Island Home is a new ferry operating between Woods Hole, Massachusetts and Martha’s Vineyard Island and represents a leap in capabilities in The Steamship Authority’s (SSA) fleet. This new double-ended ferry is significantly larger than other vessels in the SSA fleet, and features Americans with Disabilities Act compliance, lift decks, bow and stern thrusters, weathertight doors at both ends of the freight deck and a slide evacuation system. The design process started with a seakeeping analysis for the numerical modeling of realistic wave shapes and periods, which were recreated in a model basin. Tests were performed to predict ship motions and to confirm powering predictions. Numerical flow analysis was performed to identify hull form improvements. Studies assisted with decisions regarding styling, propulsion system, and the number of pilothouses. This paper follows the design process, construction period and sea trials.

INTRODUCTION
Martha’s Vineyard Island, lying 4.5 miles south of Cape Cod, is a study in contrasts. The winter population of 12,200 swells to 72,600 in the summer, when the rich and famous return to their multi-million dollar cottages and day-trippers fill the streets and stores. Islanders place high value on their privacy but depend on summer tourist dollars to carry them through the lean months of winter.

Proud of their centuries-old traditions, island residents are also quick to take advantage of new technologies. They are fiercely independent in spirit yet dependent upon the ferries for delivery of food, mail, building supplies and even medical care.

Year-round ferry service to Martha’s Vineyard is provided by The Woods Hole, Martha’s Vineyard and Nantucket Steamship Authority (SSA), an organization chartered, but not supported financially, by the Commonwealth of Massachusetts. SSA operates a fleet of vessels on the following routes:

- Woods Hole to Vineyard Haven, Martha’s Vineyard
- Woods Hole to Oak Bluffs, Martha’s Vineyard
- Hyannis to Nantucket

Particulars of the vehicle/passenger ferries operated by SSA are provided in Table 1. Note that the Islander was retired in March, 2007 when the Island Home entered service on the Woods Hole to Vineyard Haven run.
Table 1: Existing Vehicle/Passenger Vessels in the SSA Fleet

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Year</th>
<th>LOA</th>
<th>Beam</th>
<th>Vehicles /Pax</th>
<th>Speed, kts</th>
<th>HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Islander</td>
<td>1950</td>
<td>201'</td>
<td>58'-1&quot;</td>
<td>48/788</td>
<td>11.5</td>
<td>1800</td>
</tr>
<tr>
<td>Governor</td>
<td>1954</td>
<td>242'</td>
<td>64'-1&quot;</td>
<td>65/241</td>
<td>12</td>
<td>1200</td>
</tr>
<tr>
<td>Nantucket</td>
<td>1974</td>
<td>230'</td>
<td>60'-0&quot;</td>
<td>52/789</td>
<td>14</td>
<td>3000</td>
</tr>
<tr>
<td>Eagle</td>
<td>1987</td>
<td>233'</td>
<td>61'-6&quot;</td>
<td>55/800</td>
<td>14</td>
<td>3000</td>
</tr>
<tr>
<td>Martha's Vineyard</td>
<td>1993</td>
<td>230'</td>
<td>60'-0&quot;</td>
<td>55/1387</td>
<td>14</td>
<td>3000</td>
</tr>
<tr>
<td>Gay Head</td>
<td>1981</td>
<td>235'</td>
<td>40'-0&quot;</td>
<td>/138</td>
<td>13</td>
<td>3050</td>
</tr>
<tr>
<td>Katama</td>
<td>1982</td>
<td>235'</td>
<td>40'-0&quot;</td>
<td>/142</td>
<td>13.5</td>
<td>3050</td>
</tr>
<tr>
<td>Sankaty</td>
<td>1981</td>
<td>197'</td>
<td>40'-0&quot;</td>
<td>/292</td>
<td>12.5</td>
<td>2520</td>
</tr>
</tbody>
</table>

While not sister vessels, the Martha's Vineyard and Islander (Figure 1) have been paired in recent years to provide regular service over the 6.2 mile Woods Hole / Vineyard Haven route and the 7.5 mile Woods Hole / Oak Bluffs route. With daytime departures every 75 minutes, these two workhorses make about 9700 trips annually, totaling 63,000 miles. Their regularity and dependability have exemplified the SSA motto "Lifeline to the Islands."

While not sister vessels, the Martha's Vineyard and Islander (Figure 1) have been paired in recent years to provide regular service over the 6.2 mile Woods Hole / Vineyard Haven route and the 7.5 mile Woods Hole / Oak Bluffs route. With daytime departures every 75 minutes, these two workhorses make about 9700 trips annually, totaling 63,000 miles. Their regularity and dependability have exemplified the SSA motto "Lifeline to the Islands."

Islander was built in 1950 and has served SSA and its patrons dependably for these past 57 years. Islander is a double-ended vessel with a capacity of 788 passengers and 48 vehicles. Hinged doors at each end protect against boarding seas and freezing spray. Unfortunately, obsolete equipment and degraded materials have driven up operation and maintenance costs so that replacement became an obvious requirement.

SSA began the replacement process in 1997, working with a consulting naval architect to produce a concept design for a new single-ended vessel based on the designs of the Nantucket and Martha's Vineyard. This replacement design featured a capacity of 1400 passengers and 55 vehicles. However, the political dynamics within SSA changed, leading to the shelving of this first design when the island residents demanded a double-ended design.

As time passed and the Islander became increasingly expensive to operate, the urgency to restart the design and acquisition process became acute. Accordingly, SSA issued a Request for Proposal (RFP) to several naval architecture consulting firms that had been researched and judged capable of designing the replacement vessel. Each firm was invited to ride the SSA ferries so as to acquire a basic understanding of SSA's mission, as well as its opportunities and challenges, in providing its services.

Competing firms each submitted a proposal in response to the RFP. After verifying references, SSA conducted interviews and based their selection on a number of factors, including:

- Experience in ferry design
- Technical approach outlined in the proposal
- Demonstrated understanding of SSA requirements
- Firm size and depth of expertise
- Firm location
- Experience of proposed design team members.
Elliott Bay Design Group (EBDG) was pleased to be selected from the group of well-qualified naval architectural firms. As the design team formed and the lines of communication between SSA in Woods Hole and EBDG in Seattle were established, project managers on both ends reviewed, discussed and refined the fundamental design criteria for the new vessel. The established criteria were:

- Capacity for 1200 passengers with 600 inside seats
- Capacity for 70 vehicles
- Double-ended
- Designed in general compliance with American Bureau of Shipping rules
- Compliant with ADA guidelines for passenger vessels, insofar as possible
- 16 knots top speed and 14 knots cruising speed
- Hull shape to fit existing terminals
- Exceptional maneuverability
- Excellent security for the protection of passengers and crew
- 10'-6" loaded draft
- Excellent seakeeping characteristics in the steep choppy seas of Vineyard Sound

Because the existing terminals have single lane ramps, relatively long loading and unloading times are an accepted fact of operation. SSA did specify, however, that the freight deck arrangements needed to be as open as possible to accommodate tractor trailer units and to simplify car loading and parking.

One unusual specification was that the new vessel carry no more than 10,000 gallons of petroleum products so as to avoid USCG regulations pertaining to fuel transfer and loading. Because SSA vessels are dockside every night, refueling from trucks is simple to schedule and poses no operational difficulties.

Americans with Disabilities (ADA) accessibility played an important role during the development of the arrangements and was driven not only by the obvious need to provide reasonable accommodation, but also by an agreement between SSA and the Cape Organization for the Rights of the Disabled (CORD) (Reference 1). In this agreement, SSA committed to design and operate any new vessel in conformity with ADA standards, insofar as possible. SSA was fully aware that CORD would hold them to the agreement, and would be inspecting the finished vessel carefully to verify compliance.

The Islander's 11-knot speed results in a one-way trip time of 75 minutes (45 minutes in transit and 30 minutes for loading and unloading), resulting in departures at seemingly random times throughout the day. A cruising speed of 14 knots, if matched by the other vessel on the Vineyard Haven run, would permit hourly sailings, increasing the number of trips daily while making departure times easy to remember.

Although exceptional maneuverability and excellent seakeeping characteristics were requirements for the new vessel, no objective goals were provided. Instead, SSA elected to rely upon the experience of the design team, augmented by computational fluid dynamics calculations and model tank testing, both of which will be addressed later.

