
Joint High Speed Vessel (JHSV)

Follow-on Operational Test and Evaluation (FOT&E) Report



September 2015

This report on the Joint High Speed Vessel (JHSV) assesses the adequacy of testing, the operational effectiveness, and operational suitability of the JHSV.

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Director

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Summary

This document reports on the Follow-on Operational Test and Evaluation (FOT&E) of the Joint High Speed Vessel (JHSV) ship class. The events covered in this testing were not performed during the Initial Operational Test and Evaluation (IOT&E) because of the unavailability of test assets, primarily the Mobile Landing Platform with the Core Capability Set (MLP (CCS)).¹ Testers collected effectiveness data from three FOT&E events on USNS *Millinocket* (JHSV 3), and suitability data derived from the maiden voyage maintenance records of USNS *Spearhead* (JHSV 1).

Personnel from the Navy's Commander Operational Test and Evaluation Force (COTF), assisted by personnel from the Marine Corps Operational Test and Evaluation Activity (MCOTEA), conducted the FOT&E events. The first two test periods, in June 2014 and October 2014, examined at-sea equipment transfers between JHSV and the MLP (CCS).² The third FOT&E test period was devoted to launch and recovery of the U.S. Navy's Sea, Air, Land Team (SEAL) Delivery Vehicle (SDV).

JHSV interoperability with MLP (CCS) is not operationally effective since, by design (ramp limitation), it can conduct vehicle transfers when conducted in sea states with significant wave heights of less than 0.1 meters (approximates a Sea State 1), which are normally found only in protected harbors. When tested in a more operationally relevant open-ocean environment, the JHSV ramp suffered a casualty when its hydraulic ram, used to swing the ramp horizontally, tore free from its anchor point on the transom (the surface that forms the stern of a vessel). The small amount of movement between the ships, even in the very low sea state conditions, was enough to cause the damage when a truck pinned the foot of the ramp onto the raised vehicle deck of MLP (CCS) as it transited the ramp. Vehicle transfer operations were successful in the earlier test, when MLP (CCS) was at anchor in Sea State 1 conditions inside a harbor.

JHSV is capable of launching the Navy SDV in sea conditions up to and including Sea State 3 (equates to significant wave height up to 1.25 meters), but support boats required for a SDV mission are currently limited to Sea State 2 (equates to significant wave height up to 0.5 meters) launches. The SDV portion of the FOT&E did not include launch of the support boats since launch of these type boats was completed in IOT&E.

¹ "Initial Operational Test and Evaluation (IOT&E) with Live Fire Test and Evaluation (LFT&E) on Joint High Speed Vessel (JHSV)," DOT&E, July 17, 2014.

² MLP (CCS) is a heavy-lift ship based primarily on the *Alaska*-class oil tanker design, which has been modified with a raised vehicle deck, vehicle transfer ramp, and three landing craft air cushion vehicle lanes. These additions to the base heavy-lift ship are referred to as the Core Capability Set (CCS). MLP (CCS) is designed to moor skin-to-skin, at sea, with Navy Large Medium-Speed Roll-on/roll-off cargo transport ships and the JHSV for transfer of Marine Corps or Army rolling stock.

JHSV is operationally suitable, although the demonstrated availability has decreased from 98 percent, reported in the IOT&E report, to 87 percent. The 80 percent lower confidence bound is 81 percent, which meets the JHSV availability target.³ The main drivers of ship unavailability were the Ship Service Diesel Generators (SSDGs), waterjets, and the Ride Control System (RCS).

The RCS failures are a symptom of a more serious problem with the JHSV bow structure related to the ship's Safe Operating Envelope (SOE), which is designed to limit wave impact loads on the bow structure. There are two SOEs: a less restrictive SOE, used with a functional RCS, and a very restrictive SOE used when the RCS is broken or turned off. Compromises in the bow structure, presumably to save weight, were accepted when building these ships. Multiple ships of the class have suffered damage to the bow structure, and repairs/reinforcements are in progress class-wide. The reinforcement of the bow structure does not expand the SOE, but should allow full use of the ship, within the original SOE, without risk of damage. Hulls 1 through 4 are being repaired and reinforced, adding an additional 1,736 pounds to the ship's weight. This should have minimal impact to ship mission capability in regards to fully loaded range capability. From the IOT&E report, when the ship is fully loaded with troops and equipment (600 short tons), the ship's fuel tanks cannot be completely filled with fuel. The additional weight from the added bow structure displaces 250 gallons of fuel, which correlates to reducing the ship's range by only 3.5 nautical miles at 31 knots (reduced to 854 nautical miles).

The operational restriction of the SOE is a major limitation of the ship class that must be factored into all missions. To utilize the speed capability of the ship, seas must not exceed Sea State 3 (significant wave height up to 1.25 meters). At Sea State 4 (significant wave height up to 2.5 meters) the ship must slow to 15 knots. At Sea State 5 (significant wave height up to 4 meters) the ship must slow to 5 knots. Above Sea State 5, the ship can only hold position and await calmer seas. A simple example is provided in Figure 1 below, which depicts a transit from Norfolk, Virginia, to England. Figure 1 utilizes the National Oceanic and Atmospheric Agency 96-hour wind/wave forecast for the Atlantic Ocean from July 15 – 19, 2015. The red arc is an approximate great circle route, (shortest distance) between Virginia and England. Of note are the wave heights along this route, ranging from 1 meter to 3 meters. The green route adds a significant distance to the transit but keeps to seas with significant wave heights of 1.25 meters or less (Sea State 3 and below) and allows higher transit speeds while staying within the SOE for the ship. These sea state limitations are always a concern for this ship.

³ The lower confidence bound was determined by randomly resampling the data.

