ALEUTIAN ISLANDS RISK ASSESSMENT PHASE B

Purpose Designed Towing Vessel

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DOC: 12127.02.12c REV: - FILE: 12127.02	DATE: 31 December 2013	

References

1. *Aleutian Islands Risk Assessment – Phase B Work Plan*, Nuka Research & Planning Group, LLC and Pearson Consulting, LLC, 29 November 2012.
2. *Best Available Technology*, The Glosten Associates, Inc., File No. 12127.02, Report No. 12127.02.1-2c, Rev. -, 20 September 2013.
3. *Minimum Required Tug*, The Glosten Associates, Inc., File No. 12127.02, Report No. 12127.02.1-2b, Rev. A, 14 January 2013.
4. *Development of Frigate Designs with good Seakeeping Characteristics*, Thomas Eefsen, Frans van Walree, Daniele Peri, Peter van Terwisga, Hans Otto Kristensen, Roberto Dattola, and Marcel Visser, 9th Symposium on Practical Design of Ships and Other Floating Structures, 2004.
5. *MARPOL Annex 1, Regulation 12A*, International Maritime Organization, 2007.
6. *Towline Stability Criteria,* 46 CFR 173.095, 2013.

Introduction

The Aleutian Islands Risk Assessment Phase 2 Work Plan, Reference 1, includes a study of three emergency towing vessels (ETV). Two of the towing vessels are described in the *Best Available Technology* study (Reference 2). The third is a purpose-designed towing vessel as described herein.

Design Criteria

All the tugs described are required to be towing vessels with a minimum bollard pull of 110 MT and capable of operating in the Aleutian Islands throughout the year. The best technologies are those with features that maximized the tug's effectiveness in the Aleutian environment in the emergency towing role. Vessel speed is important to tug effectiveness, particularly so with the large travel distances in the Aleutians. The desirable design features identified in Reference 2 are as follows:

- Minimum bollard pull of 110 MT.
- Minimum Power (least cost).
- Maximum speed.
- Bulwarks around aft deck.

- Foc’sle.
- Double drum winch.
- Good maneuverability.

The design criteria for the purpose-designed towing vessel requires all the features of an effective ETV, while maximizing the speed with the least increase in cost. The level of detail for the design effort would be the minimum required to produce a cost and performance estimate for comparison with the other designs.

Initial Sizing

The desired speed goal was set at 30-40 knots. It was chosen to be significantly higher than the best available technology of about 20 knots, but still realistic. In order to maintain speed throughout the year in the Aleutian Islands, particular attention must be paid to maintaining that speed in very rough conditions. Planing vessels were ruled out as having too violent a motion in high sea states and imposing extreme loads on the structure. A displacement vessel would have to be very long to achieve the desired speeds. To achieve a speed of 35 knots at a Froude number (Fn) of 0.4[1], the limit for a displacement vessel, a length of 640' is required. A semi-planing vessel was chosen that operates with an Fn of 0.62. This could be achieved with a length of 350' and a speed of 40 knots, which is an ambitious but reasonable starting point. A monohull was selected for simplicity and ease of construction.

To minimize cost and maximize sustained sea speed, the vessel was kept as narrow and light as possible. A beam of 40' was chosen to allow room for the large towing winch and a reasonable deck layout. It was also hoped that a beam of 40' would result in adequate stability.

Powering

A powering study was undertaken using NAVCAD and the Mercier-Savitky series to determine the power required at various displacements. This study gave a power range of 33,000 HP at 30 knots and to 65,000 HP at 40 knots , as shown in Figure 1. This translates into an installed power of 55,000 HP to 108,000 HP, assuming a propulsor efficiency of 0.6.

[1] Froude number, $\frac{V}{\sqrt{gL}}$, the velocity divided by the square root of the acceleration of gravity times length, is a non-dimensional measure of speed and length, consistent in all units, used to compare wave making resistance between designs. The semi-planing range is for Fn= 0.4 to 1.0.