Recent heavy investments in terminal pilings, dolphins and fenders, coupled with the fact that other SSA vessels are not scheduled for replacement for some years, mandated that the new vessel fit into the existing slips with single lane boarding ramps. SSA arranged for an accurate survey of each slip so that the shape of the vessel ends could be precisely specified.

Description of Terminal Harbors

Vineyard Haven Harbor (Figure 2) is well protected by a breakwater and offers no challenges from current or prevailing wind. The channel has at least 14 ft water depth; however, it is very congested in the summer, with expensive yachts crowding the channel leading to the terminal. Wake wash is a concern, and the desire to eliminate the need to turn around in the harbor led to the demand from the island community that the vessel be double-ended. In addition to eliminating the risk involved with the turning operation, several minutes of voyage time would be eliminated.

Fig. 2: Vineyard Haven Harbor

The Oak Bluffs terminal (Figure 3), located on an exposed shoreline, is subject to strong currents and cross winds. In the worst conditions, ferries are diverted to the Vineyard Haven terminal. At normal low tides, however, the maximum safe draft at Oak Bluffs is 10'-6"; hence the design draft requirement.
The terminal at Woods Hole (Figure 4) is commonly subject to gale force winds in the winter and to tidal cross currents approaching 4 knots. Both wind and current directions are typically perpendicular to the line of approach during docking, leading to what has been described by SSA insiders as a "controlled crash" method of docking the Islander. That this is not exaggeration is verified by the regular need for repairs to the fenders, dolphins and to the dock itself. Drift ice from Buzzards Bay presents yet another source of concern during winter months.

Vineyard Sound is shallow, with an average mean low water depth of about 25 feet. As mentioned above, the Sound is also subject to strong tidal currents and to strong winds. This combination of factors frequently leads to steep, choppy wave conditions which can cause severe discomfort among the riders. As double-ended vessels are not generally noted for their seakeeping performance, extra effort would be required to marry the propulsion and seakeeping requirements. This effort is described later in this paper.

### Styling Study

Generations of island residents have grown up with the Islander as one of the primary means of transportation to and from the mainland. As the ferry has aged, its quirks and flaws have become in the public mind lovable idiosyncrasies, and SSA staff heard from many quarters that the new ferry should be "just like the Islander." Desired or not, a defacto gold standard had been established by the ridership, and SSA was determined to achieve that standard while still acquiring a vessel that would comply with current regulations and serve well for the next 40 years or more.

Understanding that both the operators and the ridership had a keen interest in the new vessel, SSA decided to include both groups in the design process by soliciting comments during the concept design phase. In addition to postings on the SSA website, three public meetings were held on Martha's Vineyard at one-month intervals. At each meeting, the EBDG project manager presented a slide show highlighting design features expected to be of general interest, and then fielded questions from the very interested attendees. SSA personnel observed at each meeting and noted trends in the comments. As appropriate, design modifications were incorporated to reflect public concerns and desires.

To accommodate the larger traffic volumes, the new ferry would necessarily have to be larger than the Islander. The requirement for the new vessel to be double ended was included to eliminate the additional time and perceived risk incurred while turning the vessel around in the congested Vineyard Haven Harbor, but forced an entirely different look which, it was feared, could displease island residents.

It was therefore decided to produce a styling study and to solicit input regarding the appearance. Four outboard profiles were produced (Figure 5):

- Modern styling with a pilothouse at each end
- Modern styling with a single pilothouse amidships
- Traditional styling with a pilothouse at each end
- Traditional styling with a single pilothouse amidships

It is apparent from the four profiles that SSA was grappling not only with the need to appeal to those who were keenly interested in appearance, but also with the issues of pilothouse visibility and security. A single pilothouse amidships would offer the advantages of improved operational control (no need for the Master to walk from one end of the vessel to the other when changing directions in an emergency) and security (Master is not exposed during the transition). A pilothouse at each end would offer the advantages of traditional appearance and improved visibility forward during the notorious Vineyard Sound foggy conditions, as well as when approaching the slip.
A simple comparison of the visibility "shadow" is shown in Figure 6. While both the single- and two-pilothouse versions have adequately small shadows, the two-pilothouse version has a much shorter distance to the water and so will offer better visibility in fog conditions.

Figure 6: Visibility Sketches

Table 2 was produced to compare visibility from the pilothouse of the existing ferry Nantucket with the single- and two-pilothouse options. The Nantucket was selected for comparison as the vessel operators generally agreed that its visibility was adequate in both dark and foggy conditions. The results of Table 2 strengthened the argument that an amidships pilothouse offered acceptable visibility.

Table 2: Visibility Comparison

<table>
<thead>
<tr>
<th></th>
<th>PH aft of stem</th>
<th>Shadow distance to target on water</th>
<th>PH to target on water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nantucket</td>
<td>81'</td>
<td>149'</td>
<td>230'</td>
</tr>
<tr>
<td>Fore &amp; aft PH's</td>
<td>39'</td>
<td>42'</td>
<td>81'</td>
</tr>
<tr>
<td>Amidships PH</td>
<td>101'</td>
<td>113'</td>
<td>214'</td>
</tr>
</tbody>
</table>

A new issue, pilothouse security, also needed to be considered. At all Maritime Security (MARSEC) levels, it is necessary to control access to the bridge. This requirement is easily met through the use of pass-key or cipher-lock doors. At MARSEC levels 2 and 3, the bridge team must be able to move freely and securely from one pilothouse to another (in the two-pilothouse version) without direct passenger interaction.

If the two-pilothouse version were selected, there are two obvious means of compliance with the security requirement:

1. Deny passenger access to the weather deck between the pilothouses.
2. Provide an enclosed crew passageway between the pilothouses on or above the weather deck.

The first of these options was deemed to be the better of two bad choices, as the enclosed passageway would divide the 03 Deck in half longitudinally, restricting access to the port side stair towers. However, it was decided to avoid both problems by selecting the single pilothouse, which also offered the potential of reducing the quantity of electronic devices through the use of repeaters.

Public forums were held to gauge public reaction, and the selected profile – modern styling with an amidships pilothouse, appeared to satisfy all concerned and so was selected. As the design process developed, however, it became evident that advocates of the two-pilothouse version, including some of the masters and pilots, were merely biding their time and marshalling resources.
Propulsion Study

While the public viewed and discussed the outboard profiles, SSA and EBDG personnel were evaluating the propulsion options. Key factors included:

- Double-ended vessel design
- Fleet commonality of main engines
- Draft limitation
- Maneuverability and control requirements
- 16-knot speed requirement

The following propulsion system options were evaluated and scored:

1. Two (one at each end) main engines with fixed-pitch propeller, high-lift rudder and two directional control pump-jet thrusters (one at each end)
2. Two (one at each end) main engines and two azimuthing thrusters (one at each end)
3. Four (two at each end) main engines and two azimuthing thrusters (one at each end)
4. Three DC generators serving two (one at each end) fixed-pitch propellers, two high-lift rudders and two directional control pump-jet thrusters
5. Three DC generators serving two (one at each end) azimuthing thrusters
6. Three DC generators serving four (two at each end) azimuthing thrusters

A scoring matrix was created and included the following factors:

Maneuverability
- At speed
- While docking
- Seakeeping
- Crash stop performance

Availability
- Reliability
- Serviceability

Cost
- Capital cost
- Operating cost
- Maintenance cost

Construction
- Arrangement impacts
- Weight
- Passenger/crew comfort

Support
- Installation history
- Regulatory compliance
- Fleet similarity
- Training
- Helmsman stress

Environmental emissions

SSA and EBDG assigned individual weighting factors and scored the six propulsion system options independently with remarkably similar results. The first, second and third choices, identical for both scorers, were Options 4, 1 and 5, respectively.

Accordingly, Option 4 was selected and the design proceeded for a diesel-electric propulsion system with high-lift rudders and DC motors driving fixed-pitch propellers and pump-jet thrusters. Significant progress in the propulsion system design was necessary before a detailed weight analysis could be performed. The results of this analysis showed a large weight increase as compared to the baseline design, Option 1. Application of the Option 4 weight into the vessel weight and stability studies revealed major problems in maintaining the maximum draft requirement of 10'-6". This issue was significant enough to force two changes in the vessel design:

- Propulsion system Option 1 was selected in lieu of Option 4 to reduce weight.
- The vessel hull was lengthened five feet to increase buoyancy.