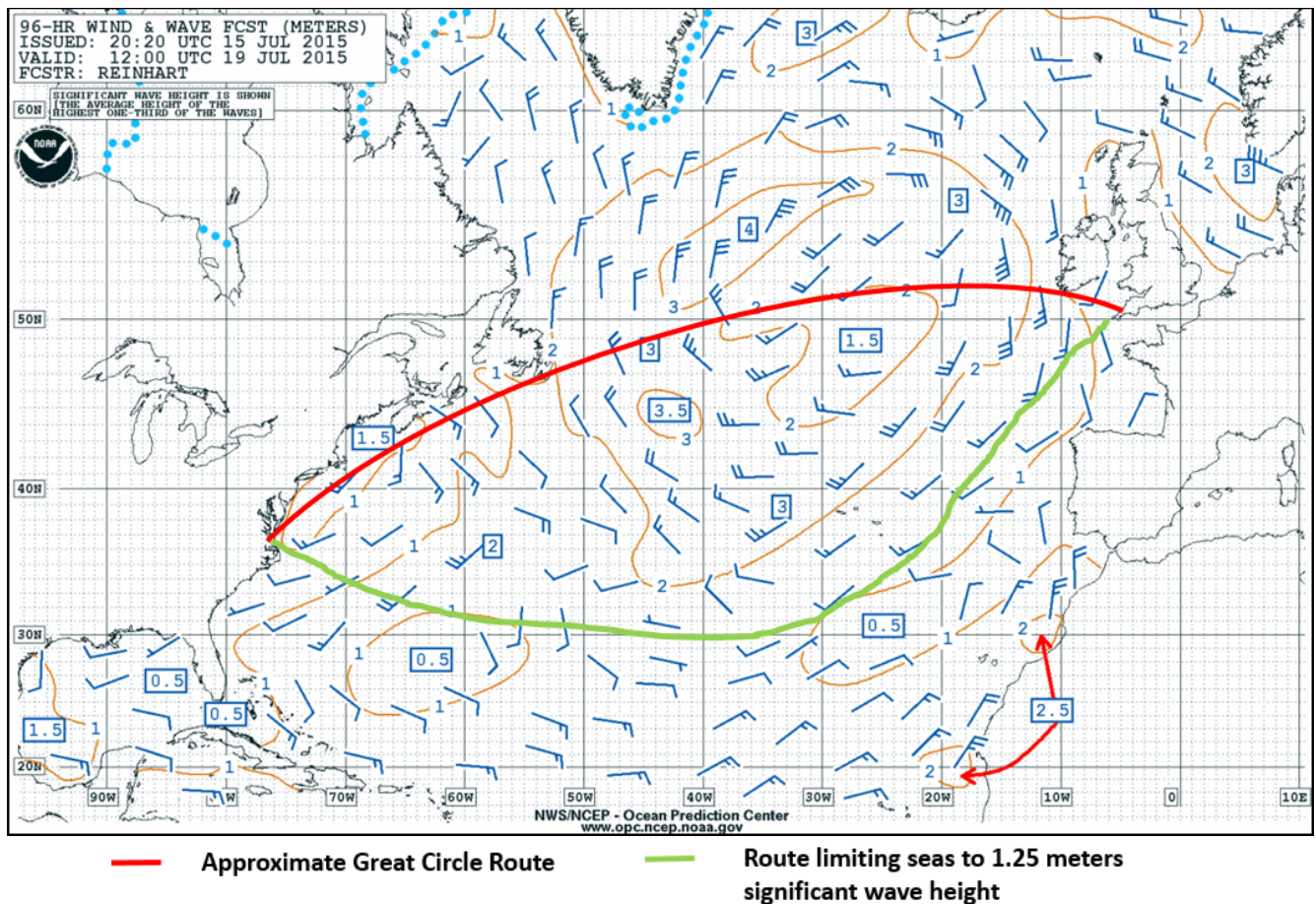


Figure 1. Routes across the Atlantic

System Overview

JHSV is a high-speed, shallow-draft surface vessel designed for intra-theater transport of personnel and medium payloads for the Joint Force, as shown in Figure 2. It is a redesign of a commercial catamaran capable of accessing relatively austere ports. JHSV can support an embarked force of 104 personnel for up to 14 days or a larger force of 312 personnel for 4 days. JHSV has a large mission bay accessible from piers or floating causeways via an integrated, stern-mounted ramp. The ramp and mission bay can accommodate both wheeled and tracked vehicles up to and including a combat-loaded M1A2 battle tank. The mission bay also can host 20-foot equivalent containers, including those that require power and data connections. JHSV has a flight deck that can support landing, fueling, and power requirements for various unarmed Navy helicopters up to and including the MH-53E. JHSV is also equipped with a stern-mounted crane used in this testing to launch the SDV, but is also capable of launching boats such as an 11-meter Rigid Hull Inflatable Boat through Sea State 2.

Characteristics

LENGTH 103.0 m (337.9 ft)
 BEAM 28.5 m (93.5 ft)
 DRAFT(F) 3.91 m (13 ft)
 FULL LOAD 2400 mt (2362 Lt)

ALUMINUM CONSTRUCTION
 CREW 42 p
 TROOP SEATS 312 p
 TROOP BERTHS 104 p

Machinery

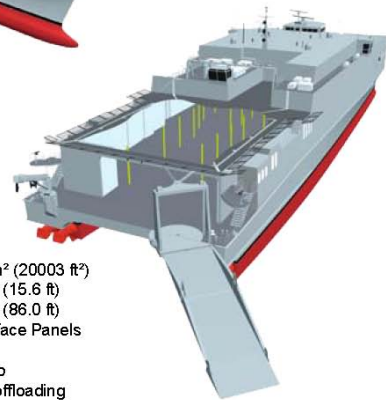
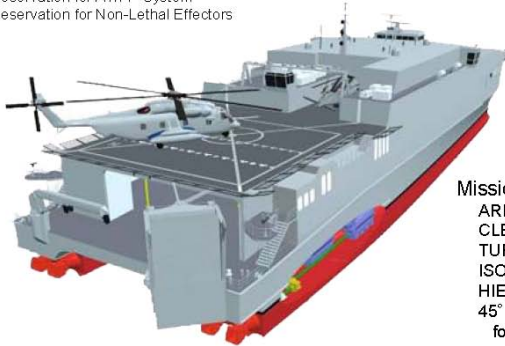
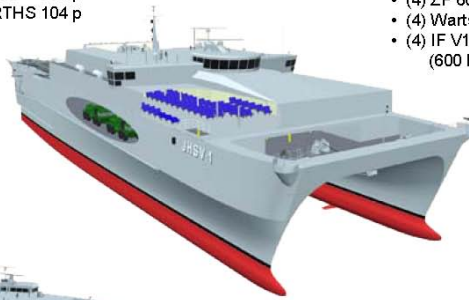
- (4) MTU 20V8000 M71L Diesel Engines (9.1 MW each, 36.4 MW total)
- (4) ZF 60000NR2H Reduction Gears
- (4) Wartsila WLD 1400 SR Waterjets
- (4) IF V1312C2ME-HPCR Diesel Generators (600 kW each, 2.4 MW total)

Aviation Facilities

- NAVAIR Level 1 Class 2 Certified Flight Deck for one helicopter
- Centerline parking area for one helicopter
- NAVAIR Level 1 Class 4 Type 2 Certified VERTREP
- Helicopter Control Station

Armament

- (4) .50 Caliber Machine Guns
- Reservation for AT/FP System
- Reservation for Non-Lethal Effectors



Mission Bay

AREA (with Tie Downs) 1858 m² (20003 ft²)
 CLEAR HEIGHT 4.75 m (15.6 ft)
 TURNING DIAMETER 26.2 m (86.0 ft)
 ISO TEU STATIONS 6 Interface Panels
 HIEX Foam Firefighting System
 45° slewing articulated quarter ramp for rapid and efficient loading and offloading

HPCR – High Pressure Common Rail

NAVAIR – Naval Air Systems

Command

VERTREP – Vertical Replenishment

lt – light tons

p – people

Manufacturers: MTU, ZF

Model name: WLD

Model number: 1400SR

AT/FP – Anti- Terrorism/Force Protection

ISO TEU – Insulated Shipping container twenty foot equivalent unit

HIEX – High Expansion

mt – metric tons



Figure 2. Joint High Speed Vessel (JHSV)

Test Adequacy

The FOT&E of JHSV was adequate to support an evaluation of the operational effectiveness of JHSV for at-sea vehicle transfers with MLP (CCS) and for launch and recovery of the Navy SDV. Testing was also adequate to evaluate the Reliability, Availability and Maintainability (RAM) of JHSV. Testing with MLP (CCS) was delayed until FOT&E because of the unavailability of USNS *Montford Point* (MLP 1), which was undergoing its own IOT&E. Additionally, test launch of the SDV was delayed until FOT&E because of the unavailability of both the SDV and Naval Special Operations Force Personnel. Table 1 shows the dates, locations, test agencies, and vessels involved with the testing. COTF conducted all tests in accordance with Director, Operational Test and Evaluation (DOT&E)-approved test plans.

Limitations to Test

COTF did not conduct testing to evaluate JHSV hosting of all equipment and personnel necessary to carry out a Navy Special Operations Force mission; therefore, testing was limited to launch and recovery of the SDV only. DOT&E accepted this as a known limitation.

Table 1. FOT&E Tests

Test	Enabling Organization	Location	Dates	Ship(s)
Post-Delivery Test and Trials (Integrated Testing)				
RAM	COTF	Transits – Atlantic Ocean; 6 th Fleet – Mediterranean Sea, West Africa	June 2014 – June 2015	JHSV 1 / JHSV 3
JHSV / MLP (CCS) Interface	COTF / MCOTEA	Long Beach Harbor, California	June, 2014	JHSV 3 / MLP 1
JHSV / MLP (CCS) Interface	COTF / MCOTEA	At-sea near Camp Pendleton, California	October 2014	JHSV 3 / MLP 1
Launch / Recovery of SDV	COTF	Inside and Outside of Pearl Harbor, Hawaii	April 2015	JHSV 3

RAM – Reliability, Availability, Maintainability; MLP (CCS) – Mobile Landing Platform with the Core Capability Set; SDV – Seal Delivery Vehicle; COTF – Commander Operational Test and Evaluation Force; MCOTEA – Marine Corps Operational Test and Evaluation Activity

Operational Effectiveness

The JHSV IOT&E ended in January 2014, demonstrating JHSV to be operationally effective at its primary mission of transporting troops and cargo. However, follow-on testing demonstrated JHSV to be not operationally effective for vehicle transfers with MLP (CCS), but operationally effective for launch and recovery of the SDV.