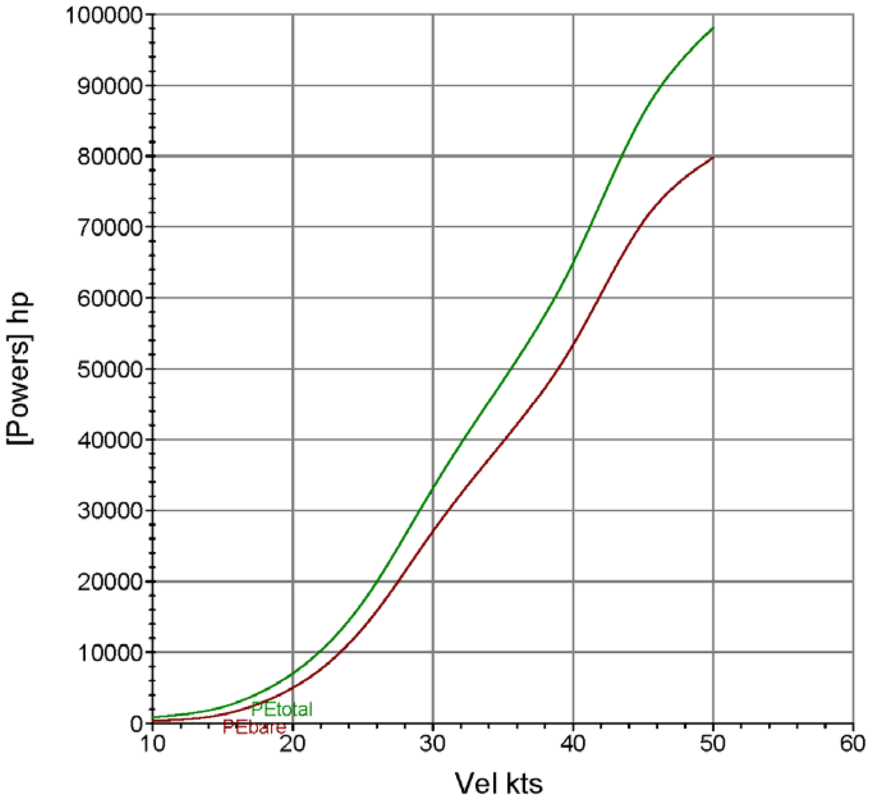


Figure 1 Speed Power Prediction

As a check on the powering prediction, a single computational fluid dynamic (CFD) run was made with a preliminary hull form at 34 knots in smooth water and resulted in a predicted resistance within 6% of the original NAVCAD estimate. Figure 2 shows the geometry and the wake. The model used for the CFD check is a first cut model intended mainly for hydrostatic estimates. No attempt was made to optimize for resistance or sea keeping.

