6 Support Requirements

All simulations should be conducted using SOLIDWORKS 2023 Flow Simulation or later.

3.4.6 ATP-0006 Test Conditions CFD Comparison Test Procedure

3.4.6.1 Introduction

With the proven effectiveness of flow simulations, CFD testing shall be performed for Test Condition 1 (TC1) and Test Condition 2 (TC2). CFD allows for exact specifications and testing conditions to be met, and will be performed on the Seacat 3 to explore the differences between TC1 and TC2 for direct comparison and redesigning purposes. The use of CFD has permitted the project to advance successfully through its main objectives.

3.4.6.2 Referenced Documents

Blended Wing Body Seaplane System Requirements Document, 10/15/24, rev. 2

3.4.6.3 Required test equipment

Description	Model Number	Accuracy
N/A	N/A	N/A

3.4.6.4 Table of Tests

Test #	**Test**	**Requirement**
1	Forces	Coefficient of Lift Coefficient of Drag Coefficient of Moment

3.4.6.5 Step by Step Procedure

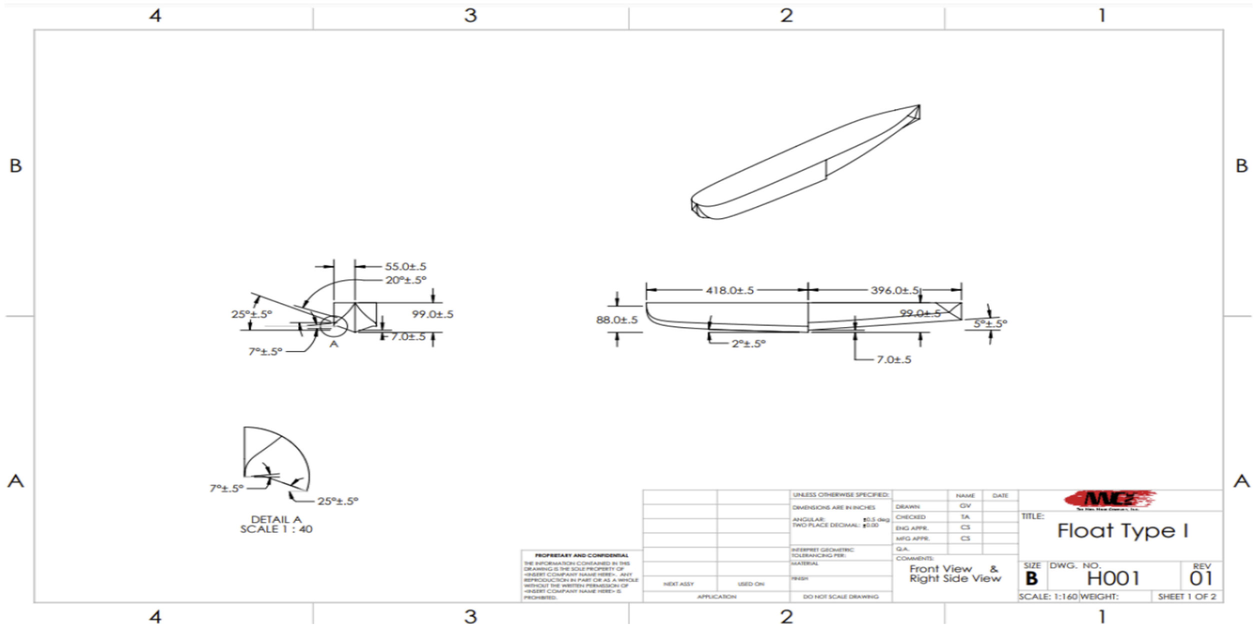
1. Measure the exact location of the center of gravity with the Evaluate Mass Properties feature.
2. Prepare the model by selecting all parts and selecting the Combine option from the Analysis Preparation tab.
3. Create a coordinate system with the center of gravity as a reference.
4. Rotate the model around the center of gravity to desired angle of attack.
5. Use the Flow Simulation wizard tool to input flow condition parameters of each test condition.
6. Establish a computational domain around the model.
7. Modify global mesh to the desired settings.
8. Establish global goals to X, Y, Z forces and torques with the coordinate system of step 3 as reference.
9. Press Run and select all cores to be used during the simulation.
10. After simulation is done, select insert Goal Plots in the results section.
11. Select X, Y, Z forces and torques, press show, and copy results to be stored.
12. Repeat steps 1-11 for all angles of attack.
13. Repeat steps 1-12 for TC1 and TC2.
14. Plot final results and compare TC1 and TC2.

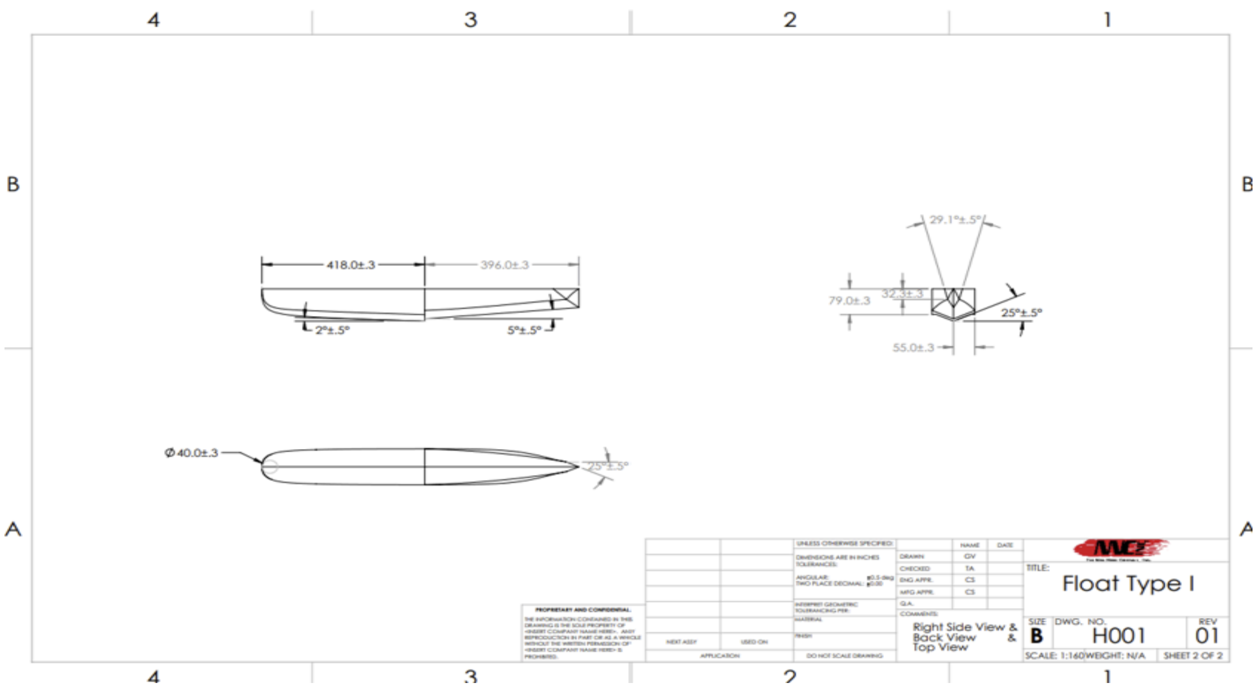
3.4.6.6 Support Requirements

All simulations should be conducted using SOLIDWORKS 2023 Flow Simulation or later.