Concept Arrangements

As these initial studies were completed and decisions made, the concept design began to take shape. It had become evident that weight would be a problem that could not be resolved by increasing the hull size, as the beam was restricted by the terminal shape and length was restricted by master and pilot concerns regarding maneuverability, and by public concerns regarding visual impact in Vineyard Haven Harbor. As discussed above, the weight issue eliminated from consideration the diesel-electric propulsion system. It also led to the decision to fabricate the pilothouse, deckhouse and upper superstructure from aluminum.

An enclosed freight deck is a standard feature in the SSA fleet, providing protection from the freezing spray common in the winter months. Doors are operated hydraulically; a variety of geometric configurations have been installed on the various vessels, with varying degrees of success. The most common problem with the currently installed doors is cracking. This issue raised concerns for the new design as well, since the decision had been made to fabricate the freight deck doors of aluminum in order to minimize weight. Looking to reduce operations-induced stresses in the doors, it was decided to develop a new design which would roll rather than lift out of the way, and the concept design incorporated this feature.

Vehicle capacity is an obvious topic of concern as the fundamental mission of the vessel is to transport vehicles over water. Less intuitive, however, is the issue of maneuvering and parking vehicles, both automobiles and tractor-trailer rigs, on the freight deck (Figure 22). One or more longitudinal "island" structures on the freight deck serve to provide passenger access to the upper decks, and to support the structure of the decks above. Location of the island or islands has a major impact not only on how many vehicles can fit on the freight deck, but also how long those vehicles will take to load and unload. As expected, narrower lanes and increased number of turns both increase the time it will take for the driver to negotiate the vehicle to the designated parking location. This is especially true for tractor-trailer rigs, which have limited ability to
maneuver in tight quarters. It should be noted here that the SSA loading ramps have only a single lane, making it difficult to maneuver large rigs too far from the vessel centerline.

Ferries in the SSA fleet have a variety of island configurations including a single centerline island as well as port and starboard islands. For the new ferry, SSA required that the ship centerline be clear of obstructions so as to facilitate rapid loading and unloading of tractor-trailers. Passenger loading mezzanines at the 01 Deck port and starboard precluded the option of locating stair towers and elevators adjacent to the side shell, so the only logical choice for the island location was at the inboard side of a mezzanine, as two islands, one at each mezzanine, would occupy too much valuable traffic lane space on the freight deck. A single island maximizes lane width, facilitating loading and unloading, as well as providing space for a wheelchair-access lane running the full length of the freight deck.

One drawback to a single off-centerline island is the long span for the transverse racking structure (Figure 7). Lengthened spans translate to deeper members which in turn dictate the height of the 02 Deck, which must allow for clearance for 13'-6" maximum legal height tractor-trailers. The height of the 02 Deck was also increased when it was decided to provide additional parking for automobiles on port and starboard lift decks. These decks, to be fabricated of aluminum to minimize weight, stow in the freight deck overhead when not needed or when a full load of tractor-trailers is loaded.

All of these factors played key roles in determining the layout of the freight deck and all the decks above. We were fortunate that none of these decisions had to be revisited as a result of the ongoing public presentations and meetings.

Fig. 7: Structural Midship Section
**Structural Arrangements**

In keeping with typical practice for double ended ferries, it was decided that the hull would be transversely framed. A frame spacing of 28 inches was selected, with half frames installed at the freight deck to minimize deck plating deformation resulting from vehicle traffic.

Also typical for double-ended ferries, Frame 0 was located at amidships, with frame numbers increasing towards each end of the vessel. To differentiate vessel ends, one end was designated the Woods Hole end and frame numbers were given the suffix "W" (1W, 2W, 3W, etc.) The opposite end was designated the Martha’s Vineyard end and frame numbers received the suffix "M.”

Transverse racking structure consisting of deep frames and bulkheads was installed at intervals of five frames (11.67 feet).

To reduce weight, longitudinal framing was specified at the 02 Deck and above. In addition, structure above the 02 Deck was fabricated from aluminum. Bimetallic welding strips were used to connect the aluminum structure to the steel 02 Deck.

**Truck Maneuvering Study**

Because the loading ramps are only a single lane wide, maneuvering long trucks into and out of parking lanes is problematic. To ensure that the proposed truck-parking lane arrangement would work, tests were performed with trucks on a full size mockup. A large vacant lot on the Seattle waterfront was located, and chalk, cones and lumber were used to mark the lanes and interferences. Loading and unloading ramps were also bordered with lumber.

Three tractor-trailer rigs, each 66 ft-5 inches long, were rented and the professional drivers demonstrated no difficulty in maneuvering to any of the three center lanes, and thence to the unloading ramp (Figure 8). The successful conclusion of this test provided great confidence that no significant parking problems could be expected when the ferry enters service.

**Concept Hull Form**

The two highest priorities in creating the hull form (Figure 9) were that the deck plan precisely match the existing slipways, and that the full load draft not exceed 10'-10". The bonding lines at the vessel ends are uncommonly long and flat to accommodate the rudders and thrusters, but the sections transition rapidly to a V-shape for improved seakeeping. A hard chine form was selected for ease of construction and reduced cost.

**Computational Fluid Dynamics Study**

Force Technology of Brøndby, Denmark, was directed to perform computational fluid dynamics (CFD) calculations at even keel with a design draft of 10'-6" and speed of 16 knots (Fn(Lpp) = 0.321).

Potential flow CFD calculations were performed using SHIPFLOW 2.4 (XPAN). Non-linear free surface boundary conditions and free dynamic sinkage/trim were specified; appendages were not included in the calculations. Results were evaluated by means of:

- Axial velocity distribution
- Tufts (streamlines)
- Wave pattern and profile

The wave system and profile were found to be consistent and typical for the vessel lines and Froude number. The wave system exhibited a pronounced bow wave, a wave trough at about 40% Lpp aft of the forward perpendicular, and a stern wave system with a peak at 110% Lpp. The calculated wave profile was found to be similar or better than that for in-house double-ended ferry CFD data.
It was recommended that the bottom flat forward of the skeg be eliminated to reduce the probability high wave impact loads in a seaway. This recommendation was not incorporated due to the need for a flat bottom for the omnidirectional thruster discharge ring.

It was also recommended that the upper and lower chines be better aligned with the calculated flow lines to reduce drag due to cross-flow over the knuckles; see Figure 10 which shows the calculated flow lines in plan view – note the flow discontinuity at the leading edge of the skeg about one third of the way from the left side of the diagram. Alignment of chines with the calculated flow lines was accomplished by raising the chines towards the ends of the vessel, creating more of a V-section. This change partially satisfied the previous recommendation regarding wave impact loads as well.

**Fig. 10: Calculated Flow Lines**
Some difficulty in course-keeping was predicted after consideration of the hull form and ratios, particularly the L/B ratio. This issue was later examined by self-propelled zig-zag tests and the concerns proved to be unfounded.

The calculated dynamic sinkage values at 16 knots were 3.1 inches and 12.7 inches at the forward and aft perpendiculars, respectively.

**Model Test Protocol**
Chine modifications recommended by the CFD study were incorporated, and Force Technology proceeded to create a self-propelled model at a scale of 1:14.69; this 17.34-foot model is shown in Figure 11. The model included the propellers, rudders and thrusters at each end. Test propellers were 5.7 inches in diameter, fixed-pitch, and four-bladed with the following full scale characteristics:

- Diameter: 6.99 feet
- Pitch/diameter ratio: 1.00
- Blade area ratio: 0.7

Draft, roll period and stability tests were conducted on the model to confirm that hydrostatic and stability properties of the model matched the predicted values. Roll and pitch mass moment distributions were corrected to provide the calculated natural periods, and added mass and damping were accounted for.