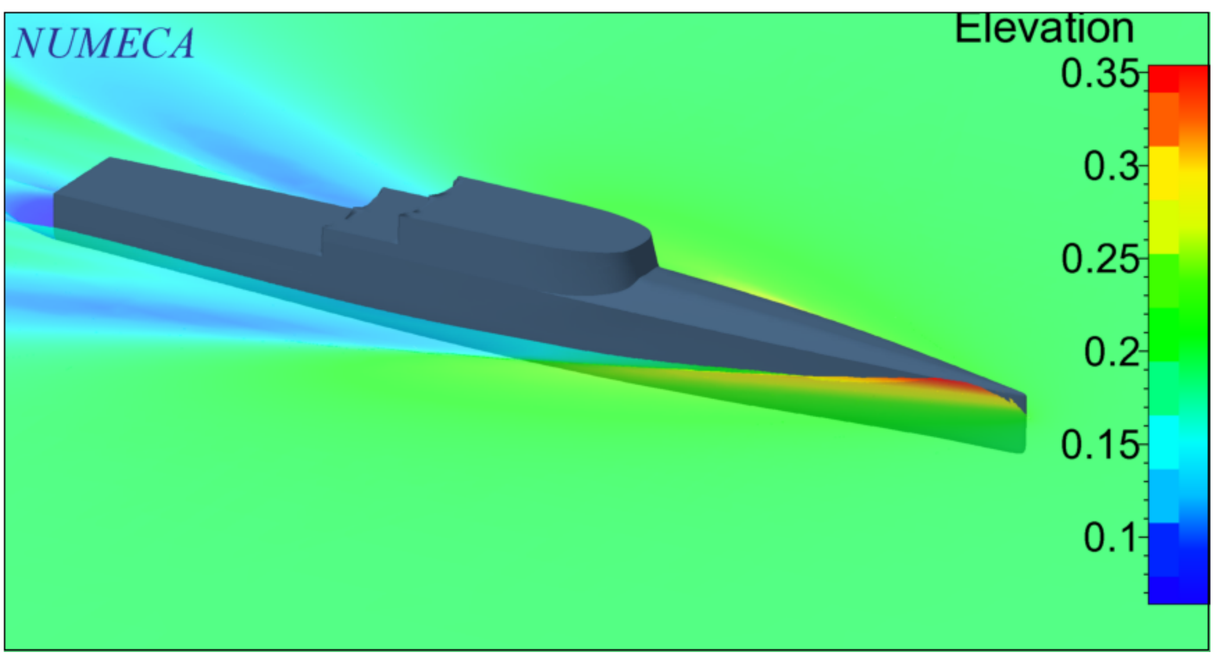


Figure 2 CFD—34 knots Showing Wave Profiles

These power levels cannot be met by using diesel engines while minimizing displacement. These power needs are typical for naval combatants that use multiple gas turbines.

At full load, gas turbines have a similar to slightly better fuel rate to diesels, or about 0.392 lb/HP compared to 0.403 lb/HP. They are approximately half the weight of diesels for the same horsepower. Gas turbines have been used in the marine environment for many years, have very good reliability, are modular for simple repairs, and are able to start quickly. Unfortunately, gas turbines have poor fuel rates at off-peak powers, which increases fuel consumption in lower speed modes.

To increase the fuel efficiency of the ETV when towing and maneuvering, it was decided to add diesels in a combined arrangement. Basically, the diesels would be used in all low power modes, with the addition of a gas turbine for high speeds.

Propulsors

In the proposed speed range, high speed vessels usually have propellers or water jets. Propellers have better performance in the lower speed ranges, but can produce high appendage drags at higher speeds. Waterjets are quite efficient at higher speeds, but tend to be heavier due to entrained water and do not perform well at bollard conditions. The 40' beam of the proposed vessel can accommodate one or two propellers, or up to three waterjets. Single propulsor arrangements were ruled out due to lack of maneuverability and the complicated multiple input gear that would be required. Double propellers or waterjets would have good maneuverability but would require double input gears for each shaft. The three-water jet arrangement retains the good maneuverability of the double propulsor arrangements, and has a stability advantage as described below.

Ultimately, in the absence of a more detailed study, the three-waterjet arrangement was chosen because of the reduced appendage drag and the stability advantages. The three-waterjet arrangement also worked well with the selected power plant.

The final configuration chosen consists of a single LM2500+G4 gas turbine driving a centerline waterjet, and two MTU 20V 8000 diesel engines driving waterjets port and starboard. Each engine drives a single shaft through a single input, single reduction gearbox. The water jets are a single, unsteerable, Kamewa 200B3 on the centerline, and two steerable, reversing, Kamewa 140S3s at port and starboard.

To aid in maneuverability and to achieve the desired bollard pull capability, a retractable, fully azimuthing, Voith VIP2300-1500 bow thruster is specified.

The final configuration, determined in consultation with Rolls Royce/Kamewa, can achieve a bollard pull of 110 MT and a top speed of 34 knots at full load displacement. A Fn of 0.52 puts the ETV at the lower end of the semi-planing range.

Mission Profile

The ETV will have four distinct modes of operation:

1. The vast majority of the life of the vessel will be spent in port in standby mode ready to depart. Enough power will be generated to maintain all hotel functions and to have all equipment warmed up and ready to get under way.

2. During the high speed sprint to the stricken vessel, all propulsion engines will be running at maximum output. The electrical loads will be for hotel, navigation, and auxiliary propulsion loads.
3. While maneuvering in port and during hookup, the gas turbine will be shut down/on standby. Propulsion will be from the two propulsion diesels and from the bow thruster powered by the generators.
4. Towing operation will be similar to maneuvering mode, with the addition of winch loads driven by the gensets.

The fuel calculation put these modes together assuming a three-month standby period followed by a high speed sprint to Attu Island from Dutch Harbor, a hook up, a tow all the way back to Dutch Harbor, and a 10% fuel margin. This calculation assumes that the ETV is refilled every three months to be able to carry out the worst case rescue at the end of the standby period. A total fuel capacity of 900 LT is required. Stationing the tug in Adak would greatly reduce the fuel requirements by shortening the required distances.