Equipment Transfers between JHSV and MLP (CCS)

JHSV is currently not capable of conducting equipment transfers with MLP (CCS) at sea. COTF, assisted by MCOTEA, conducted two tests, the first of which was during the MLP (CCS) Post-Delivery Test and Trials period in June 2014. USNS *Montford Point* (MLP 1) was at

anchor inside the breakwater in Long Beach Harbor, California. DOT&E considers this in-harbor test not operationally realistic. USNS *Millinocket* (JHSV 3) moored skin-to-skin with MLP 1, and eight Marine Corps vehicles transferred from JHSV to MLP (CCS) and then back to JHSV during daylight hours. While awaiting nightfall to conduct nighttime vehicle transfers, several mooring lines parted (broke), prompting cancellation of the night event. The Navy resolved the mooring line problem by fabricating new lines that included surge pendants. These new lines allow some limited movement of the two, skin-to-skin moored vessels without risk of parting. The test was then conducted at-sea in a realistic operational environment off the coast of California near Camp Pendleton on October 29, 2014. This test failed because the hydraulic ram used to swing the ramp port to starboard tore free from its anchor point on the JHSV transom during transfer of the first Marine Corps vehicle. The ramp was still structurally sound and the vehicle returned to JHSV, but the remaining planned vehicle transfers were cancelled.

Figure 3 shows USNS *Millinocket* the day of the second test in Sea State 3 conditions. The seas in Figure 2 look very calm, but data from the nearby National Oceanic and Atmospheric Administration buoy indicated a swell from the south with significant wave height of 2½ feet (0.7 meters) and a 12½-second period, which technically meets the North Atlantic Treaty Organization Sea State definition for Sea State 3.

Although the seas in the lee of MLP (CCS) (an area sheltered from the wind and waves), where JHSV was moored, were estimated to be Sea State 1 to 2, the vehicle transfer test failed. Figure 4 shows the two ships moored skin-to-skin with the JHSV ramp deployed. The hydraulic ram used to swing the ramp port to starboard tore free from its anchor point on the JHSV transom. The small amount of movement between the ships, even in calm Sea State 1 to 2 conditions, was enough to cause the damage when a truck pinned the foot of the ramp onto the raised vehicle deck of MLP (CCS) as it transited the ramp. The physical strength of the ramp was not compromised; the Marine Corps truck returned to JHSV, but this ended the vehicle transfer portion of the test. The Navy has not made any design changes to the JHSV ramp to enable these transfers. JHSV is not effective for operations with MLP (CCS) unless in Sea State 1 conditions, which is an unacceptable constraint for operational deployment.



Figure 3. USNS *Millinocket* (JHSV-3) in Sea State 3 Conditions near Camp Pendleton

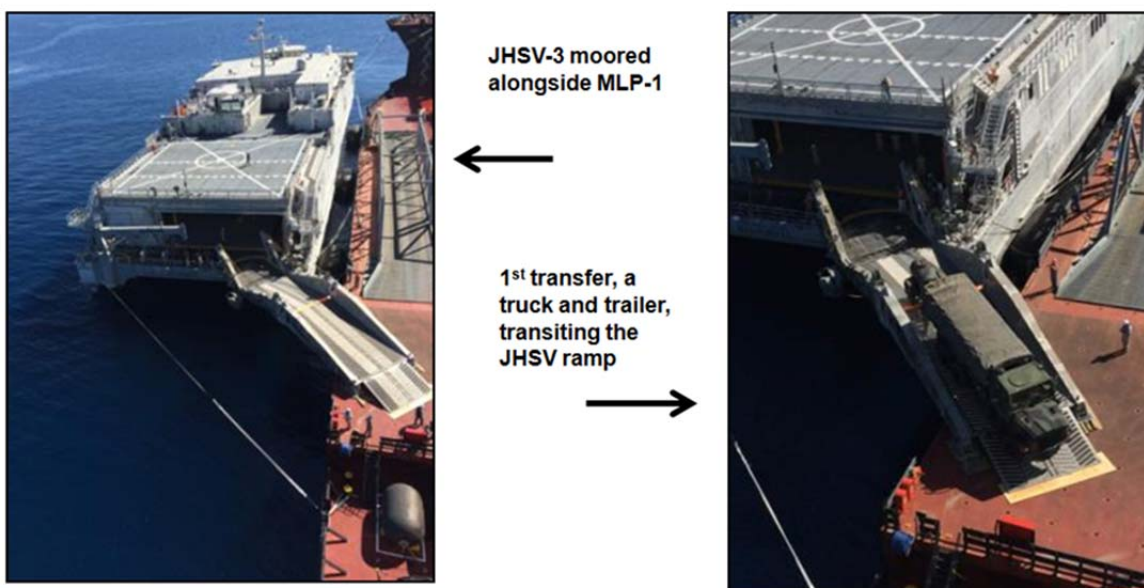


Figure 4. JHSV alongside MLP (CCS)

Launch and Recover of the Sea, Air, Land (SEAL) Delivery Vehicle (SDV)

JHSV is capable of launching the SDV in up to Sea State 3. COTF personnel performed a series of tests during the week of April 20, 2015 to determine whether JHSV was able to launch the Mark 8 Mod 1 SDV. The tests were limited to the SDV and did not include launch of support boats required for a surface launch of the SDV, or an evaluation of JHSV's ability to host a Special Forces mission package. Support boats for this test deployed from shore. The IOT&E boat launch results (Sea State 2 limitation) are applicable for other boats used by the Navy SEALs. There are no time requirements for launching the SDV, but times were recorded for analysis of the timeliness and feasibility of the operation. Testing was conducted in and

around Pearl Harbor, Hawaii, progressing from launching the SDV while pier-side, to launching it while underway (inside the harbor), to launching the SDV outside the harbor. USNS *Millinocket* (JHSV 3) crew and SDV Group One personnel teamed up to launch the SDV three times while dockside Tuesday, April 21. The same personnel launched the SDV two times in protected waters inside Pearl Harbor on Thursday, April 23, and once outside the harbor in Sea State 3 conditions later the same day. The tests were successful; timing results for underway launch and recoveries are provided in Tables 2 and 3.

Table 2. JHSV SEAL Delivery Vehicle (SDV) Underway Launch Timelines

	Lift SDV from Trailer	JHSV Declutch Engines	SDV in Water	Swimmers in Water	Lines Clear from SDV	Swimmers Clear	JHSV Engines Clutched in
1st Inside Pearl Harbor, SS1	0751	0755	0755	0755	0756	0756	0756
2nd Inside Pearl Harbor, SS1	0810	0812	0812	0812	0813	0814	0814
3rd Outside Pearl Harbor, SS3	0931	0928	0933	0933	0934	0934	0934

SDV – SEAL Delivery Vehicle

Table 3. JHSV SEAL Delivery Vehicle (SDV) Recovery Timelines

	JHSV Declutch Engines	Swimmers in water	Lines Attached to SDV	Swimmers Clear	JHSV Engines Clutched in	SDV in Cradle on Trailer
1st Inside Pearl Harbor, SS1	0759	0759	0802	0802	0802	0807
2nd Inside Pearl Harbor, SS1	0820	0820	0822	0822	0822	0824
3rd Outside Pearl Harbor, SS3	0950	0950	0952	0954	0954	1006

SDV – SEAL Delivery Vehicle

The launch of the SDV is deceptively simple. Figures 5 and 6 show the SDV after it was lifted from the trailer during a pier-side test, and just before it was placed in the water during an underway test.