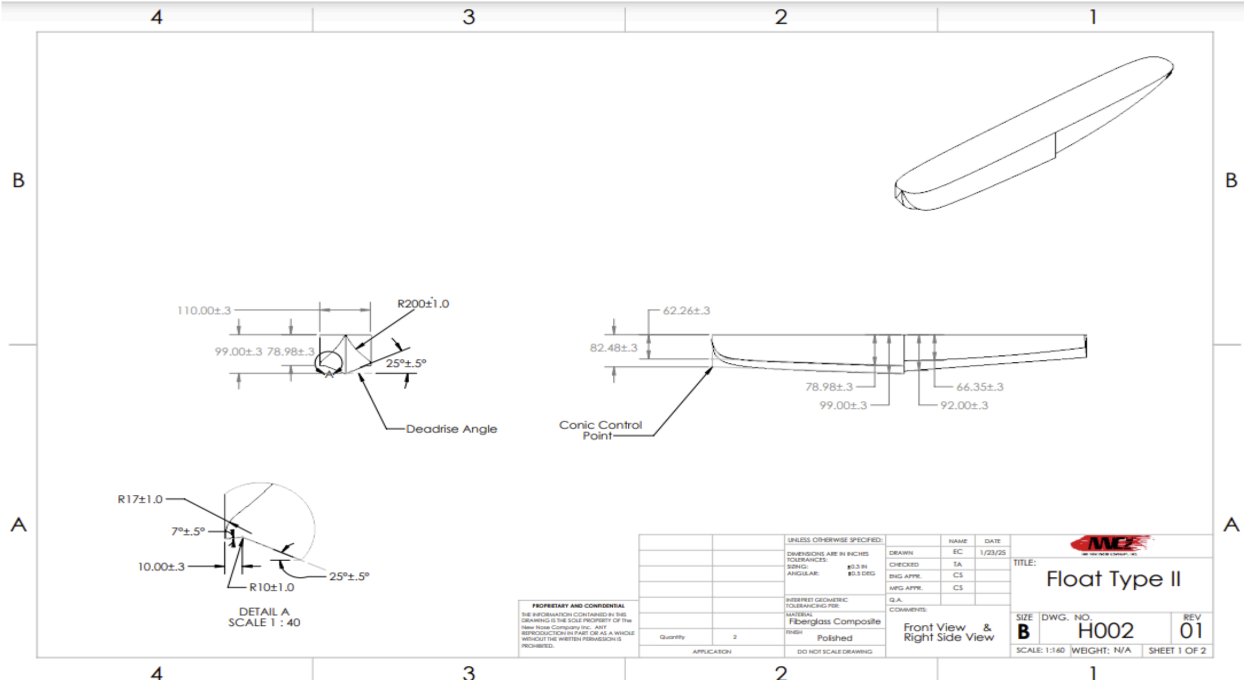
3.5 Hardware Drawing Package

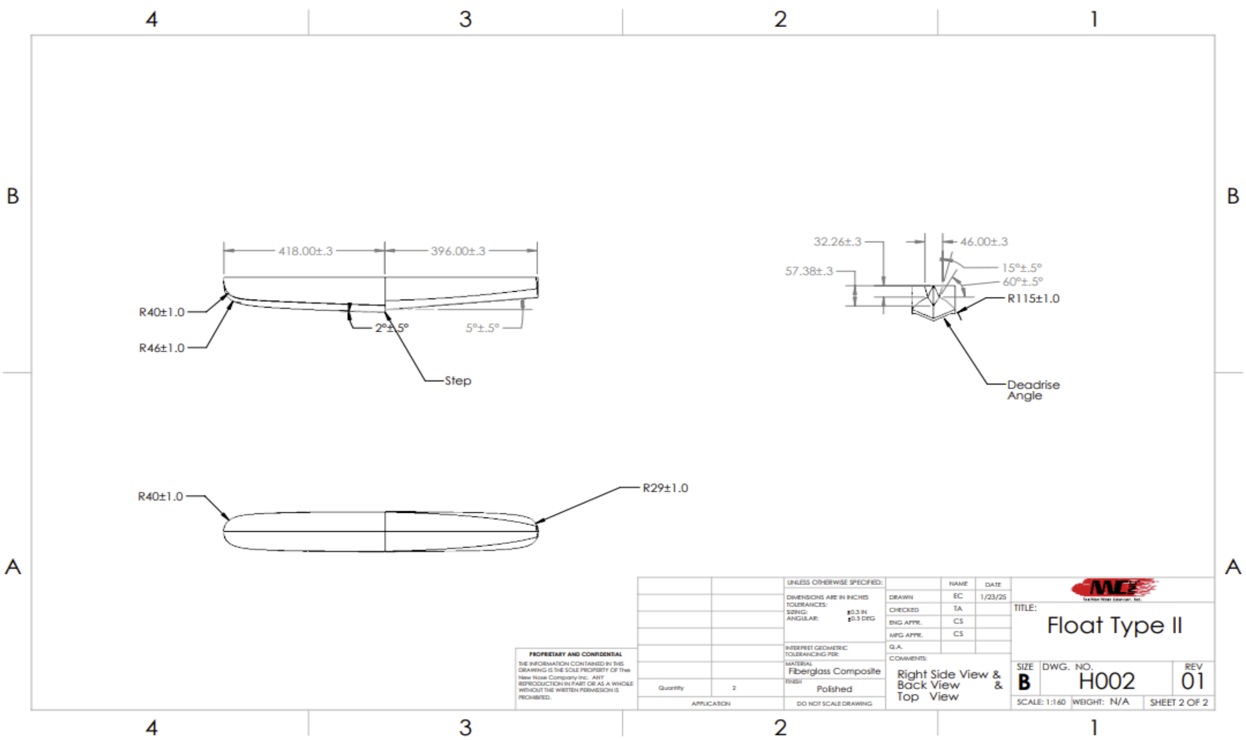
Float Type I



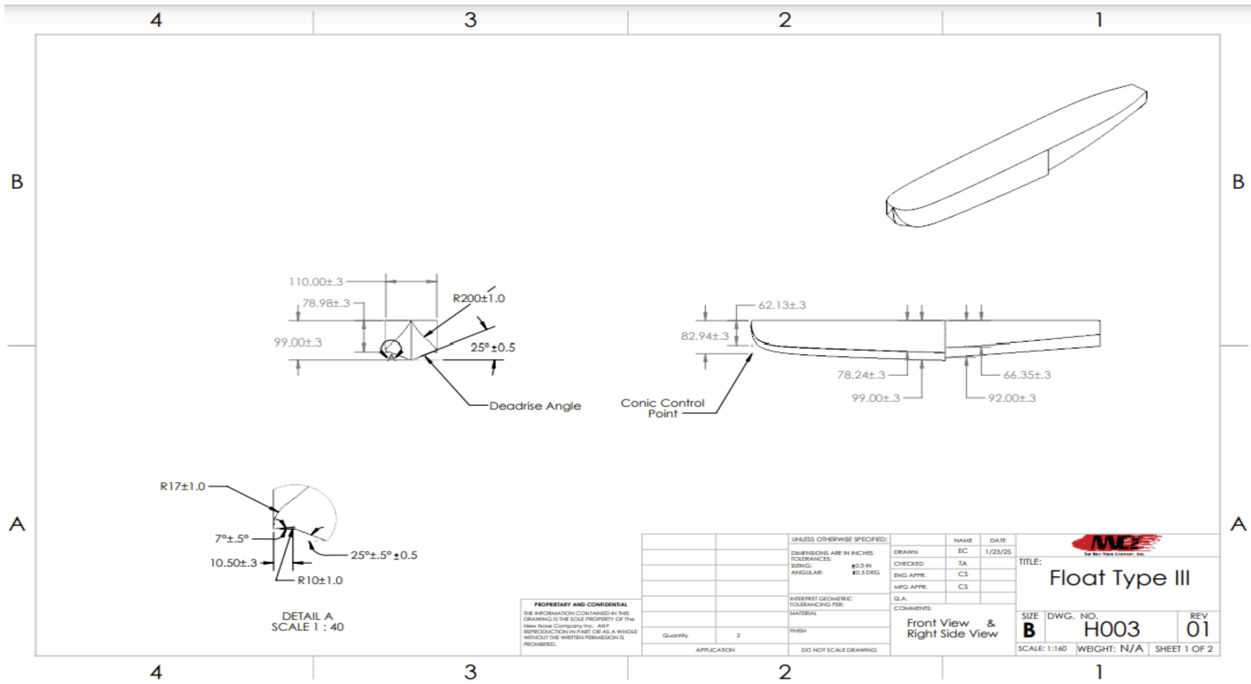


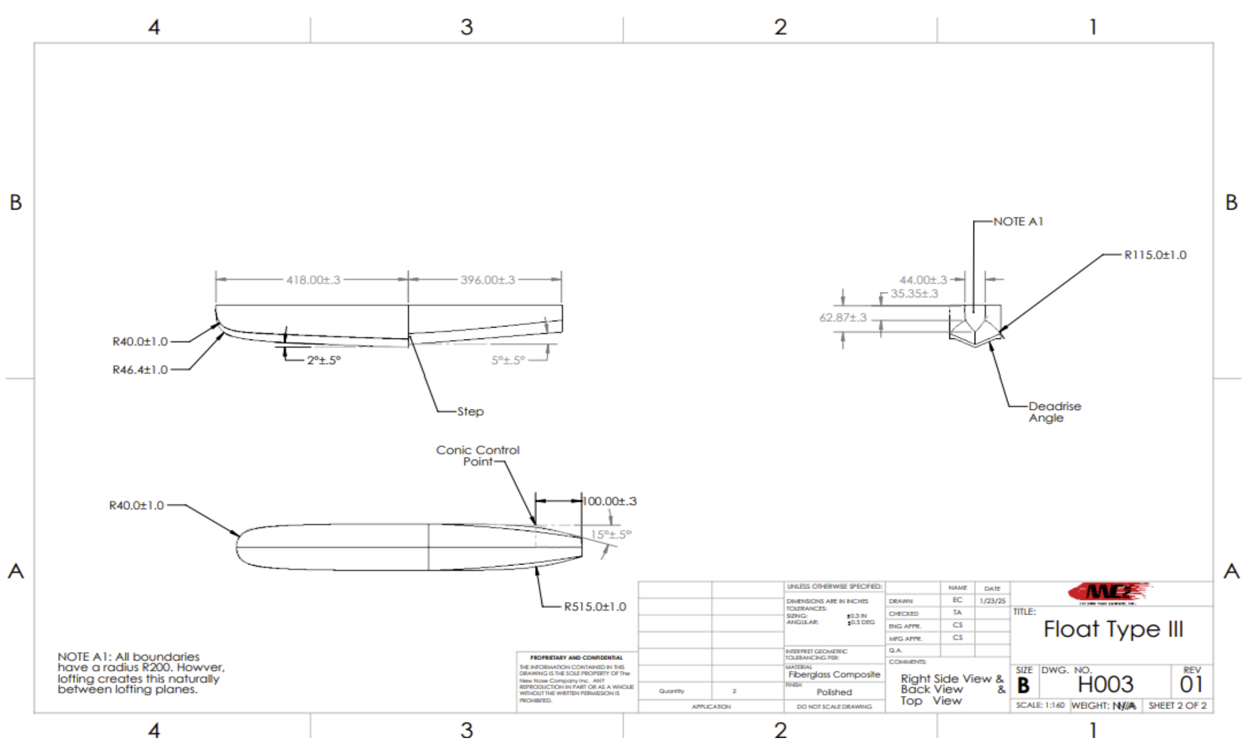
Float Type II



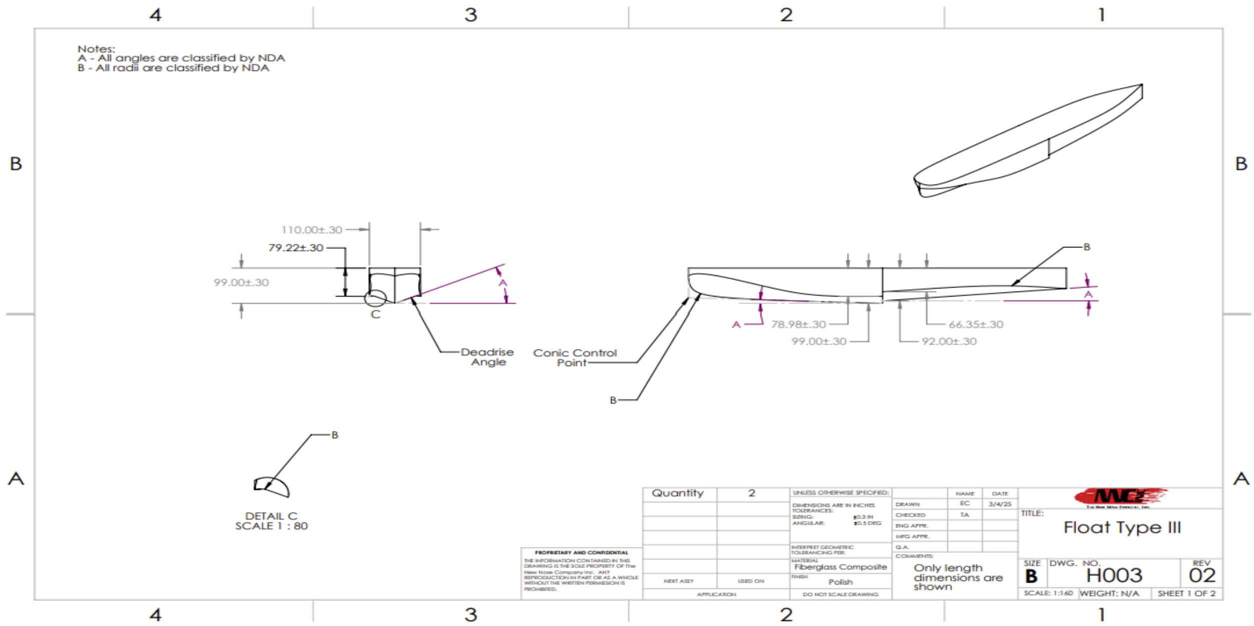


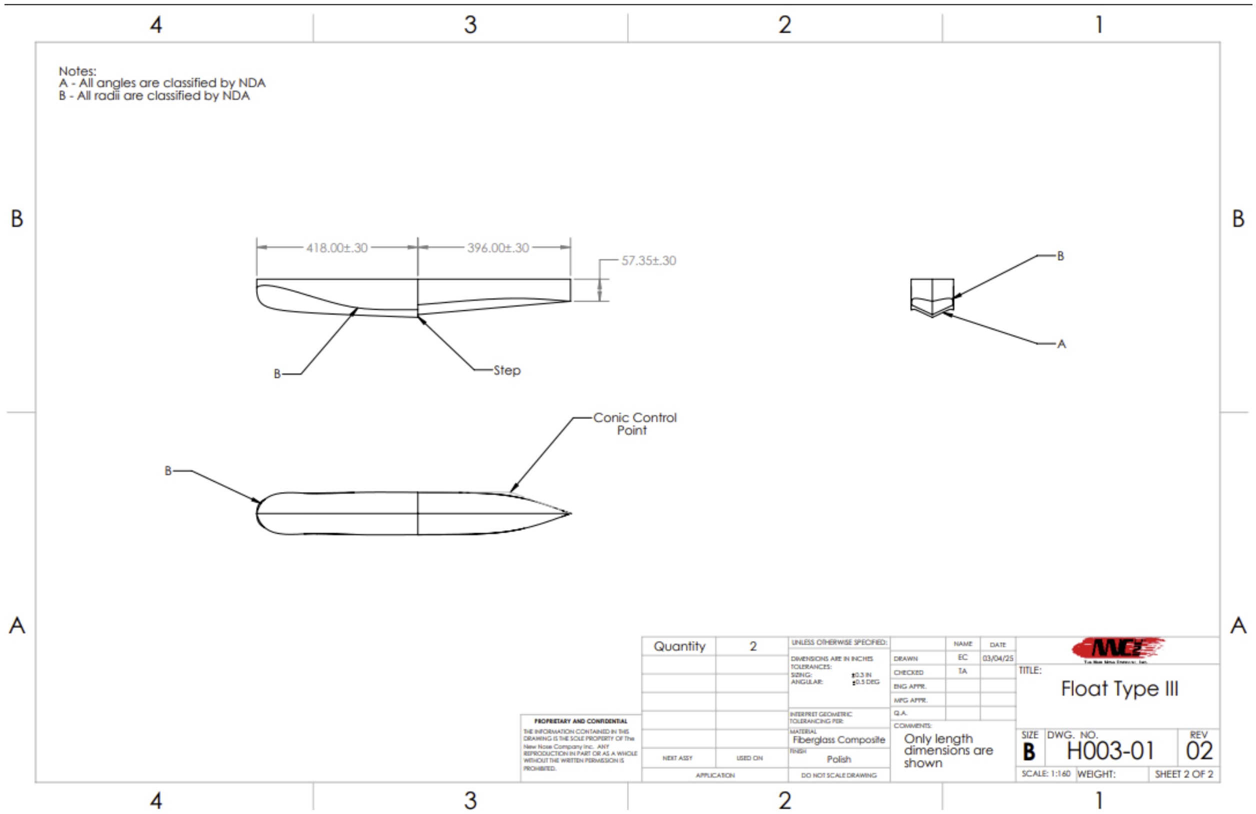
Float Type III



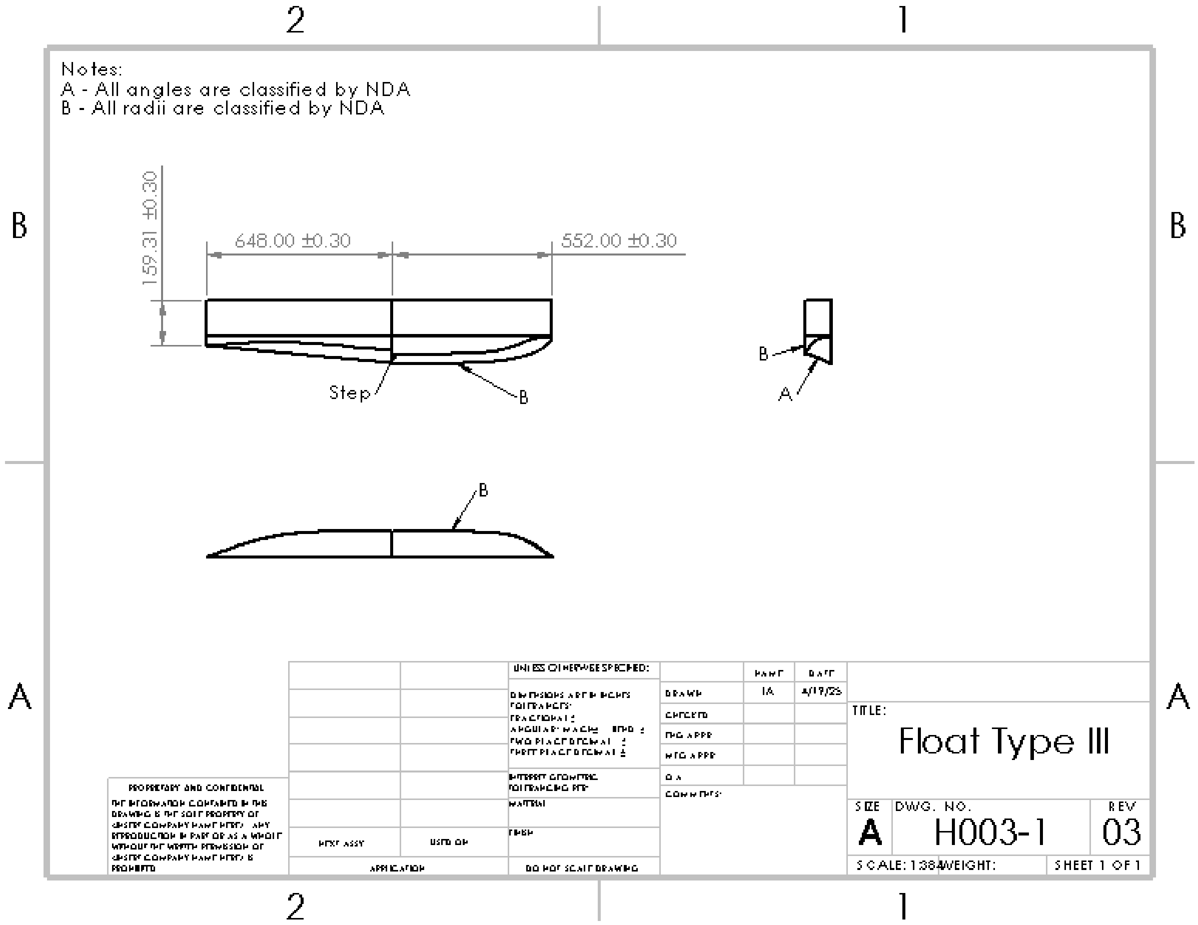


Float Type III Rev. 2

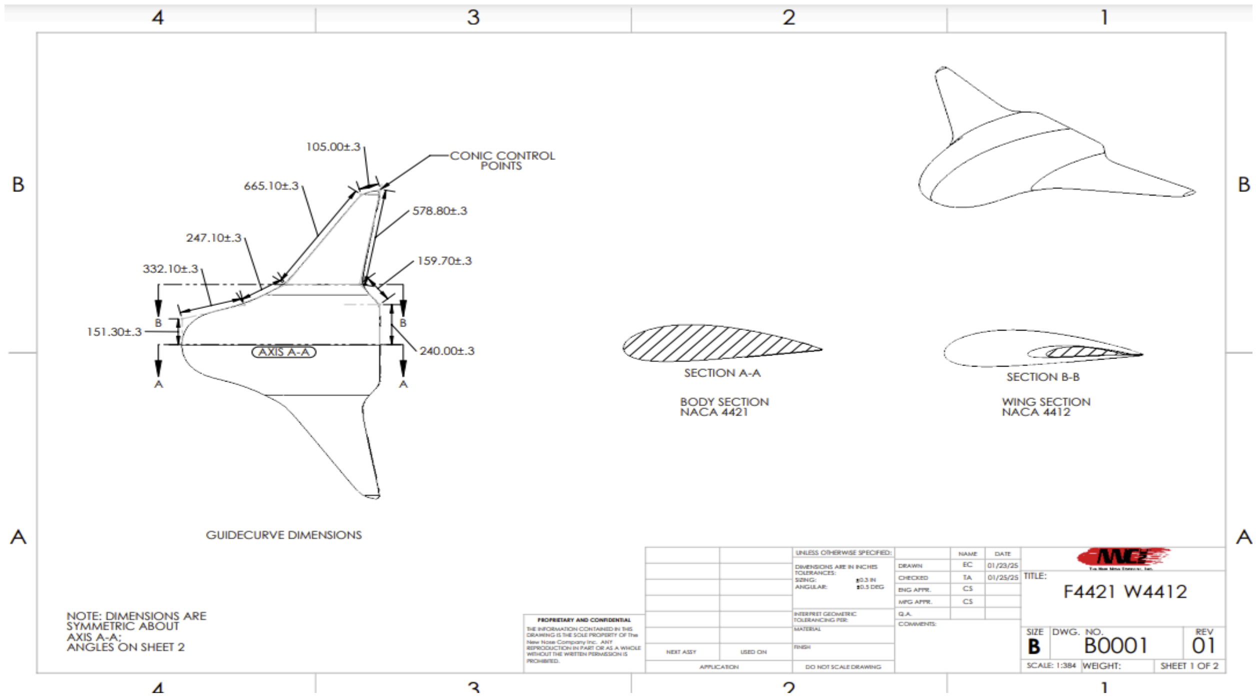




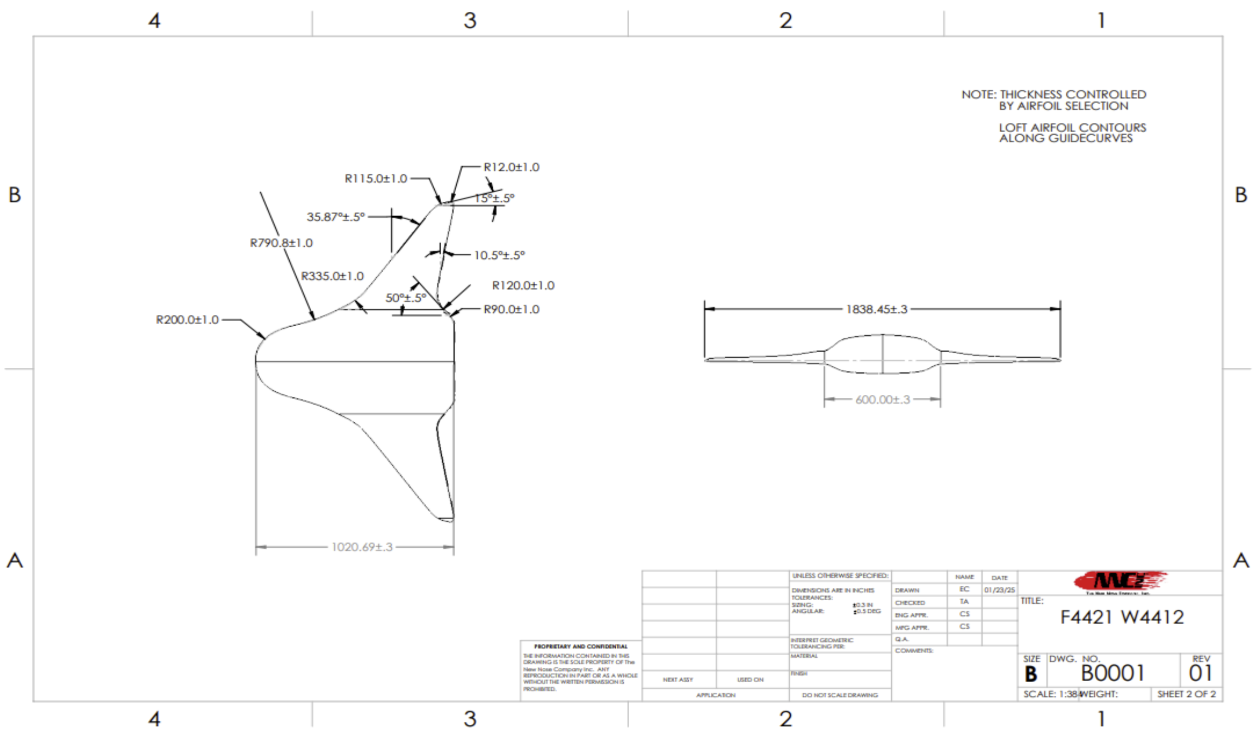
Float Type III Rev. 3



Seacat-1

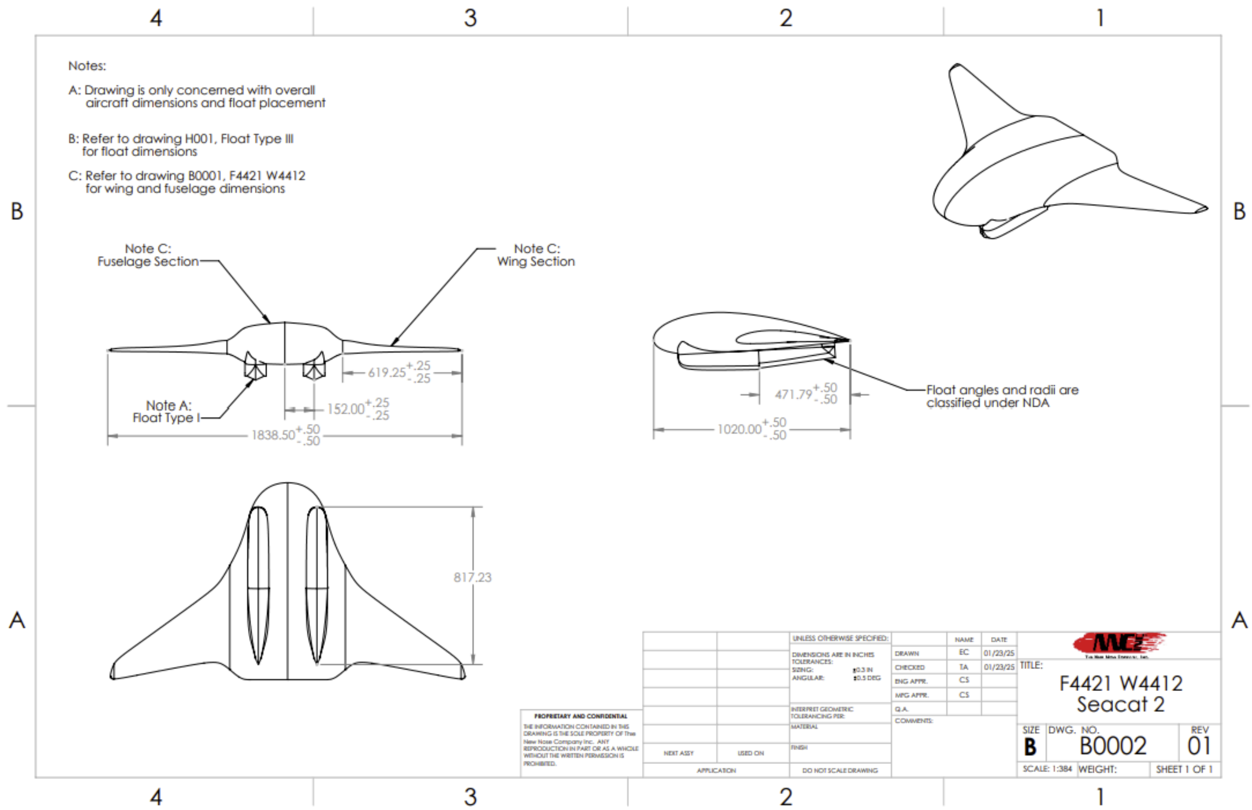


105.00±.3
CONIC CONTROL POINTS
665.10±.3
578.80±.3
247.10±.3
159.70±.3
332.10±.3
151.30±.3
AXIS A-A
240.00±.3
SECTION A-A
BODY SECTION NACA 4421
SECTION B-B
WING SECTION NACA 4412
GUIDECURVE DIMENSIONS
NOTE: DIMENSIONS ARE SYMMETRIC ABOUT AXIS A-A; ANGLES ON SHEET 2
F4421 W4412
B0001
01
SHEET 1 OF 2

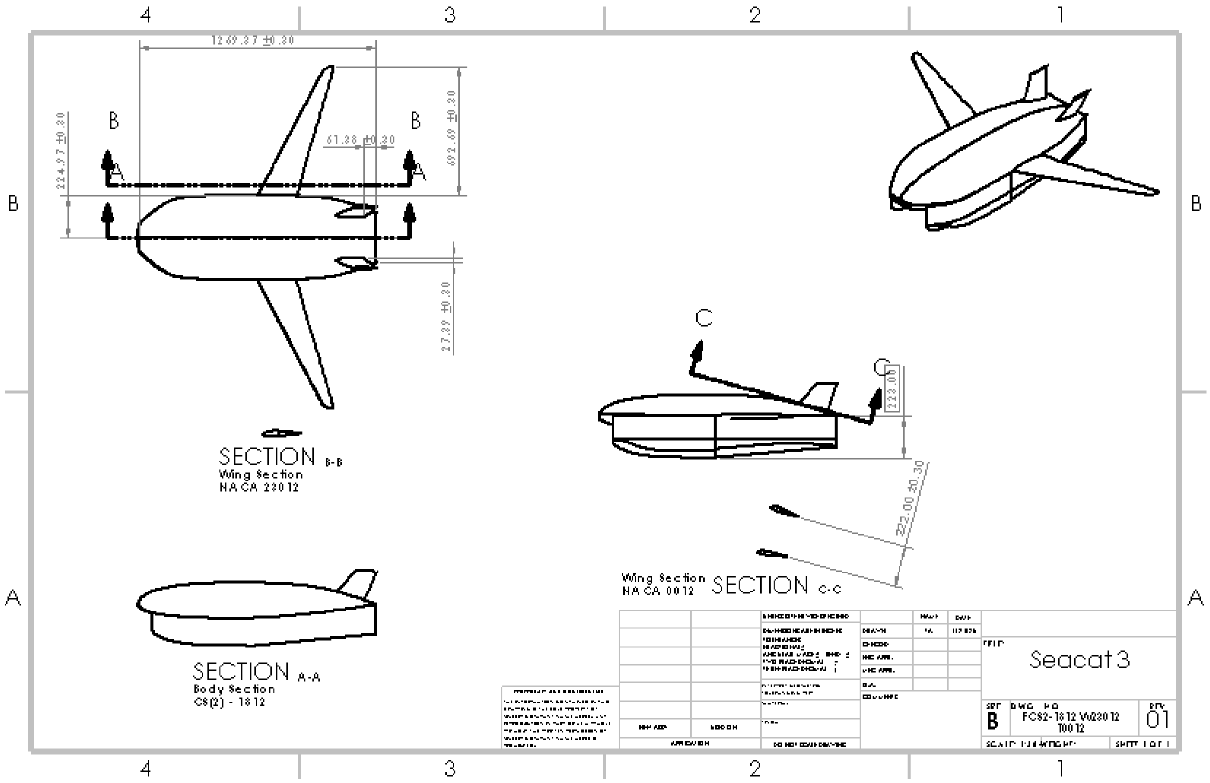


NOTE: THICKNESS CONTROLLED BY AIRFOIL SELECTION
LOFT AIRFOIL CONTOURS ALONG GUIDECURVES
R115.0±1.0
R12.0±1.0
15°±.5°
35.87°±.5°
R790.8±1.0
10.5°±.5°
R335.0±1.0
R120.0±1.0
50°±.5°
R90.0±1.0
R200.0±1.0
1838.45±.3
600.00±.3
1020.69±.3
F4421 W4412
B0001
01
SHEET 2 OF 2