Sea Keeping

Although no calculations or tests have been made during this concept phase of the design, every feature was predicated on maintenance of speed in rough weather.

Active fins are specified to reduce rolling, especially during high speed transits. A single pair has been specified, but a second pair could be installed if shown to be required during seakeeping studies.

The active fins will provide little benefit during low speed modes of operation, so an anti-rolling tank is specified. It will be a U-tank in the hull that is tuned to the vessel's natural rolling frequency. In operation, it would be empty during the high speed transit and would be filled on arrival at the distressed vessel. It is located in the hull and not, as is typical, in the superstructure. The location is chosen because of the relatively large amount of available space in the hull compared to that in the superstructure and because the lower location allows gravity to speed the filling of the tank.

The very sharp bow and the high length-to-beam ratio give the ETV good pitch characteristics. The goal of the bow design is to limit pitch accelerations, slamming, and deck wetness. The actual bow design can be further optimized during seakeeping studies. A wave piercing bow has been drawn in this concept to limit pitch response. Rather than reduced deck wetness, the foredeck is designed to be swept with waves and to shed water. An Axe-bow (Reference 4) is a possible alternate configuration that would result in a bow that is both deeper and higher.

The small superstructure naturally results in a low center of gravity, which is beneficial to stability. To an extent, the longitudinal weight distribution can be adjusted for minimal pitch response in the typical conditions.

Tow Gear

The tow winch will have two drums to hold two duplicate and independent tow wires. An automatic render-recovery feature is specified to reduce peak loadings so as to increase capabilities when using short scopes, such as shallow water, or to allow commencement of the rescue tow before the tow line is completely deployed.

Reel winches are installed to provide instant access to spare wire and towing pennants as needed.

Final Design

The final design incorporating all the above features is presented in Figure 3 and Appendix A.

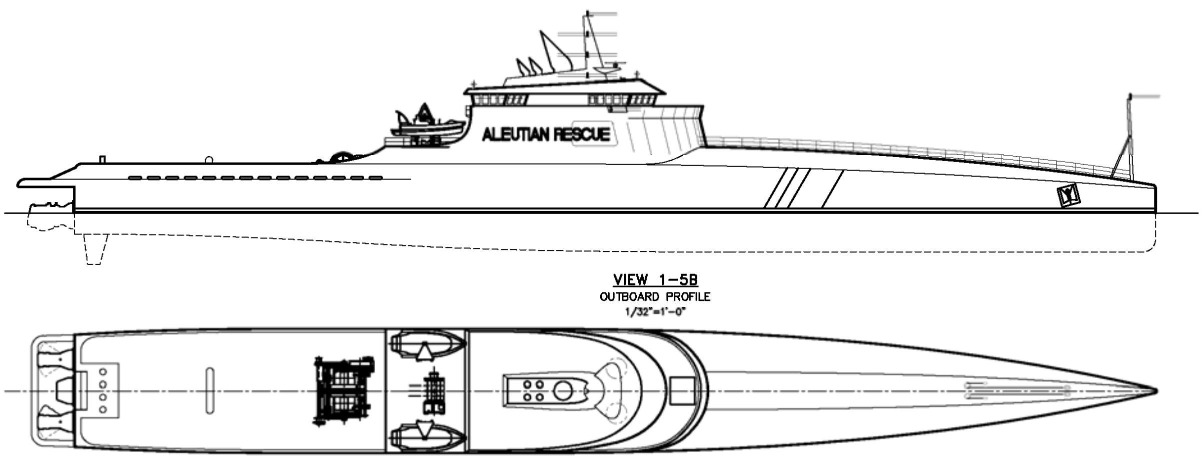


Figure 3 Purpose Designed ETV profile and Birdseye View

Staring on the weather deck, the forward third of the vessel has a wave piercing bow with a water shedding whale back foc'sle. It is not intended to use the foredeck for anything except docking and mooring. The foc'sle ends at a full width superstructure designed to protect the main deck aft. The main deck has the towing winch located in the shadow of the superstructure, with the tow pins and roller at the transom and a towing staple located midway between them.

The superstructure houses the machinery intakes and uptakes, the combustion air demisters and water separators for the gas turbines, the emergency genset, all crew staterooms, and boatswain stores. The pilothouse surrounds the uptakes for a 360-degree view. The forward end contains a single control station for high speed transit mode. The aft end contains two control stations port and starboard, with excellent views of the aft deck and tow, as well as views of the bow on each side of the vessel.