Figure 5. SDV Suspended While Trailer is Removed



Figure 6. SDV Being Placed in the Water

Figure 6 illustrates several points of interest in the SDV launch. Two tending lines, one attached at the front and the other at the back of the SDV, extend to personnel on JHSV. A third line attached at the front of the SDV is secured to a support boat. The second boat shown in the figure has Navy Special forces swimmers and divers. Turbulent water, from the JHSV waterjets, is also clearly shown in the Figure 6. Prior to swimmers and divers entering the water, the JHSV crew declutches the engines from the waterjets (they put the ship in neutral). This clears the

turbulence and protects the in-water personnel from an unlikely, but possible, ingestion by the waterjet suction. Divers equipped with scuba gear ready the SDV for use while the swimmers detach the lines. The swimmers first detach the two tending lines from the ship, and then detach the two crane suspension lines. The boat, with the last attached line, gently pulls the vehicle, directing it away from JHSV. By this time, the divers are entering the operating stations of the SDV and the swimmers detach the last line as the operators settle into position. As the swimmers exit the water, back to the support boat, and the divers drive the SDV away from JHSV, the engines can be clutched back in returning JHSV to powered operation; this all happens very quickly. As shown previously in Table 2, the swimmers are in the JHSV waterjet risk area during launch for only 1 to 2 minutes.

JHSV is easily moved by the wind when stationary with its engines declutched, as it is a light, shallow-draft vessel with a large amount of sail area. This is a characteristic that must be factored into setting up for launch or recovery of the SDV. Mariners refer to a ship's sail area when discussing how the vessel is influenced by the wind, and JHSV has a boxy structure that presents vertical flat areas on all sides that catch the wind. The shallow draft, small mass and boxy structure of JHSV makes it vulnerable to the wind, especially when not under power. The Master of the USNS *Millinocket*, with concurrence of the SDV Group One personnel, determined that the wind should be put directly on the stern of JHSV for the evolutions. When the wind pushed directly on the ship's stern, the ship was not moved from side-to-side or over the top of the SDV, swimmers, or divers during launch /recovery operations. During the open-ocean launch and recovery event, the wind speed was less than 4 knots but still had a noticeable effect. Sea State is determined both by wave height and wind speed. Wave height during the day of the open-ocean test indicated Sea State 3 conditions although the winds were very mild. Winds can be as high as 10 knots during Sea State 2 or 16 knots for Sea State 3. Higher winds would have much more influence on JHSV.

Two other items of concern uncovered by this test are the vulnerability of the SDV to a pendulum swing motion while suspended by the crane, and the possible effects on SDV operators and passengers from JHSV engine exhaust. While suspended, the SDV was vulnerable to pendulum motions during both the open-ocean launch and recovery of the SDV events, and the tending line personnel were challenged to control this. As noted, the significant wave height indicated Sea State 3 conditions during the open-ocean portion of the test. As shown previously in Table 2, the open-ocean launch time, from lifting the SDV from the trailer, launching it, and then clutching in the JHSV engines, took 3 minutes. As shown previously in Table 3, the recovery from declutching engines to placement of the SDV in the trailer cradle took 16 minutes. The extended recovery time was due to the challenges the line tenders experienced controlling the pendulum motions of the SDV. A mitigating factor for actual missions may be, by default, a Sea State 2 limitation. The support boats for this test operated from shore, but in actual operations, the boats would be launched by JHSV prior to launching of the SDV. JHSV's IOT&E demonstrated that launch or recovery of these type boats was limited to Sea State 2. At Sea State 2, the pendulum motions of the SDV should be less. Alternatively, the crane could be upgraded with a pendulation control system.

After the test, Navy Special Forces personnel completed surveys that revealed the other concern. When launching or recovering the SDV, the SDV operators are astern of JHSV, an area that can collect ship engine exhaust gasses. JHSV is a large catamaran and the ship engines exhaust between the hulls. Even with the engines declutched, they are still running. A water spray “curtain” at the transom helps to block the exhaust gasses from going astern but it is only partially effective. If the SDV mission dictates an oxygen transit, the SDV operators, along with passengers, must perform a purge to rid their systems of nitrogen. Survey results indicated that the operators had concerns about breathing exhaust gasses prior to this taking place, and were uncertain whether the exhaust gasses could be effectively eliminated during the 2-minute procedure. This is a question for medical authorities, but a dive supervisor-qualified Special Forces member, contacted while researching this issue, suggested possibly just having a longer purge procedure. If medical authorities still think the exhaust is a concern, the support craft could tow the SDV out of the exhaust area after the swimmers detach the tending and crane lines. Once out of the exhaust area, the SDV operators and passengers could approach the vehicle.

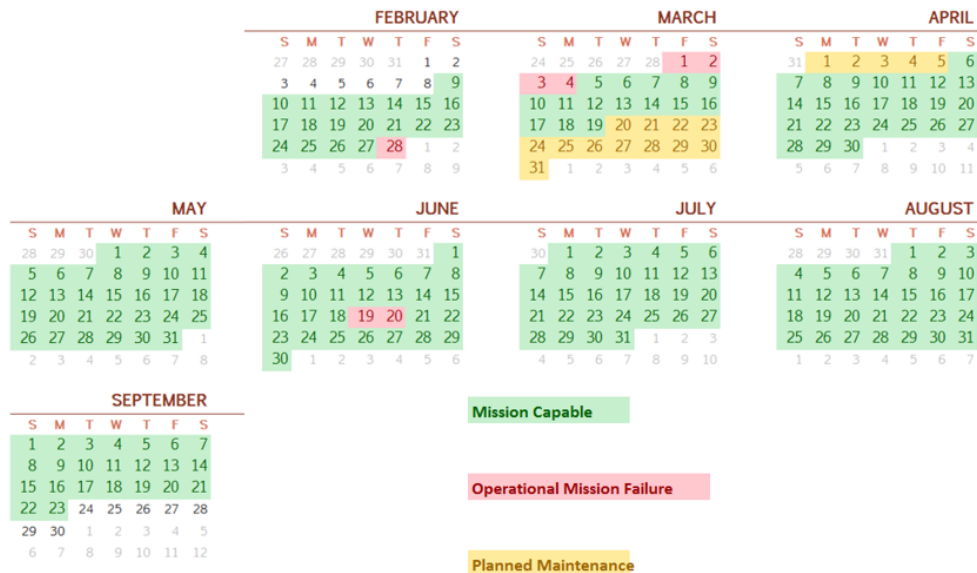
Suitability

Although JHSV remains operationally suitable, the demonstrated availability has decreased from 98 percent (reported in the IOT&E report), to 87 percent (calculated using both IOT&E and FOT&E data), Figure 7. Ship availability calculations do not include planned maintenance periods. There are no availability requirements for this ship class but there are availability targets. The ship’s availability target is 81 percent. Assuming a 15-day mean logistics delay time for parts not held onboard, the targeted (predicted) availability is 81 percent. Using the combined IOT&E and FOT&E data, the 80 percent lower confidence bound for availability is 81 percent.⁴ The main drivers of ship unavailability were the Ship Service Diesel Generators (SSDGs), waterjets, and Ride Control System (RCS).

The RCS failures are a symptom of a more serious problem with the JHSV ship design. Compromises in the bow structure, presumably to save on weight, were accepted when building these ships. Multiple ships of the class have suffered damage to the bow structure and repairs/reinforcements are in progress class wide. The reinforcement of the bow structure does not expand the SOE but should allow full use of the ship, within the original SOE, without risk of damage.

⁴ The lower confidence bound was determined by randomly resampling the data.