**Fig. 11: Test Tank Model**
Still water tests, all at a draft of 10'-6", were specified as follows:

- Propeller wake survey – bow and stern propellers operating with the vessel proceeding at 16 knots.
- Stream paint tests – determine the flow in way of the bilge keels and appendages with the vessel operating at 16 knots.
- Calm water resistance with appendages – measure resistance in two knot increments from 8 to 18 knots.
- Self propulsion test – determine optimum power loading distribution between bow and stern propellers at 16 knots with five different power ratios.
- Self propulsion test – measure power requirements (rpm, torque, power and thrust) in two knot increments from 8 to 18 knots.
Optimization of Power Distribution

Because the propellers are fixed pitch, the forward propeller operates in the reverse direction and the forward propeller blades meet the oncoming flow with their trailing edges. This is obviously far from ideal, and leads to a low efficiency for the forward propeller. In an effort to determine the optimum power ratio between forward and aft propellers, self-propelled tests were performed at 16 knots with varying power ratios. Results are provided in Table 3.

Table 3: Power Distribution Measurements

<table>
<thead>
<tr>
<th>RPM_{fwd}/RPM_{aft}</th>
<th>PD_{fwd} (HP)</th>
<th>PD_{aft} (HP)</th>
<th>PD_{fwd}/PD_{aft}</th>
<th>PD total (HP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.80</td>
<td>695</td>
<td>3160</td>
<td>.22</td>
<td>3855</td>
</tr>
<tr>
<td>.85</td>
<td>939</td>
<td>3014</td>
<td>.31</td>
<td>3953</td>
</tr>
<tr>
<td>.90</td>
<td>1176</td>
<td>2802</td>
<td>.42</td>
<td>3978</td>
</tr>
<tr>
<td>.95</td>
<td>1476</td>
<td>2643</td>
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<tr>
<td>1.00</td>
<td>1743</td>
<td>2423</td>
<td>.72</td>
<td>4166</td>
</tr>
</tbody>
</table>

Not surprisingly, the lowest total power requirement occurs when the aft propeller is most heavily loaded. The total power required to propel the vessel at 16 knots with a 0.80 RPM ratio still exceeds the available power for the aft propeller, however, so a 42% forward/aft power ratio was selected for the subsequent self-propelled testing.

Speed & Powering Prediction

Resistance and self-propulsion tests were performed at the design draft with the forward propeller running at 90% of the aft propeller speed, absorbing approximately 40% of the power of the aft propeller. Table 4 shows the propeller speed and shaft power predictions for the design speed of 16.10 knots. Table 4 and Figure 12 are reproduced from Reference 2.

Table 4: Speed and Power Prediction Summary

<table>
<thead>
<tr>
<th>Propeller</th>
<th>Forward</th>
<th>Aft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaft Power (HP)</td>
<td>1196</td>
<td>2880</td>
</tr>
<tr>
<td>Propeller RPM</td>
<td>308</td>
<td>340</td>
</tr>
</tbody>
</table>

The five-bladed propellers were designed and manufactured by Rolls Royce Naval Marine, optimized for 16 knots. Propellers are fixed pitch, 90 inches diameter with 93.5 inches (nominal) pitch, 12 degrees of skew and a developed area ratio of 0.80. Slight modifications were made to the standard pitch, skew, camber and chord distributions to improve performance in the backing direction.

3-D Wake Measurements

A five-hole pitot tube was used to perform 3-D wake measurements at the design draft and vessel speed of 16 knots. Measurements were taken at the plane of the aft propeller; the aft rudder was removed for this test to provide good access to all of the propeller disk points. It was decided not to measure the forward propeller wake as the forward propeller operates in the shadow of the forward rudder and because the forward propeller is operated in reverse, an off-design condition.

Fig. 12: Speed and Horsepower Curve

Objectives of the wake measurement test were to obtain information for adequate propeller design and to measure cavitation excitation performance. Test results determined that the axial wake is distributed evenly in both the radial and circumferential directions. The axial velocity component varies between 80% and 100% of the undisturbed flow velocity, with a mean value over the entire disk of 91%. Calculated inflow angles showed very low fluctuations, suggesting an evenly distributed circumferential axial wake, with a low risk of blade cavitation.

Transverse velocity flow components (Figure 13) demonstrated a typical buttock flow, with a very weak vortex at the 180 degree position, probably generated by the skeg. It was accordingly recommended to reduce the skeg width if possible and to round the lower edges of the skeg. This second recommendation was incorporated into the design, but it was not practical to reduce the skeg width for structural reasons.
Streamline Test
Streamline tests were performed with the vessel self-propelled (both propellers operating) at 16 knots and a draft of 10.50 feet. Resulting streamlines, shown in Figure 14, reveal typical buttock-type flow with no areas of pronounced flow separation. Streamlines aligned well with the chines in the amidships areas, but did cross the chines at a small angle toward the ends of the model. It is interesting to note that this result was predicted by the CFD modeling described above. Possible flow separation at the lower skeg edges was also observed and it was accordingly recommended to round those edges if possible. As discussed above, this change was accomplished.

Seakeeping Study – Wave Design
Data from a NOAA weather buoy at the entrance to Buzzards Bay (the closest buoy to the actual operating area) were analyzed and sea spectra wave parameters, provided in Table 5, were determined for the seakeeping tests.

Table 5: Sea Spectra Wave Parameters

<table>
<thead>
<tr>
<th></th>
<th>Sea State 4</th>
<th>Sea State 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>JONSWAP</td>
<td>Hs, feet</td>
<td>6.33</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>8.71</td>
</tr>
<tr>
<td>Tp, seconds</td>
<td>9</td>
<td>8.5</td>
</tr>
<tr>
<td>Gamma</td>
<td>3.2</td>
<td>3.2</td>
</tr>
<tr>
<td>Alpha</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Seakeeping Tests
Roll and pitch decay tests were performed at the design displacement and with a mass distribution that mimicked the estimated vessel radius of gyration and metacentric height. Because of the high natural restoring forces for roll and pitch motions, a weight of about 180 pounds (a staff member) was applied and released to initiate motions. Natural periods were then calculated to be:

\[
T_{Roll} = 5.8 \text{ seconds}
\]

\[
T_{Pitch} = 5.37 \text{ seconds}
\]

Attempts to perform a heave decay test were unsuccessful due to the huge heave restoring force.

Seakeeping tests were performed with the vessel at a draft of 10.50 feet for the two sea states specified in Table 5 and at three headings (beam, following and head seas.) Tests in beam seas were conducted at zero speed. Tests in head seas and following seas were conducted at three speeds corresponding approximately to 100% MCR, 75% MCR and 50% MCR.

Vertical accelerations were measured by accelerometers at the locations listed in Table 6.

Table 6: Accelerometer Locations

<table>
<thead>
<tr>
<th>Location</th>
<th>X, ft</th>
<th>Y, ft</th>
<th>Z, ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot house</td>
<td>20</td>
<td>0</td>
<td>60</td>
</tr>
<tr>
<td>Passenger deck</td>
<td>72</td>
<td>26</td>
<td>38</td>
</tr>
<tr>
<td>Fwd bicycle area</td>
<td>95</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>Aft bicycle area</td>
<td>-95</td>
<td>21</td>
<td>19</td>
</tr>
</tbody>
</table>

X, Y and Z coordinates are referenced to amidships, centerline and baseline, respectively.
Table 7: Summary of Motions (RMS) in Head and Beam Seas

<table>
<thead>
<tr>
<th>Speed (Knots)</th>
<th>Wave height (Hs)</th>
<th>Roll (Deg)</th>
<th>Pitch (Deg)</th>
<th>Heave (Feet)</th>
<th>Vert Accel. Pilot house (G)</th>
<th>Vert Accel Pass space (G)</th>
<th>Vert Accel Fwd Bike (G)</th>
<th>Vert Accel Aft Bike (G)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.14</td>
<td>6.33</td>
<td>1.16</td>
<td>0.36</td>
<td>0.06</td>
<td>0.09</td>
<td>0.11</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>12.60</td>
<td>6.33</td>
<td>1.15</td>
<td>0.35</td>
<td>0.06</td>
<td>0.10</td>
<td>0.12</td>
<td>0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>14.21</td>
<td>6.33</td>
<td>1.03</td>
<td>0.33</td>
<td>0.06</td>
<td>0.09</td>
<td>0.12</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>0</td>
<td>6.33</td>
<td>3.17</td>
<td>0.47</td>
<td>0.03</td>
<td>0.06</td>
<td>0.05</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>10.13</td>
<td>8.71</td>
<td>1.63</td>
<td>0.52</td>
<td>0.07</td>
<td>0.11</td>
<td>0.14</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>11.64</td>
<td>8.71</td>
<td>1.60</td>
<td>0.52</td>
<td>0.08</td>
<td>0.12</td>
<td>0.15</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>12.97</td>
<td>8.71</td>
<td>1.55</td>
<td>0.52</td>
<td>0.08</td>
<td>0.12</td>
<td>0.15</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>0</td>
<td>8.71</td>
<td>3.70</td>
<td>0.61</td>
<td>0.04</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
</tr>
</tbody>
</table>

The measured roll angles and vertical accelerations, summarized in Table 7, are higher than would likely be comfortable for passengers on voyages longer than two hours. However, the master does have the option of slowing down, and the length of exposure to rough seas on the intended route is well under one hour, so these values are considered to be acceptable.