Below the weather deck are void spaces, and fuel and ballast deep tanks. Just forward of the engine room is located the crew mess, galley, and stores. Below the super structure, the engine room is divided into two spaces: one for the gas turbine, and one aft for the diesels. Proceeding aft is the winch machinery room, boatswain stores, and the waterjet room.

In order to minimize oil outflow in the event of hull damage, the tankage is arranged with fuel on centerline surrounded by ballast or voids located port and starboard. The fuel is located in deep tanks forward, and in double bottoms from the engine rooms aft. As the aggregate fuel oil capacity is above 600 m^3, an oil outflow calculation will be necessary to determine the extent of required double bottom voids per MARPOL Annex 1, Reference 5.

The main particulars of the purpose designed ETV are shown in **Table 1**, along with the vessels identified in Reference 2.

Table 1 Towing Vessels—Main Particulars

	Alert	Barentshav	Purpose Designed Towing Vessel
Length, Overall	140 ft	305 ft	368 ft
Length, Waterline	130 ft	270 ft	350 ft
Breadth	42 ft	54 ft	40 ft
Depth, Main Deck	20 ft	28 ft	23.5 ft
Draft	16 ft	19 ft	12.5 ft
Displacement	1,534 LT	3,251 LT	3,100 LT
Propulsion BHP	10,192 hp	8,660 hp	71,370 hp
Propulsion Type	Z-drives	fixed prop with thrusters	water jets with thruster
Bollard Pull	136 MT	110 MT	110 MT
Crew Capacity	16 persons	40 persons	16 persons
Fuel Capacity	129,500 gal	238,100 gal	236,000 gal
Max Speed	16 kt	20 kt	34 kt
2013 Construction Cost	$30.3 M	$65.1 M	$84.7 M

Weight Estimate

The steel weight was calculated based on the structural design. The weights of other systems are based on vendor quotes and on scaling similar systems from other vessels. The margins used are typical for the stage of design.

Table 2 Weights

SWBS	Entry Description	Margin (%)	Weight (LT)	LCG (ft-FR 0)	VCG (ft-ABL)
100	Hull Structure		798.45	176.56	14.70
100	Welding Allowance	1.5%	11.98	176.56	14.70
100	Mill Tolerance Allowance	2.0%	15.97	176.56	14.70
100	Misc. Structure Allowance	2.0%	15.97	176.56	14.70
200	Propulsion System		505.61	43.26	8.93
300	Electrical System		51.30	145.61	21.55
400	Command and Surveillance		4.50	10.11	2.85
500	Auxiliary Systems		186.43	151.62	20.64
600	Outfitting and Furnishings		51.94	164.16	24.72
	Lightship without Margins		**1642.15**	**130.87**	**14.10**
	Design and Build Weight Margin	20.0%	328.43	130.87	14.10
	Design and Build VCG Margin	14.0%			1.97
	Contract Mods Weight Margin	2.00%	32.84		
	Contract Mods VCG Margin	2.00%			0.28
	Total Lightship Weight		**2003.42**	**130.87**	**16.35**
	Service Life Allowance	5.00%	100.17		**0.5**
	Total Lightship Weight (End of Life)		**2103.59**	**130.87**	**16.85**

Stability

The stability characteristics of such a narrow design were a concern during the initial sizing phase. With an accurate weight estimate and a hull shape definition, the applicable stability criteria were checked. The standard tugboat criteria were used for this vessel, consisting of an intact and a towline criteria. A floodable length calculation was made to locate watertight bulkheads for a one compartment flooding standard. The speed at which the stricken vessels drift is related to the weather condition. With its small deckhouse and high freeboard, the design easily meets the intact stability criteria.

Of particular concern was the towline criteria given in Reference 6. These criteria depend on the installed power being directed transversely, with a vertical heeling arm from the tow point to the propulsor. This moment is divided by the displacement. A low displacement, a high power, and a narrow beam will all negatively affect these criteria. The displacement and narrow beam are integral to the vessel design and cannot be altered without detracting from the performance. The choice of water jets allows a reduction in the heeling arm, since the jets are centered at the design water line and not suspended under the hull. In addition, the choice of three jets allows the center jet to be fixed and non-steerable, while retaining good maneuverability. This dramatically reduces the power that can be directed transversely. These two features influenced the choice of water jets, as they allow the vessel to meet the towline criteria.