Seacat-2

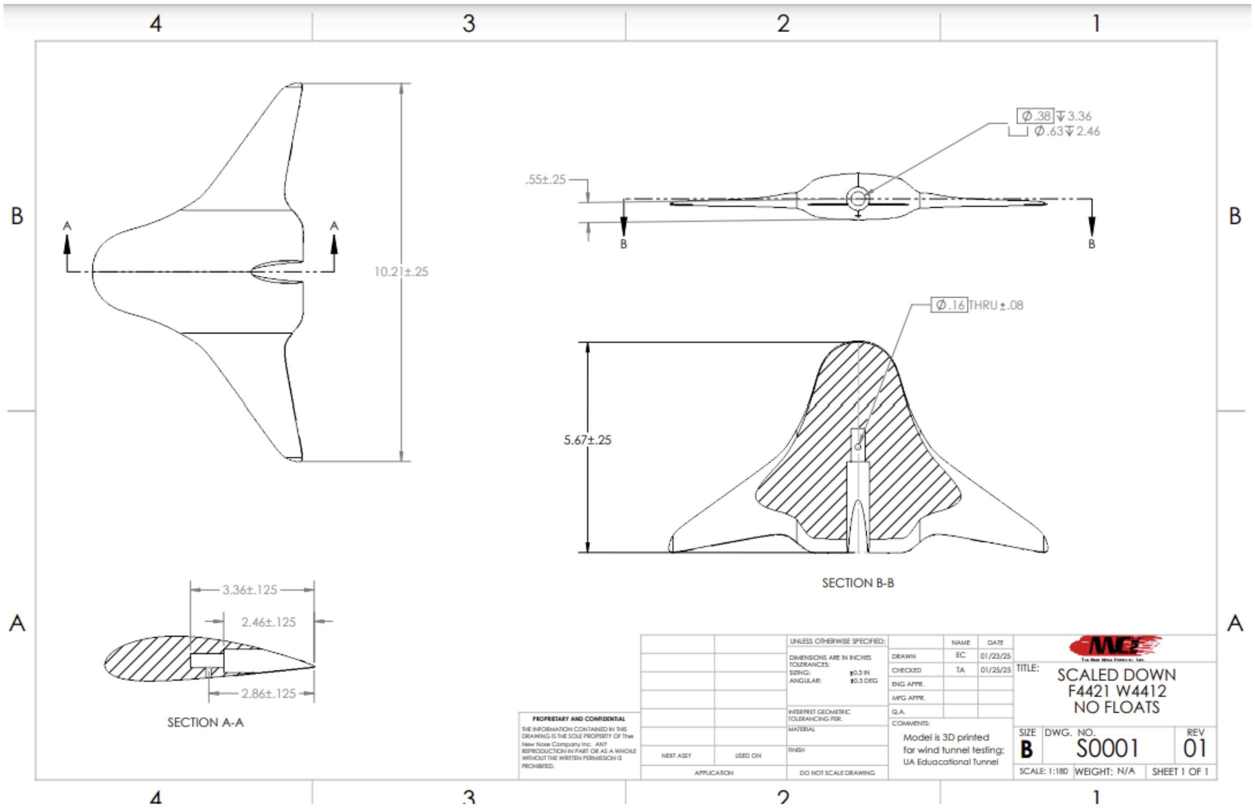

Notes:
A: Drawing is only concerned with overall aircraft dimensions and float placement
B: Refer to drawing H001, Float Type III for float dimensions
C: Refer to drawing B0001, F4421 W4412 for wing and fuselage dimensions
Note C: Fuselage Section
Note C: Wing Section
Note A: Float Type I
619.25 +.25 -.25
152.00 +.25 -.25
1838.50 +.50 -.50
471.79 +.50 -.50
1020.00 +.50 -.50
Float angles and radii are classified under NDA
817.23
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
SIZING: ±0.3 IN
ANGULAR: ±0.5 DEG
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN EC 01/23/25
CHECKED TA 01/23/25
ENG APPR. CS
MFG APPR. CS
Q.A.
COMMENTS:
TITLE:
F4421 W4412
Seacat 2
SIZE B
DWG. NO. B0002
REV 01
SCALE: 1:384
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL

Seacat-3



SECTION B-B
Wing Section
NACA 23012
SECTION A-A
Body Section
CS(2) - 1812
Wing Section
NACA 0012
SECTION C-C
Seacat 3

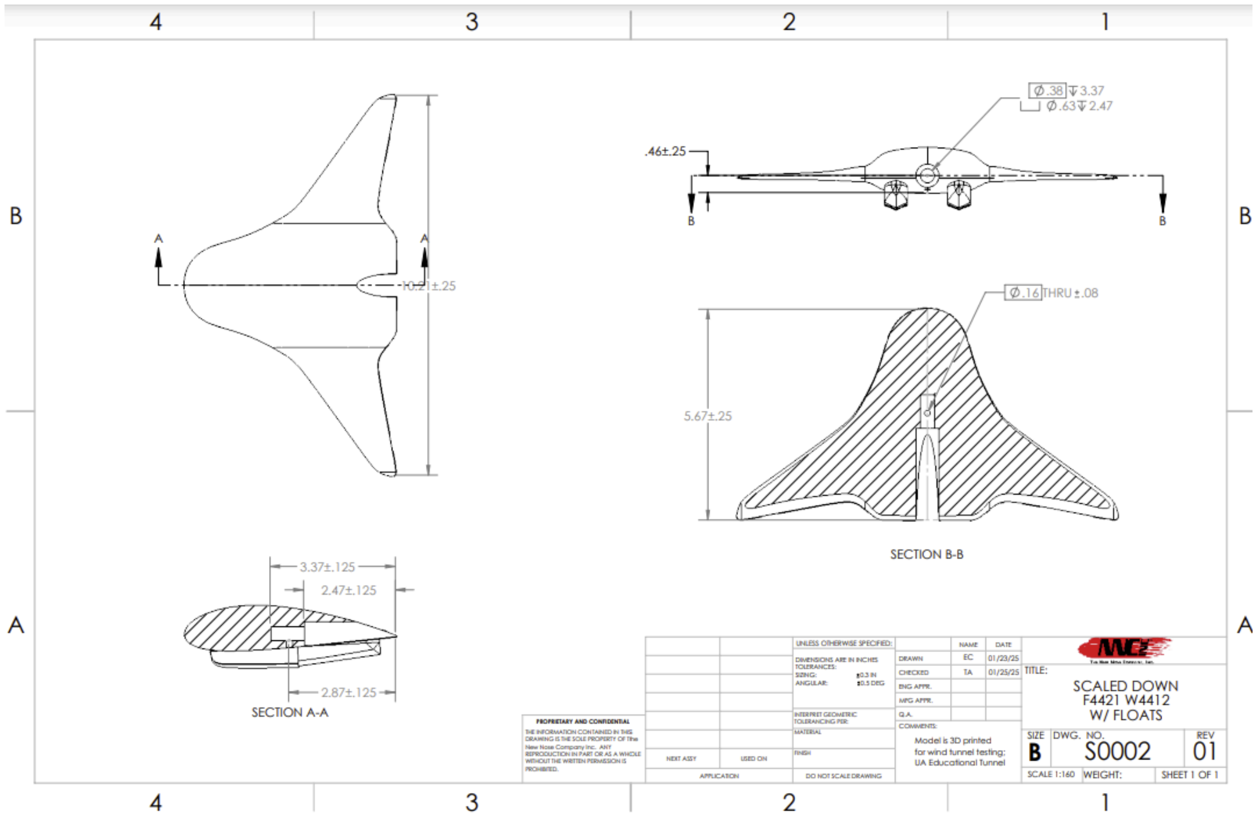
WT Scaled Seacat-1



NOTE:

The wind tunnel required both scaled down models to have a counterbored hole for mounting purposes. Also, another hole located perpendicular to the shaft hole was needed for a set screw to secure the model to the mount.

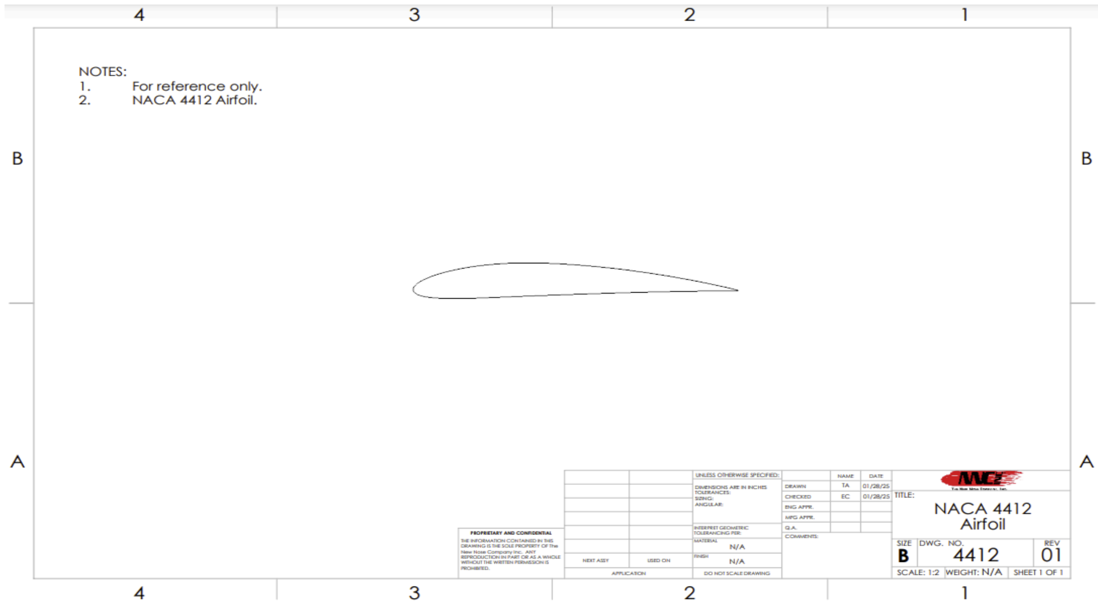
WT Scale Seacat-2



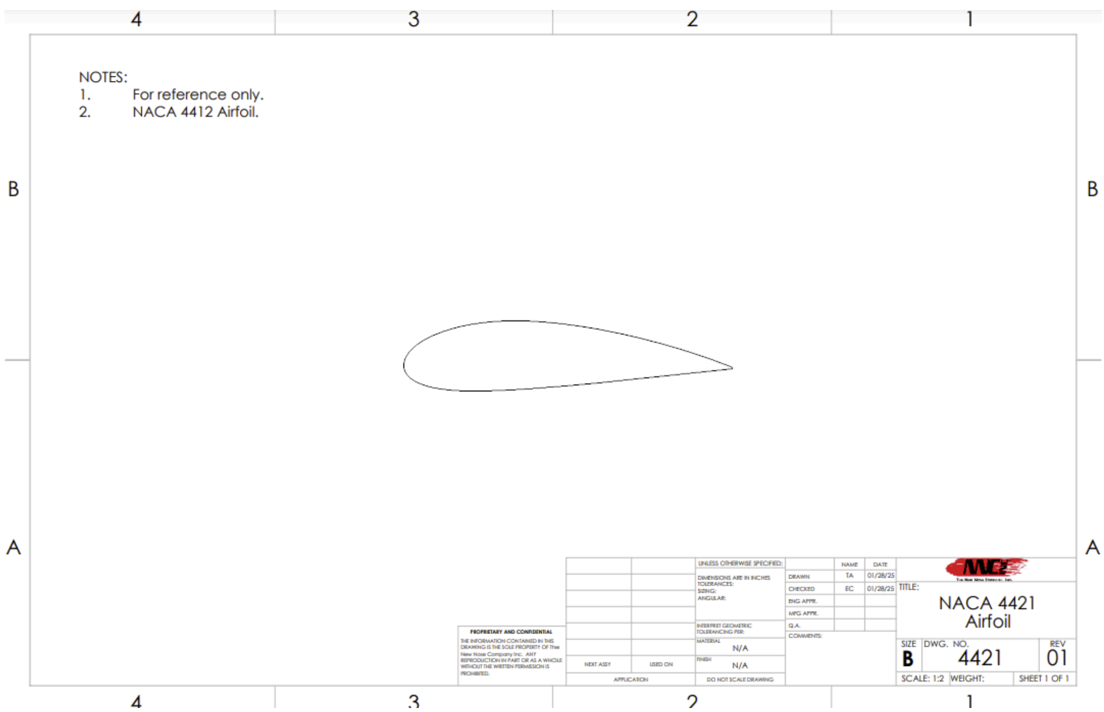
NOTE:

When assembling the blended wing body model with Float Type III in Solidworks, the floats were aligned on either side of the cargo bay, and extruded upwards into the bottom surface of the aircraft. This integrated the floats into the whole design, which added more surfaces where the openings had to be filled in.

Airfoil 4412



Airfoil 4421



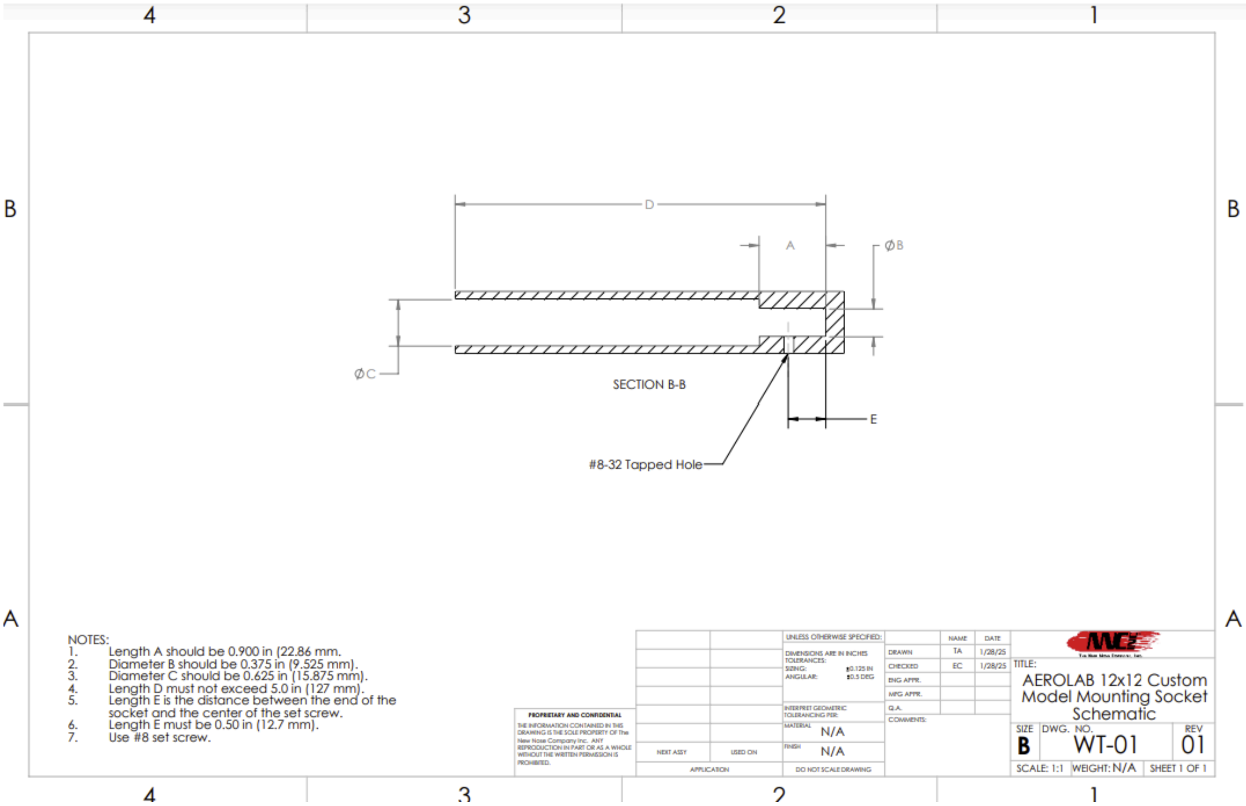
Note:

COLLEGE OF ENGINEERING
Craig M. Berge Engineering Design Program

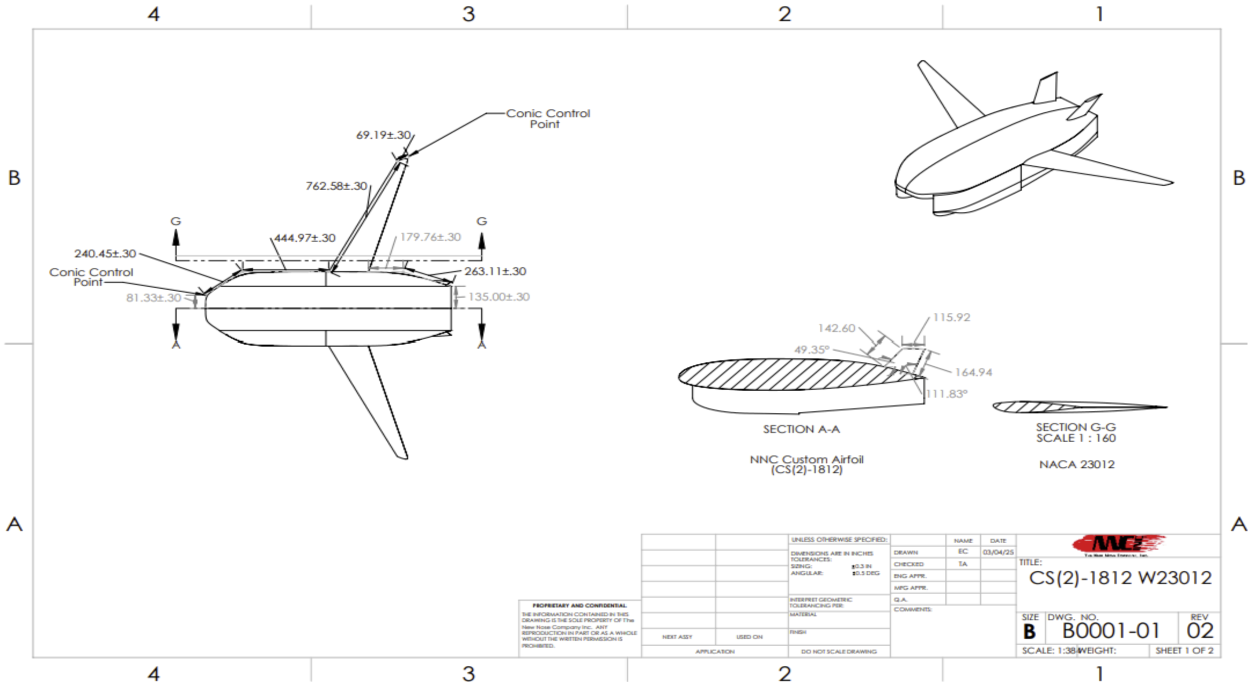
THE NEW NOSE COMPANY, INC.

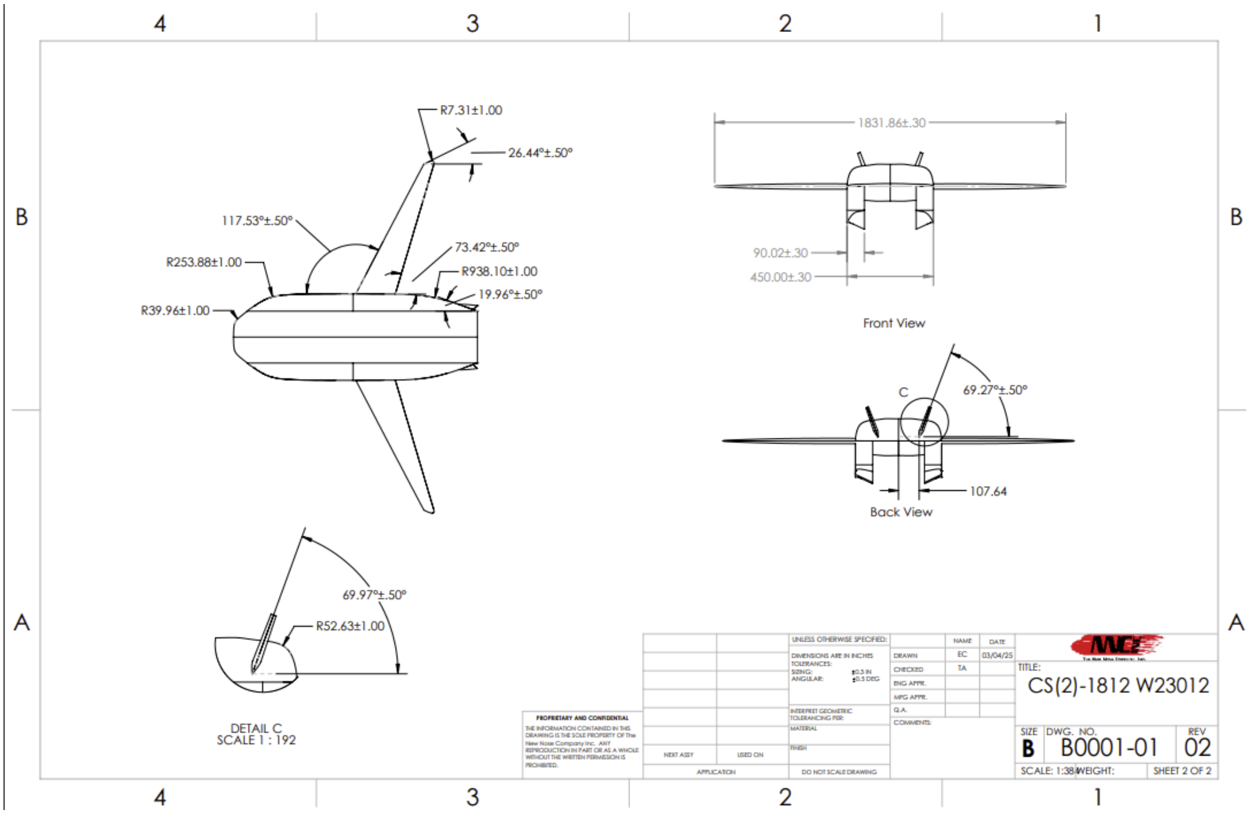
Both airfoils are for reference only. The thickness is controlled by the length of the airfoil. Airfoil 4412 is designated for the wings of the first model, while airfoil 4421 is designated for the body of the blended wing body.