**Speed Loss Calculation**

Based upon the maximum predicted speed in calm water of 16.1 knots, and assuming constant power output, speed loss was calculated as the difference between the speed/power curves in the corresponding sea state and the still water reference; see Table 8. Speed / power curves were calculated from the measured propeller torque and revolutions. Predictions included wind resistance for wind speeds of 31 ft/sec and 37 ft/sec for the two sea states, respectively.

Table 8: Speed Loss (knots)

<table>
<thead>
<tr>
<th>Sea State</th>
<th>Head sea Max speed</th>
<th>Head sea Speed loss</th>
<th>Foll. sea Max speed</th>
<th>Foll. sea Speed loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hs = 6.33’</td>
<td>14.1</td>
<td>2.0</td>
<td>15.7</td>
<td>0.4</td>
</tr>
<tr>
<td>Hs = 8.71’</td>
<td>12.3</td>
<td>3.8</td>
<td>15.1</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Course Stability**

Self-powered maneuvering tests (zig-zag maneuvers) were conducted in still water with the vessel operating at the design draft with a GM of 26.05 ft. and 16 knots initial speed. Three series of zig-zags were performed, at rudder yaw angles of 4 -4 degrees, 6 – 6 degrees and 10 – 10 degrees (Reference 3).

One key measurement of course stability is the "overshoot angle," measured in degrees and defined as the heading deviation from the moment the rudder is reversed to the moment that rate of change of heading is zero. For ships longer than 100 meters, IMO Maneuvering Resolution A.751(18) specifies that for the 10-10 degree zig-zag criterion, the vessel maintains good course stability when the first and second overshoot angles are less than 10 and 25 degrees, respectively. The procedure for the 10-10 degree zig-zag maneuver is to set the aft rudder 10 degrees to port (for example) until the vessel achieves a heading of 10 degrees to port, at which time the rudder is reversed to 10 degrees starboard until the vessel course is 10 degrees starboard. The forward rudder was fixed on centerline for all maneuvering tests.

<table>
<thead>
<tr>
<th>Rudder Angle</th>
<th>First Overshoot (deg)</th>
<th>Second Overshoot (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMO 10/10 Zig-zag</td>
<td>10° max</td>
<td>25° max</td>
</tr>
<tr>
<td>4°</td>
<td>4.0°</td>
<td>3.6°</td>
</tr>
<tr>
<td>6°</td>
<td>5.8°</td>
<td>7.0°</td>
</tr>
<tr>
<td>10°</td>
<td>7.5°</td>
<td>12.0°</td>
</tr>
</tbody>
</table>

Zig-zag test results are provided in Table 9 and Figure 15. Both the first and second overshoot angles were found to be well within the IMO criterion; it was therefore concluded that course stability would not be a problem.

It should be noted that low speed maneuvering was not tested as the combination of a thruster and a rudder at each end of the hull was expected to provide exceptional control.

**Pilothouse Issue Revisited**

As mentioned earlier, the decision to design the vessel with a single pilothouse amidships was well-considered but not unanimous. Over a period of several months, smoldering disagreement evolved into active dissent and letters expressing concern about visibility in foggy conditions began to appear in the local newspapers. SSA personnel took notice and held public forums to determine the strength of the dissent.

After much discussion and careful consideration of the consequences of changing the design, it was finally decided to redesign the vessel with two pilothouses. Unfortunately, the structural design had been completed some time earlier and much additional design work was required to reconcile the new arrangements and structure. The final cost of this change, including engineering and additional materials, labor and equipment, was estimated at about one million dollars.

**Disabilities Accommodations**

As stated earlier, it was the intention of SSA to comply insofar as practical with the standards of the Americans with Disabilities Act (ADA) (Reference 4).
Many of these standards are relatively simple to achieve, but all require the designer to maintain focus on the standards throughout the design process so as not to compromise the disabilities accommodations. Typical of the standards for accommodations are:

- Clear height through doorways of 80 inches
- Clear passage widths of 32 inches
- Signage in Braille
- Automated door openers
- Provision for wheelchair seating throughout the passenger areas
- Flashing light alarm signals

Another accommodation for disabilities required more careful planning to include in the design. The most obvious need was for an elevator providing access to upper decks for the mobility-impaired. The Steamship Authority's experience indicated that when a single elevator is installed on a vessel, passengers and food service contractors frequently compete for its use. Early in the design process, therefore, SSA made the decision to provide two elevators with one being for the exclusive use of passengers.

Elevator size was constrained by the available length and width of the freight deck island (Figure 22), which in turn was constrained by the need to maximize traffic lane width on a deck with limited beam and length. Careful design of the island made it possible to fit the uptakes, three stair towers, utility trunks and two elevators, but there was inadequate deck space for fully ADA-compliant elevators. ADA standards anticipated this situation by offering a reduced size elevator, termed Limited Use Limited Availability (LULA). LULA elevators are required to have clear inside dimensions of 42 inches width × 54 inches depth with a door clear opening width of 32 inches. Both elevators comply with LULA standards.

An elevator would do little to provide access for the mobility-impaired unless convenient access is to the elevator is provided. This was accomplished by providing a pedestrian path for the full length of the freight deck. The pedestrian path is 36 inch wide, adequate for wheelchair passage, and painted high-visibility yellow to assist drivers in keeping clear.

Evacuation Arrangements
Given the USCG requirement to evacuate the full passenger load of 1200 people within thirty minutes, efficiency in every aspect of the evacuation process was essential. Early in the design process, SSA decided that passengers would evacuate from the 01 Deck rather than from the freight deck, reasoning that the freight deck was much more likely to be involved in a fire than the 01 Deck passenger spaces.

Evacuation from the 01 Deck, located 15 ft-6 inches feet above the full load waterline, would require either a chute or a slide from the 01 Deck to the escape platform. SSA carefully considered these two options and selected a slide arrangement, believing that it would be easier to coax passengers, including the elderly and small children, onto a slide.

At the lower end of each slide, evacuees land on the escape platform, a floating raft which serves as a queue while the evacuees are directed by a crew member into the adjoining life rafts. Two evacuation systems are provided, one located at the Woods Hole end of the vessel, port side, and the other at the Martha's Vineyard end, starboard side. Each slide, platform and raft assemblage is intended to serve 600 passengers.

Before the Island Home entered service, an evacuation drill was performed under the watchful eye of the USCG in January, 2007, at Fairhaven, MA. Frigid conditions (16°F with 20 knot winds) necessitated the support of two small craft to push the sea ice away from the evacuation system deployment area. The sample size of two crew members and ten hardy volunteers was able to evacuate in 20 seconds. Extrapolating the evacuation time to 600 passengers, and allowing for the 80 second slide and raft deployment time, it was determined that a full load of 1200 passengers could evacuate in 22 minutes.

Rescue Boats
The two rescue boats are SOLAS-approved, each 4.3 meters long with a 6-person capacity and fitted with a 30 HP outboard motor. A SOLAS-approved davit was furnished for launching and retrieving each boat.

As with the evacuation systems, SSA wanted the rescue boats to be located in the most efficient locations. Past experience with launching rescue boats in high wind conditions convinced SSA that the boats should be located as close to the waterline as practical. Therefore, space on the freight deck was allocated for the rescue boats, which are located at the Woods Hole end, starboard side and Martha's Vineyard end, port side, as shown in Figure 16.

Numerous drills conducted during crew training confirmed the wisdom of this decision, as quick launches and rapid recoveries were performed in a variety of weather conditions.

Lift Decks
The original design concepts did not include lift decks, but after inspecting successful installations of lift decks in other ferry operations, SSA elected to include them in the new design. The rationale for the lift decks was to increase automobile capacity without reducing truck capacity. Increased automobile capacity would reduce waiting time for drivers during the busy summer months while simultaneously increasing revenue.