Cost Estimate

The cost estimate is based on vendor quotes, scaling of other designs, and direct calculations. The labor rates and margins from Reference 2 were used to enable comparison between designs. The propulsion system has the majority of the costs and is, therefore, most amenable to further design refinement and optimization.

Table 3 Purpose Designed ETV Cost Estimate

SWBS Number	Description	Labor (Hours)	Materials ($)	Subtotal ($)
000	Shipyard Engineering and Services	25,691		1,798,400
100	Structure	54,753	1,151,000	4,983,700
200	Propulsion	31,260	39,029,200	41,217,400
300	Electric Plant	25,965	1,786,600	3,604,200
400	Command and Surveillance	11,260	970,000	1,758,200
500	Auxiliary Systems	37,041	7,072,100	9,665,000
600	Outfit and Furnishings	10,996	694,800	1,464,500
	Subtotal	196,966	$50,703,700	$64,491,400
	Labor Rate	$70	PER HOUR	
	Material Markup	15%		7,605,600
	Estimate Contingency	15%		9,673,700
	Construction Cost Subtotal			$81,770,700
	Builder's Risk Insurance	0.5% APR	18 MONTHS	$291,000
	Regulatory Review and Inspection			$817,707
	Cost Subtotal	3% APR	18 MONTHS	$82,879,407
	Project Financing			$1,785,000
	TOTAL COST ESTIMATE			**$84,664,407**

Conclusions

An emergency towing vessel has been designed for operation in the Aleutian Islands. With similar bollard pull characteristics, it is significantly faster than existing designs and should be able to maintain that speed in severe weather. It will be approximately 30% more costly than the best designs currently available.

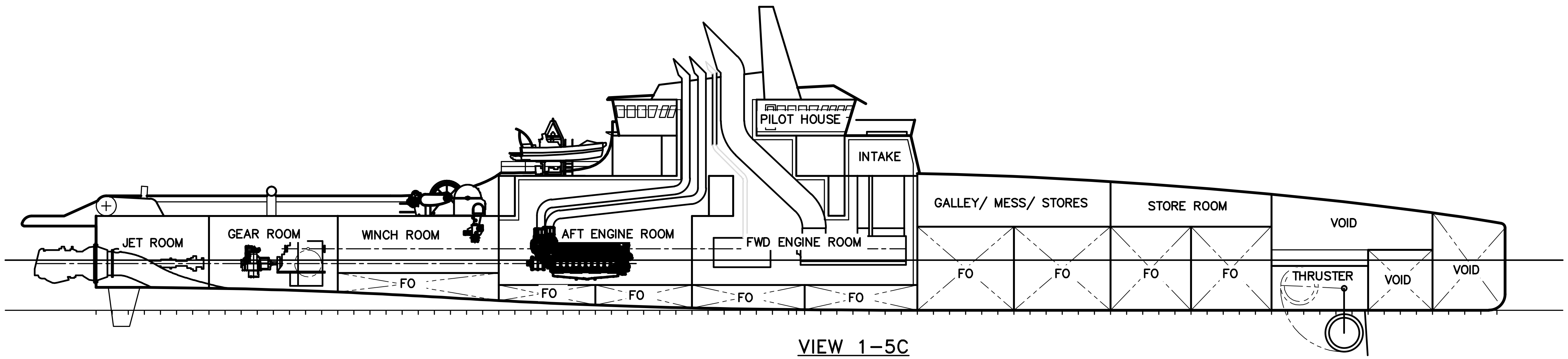
The increased speed will allow for quicker response to incidents throughout the chain of islands without having multiple vessels. The ability to rely on a single vessel may compensate for the increased cost.