Custom Wind Tunnel Model Mounting Socket

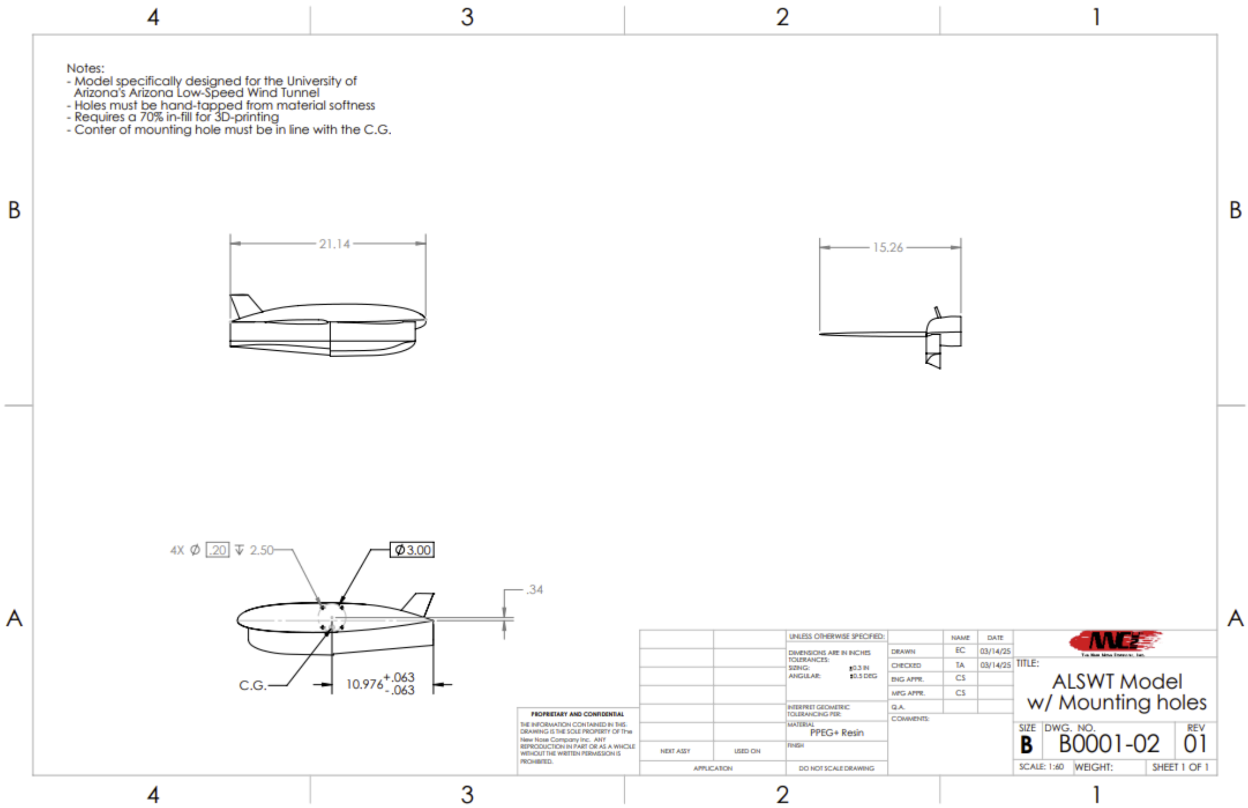


WT Scale Seacat-3

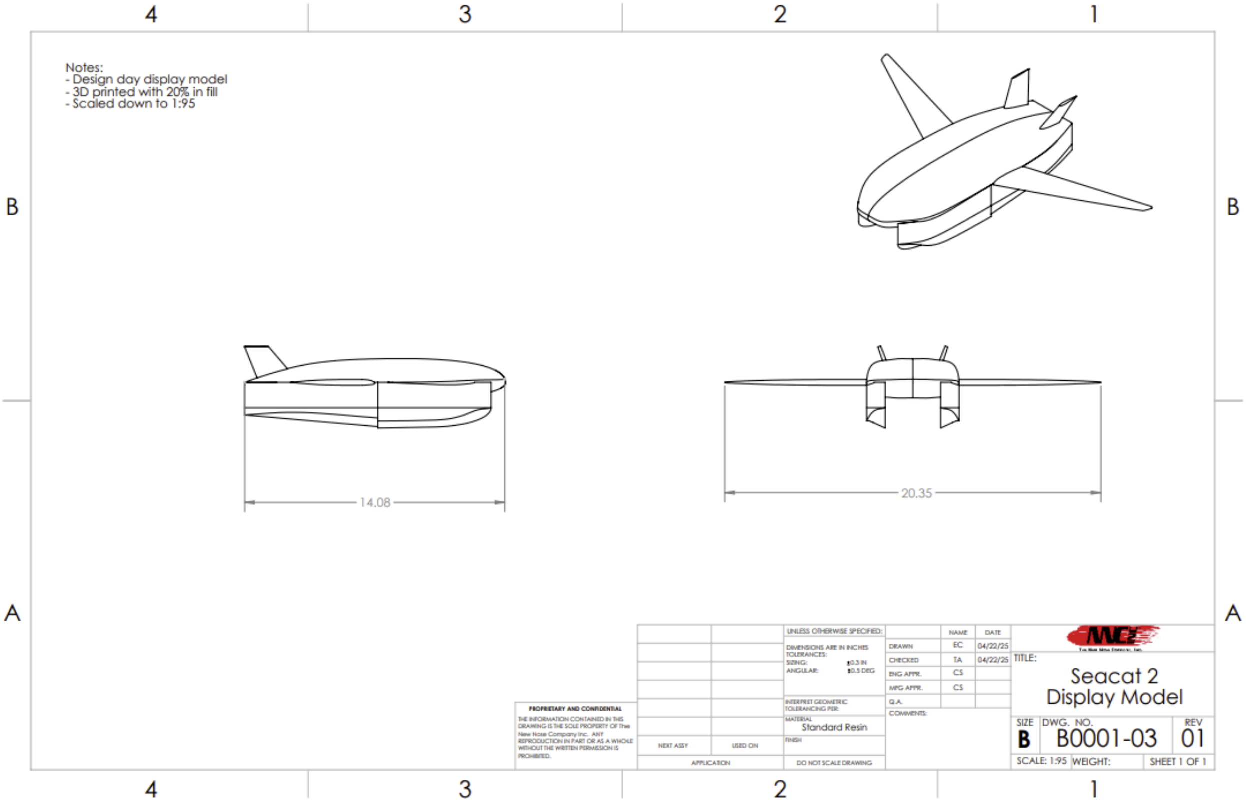




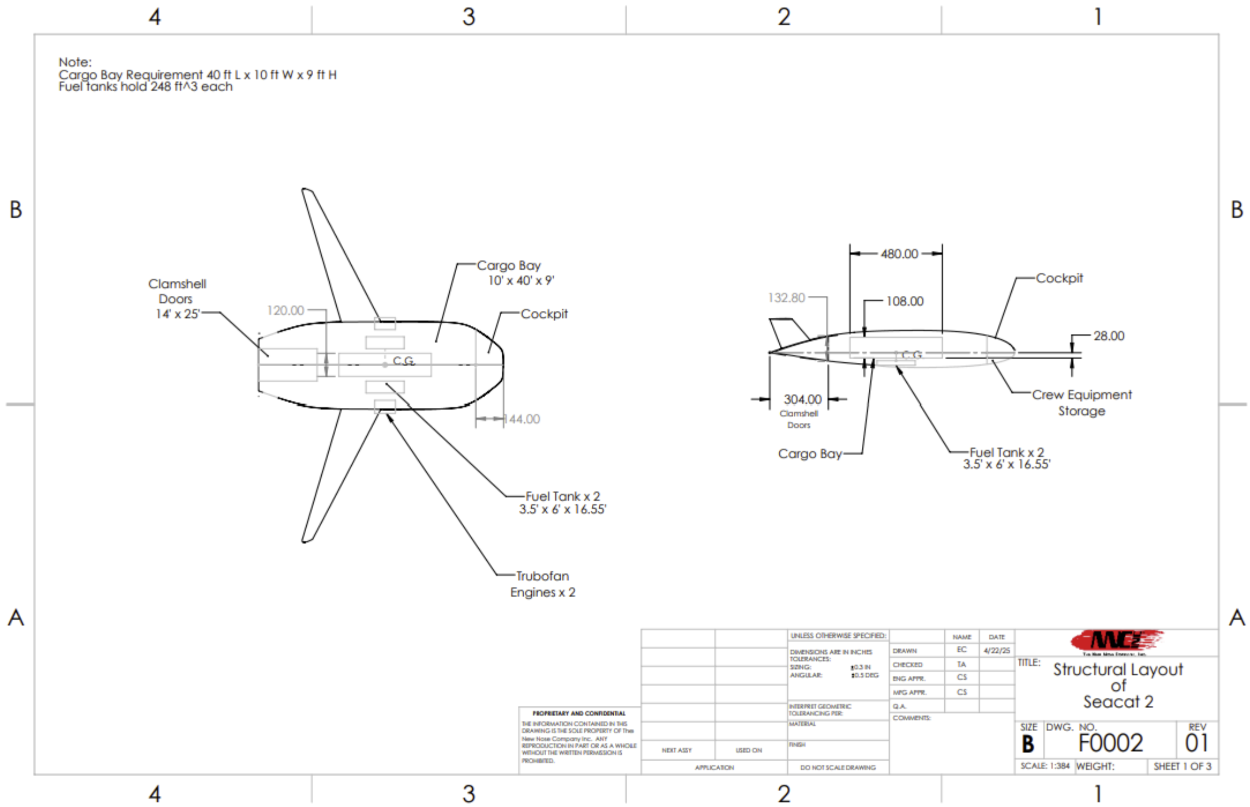
ALSWT Scale Seacat-3 Model



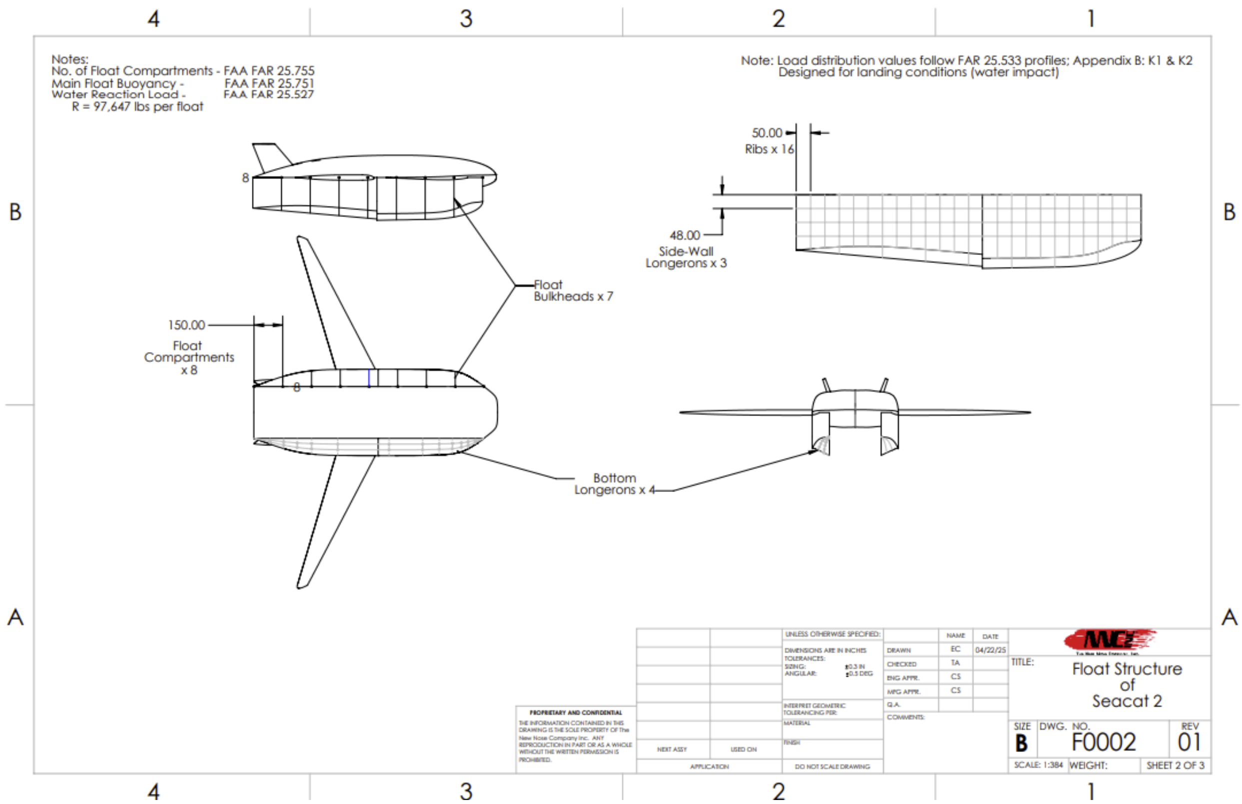
Scaled Down Seacat 3 Display Model



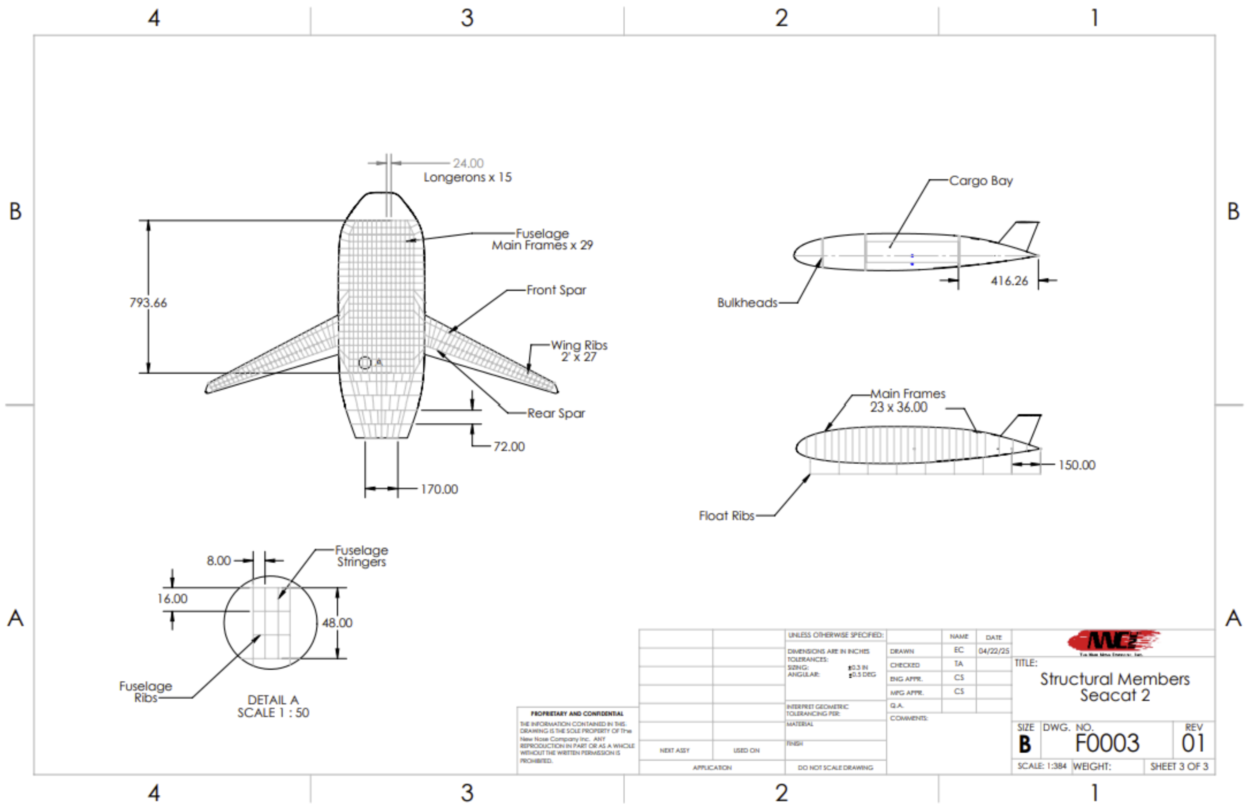
Seacat 3 Structural Layout



Seacat 3 Float Structural Layout



Seacat 3 Fuselage Structural Layout



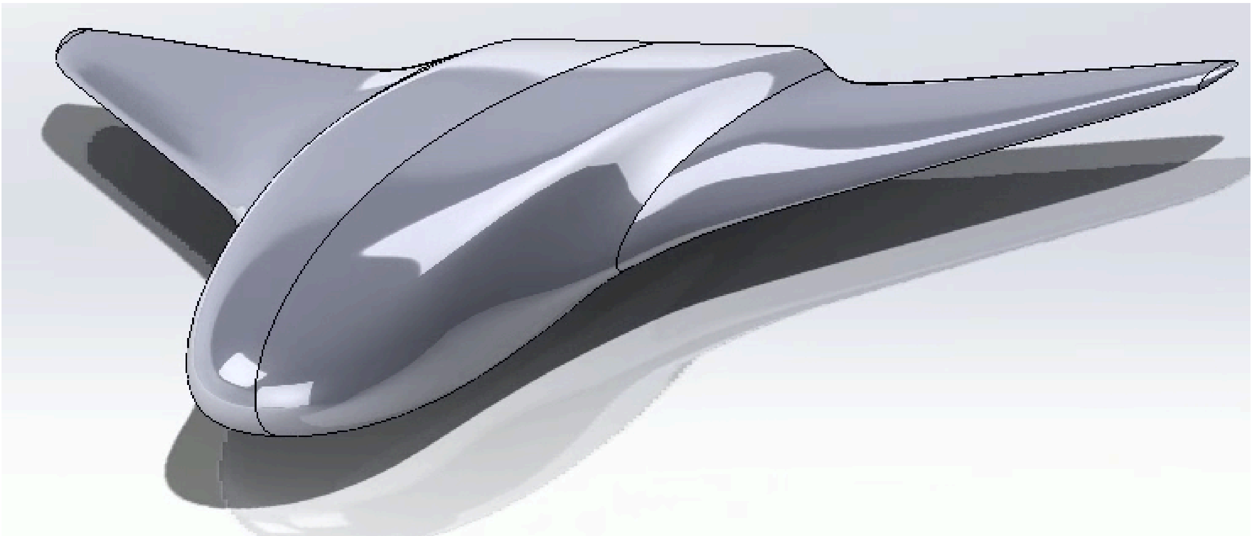
3.6 Software Documentation

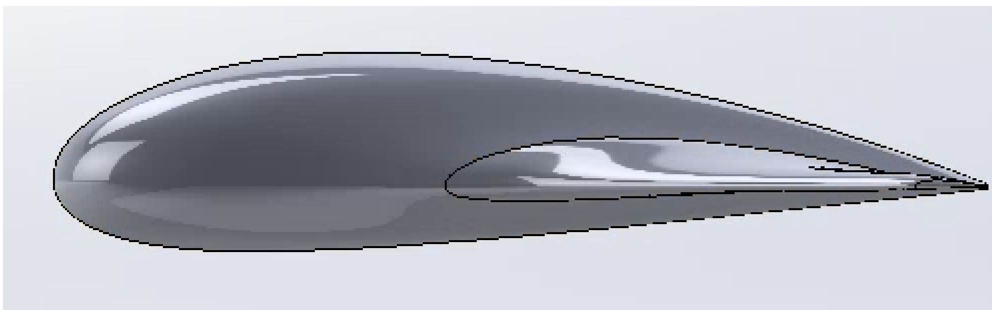
Due to the scope of this project, no software development was necessary to achieve the deliverables.