To avoid reducing truck capacity, the lift decks needed to stow in the overhead of the freight deck, maintaining 14.5 feet clear underneath for the tallest road-legal trucks in Massachusetts. A variety of mechanisms to accomplish this were evaluated and some consideration was given to providing the lift deck design as part of the contract package. In the end, it was decided to leave responsibility for the design with the shipyard so as to provide the best opportunity for integration of the lift decks with the vessel structure and systems.
**Island Home Particulars**

- Length overall: 254'-8"
- Length, waterline: 238'-8"
- Beam, molded: 64'-0"
- Depth at amidships, molded: 17'-6"
- Design draft: 10'-10"
- Vehicle capacity: 76
- Passenger capacity: 1200
- Fuel oil capacity: 8700 gallons
- Fresh water capacity: 1000 gallons

---

Figure 16: *Island Home* Profile and Arrangements
Huber, Inc. of New Orleans was awarded the design of the lift decks and produced the successful results seen in Figure 17. Each of the two lift decks is 140 feet long and has a capacity of eight typical automobiles. In addition to the complex geometry involved in the scissors-lift for the center sections and the hydraulic cylinders to operate the ramps, it was necessary to develop practical details for folding handrails, safety interlocks for the access doors at the 01 Deck, and sprinkler piping and heads on the underside of the ramps.

Security Features
Security concerns typical of present day operations were addressed in the design phase of this project. In addition to the omnipresent security cameras and cipher locks on doors accessing secure spaces, the design includes a crew-only stair tower providing secure access from the engine room to the crew spaces on the 03 Deck.

The original design had an amidships pilothouse; this stair tower originally terminated inside the pilothouse. However, the change to the installation of two pilothouses eliminated the possibility of accessing pilothouses without passing through passenger spaces. The final design configuration requires that passengers be prohibited from the 03 Deck when heightened security measures are in force, so that the master and pilot can transit between pilothouses without passenger contact.

Machinery Arrangements
The engine room arrangement is shown in Figure 18. An Engineer Operating Station (EOS) is located at the engine room port side, with direct access to the crew stair tower. The EOS provides good visibility of the engine room and also has several monitors to permit the engineers to view activity in the steering gear rooms, reduction gear rooms, and auxiliary machinery room. The main switchboard and motor control center are also located within the EOS.

Perhaps the most obvious feature of the engine room is the location of the two main engines. Also obvious is the lack of reduction gears, which are installed in the reduction gear rooms close to the ends of the vessel. The reason for the separation of engines and reduction gears is that the maximum compartment length, as determined by the floodable length regulations, does not allow all four pieces of machinery to fit in the engine room. A benefit of separation of engines and reduction gears is the ability to use smaller diameter, high speed shafting to transmit power from the engines to the reduction gears, saving weight and cost.

The Auxiliary Machinery Room (AMR) is adjacent to the engine room with access through an automatic watertight door. Primary machinery in the AMR includes the sewage treatment system and refrigeration compressors. The AMR arrangement can be seen in Figure 19.
Rudders

One measure of success for the design of the Island Home would be its ability to accomplish controlled dockings under the adverse conditions so common at the Woods Hole terminal. High efficiency rudders were therefore very appealing, and Becker articulating rudders were selected for this application. So as to keep steering torque requirements (and therefore steering gear capacity) at reasonable values, it was decided that the forward rudder would not be operable at vessel speeds exceeding 5 knots.

The rudder installation is shown in Figure 20; note the ice knife located at the forward end of the rudder, designed to protect the rudder from ice flows.

Thrusters

SSA has had successful experience with the use of Eliot Whitegill (subsequently named Tees) jet thrusters, and elected to supplement the articulating rudders with a 400 HP electric motor-driven Tees thruster at each end of the vessel. This decision, which was made early in the design process, had a significant impact on the hull shape and location of the rudders.

It was necessary to locate the pump inlet as far below the design waterline as possible so as to minimize ingestion of ice or other floating debris. To maximize the effectiveness of the water jet, it was necessary to locate the pump discharge as close to the end of the vessel as possible while trying to minimize systemic losses resulting from friction and turbulence between the inlet and the pump. These two requirements can normally be reconciled easily in a bow thruster installation on a conventional hull, but seem at odds when trying to locate them around the propeller and rudder. The end result can be seen in Figure 21.

Shipyard Selection

The size and complexity of the vessel limited the number of qualified and interested shipyards, as did the requirement for construction bonding. VT Halter Marine (VTHM) of Pascagoula, MS was ultimately awarded the construction contract and immediately proceeded with the detail design engineering.
Vibration Predictions

VTHM was required to produce a vibration analysis to predict natural frequencies, global mode shapes and forced vibration response in the hull structure. Once the structural design was largely completed, Noise Control Engineering performed this analysis using a marine-based FEA code to model the hull and superstructure, and a general purpose FEA code to conduct the forced response analysis. Outfitting weights and liquids in tanks were included in the model, but the weights of passengers and vehicles were not. Forcing frequencies, excerpted from Reference 5, are provided in Table 10.

Table 10: Forcing Frequencies for Engines, Shafts and Propellers, Hz

<table>
<thead>
<tr>
<th>Vessel speed (knots)</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed (RPM)</td>
<td>400</td>
<td>500</td>
<td>600</td>
<td>700</td>
<td>800</td>
<td>900</td>
</tr>
<tr>
<td>Shaft speed (RPM)</td>
<td>131.8</td>
<td>164.7</td>
<td>197.6</td>
<td>230.6</td>
<td>263.5</td>
<td>296.4</td>
</tr>
<tr>
<td>Engine rotation frequency (Hz)</td>
<td>6.7</td>
<td>8.3</td>
<td>10.0</td>
<td>11.7</td>
<td>13.3</td>
<td>15.0</td>
</tr>
<tr>
<td>Shaft rate frequency (Hz)</td>
<td>2.2</td>
<td>2.7</td>
<td>3.3</td>
<td>3.8</td>
<td>4.4</td>
<td>4.9</td>
</tr>
<tr>
<td>Blade passing frequency (Hz)</td>
<td>11.0</td>
<td>13.7</td>
<td>16.5</td>
<td>19.2</td>
<td>22.0</td>
<td>24.7</td>
</tr>
</tbody>
</table>

Reference 4 predicted "resonant coincidences between the propeller shaft rotation rate primary and second harmonics and natural frequencies at 3.9 and 7.8 Hertz. The first resonant condition is within 10% of the first vertical mode and the second coincidence is within 10% of the fourth vertical mode/third torsional mode." It was recommended that these frequency coincidences be avoided by "ensuring proper balance, shaft concentricity and shaft coupling alignment." These precautions were taken to heart, and the line shaft material was changed from steel to carbon fiber to further alter the natural frequency of the shafting systems.

Serious excesses to the American Bureau of Shipping "COMF" Class vibration criteria (Reference 6) were also predicted, caused by vibration from the propulsion diesel engines and the shafting between the gearboxes and propellers. The precautions adopted as described above should also address the shafting vibration issue, but the diesel engine vibration issue would require additional measures.

The two practical options for reducing main engine-induced vibration were:
- Increasing structural mass to alter the natural frequency
- Resiliently mounting the main engines

Draft limitations precluded serious consideration of the first option, and the builder strongly advocated the use of resilient mounts. Accordingly, SSA chose to proceed with the installation of resilient mounts under the main propulsion engines.

Design Changes

Every significant engineering design could have been improved with the advantage of 20/20 hindsight, and this effort was not an exception. Despite extensive experience in the design of passenger/vehicle ferries, the designers did not always interpret the regulations correctly, did not anticipate some new USCG interpretations, and did not avoid all of the opportunities for what can only be called mistakes. Resolving unexpected challenges can be true test of a team's cohesiveness, and it is a testament to the team of SSA, EBDG and VTHM that technical challenges were overcome professionally, without rancor and without schedule delay.
The first technical surprise involved stability, downflooding, and the joiner doors on the outboard (port) side of the island. Several of these doors provide access to companions leading below the freight deck and so are potential downflooding points. Calculations performed during the contract design indicated that the vessel met the applicable stability criteria without the need for weathertight doors at these locations. It is an unfortunate quirk of the stability software used for the calculations that the software defaults to starboard heel when calculating righting energy. As the doors are located on the port side, it is necessary to either mirror the downflood points to the starboard side, or to direct the software to heel both port and starboard. This need was overlooked; fortunately VTHM discovered the error before the doors were installed, and arranged to install weathertight rather than joiner doors.