JHSV Availability during IOT&E, February 9 – September 23, 2013



JHSV Availability during FOT&E, June 23, 2014 – June 2, 2015

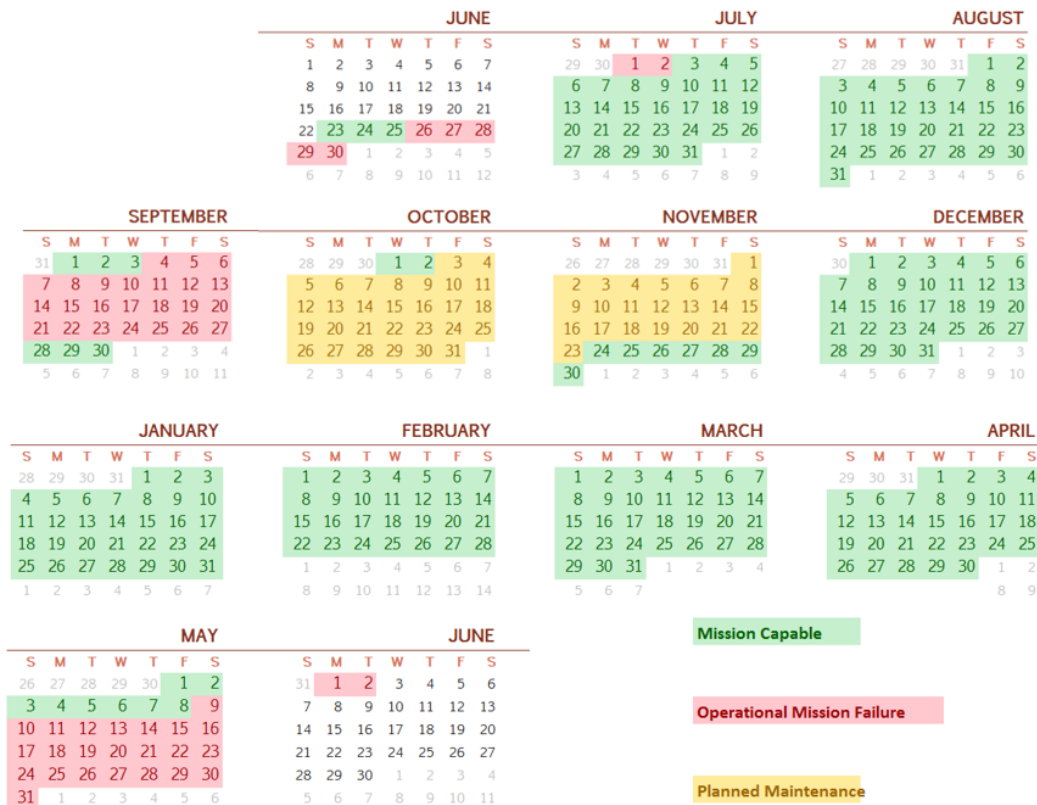


Figure 7. USNS *Spearhead* Availability during Test Periods

Ship Service Diesel Generators (SSDGs)

The ship's electric power is supplied by Fincantieri-manufactured SSDGs, which are failing at a much greater rate than predicted. There are two SSDG's per catamaran hull for a total of four. At least one must be operational in each hull to avoid an operational mission failure. The SSDGs were singled out in the IOT&E report because of their high failure rate, demonstrating a Mean Time Between Failure (MTBF) of 208 hours. During this test period, there were nine failures. Assuming two SSDGs were operating at all times during the FOT&E period, except during the planned maintenance period, the total SSDG run time was 14,064 hours for a MTBF of 1,563 hours. The 80 percent confidence, one-sided lower bound increased from 157 hours during IOT&E to 1,123 hours during FOT&E. Although the reliability of the SSDGs has increased, it is still far below the targeted MTBF of 8,369 hours. The causes of these failures are explained below.

Connecting Rods

Connecting rods that connect the reciprocating pistons to the crank shaft (Figure 8) have failed in SSDGs installed in the JHSV ship class. Currently, all new and rebuilt Fincantieri-manufactured SSDGs are being fitted with a third-generation connecting rod, including a rebuilt of # 4 SSDG on USNS *Spearhead*.

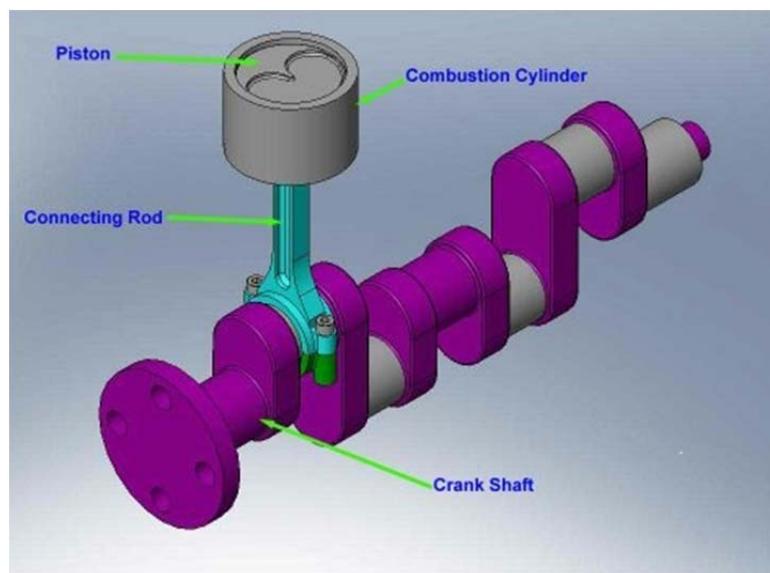


Figure 8. Piston, Connecting Rod, Crank Shaft

Intercoolers

The SSDGs are turbocharged, relying on seawater-cooled intercoolers that have been leaking (Figure 9). Internal combustion engine power output is largely determined by the displacement of the cylinders. A normally aspirated engine relies on ambient air pressure to fill the cylinders with air and the fuel is added in proportion to the amount of air. Turbochargers, powered by exhaust gas from the running engine, are used to compress incoming combustion air so that more fuel can be injected and power output is increased. All turbocharged engines have an intercooler that cools the air after it is compressed and before combustion. For these engines,

the working fluid for the intercoolers is seawater. All four intercoolers had seawater leaks during this test period. USNS *Spearhead*'s SSDGs suffered heavy piston and valve train damage, likely a result of corrosion from exposure to seawater.

Cylinder Heads

Many of the individual cylinder heads (Figure 9) of the Fincantieri-manufactured SSDGs have developed cracks that allow engine coolant to leak into the cylinders. Each cylinder head contains four valves, two for fuel/air intake and two for exhaust. Manufacturing issues, both in head castings and assembly, are the cause for erosion and cracking of the heads. All 12 heads were replaced on two of four USNS *Spearhead* SSDGs during this test period. Figure 10 shows the flame face surface of one cylinder head and the close up of another cylinder head showing erosion. The same cylinder head in the close up has been sectioned to show an intake port in Figure 11. The right hand picture in Figure 11 shows a Magnaflux inspection that verifies the location of a crack in the intake bridge.