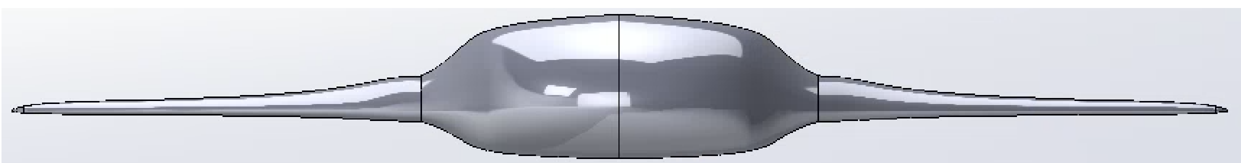
3.7 Models

Seacat-1

Part: F4421 W4412 0001
Drawing: B0001







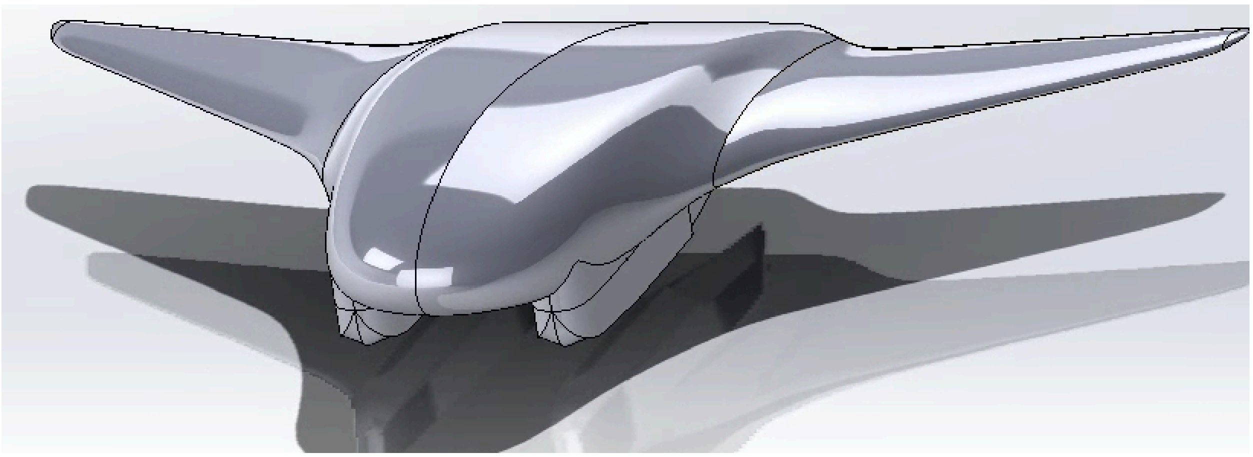
Test:

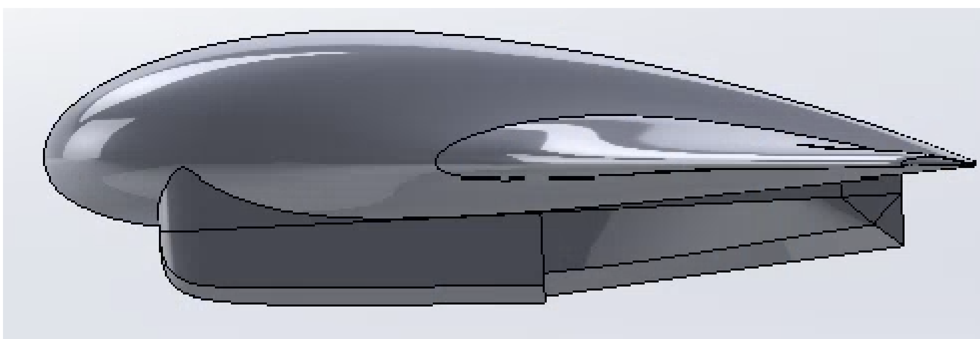
The full size model was verified using CFD testing with Ansys.

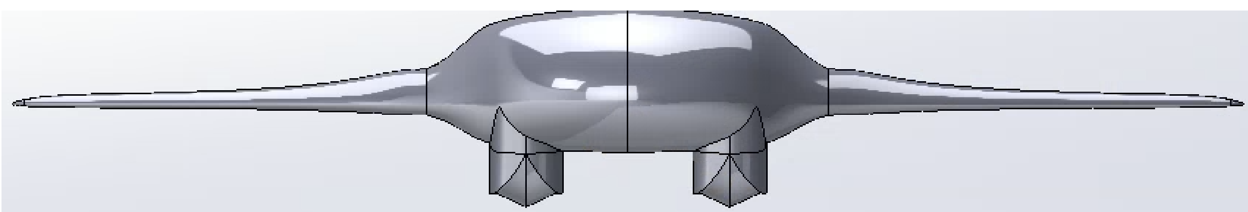
Seacat-2

Parts: F4421 W4412 0001
Float Type III

Drawing: B0002







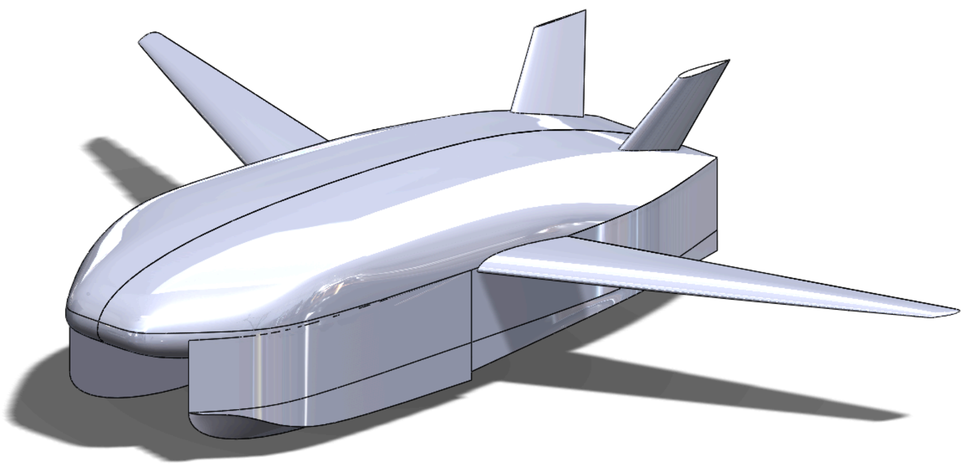
Test:

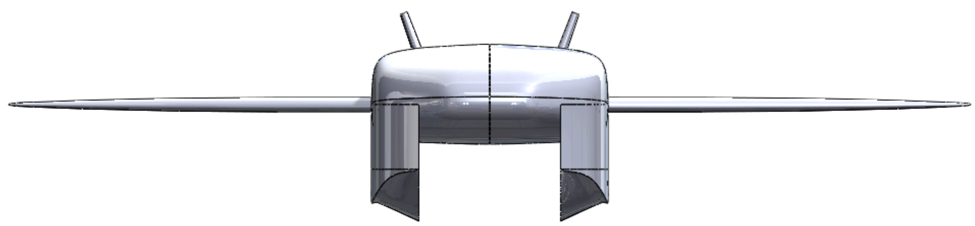
Full scale model was tested using CFD testing in Ansys. Note that the floats extrude directly upwards, in order to mate with the body surface and have no gaps in between.

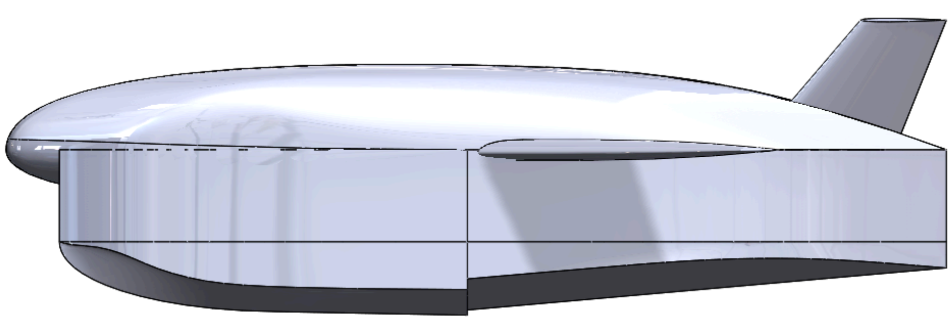
Seacat-3

Parts: **FCS2-1812 W23012 T0012**
Float Type III Rev. 3

Drawing: B0003





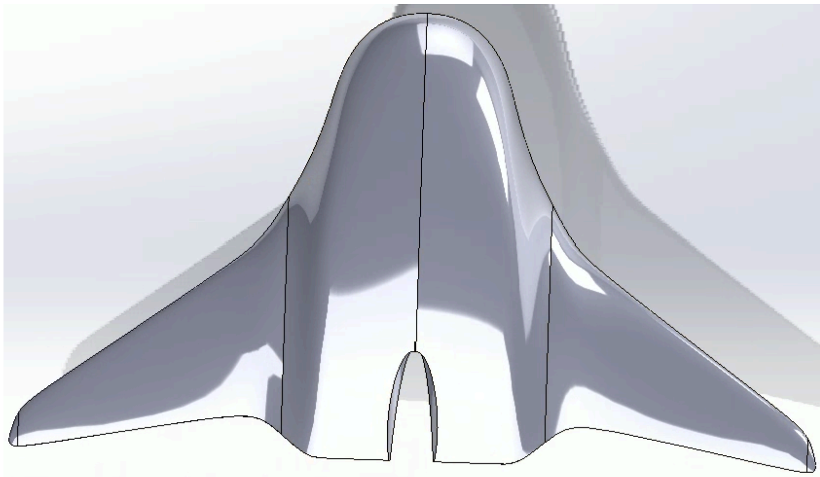


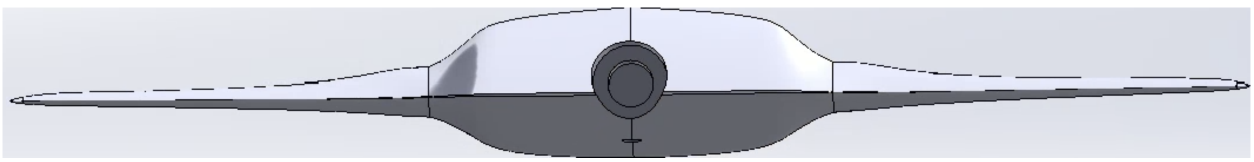
Test:

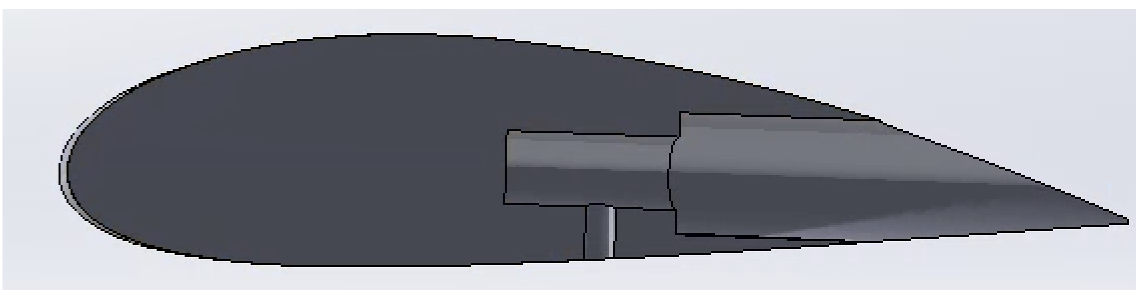
Full scale model was tested using CFD testing in Ansys. Note that the floats extrude directly upwards, in order to mate with the body surface and have no gaps in between.

WT Scale Seacat-1

Part: F4421 W4412 00001
Drawing: S0001





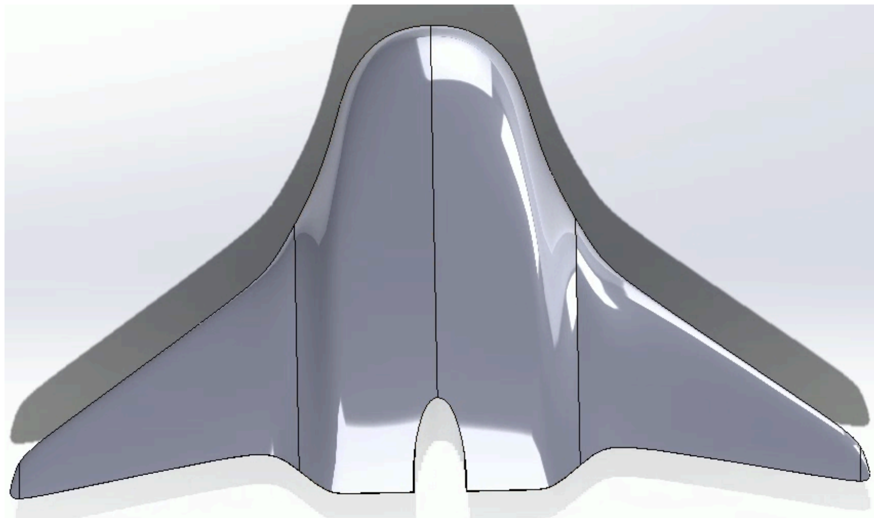


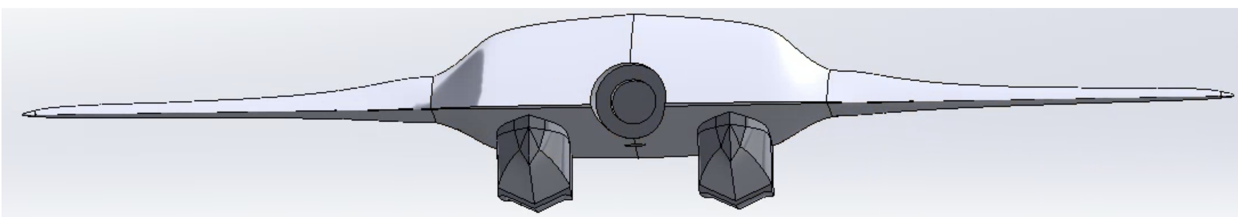
Test:

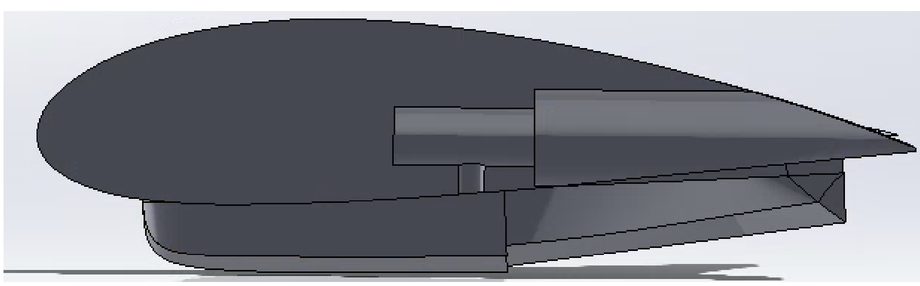
The scaled down model was tested in the wind tunnel to obtain deliverables.

WT Scale Seacat-2

Part: F4421 W4412 00002
Drawing: S0002





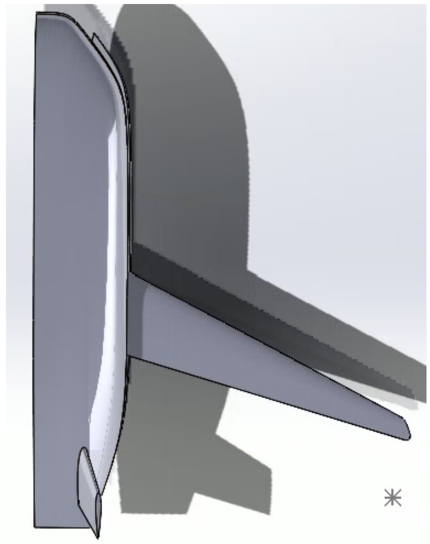


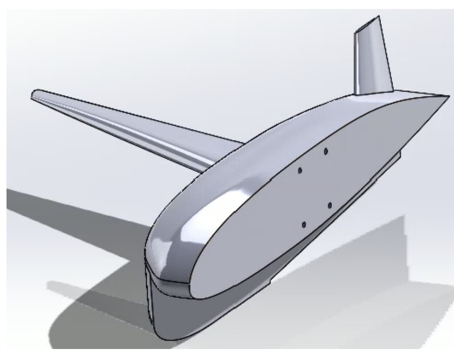
Test:

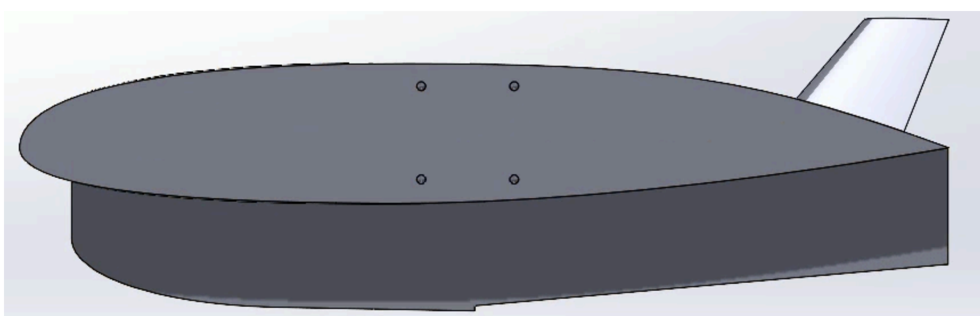
The scaled down model was tested in the wind tunnel to obtain deliverables.

WT Scale Seacat-3

Part: FCS2-1812 W23012 T0012
Drawing: S0002





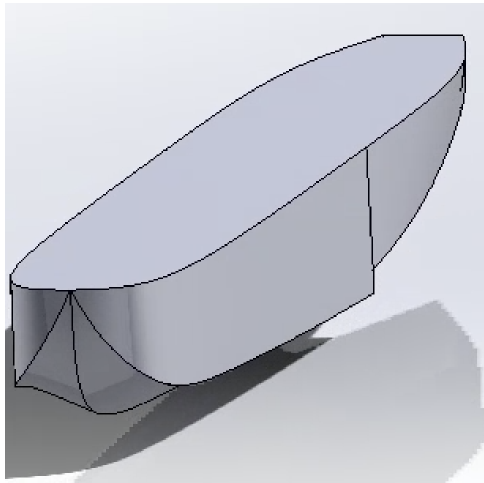


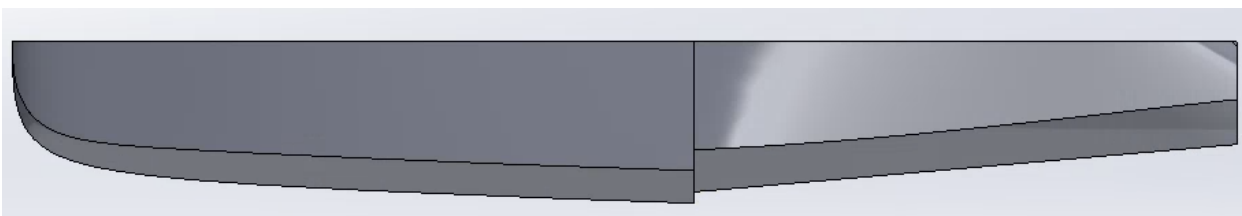
Test:

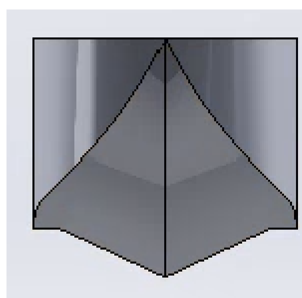
The scaled down model was tested in the ALSWT wind tunnel to obtain deliverables.