The second technical surprise also involved stability but resulted from a carefully considered decision rather than an oversight. 46 CFR 171.072 establishes permeabilities for different types of spaces, specifically 0.85 for machinery spaces and 0.95 for "other" spaces. During the contract design phase, the reduction gear rooms were considered to be a machinery spaces with a defined permeability of 0.85, a decision based on numerous USCG approvals of nearly identical arrangements. Unfortunately for this project, the precedent of former interpretations was deemed no longer appropriate by the USCG, which applied a permeability of 0.95. Equally unfortunate, the greater permeability more accurately reflected reality, eliminating the opportunity for using a calculated value.

The solution to this issue was expensive and difficult; it was necessary to relocate the inboard portions of the already-fabricated transverse bulkheads at frames 19W and 19M, creating stepped bulkheads (Figure 22) to reduce the volume of the reduction gear rooms. A positive outcome of this development was the opportunity to expand the crew quarters and auxiliary machinery room.

Two regulatory issues related to the aluminum structure caught the designers by surprise. The first was the need for steel stairs within the A-60-insulated stair towers, and the other was the need to insulate both sides of aluminum structure in order to achieve A-60-level protection for stair tower bulkheads.

Each project has several features that would be changed on the next hull built to the same design, and the Island Home is again no exception to this truism. Given the opportunity, we would locate the fresh water tank on the starboard side of the Martha's Vineyard end rather than the port side of the Woods Hole end so as to counterbalance the port side island structure. An even more minor improvement would be to delete the tonnage opening in the crew lounge on the 03 Deck – this opening proved to be unnecessary insurance.

The last significant technical issue to be raised occurred just days before the Island Home departed on the delivery voyage. 46 CFR 112.05(d) requires "Each compartment containing this equipment [the emergency power source] must be readily accessible from the open deck …" This requirement was met in the concept design, but concerns over vessel security led to a decision to move the access to a passageway in the secure crew accommodations. The regulations were not revisited during the contract design, and USCG approved the arrangements without comment, leaving this violation to be discovered by OCMI. The solution was to add a watertight hatch for access from the exterior, a solution which meets the letter of the law while still discouraging passengers from unwanted exploration.

One final OCMI requirement delayed the delivery voyage departure by a day when it became necessary to replace the plastic tubes serving the soft-drink dispenser with stainless steel tubes.

**Hurricane Katrina**
Hurricane Katrina arrived right in the middle of the construction program. Several of the amidships hull modules had been erected on the building ways, but the end modules and upper levels were at ground level still undergoing fitting and welding.

At the peak of the storm surge about ten feet of sea water flooded the shipyard. One large vessel moored and anchored at the yard broke free and floated inland, requiring a half mile channel to be excavated to extract the vessel from the marshes.
The Island Home was much more fortunate – the erected modules suffered very little damage and the units on the ground were undamaged, although a variety of snakes and other reptiles inhabited the nooks and crannies when the yard workers were able to return and begin the cleaning up operations.

The shipyard suffered extensive damage to its buildings and shops. All ground level offices and facilities were completely destroyed, including machine shops, prefab shops and the Owner's trailer office. The warehouse was flooded, destroying the ship's generator sets and other equipment. Fortunately, the main engines had been blocked high and appeared to be undamaged, but were returned to the supplier for inspection as a precaution and to validate the warranty.

VT Halter was able to reopen in remarkably fast time, but restoration of full capabilities was long delayed by the inability to obtain equipment, fuel and supplies as every remaining viable business competed for scarce resources. Probably the hardest resource to get back on line was labor, as many of the production workers lost their homes and had to either relocate out of the area or spend months rebuilding.

The net result for the Island Home project was a delay of about nine months, a remarkably short period when the devastation to the shipyard and surrounding towns and homes is considered.

Sea Trials Results
The sea trials agenda was based on Reference 7. Sea trials were conducted in the Gulf of Mexico south of Pascagoula, MS on January 12, 2007. Test conditions were as follows:

- Water depth: 45 feet
- Wave size: 4 – 6 feet
- Wave direction: NW
- Wind velocity: 8 – 12 knots
- Wind direction: SE
- Draft forward: 10'-0"
- Draft aft: 9'-10"

Speed trials were conducted at a shaft speed of 300 RPM, resulting in an average speed of 16.25 knots. The highest recorded speed for a 10 minute run was 17.0 knots.

Whole Body Vibration Survey
A whole body vibration survey was conducted to confirm compliance with the contract requirement that the vessel comply with the American Bureau of Shipping "COMF" level criteria, Reference 6. The "COMF" requirement is an acceleration level of not more than 0.315 meters/second^2 through the frequency range of 0.5 to 80 Hertz.

Testing was performed by Noise Control Engineering, Ltd. (NCE). Test instruments were configured to measure one-third octave band vibration from the 1 Hertz to the 80 Hertz one-third octave bands with an rms averaging period of 60 seconds. Note that this measurement range does not match the "COMF" range due to limitations of the test instruments and because vibrations in the range under 2 Hertz tend to be controlled by sea state rather than equipment vibration.

<table>
<thead>
<tr>
<th>Deck</th>
<th>Space</th>
<th>Frame</th>
<th>Side</th>
<th>Vibration m/sec^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight</td>
<td>Vehicle</td>
<td>30M CL</td>
<td></td>
<td>0.227</td>
</tr>
<tr>
<td>Freight</td>
<td>Vehicle</td>
<td>0 CL</td>
<td></td>
<td>0.169</td>
</tr>
<tr>
<td>Freight</td>
<td>Vehicle</td>
<td>30W CL</td>
<td></td>
<td>0.160</td>
</tr>
<tr>
<td>01 Passenger</td>
<td>15M Port</td>
<td></td>
<td></td>
<td>0.335</td>
</tr>
<tr>
<td>01 Passenger</td>
<td>15M Stbd</td>
<td></td>
<td></td>
<td>0.220</td>
</tr>
<tr>
<td>01 Passenger</td>
<td>15W Port</td>
<td></td>
<td></td>
<td>0.292</td>
</tr>
<tr>
<td>01 Passenger</td>
<td>15W Stbd</td>
<td></td>
<td></td>
<td>0.247</td>
</tr>
<tr>
<td>02 Dining</td>
<td>30M CL</td>
<td></td>
<td></td>
<td>0.358</td>
</tr>
<tr>
<td>02 Passenger</td>
<td>30W CL</td>
<td></td>
<td></td>
<td>0.289</td>
</tr>
<tr>
<td>03 Passenger</td>
<td>30M CL</td>
<td></td>
<td></td>
<td>0.403</td>
</tr>
<tr>
<td>03 Passenger</td>
<td>30W CL</td>
<td></td>
<td></td>
<td>0.310</td>
</tr>
<tr>
<td>04 Pilothouse</td>
<td>36M CL</td>
<td></td>
<td></td>
<td>0.338</td>
</tr>
<tr>
<td>04 Pilothouse</td>
<td>36W CL</td>
<td></td>
<td></td>
<td>0.443</td>
</tr>
</tbody>
</table>

Vibration measurements were taken at the locations indicated in Table 11 above using a triaxial accelerometer affixed to the freight deck with magnetic mounts and to locations above the freight deck with bees wax. Vibration readings were in decibels relative to micro-g (dB/µg) and later converted to linear accelerations in meters/second^2.

Both main engines were operated at full power during the whole body vibration survey. It can be seen in Table 11 that several locations exhibited vibrations in excess of the 0.315m/sec^2 limit. It is believed that these excessive values are due in large part to the fact that both propellers were operating at full power, with the forward propeller cavitating heavily. Because the forward propeller will not normally be operated above 75% power, it is believed that vibrations will be reduced to an acceptable level during normal operations.

Engine Vibration and Displacement Survey
The purpose of the engine vibration and displacement survey was to confirm that the main engine vibration isolators were properly selected and installed so that the engines, EMD model 12-710G7B, exhibited reasonable displacements throughout the full power range. The maximum allowable static displacement of the engines, limited by the flexible coupling on the turbocharger intake, is 22mm (0.867 inches).