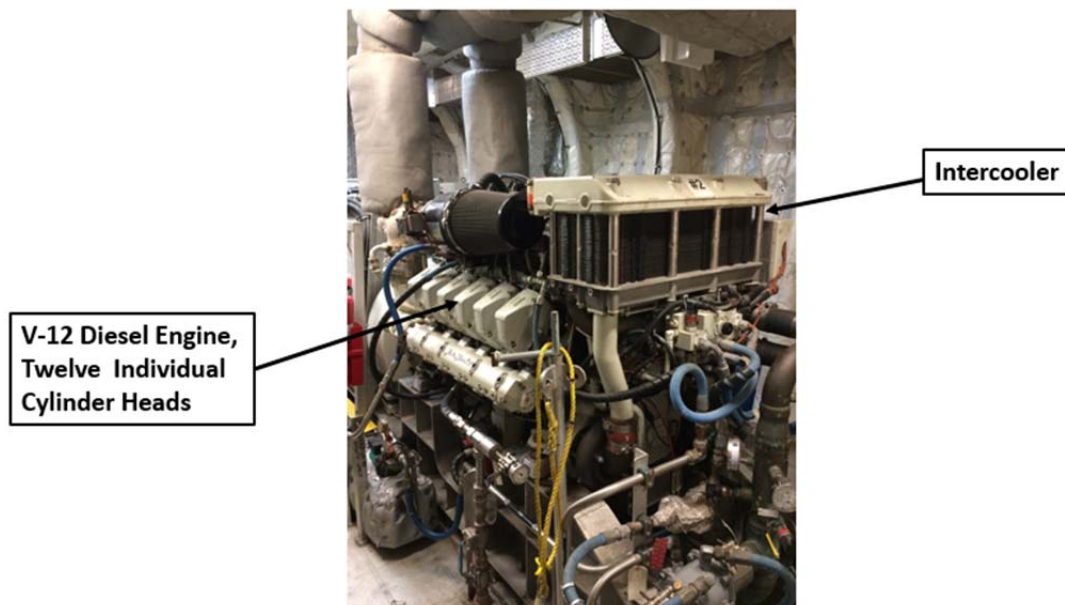


Figure 9. SSDG Number 2, USNS *Spearhead*



Figure 10. Flame Face Surface Pictures of SSDG Cylinder Head



Figure 11. Section Cylinder Head Showing Crack of internal Port

Waterjets

All four waterjets suffered broken or failing reversing plates. The reversing plates are used to redirect the waterjet outlet flow to allow neutral thrust or reverse propulsion (Figure 12). An analysis by the waterjet manufacturer suggests the failure of the reversing plates was due to high-cycle, low-load, bending fatigue.⁵ A sideways loading is suspected to have caused the failures. When not positioned for neutral or reverse propulsion, the plate stiffeners interact with the water flow as the ship is moving forward in the water. As shown in Figure 12 below, the waterjet is set for forward thrust and the underside of the reversing plate is exposed to water flow proportional to the ship's speed through the water. In Figure 13, the modeled reversing plate shows three plate stiffeners that are highlighted in red. The loading that is suspected to have caused the failures is caused by a sideways force on these plate stiffeners. Modifications have been made to the reversing plates to lessen the sideways force by as much as two-thirds. Additionally the weld around the lower support tube in Figure 14 has been machined to a smooth surface so that the stresses are not amplified by small fluctuations of the weld surface. Figure 15 shows close ups of this weld. The autopilot control has been modified to lessen the cycling of the jets side to side as the ship maintains heading, which is intended to reduce the number of load cycles and further delay the initiation of any fatigue cracks.

⁵ Wärtsilä Netherlands B.V. Ship Power's internal report dated December 19, 2014 (reverse plate problem).

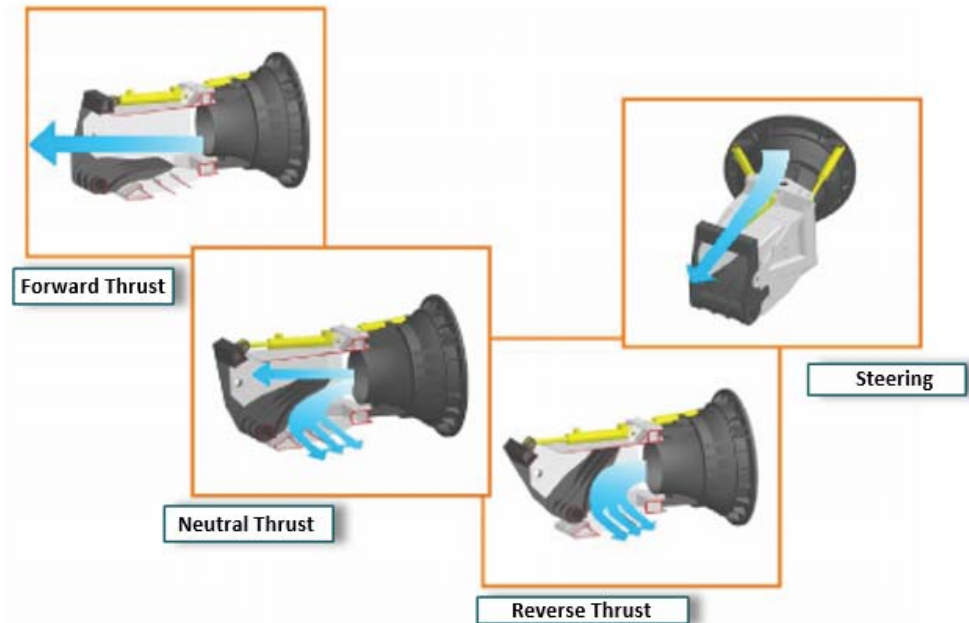


Figure 12. Ship Waterjet Positions for Various Directional Thrusts

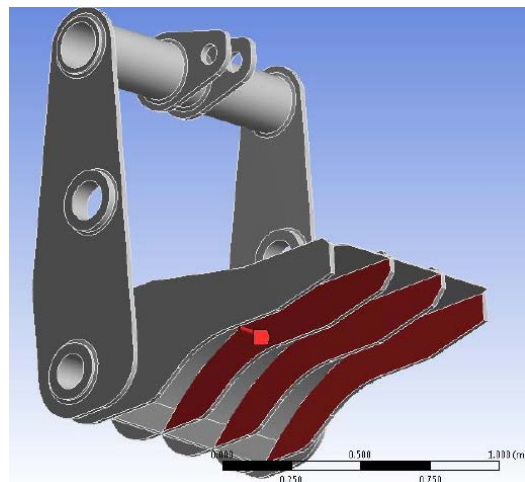


Figure 13. Model of Reversing Plate with Red Shading showing Side Force



Figure 14. USNS *Spearhead* Port Waterjet Reversing Plate showing Fatigue Crack

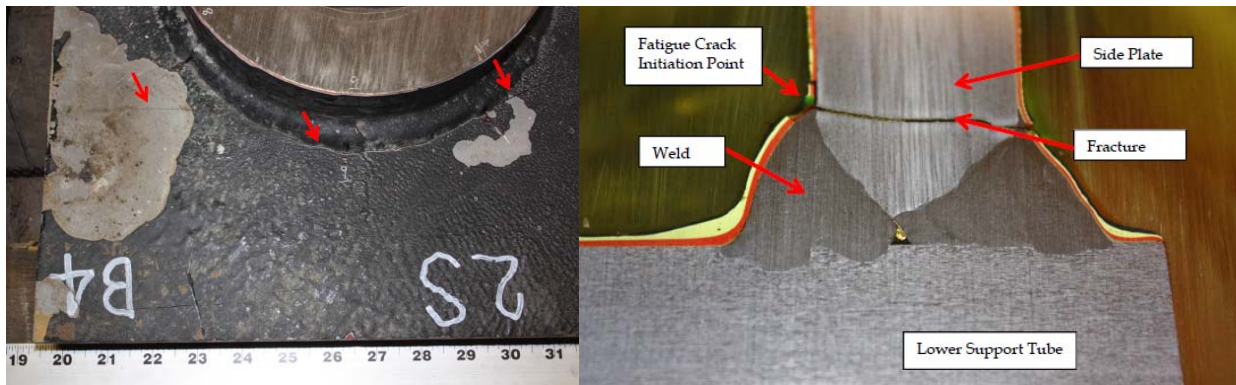


Figure 15. Details of Weld and a Crack Initiation Point

Ride Control System

The USNS *Spearhead* RCS has suffered failures of the internal mechanism for the forward foils. The JHSV ship class uses a RCS that provides active pitch/roll damping using four control surfaces, two forward and two aft. The system is designed to not only smooth out the ride, but to limit structural loading on the ship bow. It is required to be operational for ship speeds greater than 15 knots. Even with the RCS operating, the ship is limited in speed through the water both by sea state and orientation of the seas. Figure 16 shows the location of the two forward ride control foils and the internal mechanism for one of these that holds the foil in place and positions it. The aft RCS consists of two hydraulically actuated, horizontal foils that interact

with the flow of water passing under the ship in the vicinity of both the port and starboard waterjets.