Float Type I

Part: H001-001
Drawing: H001





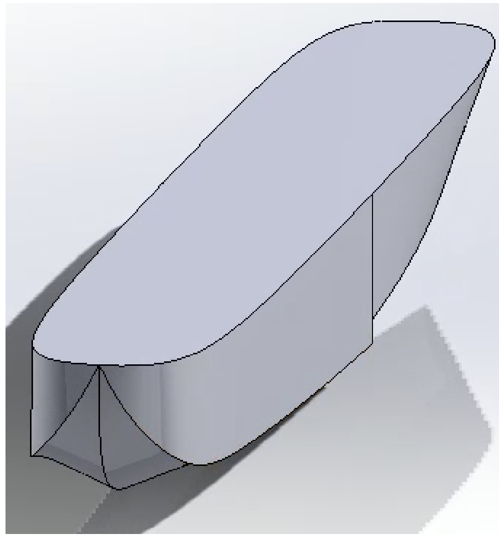


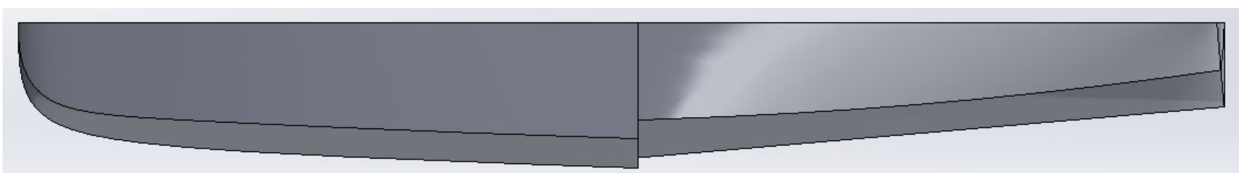
Test:

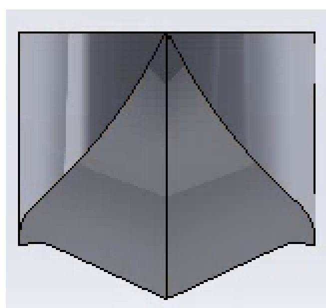
Float Type I was tested by itself with CFD in Ansys in order to measure the amount of drag it created. It is the chosen float type for the blended wing body.

Float Type II

Part: H002-001
Drawing: H002





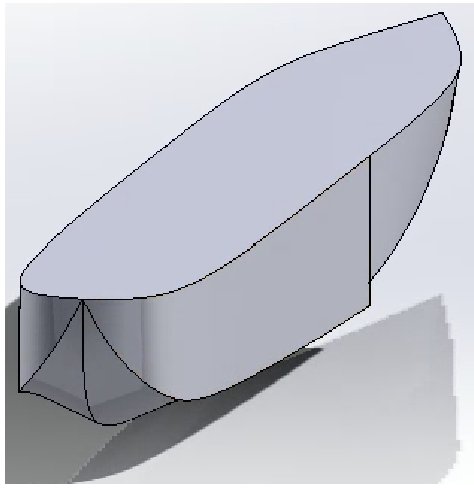


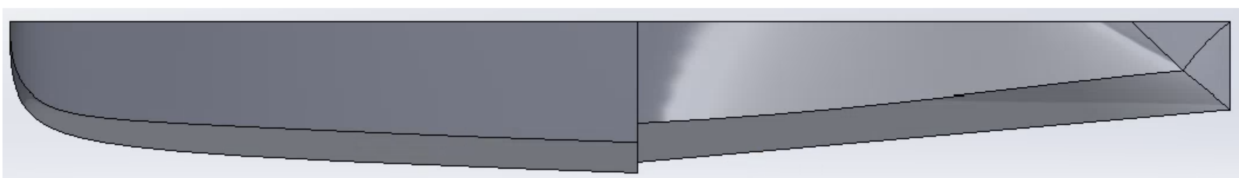
Test:

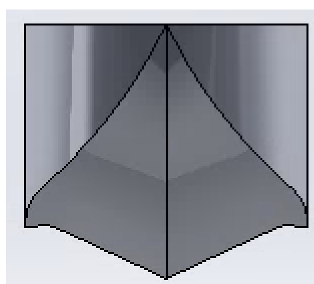
Float Type II was tested by itself with CFD in Ansys in order to measure the amount of drag it created

Float Type III

Part: H003
Drawing: H003





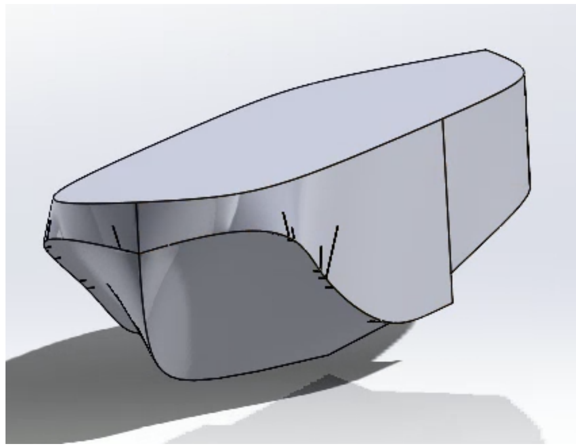


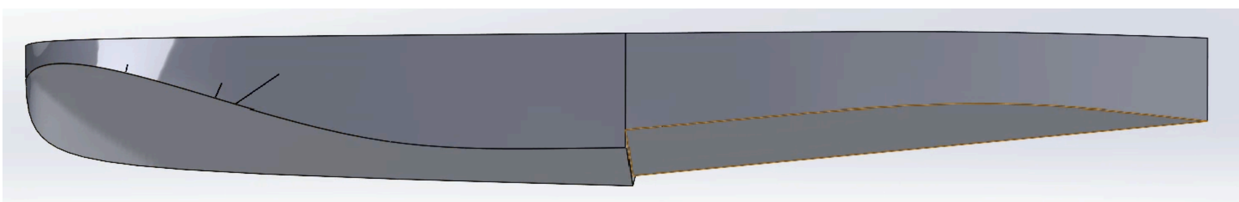
Test:

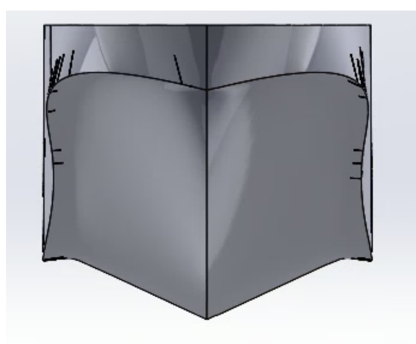
Float Type III was tested by itself with CFD in Ansys in order to measure the amount of drag it created

Float Type III Rev 2

Part: H003-01
Drawing: H003-01 Rev 2



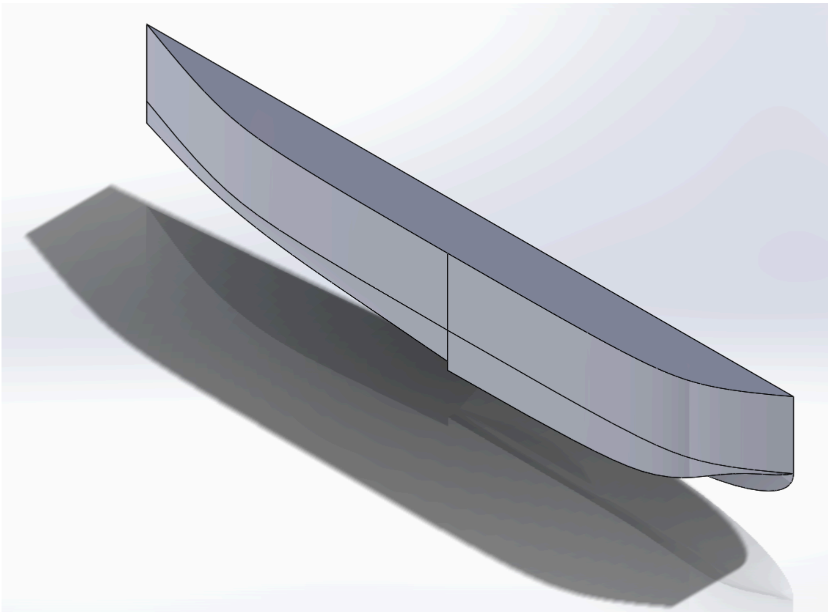


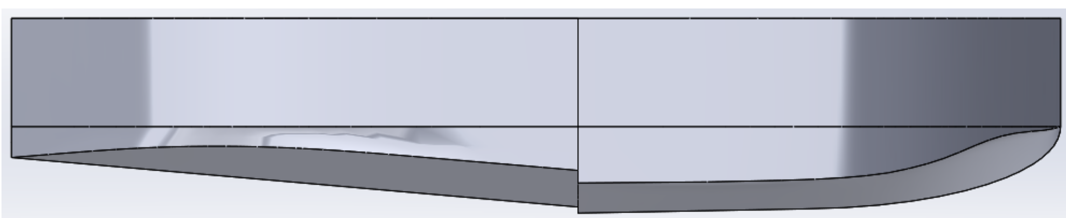


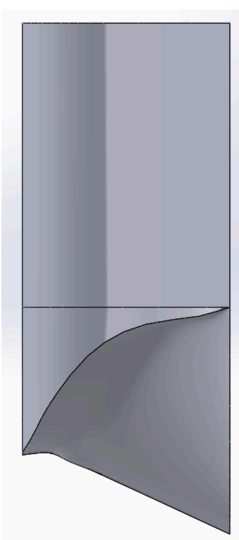
Float Type III Rev 3

Part: H003-1

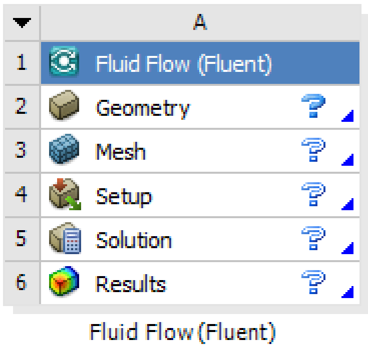
Drawing: H003-1







ANSYS Fluent Simulation Workflow Model



Test: All fluid flow simulations using ANSYS follow this workflow. The geometry is imported from the SOLIDWORKS model, meshed, and then set up according to the test condition requirements.

4.0 Models / Analysis Predictions

This section presents the results from our wind tunnel and CFD testing. The models specifically evaluated include Seacat 1, 2, and 3. Seacat models 1 and 2 were tested at 1:180 scale in the Arizona Educational Wind Tunnel, while Seacat 3 was tested at a larger 1:60 scale in the Arizona Low Speed Wind Tunnel. Datasheets containing test data are located in the appendix.

The primary objective of these tests is to inform and guide the next iteration of the Seacat design by providing more accurate estimates of lift and drag across various configurations. By analyzing the aerodynamic performance through both computational and experimental methods, we can make data-driven improvements to enhance overall efficiency and stability. A secondary, yet equally important goal is to validate the accuracy of our CFD simulations by comparing them directly with wind tunnel results. This comparison helps assess the reliability of our computational models and identify any discrepancies that may require refinement in the simulation setup or mesh resolution. Finally, we will test our final full-scale model at two testing conditions, take-off and landing.

4.1 Seacat-1 & 2 Results

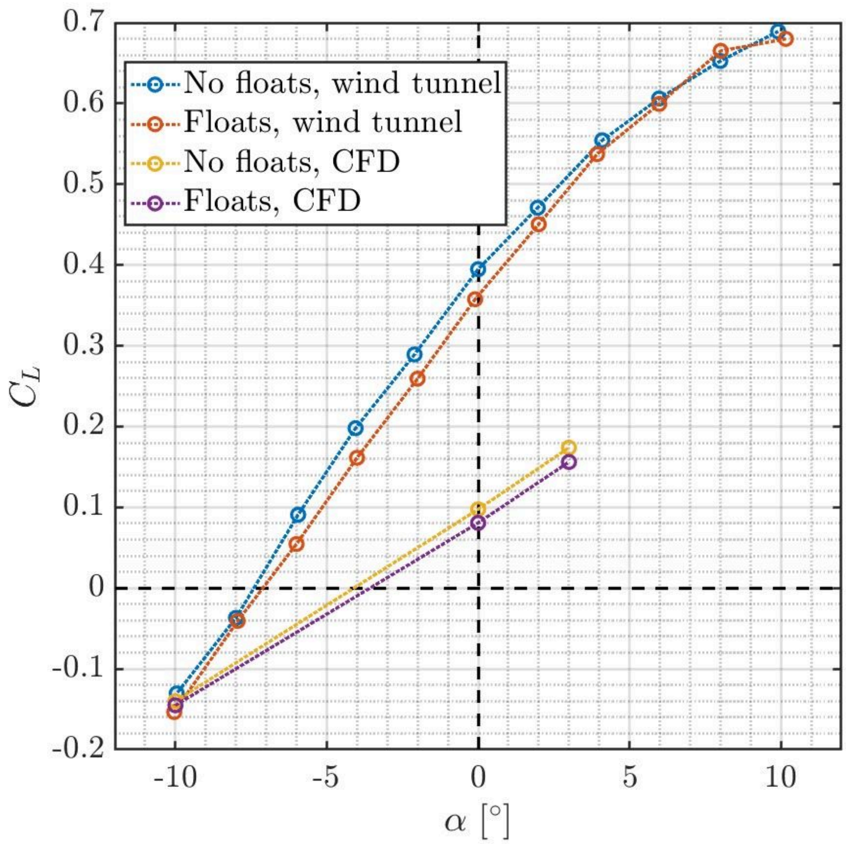
The objective of this test was to see the performance of our first design iteration. Additionally, we wanted to see how the addition of floats would affect the performance of the Seacat. With the float being a vital part of a seaplane, we knew that there would be some penalty in performance, particularly in drag and lift. The reason is that the floats contribute to more disturbances during flight, causing a reduction in lift and an increase in drag.

Another crucial part of this project is to check the validity of our CFD results. In the testing of Seacat 1 & 2, we used Ansys Fluent as the software. During wind tunnel testing, we made note of the conditions of the lab, such as temperature and pressure. This was then used in Ansys in order to rule out any errors in the results.

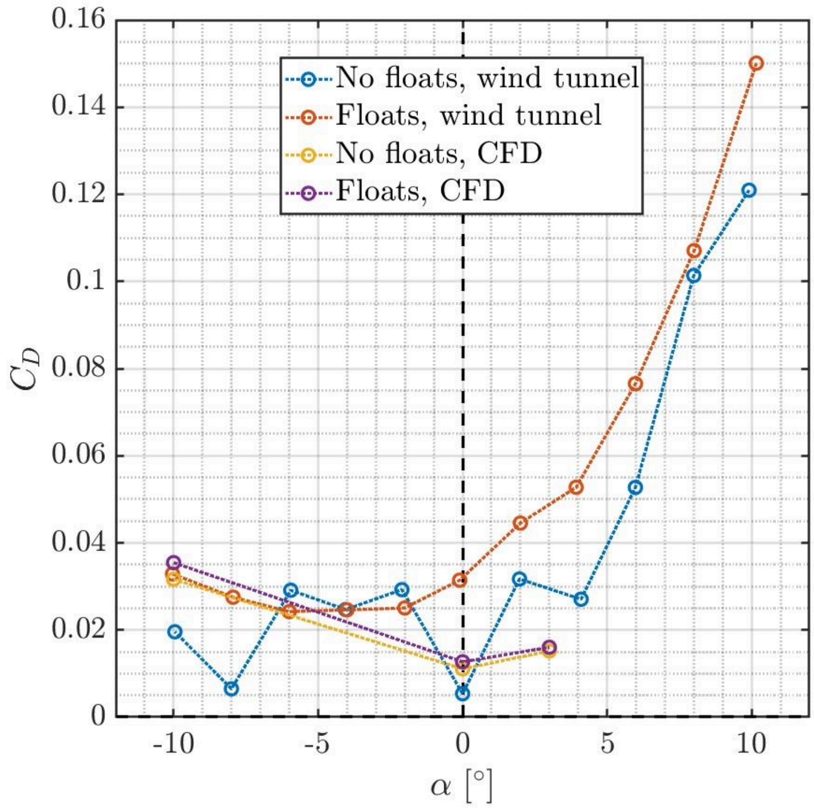
This model features a NACA 4421 airfoil for the body and a NACA 4412 airfoil for the wings. The section of these airfoils was primarily driven by the requirement for a maximum lift coefficient of 1.6. Among the airfoils evaluated, these two provided an optimal balance of high lift and low drag, making them well-suited for efficient performance in subsonic flight conditions.

4.2.1 Seacat 1 & 2 Wind Tunnel & Ansys Comparison

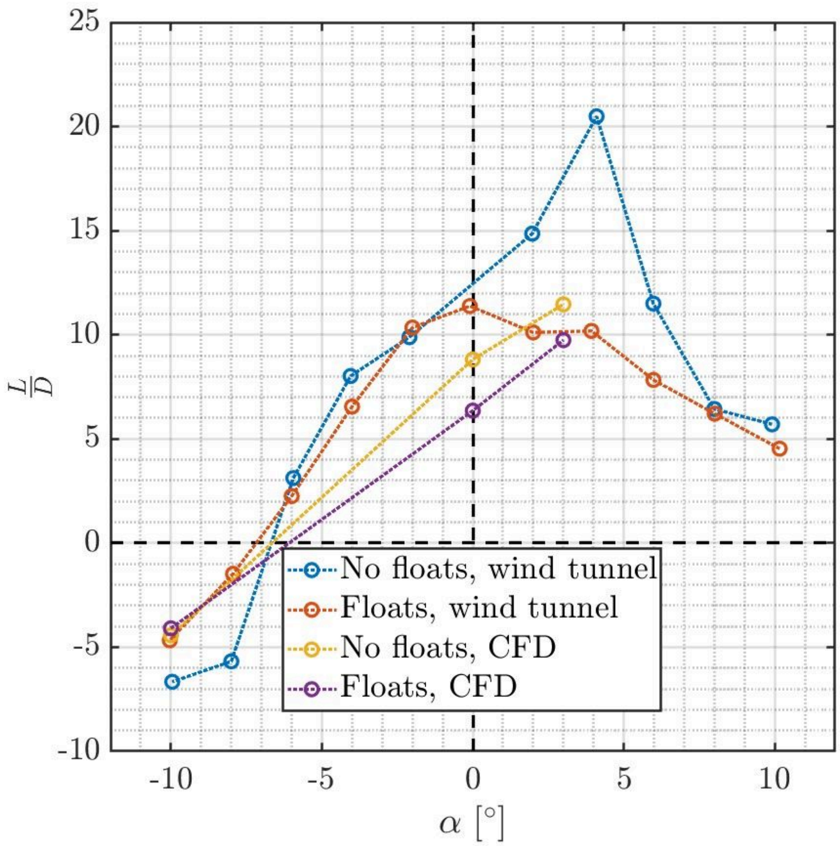
Coefficient of Lift as a Function of Angle of Attack



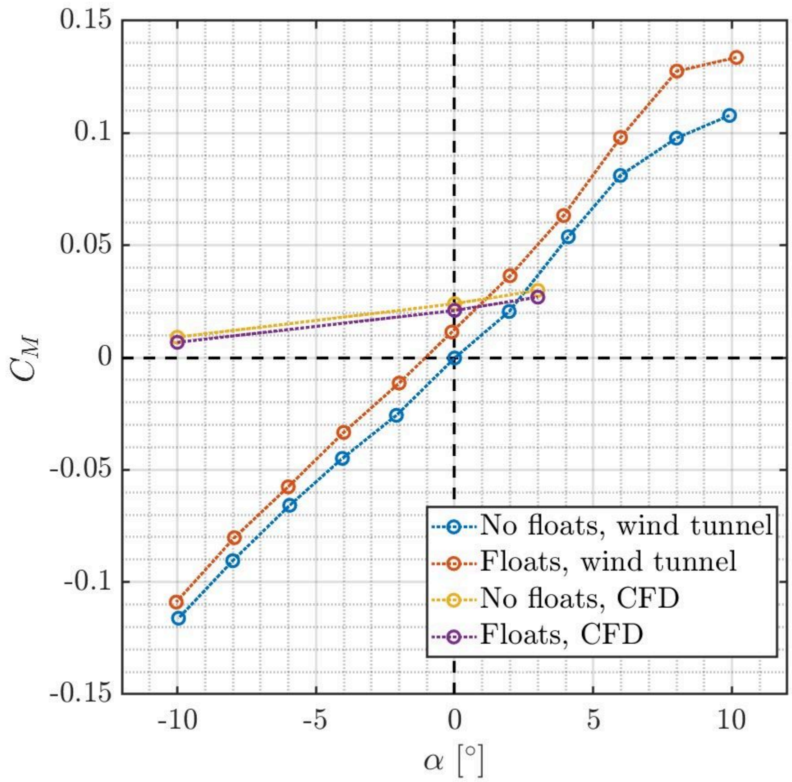
Coefficient of Drag as a Function of Angle of Attack



Lift over Drag as a Function of Angle of Attack



Coefficient of Moment as a Function of Angle of Attack



The results above compare the wind tunnel and CFD data for Seacat 1 and 2. One of the most notable observations is the 26.9% increase in drag resulting from the addition of the floats. This increase was expected, as the floats are not designed with aerodynamic efficiency in mind for cruise conditions. Their primary function is to provide buoyancy and stability during waterborne operations, and their geometry reflects this purpose. Since the floats are a critical design requirement mandated by our sponsor, there is little flexibility to alter or optimize them to reduce drag.