Vibration measurements were performed by NCE using a 16-channel data collection system. Data was collected in the 10 Hertz to the 10,000 Hertz one-third octave bands using tri-axial accelerometers with rms averaging for 30 second periods. Readings were taken in decibels relative to micro-g (dB/µg). Accelerometers were located at the back engine foot (above the vibration isolator), the front engine foot (above the vibration isolator), above and at the side of the air intake. Table 12 is a sample of the results obtained from the measurements.
Table 12. Static Transverse Displacement

<table>
<thead>
<tr>
<th>Engine Speed (rpm)</th>
<th>Ship Speed (knots)</th>
<th>Minimum Displacement (inches)</th>
<th>Maximum Displacement (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>350</td>
<td>3.8</td>
<td>-0.005</td>
<td>+0.007</td>
</tr>
<tr>
<td>400</td>
<td>5.3</td>
<td>0.000</td>
<td>+0.008</td>
</tr>
<tr>
<td>450</td>
<td>6.5</td>
<td>0.000</td>
<td>+0.010</td>
</tr>
<tr>
<td>500</td>
<td>6.4</td>
<td>-0.001</td>
<td>+0.020</td>
</tr>
<tr>
<td>550</td>
<td>7.5</td>
<td>-0.001</td>
<td>+0.028</td>
</tr>
<tr>
<td>600</td>
<td>8.0</td>
<td>0.000</td>
<td>+0.030</td>
</tr>
<tr>
<td>650</td>
<td>8.4</td>
<td>0.002</td>
<td>+0.030</td>
</tr>
<tr>
<td>700</td>
<td>10.2</td>
<td>+0.020</td>
<td>+0.040</td>
</tr>
<tr>
<td>750</td>
<td>12.2</td>
<td>+0.020</td>
<td>+0.050</td>
</tr>
<tr>
<td>800</td>
<td>12.6</td>
<td>+0.030</td>
<td>+0.060</td>
</tr>
<tr>
<td>850</td>
<td>14.0</td>
<td>+0.040</td>
<td>+0.070</td>
</tr>
<tr>
<td>900</td>
<td>14.2</td>
<td>+0.050</td>
<td>+0.070</td>
</tr>
</tbody>
</table>

A temporal variation in the data of 0.02 inches with a 5 second period was observed and was ascribed to vessel motions. Trials were conducted in high Sea State 1 conditions and the vessel was experiencing "moderate" rolling conditions.

No resonant conditions were observed. The greatest recorded transverse-direction motion was less than 0.01 inches and well below the allowable 0.867 inches as determined by the turbo-charger flexible coupling. Measurements taken above and below the isolation mounts exhibited vibration attenuation in excess of 20 decibels.

Airborne Noise Survey

The initial contract specification established desired and maximum allowable noise levels during normal conditions with the main engines operating at full power and the HVAC system operating. During contract negotiations, SSA agreed to change the maximum values to "goals" rather than firm requirements. All noise levels were specified and measured in a-weighted decibels (dB(A)).

Sound pressure level measurements were performed using a hand-held sound level meter with a ½ inch microphone shielded with an acoustically transparent windscreen. Integration response was set to "slow" (one second rise-time) and RMS averaging was performed for at least ten seconds.

Excluding the freight deck, one measurement was taken per compartment. Measurements were taken at typically occupied locations but normally at least three feet from large flat surfaces. Desired values, "goal" values and measured values, all in dB(A), are included in Table 13.

Table 13. Airborne Noise Measurements

<table>
<thead>
<tr>
<th>Space</th>
<th>Desired Value</th>
<th>Goal Value</th>
<th>Measured Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>02 Dk Pass Area</td>
<td>60</td>
<td>65</td>
<td>62</td>
</tr>
<tr>
<td>02 Dk Outside</td>
<td></td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>01 Dk Pass Area</td>
<td>60</td>
<td>65</td>
<td>68</td>
</tr>
<tr>
<td>Dining Area</td>
<td>65</td>
<td>70</td>
<td>63</td>
</tr>
<tr>
<td>Pilotheuses</td>
<td>55</td>
<td>65</td>
<td>68</td>
</tr>
</tbody>
</table>

Excessive noise values were in most cases ascribed to cavitation noise from the forward propeller; actual operating noise levels will normally be lower as the forward propeller will not be operated at full power.

Unfortunately and surprisingly, no measurements were recorded in the Engineers Operating Station.

Illumination Survey

The VTHM survey procedure specified the grid system data point method for the illumination survey. Measurements were taken at a distance approximately thirty inches above the deck and after fluorescent fixtures had been lighted for at least thirty minutes. In high traffic areas such as passageways and stairways, measurements were taken at the deck level, at both the top and bottom of stairs. Compartments were divided into 3 foot square grids from the center out and illumination levels were measured at each grid intersection. Readings were averaged and compared with the standard established by Reference 8.

Typical results are included in Table 14. Note that the dining area measured 8% below the required value; SSA elected to accept this minor短coming.

Table 14. Illumination Levels

<table>
<thead>
<tr>
<th>Space</th>
<th>Required Footcandles</th>
<th>Measured Footcandles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strg Gear Room</td>
<td>30</td>
<td>53.7</td>
</tr>
<tr>
<td>Thruster Room</td>
<td>30</td>
<td>39.7</td>
</tr>
<tr>
<td>Red Gear Room</td>
<td>30</td>
<td>34.7</td>
</tr>
<tr>
<td>Aux Machy Rm</td>
<td>30</td>
<td>53.1</td>
</tr>
<tr>
<td>Engine Room</td>
<td>30</td>
<td>34.8</td>
</tr>
<tr>
<td>EOS</td>
<td>30</td>
<td>30.5</td>
</tr>
<tr>
<td>Crew Stateroom</td>
<td>10</td>
<td>14.9</td>
</tr>
<tr>
<td>Crew Passage</td>
<td>8</td>
<td>41.2</td>
</tr>
<tr>
<td>Freight Deck</td>
<td>15</td>
<td>19.3</td>
</tr>
<tr>
<td>Elevator</td>
<td>15</td>
<td>29.8</td>
</tr>
<tr>
<td>01 Dk Pass Area</td>
<td>15</td>
<td>22.8</td>
</tr>
<tr>
<td>Restrooms</td>
<td>20</td>
<td>20.2</td>
</tr>
<tr>
<td>Ship's Office</td>
<td>20</td>
<td>21.9</td>
</tr>
<tr>
<td>02 Dk Pass Area</td>
<td>15</td>
<td>16.6</td>
</tr>
<tr>
<td>Dining Area</td>
<td>20</td>
<td>18.3</td>
</tr>
<tr>
<td>Food Prep Area</td>
<td>20</td>
<td>24.8</td>
</tr>
<tr>
<td>Crew Pantry</td>
<td>15</td>
<td>29.6</td>
</tr>
<tr>
<td>HVAC Room</td>
<td>15</td>
<td>33.4</td>
</tr>
<tr>
<td>Emerg. Gen Room</td>
<td>30</td>
<td>60.7</td>
</tr>
</tbody>
</table>
Delivery Trip Results
The delivery trip from Pascagoula to Woods Hole was largely uneventful. Most of the trip was accomplished with a stern propeller RPM of 750 and a bow propeller RPM of 550, resulting in a fuel consumption of about 110 gallons per hour. Although waves up to 15 feet and wind gusts to 50 knots were encountered, there were no injuries and no damage to the vessel.

Commissioning and First Months of Service
The Island Home was dedicated in a ceremony at Vineyard Haven on Martha's Vineyard, Massachusetts on March 3, 2007, and entered full service on March 5. With far fewer than expected start-up issues to be resolved, passenger reaction has been almost unanimously positive. Although the initial impressions seemed to focus on the substantial difference in size between the Island Home and the Islander, the tremendous improvement in interior accommodations has won over virtually all of the skeptics and traditionalists, and SSA can look forward to the start of a new tradition.

ACKNOWLEDGEMENTS
It is safe to say that Capt. Ed Jackson, recently retired from SSA, deserves most of the credit for this highly successful project. His patience, diplomacy and untiring efforts were instrumental in negotiating compromises and maintaining production under uncommonly adverse conditions.

REFERENCES