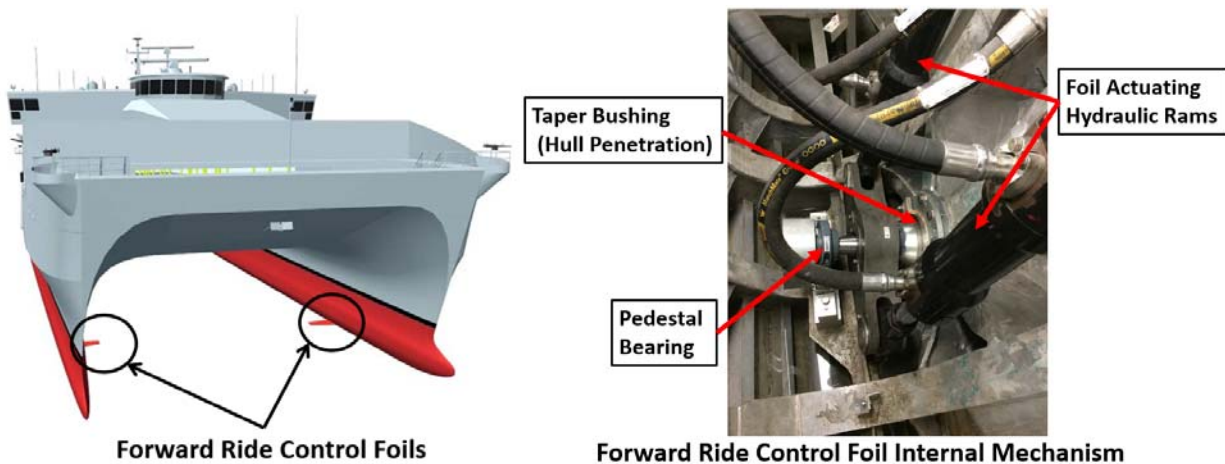


Figure 16. JHSV Forward Ride Control System (RCS)

Several structural issues with the RCS forward foil mechanism have required repairs. Figure 17 shows failed pedestal bearing housings from 2014 and 2015. Alignment problems have prompted machining, shimming, and re-boring of holes for the base bolts of this bearing structure. The taper bushing assembly shown in Figure 16 has also drawn concern both for fit of the pieces and under-torque of the bolts holding it in place.

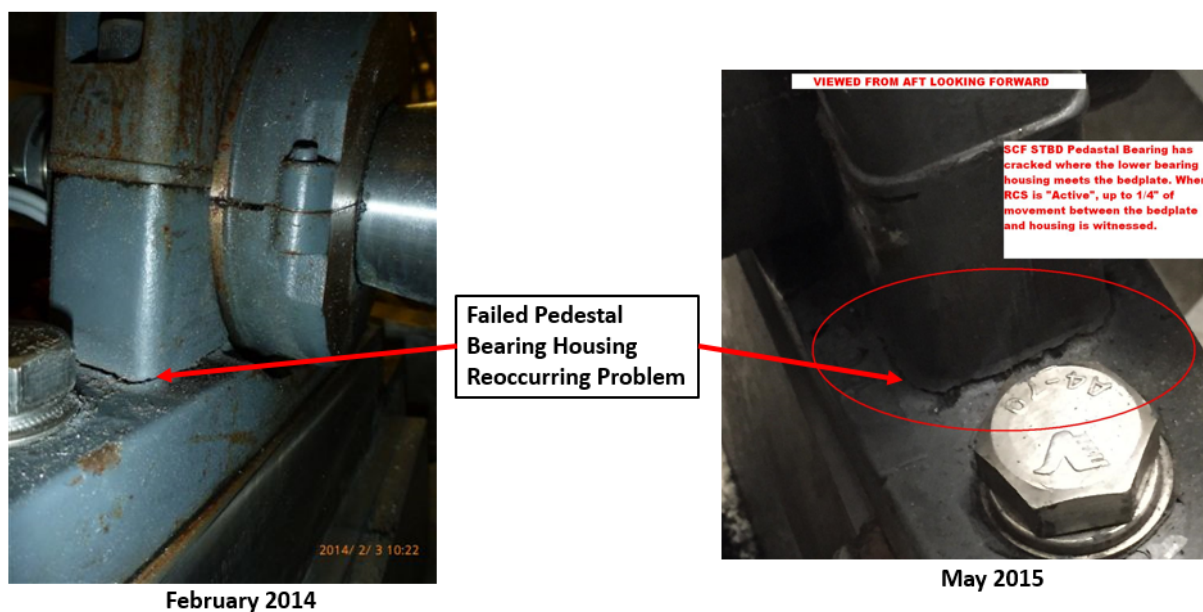


Figure 17. Failed Pedestal Bearing Housing

Bow Structure Reinforcement

The entire ship class requires reinforcing structure for the bow structure in the forepeak space, which is the forward structure of the ship between the two hulls, as shown in Figure 18. The American Bureau of Shipping originally recommended that the bow structure in the

forepeak area be built to withstand 26.1 pounds per square (psi) loading caused by wave slamming. The ship manufacturer, Austal USA, proposed a revised Safe Operating Envelope (SOE) to eliminate the likelihood of head seas and recommended a design to withstand pressures up to only 17 psi. The ship design manager approved the Austal USA proposal and the Navy Program Manager concurred.



Figure 18. JHSV Forepeak

The decision to accept a limiting SOE and build the ships to withstand only 17 psi loading from wave slamming has resulted in a ship class that is easily damaged. The SOE defines allowable speeds in varying sea states and angle of wave motion to ship's heading. Figure 19 shows the ship class SOE with and without an operational RCS. Operating the ship outside of the SOE or encountering a rogue wave that is outside of the current sea state can result in sea slam events that cause structural damage to the bow structure of the ship. Figure 20 shows internal bent scantlings in the forepeak area of JHSV 1.

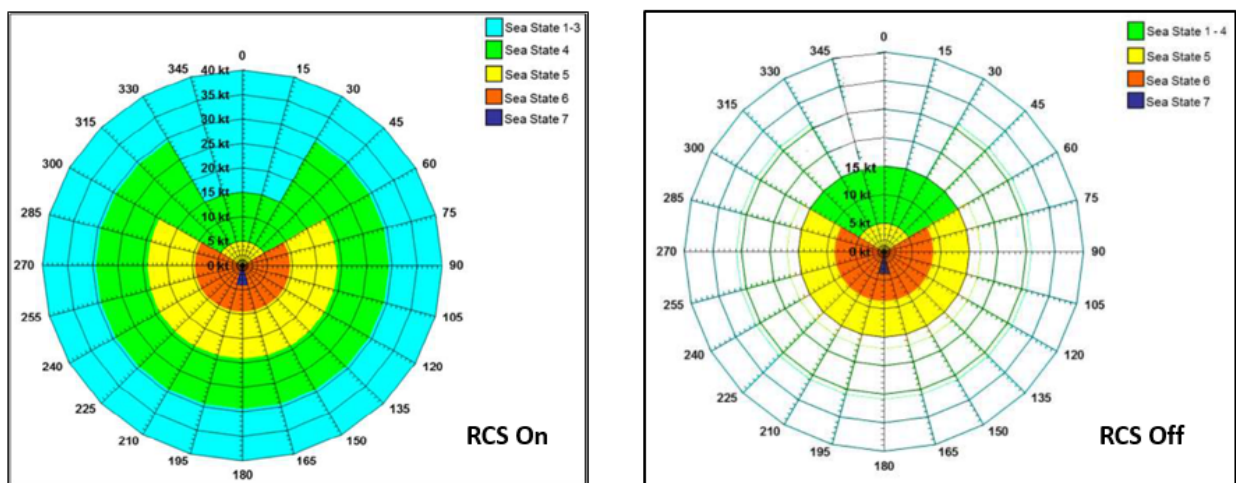


Figure 19. JHSV Ship Class Safe Operating Envelope (SOE)