Further Analysis

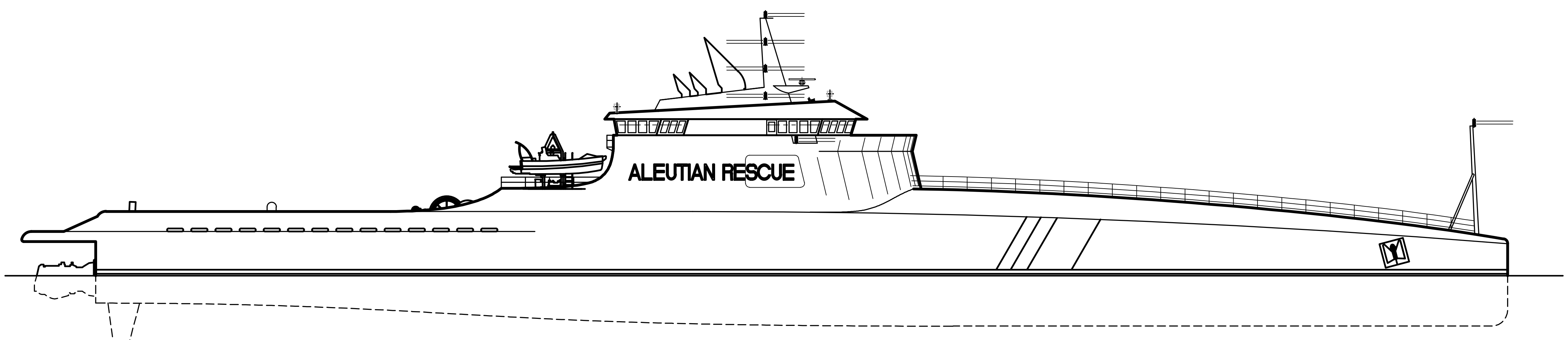
If the concept of a single but higher-priced ETV warrants further study, the following areas are of the greatest importance.

Seakeeping studies must be undertaken to maximize the vessel's ability to maintain speed in adverse conditions. These studies will include hull shape optimization, with the goal of minimizing stresses on both the vessel and the crew. The study can also be used to determine the effectiveness of the active fin stabilizers and anti-rolling tank. A more complete study of the propulsion arrangement should be undertaken to allow an optimum selection of the propulsion system for cost and performance.

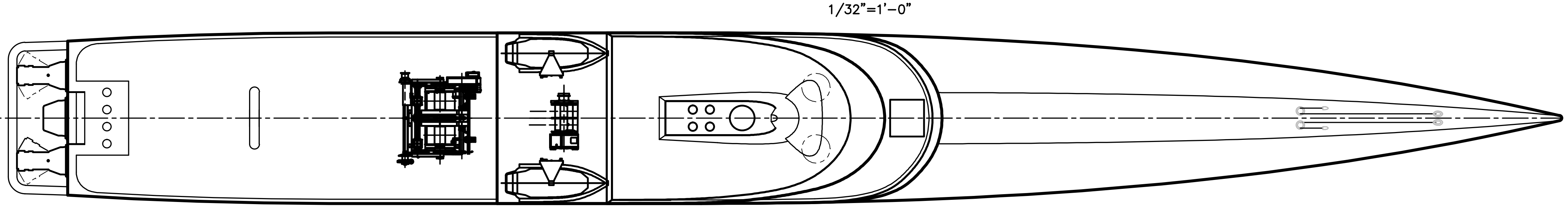
Appendix A Arrangement Drawings



VIEW 1–5C
INBOARD PROFILE
1/32"=1'–0"



VIEW 1–5B
OUTBOARD PROFILE
1/32"=1'–0"



VIEW 1–5A
BIRDS EYE VIEW
1/32"=1'–0"

GENERAL NOTES

LWL	350'–0"	PROPULSION POWER	71,370 HP
LOA	368'–6"	SPEED	34 KT
BEAM	40'–0"	RANGE (TYP)	1600 NM
HULL DEPTH	23'–6"	BOLLARD PULL	110 MT
DESIGN DRAFT	12'–6"	CREW	16
AIR DRAFT	63'–0"		
DISPLACEMENT	3100 LT		
FUEL OIL	236,000 GAL		

REFERENCES

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPD

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ALEUTIAN ISLANDS RISK ASSESSMENT
PURPOSE DESIGNED EMERGENCY TOWING VESSEL
PROFILES & BIRDS EYE VIEW