When analyzing the CFD results in comparison to the wind tunnel results, some discrepancies are evident. These differences can largely be attributed to the limitations of the computational setup. Running high-fidelity simulations in Ansys is very computationally demanding, often requiring several hours per case. As a result, we were only able to generate a limited number of CFD data points, which constrains results that align reasonably well with the overall trends observed in the wind tunnel test. This correlation supports the validity of our CFD model as a useful tool for gaining insight into the aerodynamic performance of the Seacat configurations, even if it cannot fully replicate the precision of physical testing.

Additionally, the coefficient of moment results indicate signs of instability. The moment coefficient does not exhibit a restoring force, suggesting the model lacks sufficient pitch stability. This behavior is also pronounced in the CFD data, and was also reflected in the wind tunnel results, highlighting a need for design refinement in airfoil selection or a tail addition. Everything discussed here helped guide the configuration of the next seacat.

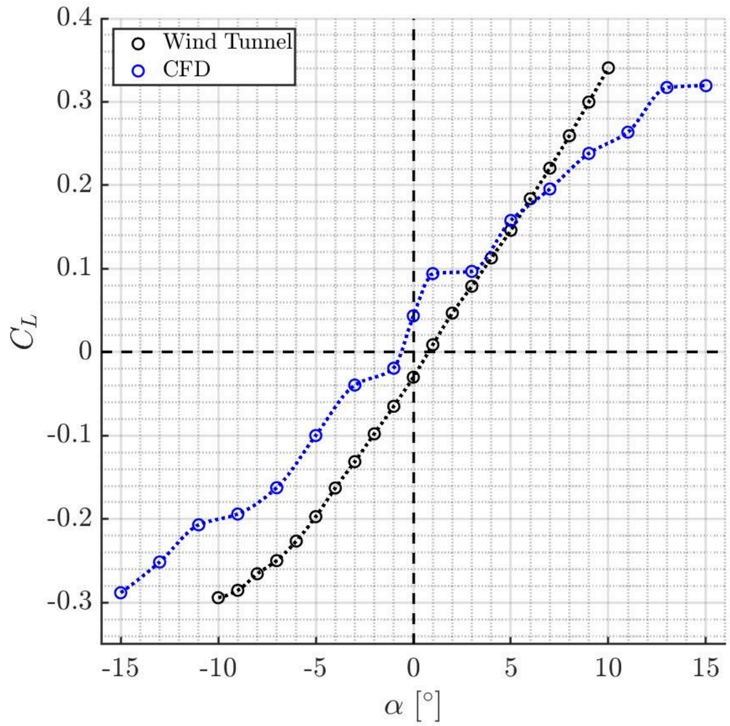
4.2 Seacat-3 Results

Seacat 3 features a completely redesigned aerodynamic profile. The new design was mainly focused on fixing some of the issues with Seacat 2. In addition, we improved the floats so that a 15-degree angle of attack at take-off from water would be achievable. Lastly, we have improved the fuselage to accommodate the payload compartment without the unnecessary addition of dead space.

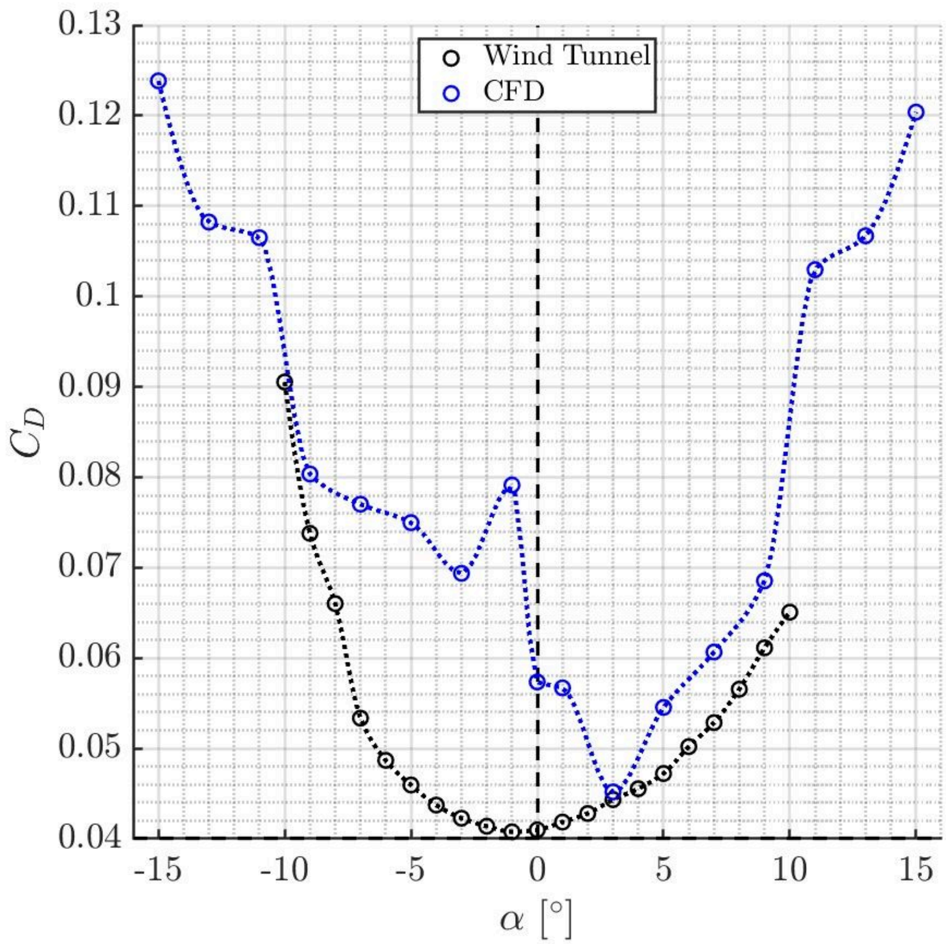
The main body utilizes a custom airfoil, designated CS(2)-1812, which was developed based on the SC(2)-0012. Through a series of modifications and geometric extensions, the CS(2)-1812 was tailored to better meet the performance requirements of the Seacat platform as well as the reduction of dead space. For the wing, we selected the NACA 23012 airfoil, known for its more stable moment coefficient characteristics, in order to address the pitch instability observed in Seacat 2. The tail section incorporates a NACA 0012 airfoil, offering additional help in maintaining balanced pitch control.

4.2.1 Seacat 3 Wind Tunnel and SolidWorks Comparison

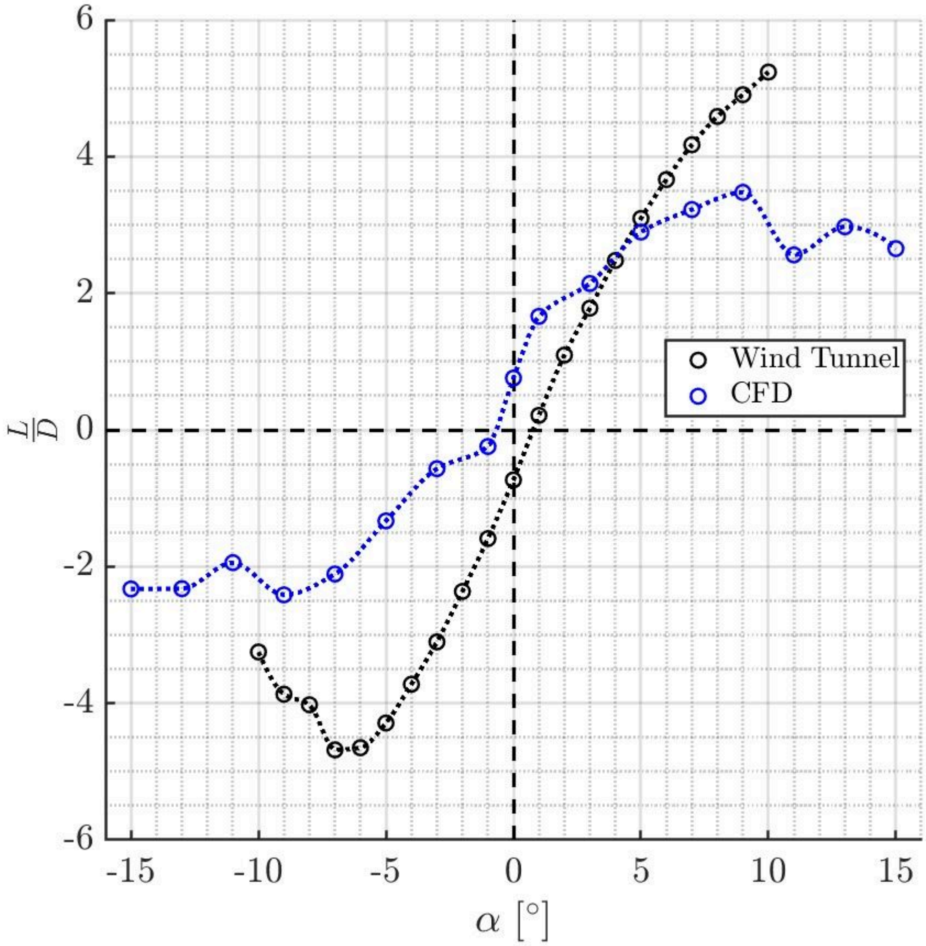
Coefficient of Lift as a Function of Angle of Attack



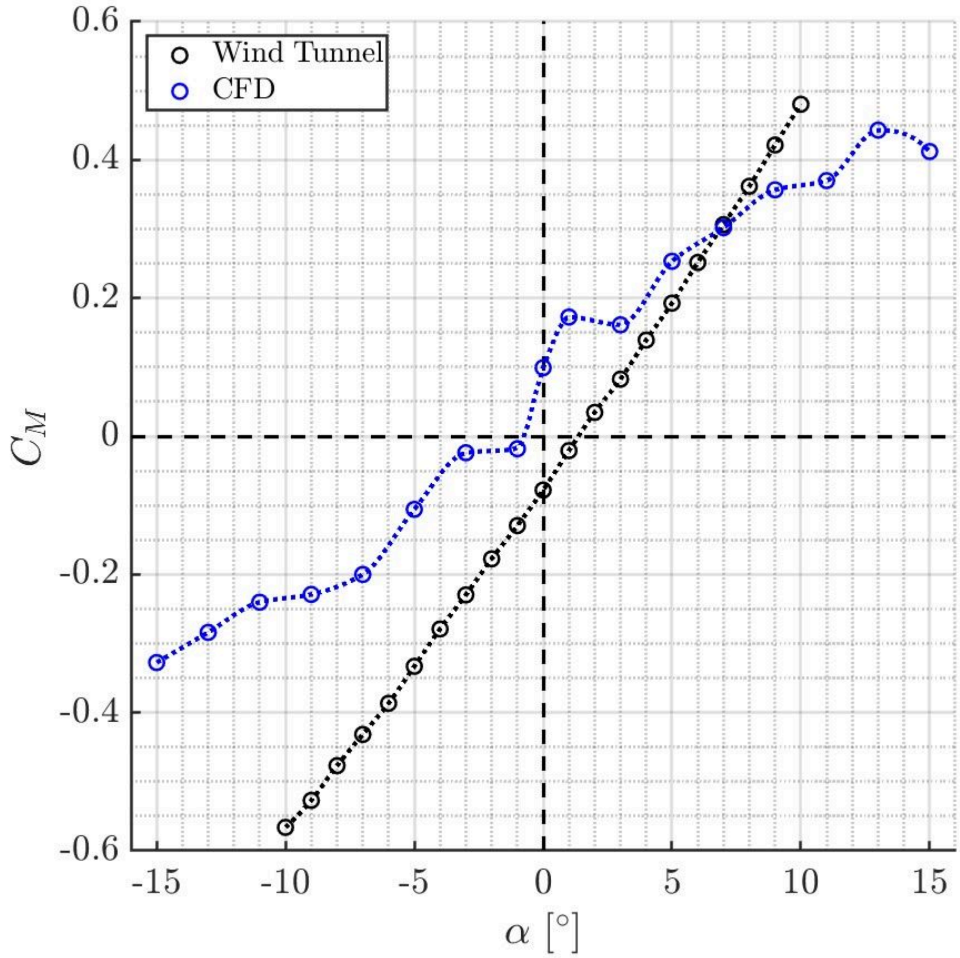
Coefficient of Drag as a Function of Angle of Attack



Lift of Drag as a Function of Angle of Attack



Coefficient of Moment as a Function of Angle of Attack



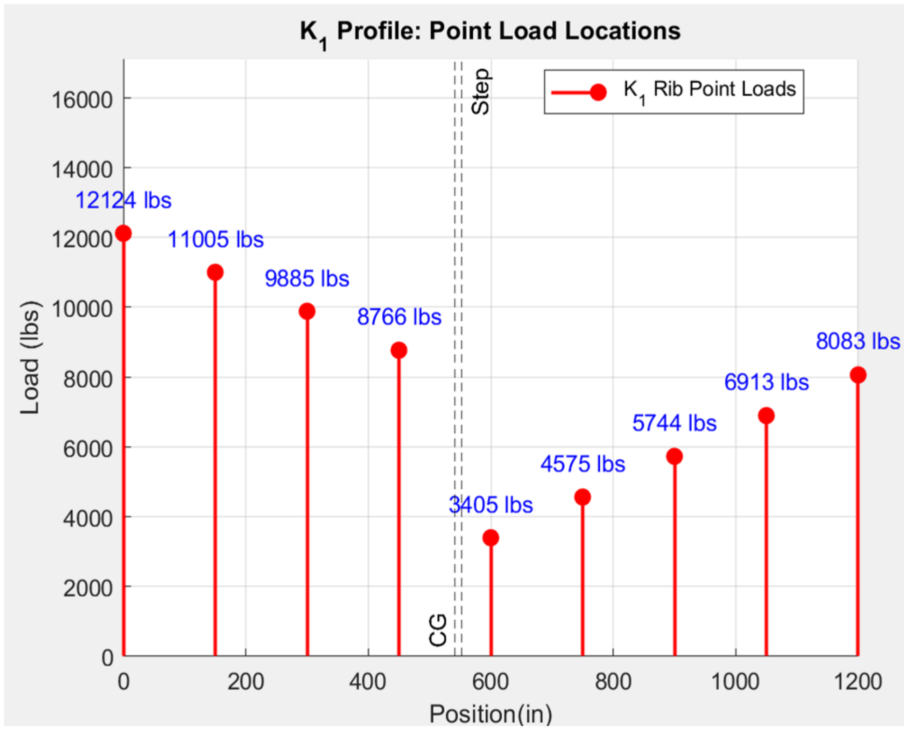
After evaluating the results, we observed that our CFD data closely followed the same trends as the wind tunnel measurements, reinforcing the consistency and reliability of our simulations. For this phase of testing, we utilized SolidWorks Flow Simulation instead of Ansys. The decision to switch was primarily driven by Ansys's high computational demands, which significantly limited the number of cases we could run. SolidWorks offered much faster simulation times, allowing us to gather a greater number of data points without compromising the overall quality of the results.

This model was tailored towards solving both the stability issues and the takeoff requirements for water operations. A slight increase in total drag can be seen in the results. This increase is likely attributed to the absence of a blended-wing-body configuration, which typically helps minimize interference drag and improve flow continuity between components. Despite this drawback, the selected airfoils were chosen for their relatively low drag characteristics in subsonic regimes, helping to mitigate some of the drag penalty. If the body were to be blended, we strongly predict that the overall drag would be reduced.

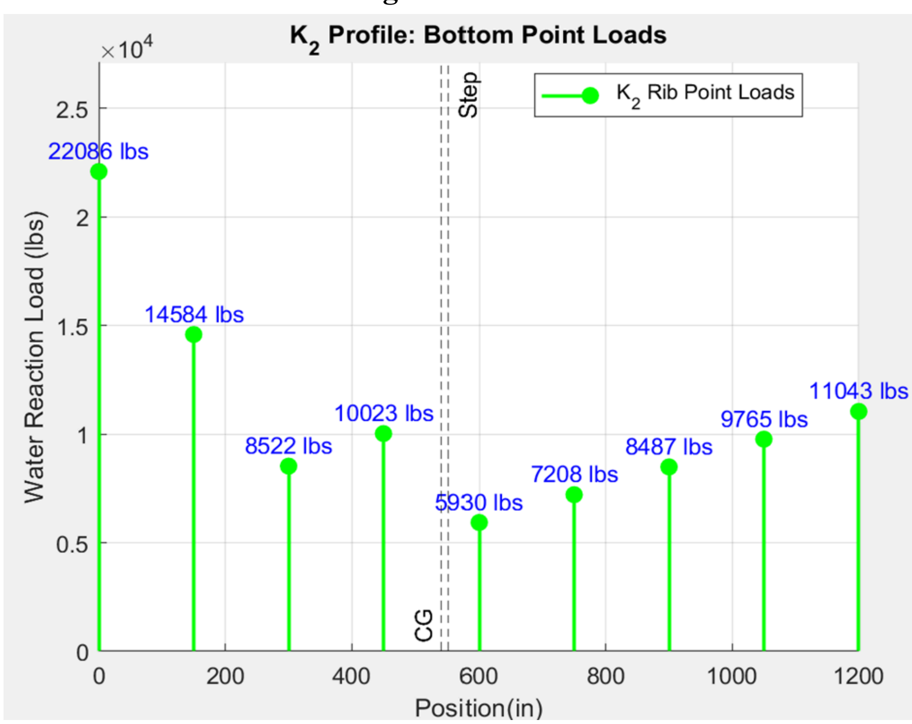
Despite these improvements, the moment coefficient curve continues to show signs of aerodynamic instability, particularly in pitch. To address this, an active control system will be necessary to maintain stability during flight. Achieving static pitch stability requires positioning the center of gravity ahead of the aerodynamic center. However, moving the wings further aft to facilitate this shift would interfere with the seaplane's required 15-degree angle of attack for waterborne takeoff. This highlights the design trade-offs between stability, performance, and operational constraints in the current configuration.