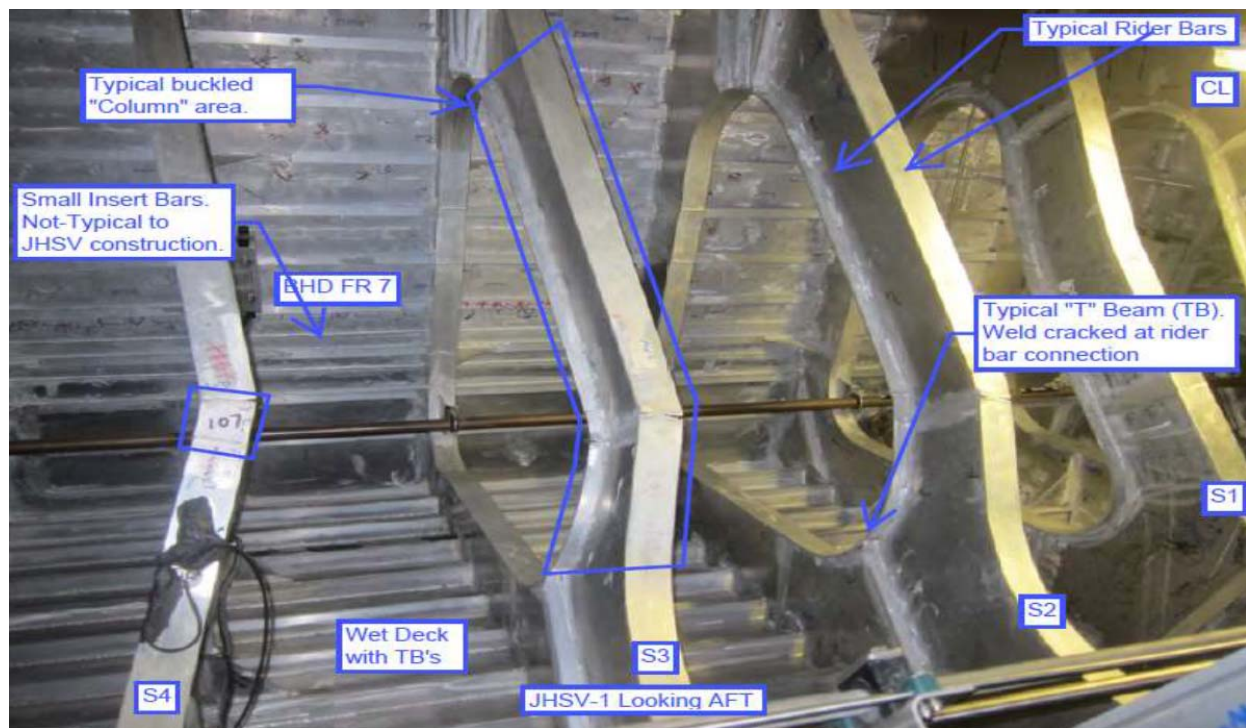


Figure 20. Internal Bow Damage in Forepeak Space, JHSV 1

Hulls 1 through 4 have been repaired and reinforced, adding an additional 1,736 pounds to the ship's weight. This should have minimal impact to ship mission capability in regards to fully loaded range capability. From the IOT&E report, when the ship is fully loaded with troops and equipment (600 short tons), the ship's fuel tanks cannot be completely filled with fuel. The additional weight from the added bow structure displaces 250 gallons of fuel, which correlates to 3.5 nautical miles of reduced range at 31 knots (reduced to 854 nautical miles).

The necessity of avoiding high sea states while transiting is a potential operational limitation that was not examined in the IOT&E report. At wave heights of 2 meters, the ship needs to slow to 15 knots or less, and at 3 meters, the ship can transit at only 5 knots or less. Figure 21 is a 96-hour wind/wave forecast for the Atlantic Ocean from July 15 – 19, 2015, from the National Oceanic and Atmospheric Agency. The red arc is an approximate great circle route, (shortest distance) between Virginia and England. Of note are the wave heights along this route, ranging from 1 meter to 3 meters. The green route adds a significant distance to the transit but keeps to seas with significant wave heights of 1.25 meters or less (Sea State 3 and below) and allows higher transit speeds while staying within the SOE for the ship. These sea state limitations are always a concern for this ship.

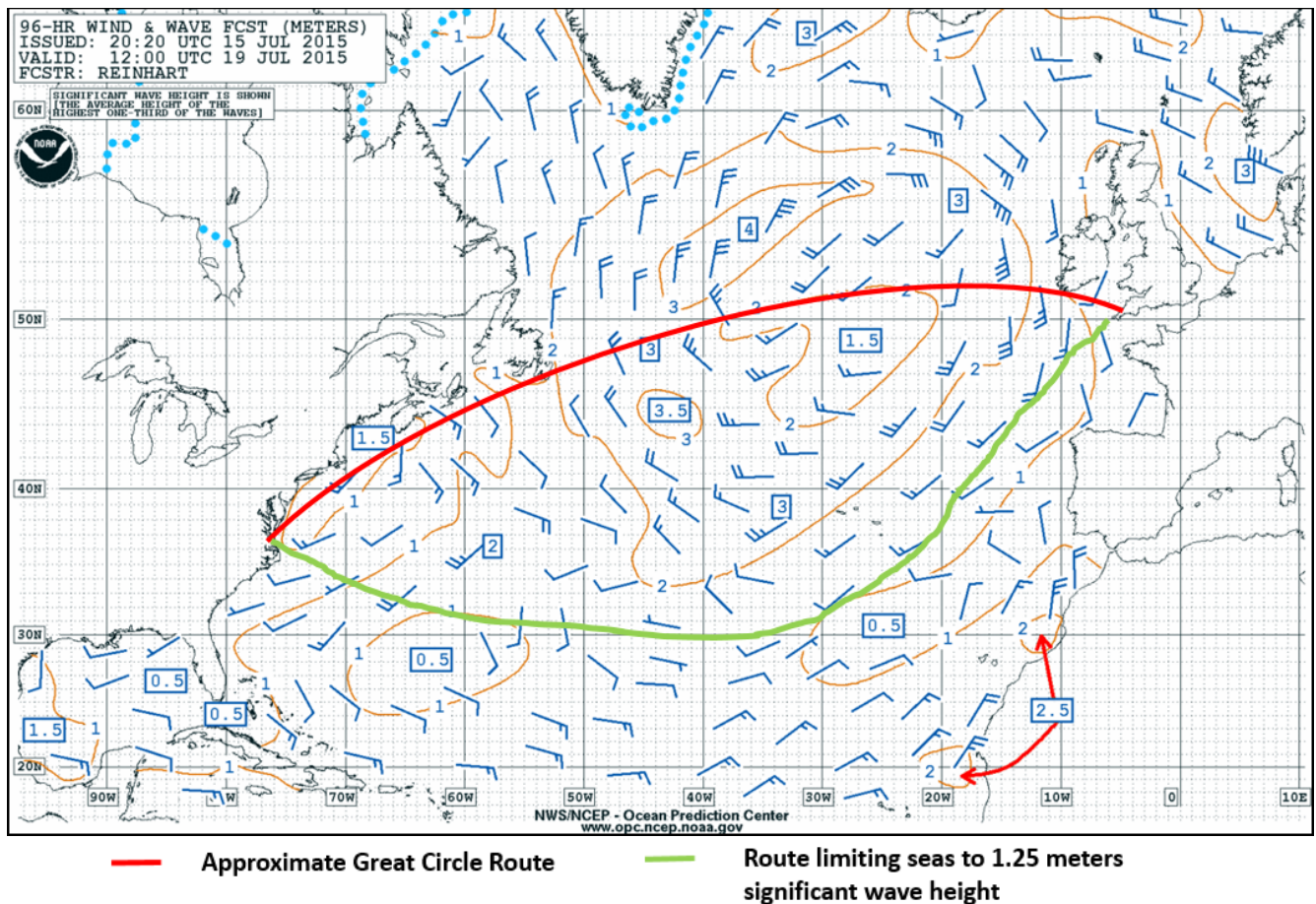


Figure 21. Routes across the Atlantic

Recommendations

In order for the Navy to conduct open ocean equipment transfers between JHSV and MLP (CCS), DOT&E recommends that the Navy modify the JHSV ramp to increase its sea state rating, or develop a new, higher sea state rated ramp, then retest at-sea equipment transfers with MLP (CCS).

In order for the Navy to use JHSV for Special Operations Forces (SOF) missions, DOT&E recommends the Navy:

- Investigate the availability of a pendulation control system for the JHSV stern-mounted crane.
- Evaluate the effect of JHSV exhaust gases on SOF personnel readying for oxygen transits.
- Evaluate JHSV capabilities to support personnel and equipment for various SOF mission packages.

In order to increase the availability of the ship class, DOT&E recommends that the Navy:

- Continue aggressively determining the root cause of ship service diesel generator casualties and fixing them fleet-wide.
- Evaluate whether repairs and alterations to the waterjet reversing buckets, along with alterations to the ship autopilot system, resolve the failure mode of this equipment, or, alternately, investigate a replacement schedule to minimize waterjet casualty downtime.
- Evaluate whether the repairs and alterations to the internal operating mechanism of the forward ride control foils resolves the failure mode.
- Complete structural reinforcement of bow structure on remaining ships of the class.