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Scale	Drawing Number	Sheet	of	Revision
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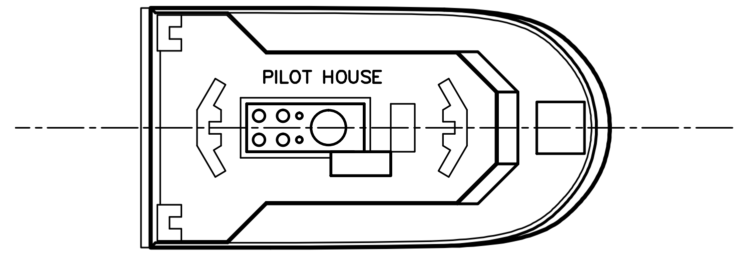
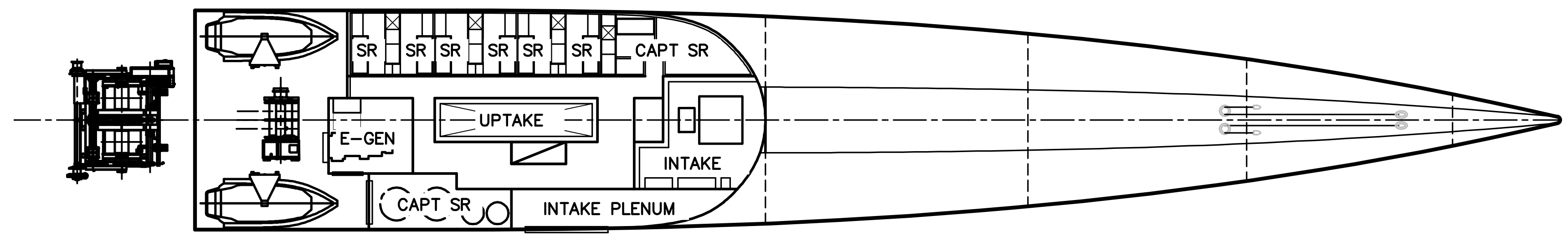
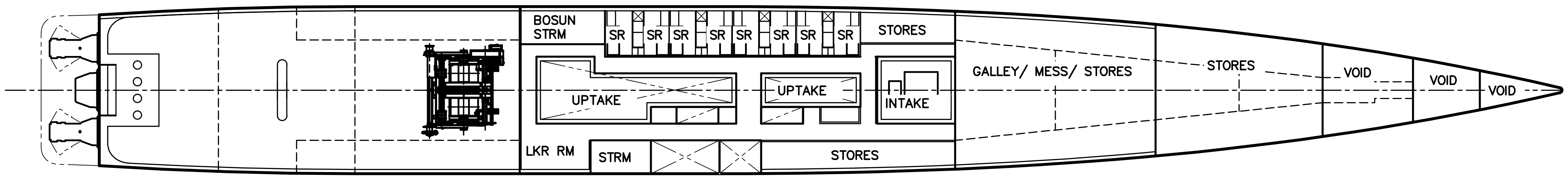


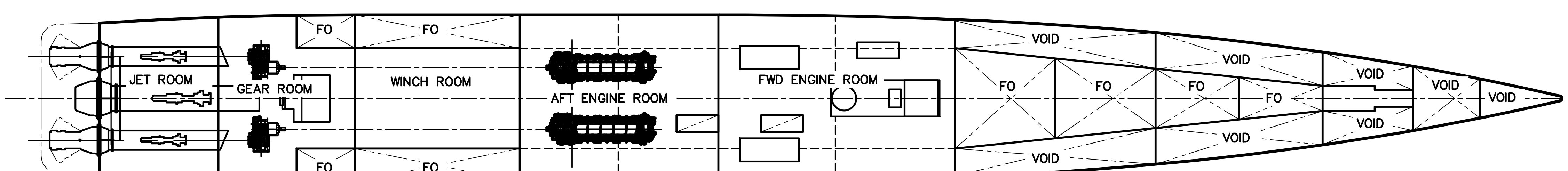
VIEW 2–5D
PILOT HOUSE
1/32"=1'–0"



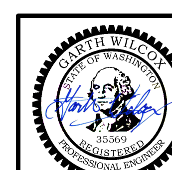
VIEW 2–5C
01 LEVEL
1/32"=1'–0"



VIEW 2–5B
MAIN DECK
1/32"=1'–0"



VIEW 2–5A
ENGINE ROOM AND TANKAGE
1/32"=1'–0"



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ALEUTIAN ISLANDS RISK ASSESSMENT
PURPOSE DESIGNED EMERGENCY TOWING VESSEL
DECK ARRANGEMENTS

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