4.2.2 Seacat 3 Structural Analysis

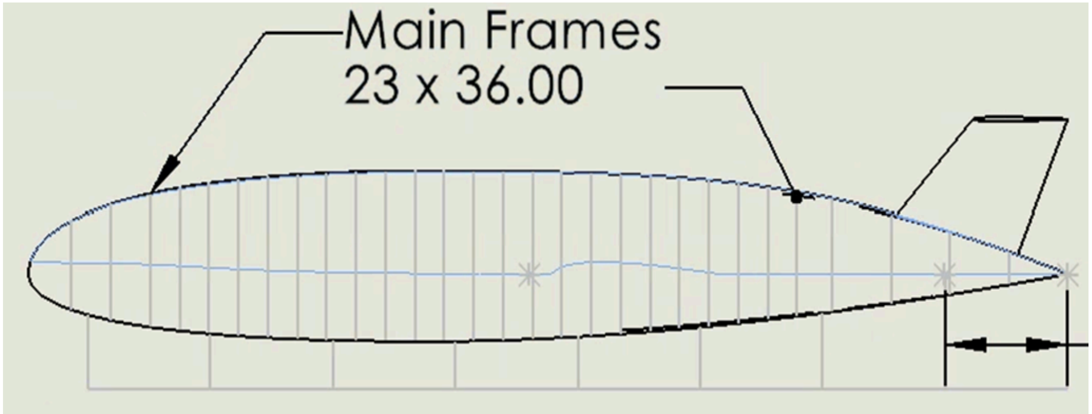
Seacat 3 K1 Vertical Load Profile Through Float Bulkheads

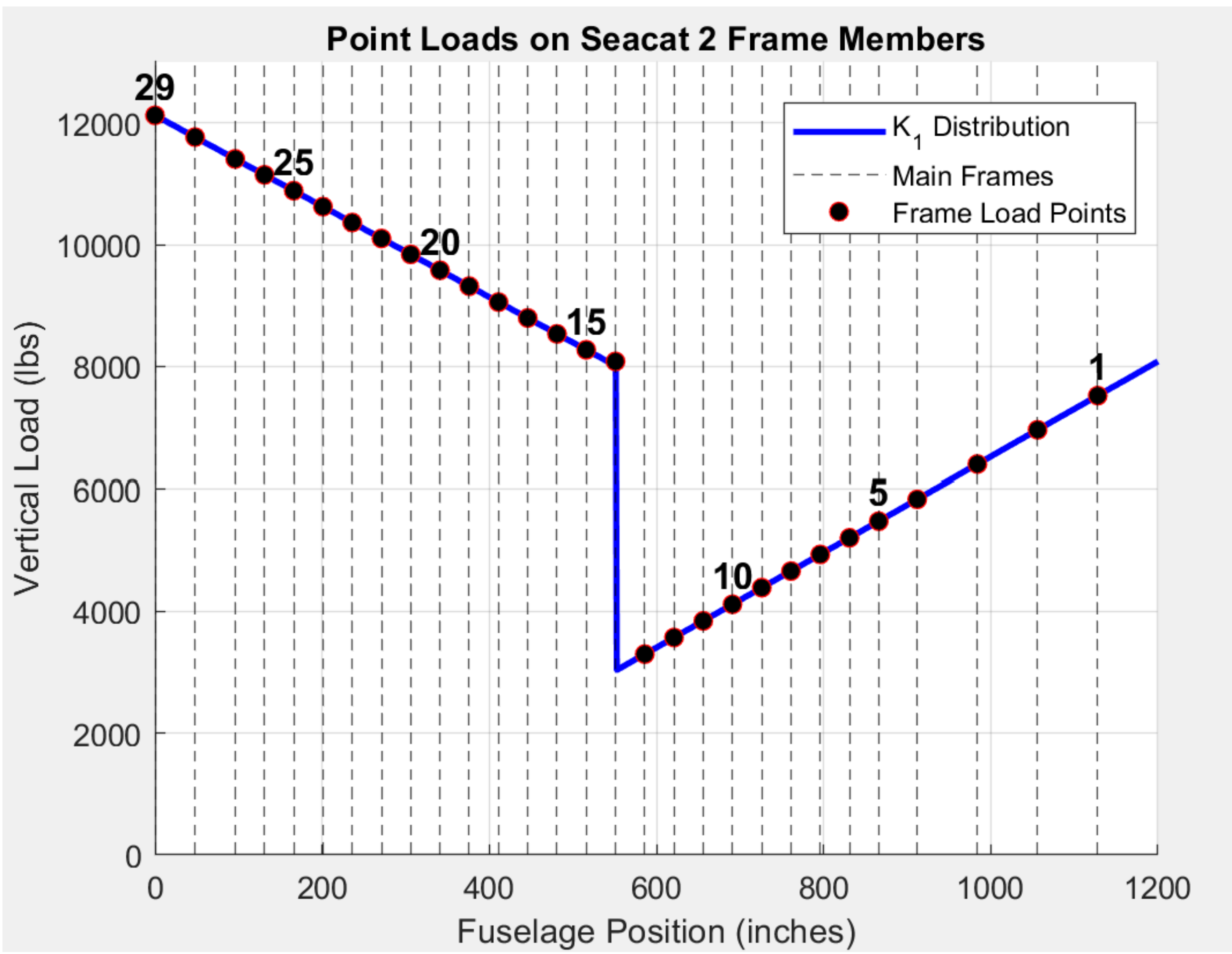


Seacat 3 K2 Bottom Load Profile Through Float Bulkheads



Seacat 3 K1 Vertical Load Profile Through Fuselage Mainframes





5.0 Verification Results

Interface Requirements	Method	Limit/Reference	Measured/Ref. Value	Pass/Fail	Notes
The system shall utilize a conventional mechanical control system to ensure longitudinal stability	A	$\frac{\delta C_M}{\delta \alpha}$	SeaCAT 1: 0.005 (w/o floats) 0.0043 (floats) SeaCAT 2: 0.0526	Fails in current iteration	A negative value of coefficient of moment with respect to AoA indicates a restoring moment with respect to AoA in the event of a perturbation Instability may be solved by a fly-by-wire system

Environmental Requirements	Method	Limit/Reference	Measured/Ref. Value	Pass/Fail	Notes
Performance requirements shall be met at: ISA Sea Level +15 ∘C	A	Standard Atmospheric Parameters at Sea Level Standard Atmospheric Parameters at Sea Level +15 ∘C.	p = 101325 Pa ρ = 1.225 kg/m^3 a = 340.3 m/s μ = 1.81E-5 Pa·s p = 101325 Pa ρ = 1.164 kg/m^3 a = 350 m/s μ = 1.89E-5 Pa·s	Pass	Sizing calculations consider the appropriate parameters such as density, dynamic viscosity, and pressure.

Customer Constraints	Method	Limit/Reference	Measured/ Ref. Value	Pass/Fail	Notes
The system shall utilize a BWB configuration	D	Drawing B0001	Drawing B0001	Pass	
The system shall utilize a catamaran hull configuration	D	Drawing H0003	Drawing H0003	Pass	
The system shall consist of a maximum of a 3 person crew	A	CS Carpet Plot	660 lbs total Includes passenger weight and personal cargo	Pass	Sizing calculations account for a crew of 3.

The system shall be capable of loading and unloading M-6 sized payload pallets	I	40L x 10W x 9H ft payload bay	40L x 10W x 9H ft payload bay	Pass	
The general airframe configuration must accommodate a 15° nose up attitude on takeoff from the water	I	Drawing B0003	Drawing B0003	Pass	
The system shall comply with FAA FAR 25 standards	A	CS Carpet Plot	CS Carpet Plot	Pass	Accounted for in the sizing calculations and design point choice

Performance Requirements	Method	Limit/Reference	Measured/ Ref. Value	Pass/Fail	Notes
The system shall have a potential range of greater than or equal to 1000 naut miles	A	≥ 1000 nautical miles Takeoff Weight - Jet	1000 nautical miles	Pass	Each performance requirement is accounted for in the sizing calculations and selection of the design point according to the carpet plot.
The system must be capable of holding a payload	A	40,000 lbs Takeoff Weight - Jet	40,000 lbs	Pass	

weight of at least 40,000 lbs					
The system shall be capable of achieving a maximum speed of at least 330 kts at 20,000 ft	A	≥ 330 kts Takeoff Weight - Jet	2 Jet Engines produce sufficient lift to reach this cruise speed	Pass	
The system must be capable of achieving a cruise speed of at least 300 kts at 10,000 ft	A	≥ 300 kts	300 kts	Pass	
The system shall have a stall speed of less than or equal to 85 kts	A	≤ 85 kts	85 kts	Pass	
The system shall meet the requirements of FAR 25.111, 25.119, & 25.121 for single engine rate of climb	A	Jan Roskam-Airplane Design Volume 2	Two turbojet engines possess the capability to meet all standards.		
The system shall comply with FAR 25 with regards to takeoff distance	A	≤ 3250 ft CS Size Matching - Jet	3250 ft	Pass	

The system shall comply with FAR 25 with regards to landing distance	A	≤ 2700 ft CS Size Matching - Jet	2700 ft	Pass	

Customer Testing Requirements	Method	Limit/Reference	Measured/ Ref. Value	Pass/Fail	Notes
The system shall provide modeling for CFD and wind tunnel testing for specific flight conditions	T	Test Condition 1 Cruise	ISA +15 °C T = 10.19 °C H_P = 10,000 ft v = 300 kts M = 0.457 AoA Range = -8° to 8°	Pass	The term “clean” refers to the status of configuration of the aircraft, namely having the landing gear retracted.
		Test Condition 2 Low Speed Clean	ISA +15 °C T = 30 °C H_P = 0 ft v = 110 kts M = 0.162 AoA Range = -8° to 15°	Pass	

6.0 Final Budget

Items	Quantity	Price	Total
3D Printed ALSWT Model	1	$476.90	$476.90
3D Printed Design Day Display Model	1	$380.00	$380.00
AIAA Memberships	5	$33.00	$165.00
Conference Fees	6	$20.00	$120.00
AIAA Conference Lodging Expenses	1	$1,432.56	$1,432.56
AIAA Conference Travel Expenses	1	$610.00	$610.00
Team Shirts + Embroidery	7	$54.38	$410.66
Video and Editing	1	$120.00	$120.00
Poster	1	$125.00	$125.00
Total:			**$3,840.12**

3D Models (19.0%)

Conference (51.7%)

Project Materials (14.6%)

7.0 Lessons Learned and Next Steps

This project came with a range of technical and logistical challenges that ultimately shaped our approach and deepened our understanding of the design and analysis process. Running ANSYS simulations was more computationally intensive than expected, especially given our limited prior experience with the software. Early CFD results were skewed by wall effects, and we faced design hurdles related to longitudinal stability and 3D printing constraints, including surface finish and model size. These obstacles taught us the value of early task delegation and the importance of establishing good simulation practices from the start. Hands-on experience proved to be the fastest way to learn, and we quickly realized how critical proper domain sizing and boundary conditions are to achieving accurate CFD results. Through testing, we found that airfoils with gentler pitching moment curves offer more stable performance, an insight particularly relevant to BWB aircraft. Outsourcing our model fabrication enabled us to build larger test models and reach more representative Reynolds numbers. Moving forward, accounting for the center of gravity and moment balance during the design phase and planning for manufacturing limitations early on will be key to avoiding setbacks and improving workflow efficiency.

As our involvement in this project comes to a close, the next phase will be carried forward by future design teams. With a solid foundation in place, they will have the opportunity to build on our initial work through additional design iterations aimed at refining aerodynamic performance and improving longitudinal stability. One major area for advancement lies in implementing more advanced and efficient CFD methods, potentially using higher-fidelity turbulence models and mesh refinement techniques to capture complex flow behavior more accurately. Further exploration of stability augmentation strategies and center of gravity optimization will also be critical, particularly given the unique characteristics of blended wing body platforms. With the groundwork we've laid, alongside the lessons we've documented, future teams will be well-positioned to push the design forward with greater confidence and technical capability.

Appendix A - Analysis Documentation

Wind Tunnel Test Data Sheet 1
Referenced ATP Paragraph Number: 3.4.2
Analysis Referenced (for verification by T/A): N/A
Name of Test: Wind Tunnel Design Evaluation Test 1
Unit Under Test (UUT): Name: Seacat 1 Part Number: SC-001 Serial Number: N/A

Date of Test:			
AoA	Coefficient of Lift	Coefficient of Drag	Coefficient of Pitching Moment
-10	-0.13045	0.019581	-0.11611
-8	-0.03689	0.006492	-0.09051
-6	0.090848	0.029118	-0.06582
-4	0.197963	0.024683	-0.04492
-2	0.289302	0.029259	-0.02574
0	0.394827	0.00537	-0.00021
2	0.470918	0.031696	0.020508
4	0.554424	0.02706	0.053814
6	0.606152	0.052716	0.081103
8	0.652625	0.101366	0.097716
10	0.689252	0.120933	0.107825

Signatures: Tester ______________________________ Customer ___________________________

Wind Tunnel Test Data Sheet 2			
Referenced ATP Paragraph Number: 3.4.2			
Analysis Referenced (for verification by T/A): N/A			
Name of Test: Wind Tunnel Design Evaluation Test 2			
Unit Under Test (UUT): Name: Seacat 2 Part Number: SC-002 Serial Number: N/A			
Date of Test:			
AoA	Coefficient of Lift	Coefficient of Drag	Coefficient of Pitching Moment
-10	-0.15348	0.032866	-0.10892
-8	-0.04071	0.027523	-0.08023

-6	0.054564	0.024204	-0.05759
-4	0.161311	0.024616	-0.03335
-2	0.259249	0.025057	-0.01138
0	0.357636	0.03143	0.011378
2	0.450408	0.044532	0.036434
4	0.537234	0.052754	0.063257
6	0.599426	0.076526	0.097988
8	0.665094	0.107073	0.127568
10	0.679964	0.150096	0.133661

Signatures:

Tester ______________________________

Customer ___________________________

<u>Computational Fluid Dynamics Test Data Sheet 1</u>
Referenced ATP Paragraph Number: 3.4.3

Analysis Referenced (for verification by T/A): N/A
Name of Test: Computational Fluid Dynamics Design Evaluation Test 1
Unit Under Test (UUT): Name: Seacat 1 Part Number: SC-001 Serial Number: N/A
Date of Test:

AoA	Coefficient of Lift	Coefficient of Drag	Coefficient of Pitching Moment
-10	-0.14007	0.031633	0.009058
0	0.097492	0.011057	0.02398
3	0.17387	0.015172	0.029906

Signatures: Tester ________________________________ Customer _____________________________

Computational Fluid Dynamics Test Data Sheet 2			
Referenced ATP Paragraph Number: 3.4.3			
Analysis Referenced (for verification by T/A): N/A			
Name of Test: Computational Fluid Dynamics Design Evaluation Test 2			
Unit Under Test (UUT): Name: Seacat 2 Part Number: SC-002 Serial Number: N/A			
Date of Test:			
AoA	Coefficient of Lift	Coefficient of Drag	Coefficient of Pitching Moment
-10	-0.14515	0.035452	0.006761
0	0.080683	0.01269	0.020979
3	0.156138	0.016026	0.026902

Signatures: Tester ______________________________ Customer ___________________________

Wind Tunnel Test Data Sheet 3
Referenced ATP Paragraph Number: 3.4.4
Analysis Referenced (for verification by T/A): N/A
Name of Test: Wind Tunnel Design Evaluation Test 3
Unit Under Test (UUT): Name: Seacat 3 Part Number: SC-003 Serial Number: N/A
Date of Test:

AoA	Coefficient of Lift	Coefficient of Drag	Coefficient of Pitching Moment
-10	-0.29421	0.090537	-0.56617
-9	-0.2854	0.073789	-0.52712

-8	-0.26553	0.066018	-0.47687
-7	-0.24976	0.05335	-0.43162
-6	-0.22638	0.048682	-0.38662
-5	-0.19711	0.045956	-0.33305
-4	-0.16275	0.043734	-0.279
-3	-0.13118	0.04228	-0.22966
-2	-0.09787	0.041396	-0.17752
-1	-0.06483	0.040772	-0.12934
0	-0.03002	0.040995	-0.07787
1	0.008899	0.041855	-0.02081
2	0.046873	0.042806	0.034473
3	0.078956	0.044341	0.082597
4	0.1129	0.045544	0.139133
5	0.146088	0.047227	0.192611
6	0.183895	0.050205	0.25141

7	0.220534	0.052858	0.306406
8	0.259323	0.056551	0.361778
9	0.299799	0.061129	0.421517
10	0.340703	0.065069	0.480484

Signatures:

Tester ______________________________

Customer ___________________________

Wind Tunnel Test Data Sheet 4
Referenced ATP Paragraph Number: 3.4.4
Analysis Referenced (for verification by T/A): N/A
Name of Test: Wind Tunnel Design Evaluation Test 4
Unit Under Test (UUT): Name: Seacat 3 Part Number: SC-003 Serial Number: N/A

Date of Test:			
AoA	Coefficient of Lift	Coefficient of Drag	Coefficient of Pitching Moment
-15	-0.34142	0.147177	-0.73457
-14	-0.33361	0.132759	-0.70192
-13	-0.32188	0.122213	-0.66834
-12	-0.30328	0.111638	-0.62319
-11	-0.28582	0.101779	-0.58303
-10	-0.26971	0.089669	-0.53876
-9	-0.25003	0.080141	-0.49381
-8	-0.23995	0.068436	-0.45252
-7	-0.22399	0.057366	-0.4005
-6	-0.19808	0.051164	-0.35211
-5	-0.16788	0.049423	-0.30003
-4	-0.13486	0.047373	-0.24289

-3	-0.10184	0.045899	-0.19147
-2	-0.06729	0.045299	-0.13811
-1	-0.0388	0.046258	-0.08937
0	-0.00694	0.04653	-0.03963
1	0.027576	0.047827	0.013315
2	0.068248	0.049758	0.070157
3	0.104636	0.051237	0.127018
4	0.14111	0.053051	0.186478
5	0.17585	0.05491	0.23816
6	0.212054	0.057807	0.294661
7	0.249482	0.062335	0.352856
8	0.287879	0.066104	0.411799
9	0.325893	0.070387	0.469385
10	0.363298	0.075455	0.526089
11	0.401754	0.080215	0.585588

12	0.436853	0.08705	0.642493
13	0.465746	0.092465	0.690804
14	0.48795	0.099423	0.735226
15	0.510677	0.10778	0.785577
16	0.527209	0.118831	0.831017
17	0.53845	0.130598	0.865506
18	0.534616	0.146806	0.876703
19	0.487338	0.181001	0.86941
20	0.479945	0.203753	0.875778
21	0.485392	0.222492	0.900662
22	0.500738	0.237701	0.938307
23	0.515551	0.252828	0.974733
24	0.534823	0.270304	1.016986
25	0.547549	0.286646	1.050627
26	0.559765	0.302441	1.080514

27	0.577355	0.31979	1.125136
28	0.589852	0.333375	1.164086
29	0.603638	0.350321	1.200036
30	0.618171	0.369183	1.238427
31	0.63328	0.39056	1.273215
32	0.6461	0.411066	1.297234
33	0.661949	0.432236	1.335844
34	0.6755	0.455185	1.363164
35	0.690094	0.481056	1.393605

Signatures:

Tester ______________________________

Customer ___________________________

Computational Fluid Dynamics Test Data Sheet 3			
Referenced ATP Paragraph Number: 3.4.5			
Analysis Referenced (for verification by T/A): N/A			
Name of Test: Computational Fluid Dynamics Design Evaluation Test 3			
Unit Under Test (UUT): Name: Seacat 3 Part Number: SC-003 Serial Number: N/A			
Date of Test:			
AoA	Coefficient of Lift	Coefficient of Drag	Coefficient of Pitching Moment
-15	-0.28831	0.123848	-0.32764
-13	-0.25145	0.108228	-0.28391
-11	-0.20687	0.106498	-0.24023
-9	-0.19397	0.080356	-0.22893
-7	-0.16241	0.077016	-0.20008

-5	-0.09985	0.074977	-0.10581
-3	-0.03938	0.06937	-0.02391
-1	-0.01923	0.079136	-0.01812
0	0.043491	0.057354	0.09916
1	0.094174	0.056699	0.172537
3	0.096804	0.045194	0.161235
5	0.157836	0.054533	0.253183
7	0.195575	0.060668	0.301968
9	0.23821	0.068541	0.356659
11	0.263615	0.102958	0.369949
13	0.317192	0.106708	0.443098
15	0.319368	0.120389	0.412089

Signatures:

Tester ______________________________

Customer ___________________________

Computational Fluid Dynamics Test Data Sheet 4			
Referenced ATP Paragraph Number: 3.4.6			
Analysis Referenced (for verification by T/A): N/A			
Name of Test: Computational Fluid Dynamics Design Evaluation TC1			
Unit Under Test (UUT): Name: Seacat 3 Part Number: SC-003 Serial Number: N/A			
Date of Test:			
AoA	Coefficient of Lift	Coefficient of Drag	Coefficient of Pitching Moment
-15	-18.0897	7.563314	6.790768
-13	-15.2128	6.440173	6.58132
-11	-12.2975	6.214426	5.385637
-9	-9.97562	4.430347	5.360657
-7	-8.45371	4.454905	3.913304

-5	-6.47855	4.248005	2.503604
-3	-2.29573	4.060642	2.050121
-1	0.121414	4.299568	1.392157
0	2.586845	3.753209	1.660549
1	4.476756	2.681751	1.560711
3	7.246448	2.785508	1.150012
5	10.33128	3.195831	0.553864
7	12.89286	3.887216	0.060165
9	14.29395	4.247403	-1.36556
11	16.43753	6.113957	-2.54267
13	17.69155	5.978822	-4.56795
15	19.3436	7.630557	-5.45136

Signatures:

Tester ______________________________

Customer ___________________________

<u>Computational Fluid Dynamics Test Data Sheet 5</u>
Referenced ATP Paragraph Number: 3.4.6
Analysis Referenced (for verification by T/A): N/A
Name of Test: Computational Fluid Dynamics Design Evaluation TC2
Unit Under Test (UUT): Name: Seacat 3 Part Number: SC-003 Serial Number: N/A
Date of Test:

AoA	Coefficient of Lift	Coefficient of Drag	Coefficient of Pitching Moment
-15	-17.6013	7.330554	-20.7
-13	-15.5053	6.59817	-17.57
-11	-12.6158	6.379191	-14.66
-9	-11.9299	5.301301	-14.12
-7	-8.91406	4.463777	-10.37

-5	-5.7894	4.273588	-3.03
-3	-2.81257	4.004987	-2.53
-1	-0.06577	3.95462	1.47
0	1.965864	3.583516	4.36
1	5.096083	3.281899	9.59
3	6.814739	2.811991	12.25
5	10.50332	3.131323	17.59
7	12.70188	3.792104	20.25
9	14.81571	4.126698	22.83
11	16.01151	5.87117	22.91
13	18.18795	5.948842	25.02
15	19.33997	7.723537	26.37

Signatures:

Tester ______________________________

Customer ___________________________