HISTORIC AMERICAN ENGINEERING RECORD

SPACE TRANSPORTATION SYSTEM,
MOTOR VESSELS *LIBERTY STAR & FREEDOM STAR*

HAER No. TX-116-M

Location:

Lyndon B. Johnson Space Center
2101 NASA Parkway
Houston
Harris County
Texas

Motor vessels *Liberty Star* and *Freedom Star* were docked at the Hangar AF Wharf in the Industrial Area of the Cape Canaveral Air Force Station (CCAFS), located at latitude: 28.489342, longitude: -80.588955, during their period of performance with the National Aeronautics and Space Administration (NASA). These coordinates were obtained on August 24, 2012, through Google Earth™. The coordinates' datum are North American Datum 1983.

Dates of Construction:

Liberty Star was built in 1980 and *Freedom Star* was built in 1981 and delivered as *UTC Liberty* and *UTC Freedom*, respectively. Their corresponding name changes were effective in 1984.[1]

Architect/Engineer/ Builder:

Architect: Rudolph F. Matzer and Associates, Jacksonville, Florida; Builder: Atlantic Marine Shipyard, Fort George Island, Florida.

Original Owner and Use:

Original Owner: United Space Boosters, Inc. (USBI) of Huntsville, Alabama, a subsidiary of United Technologies Corporation (UTC) of Sunnyvale, California.

Original Use: Recovery at sea and towback to Hangar AF of the expended Space Shuttle Solid Rocket Boosters (SRBs)[2] and their associated flight hardware following launch.

[1] For simplicity's sake, the names *Liberty Star* and *Freedom Star* will be used throughout the document.
[2] The SRBs, also referred to as the 'booster stacks,' were comprised of four reusable solid rocket motor case segments joined to reusable solid rocket booster forward skirt and aft skirt assemblies. Each SRB also had three main parachutes, one drogue parachute, and one pilot parachute. The main and drogue parachutes were always recovered; the pilot parachute was only recovered when possible.

Present Owner And Use: *Liberty Star* and *Freedom Star* were excessed through the U.S. General Services Administration processing system with subsequent transfer to the U.S. Department of Transportation Maritime Administration in September 2012. *Liberty Star* was assigned to the National Defense Reserve Fleet and relocated to the U. S. Merchant Marine Academy in Kings Point, New York, for use as a training vessel for midshipmen. *Freedom Star* was relocated to the Maritime Administration James River facility in Jamestown, Virginia.

Significance: *Liberty Star* and *Freedom Star* were designed and constructed specifically for the task of SRB retrieval; each returned one of the two solid rocket boosters (SRBs) (*Liberty Star* retrieved and towed back the right booster stack and *Freedom Star* retrieved and towed back the black-striped forward skirt left booster stack) to CCAFS Hangar AF following launch. In 1998, the task of transporting external tanks (ETs) from Michoud Assembly Facility (MAF) in Louisiana, to the John F. Kennedy Space Center (KSC) was added. In addition, both retrieval vessels participated in the seven-month recovery mission (January 28 through August 28, 1986) following the *Challenger* accident. Their key function as SRB recovery vessels allowed NASA to reuse the boosters, thereby reducing costs and contributing significantly to the on-going operations of the Space Shuttle Program (SSP). Their use in towing the ET-carrying barge also was a NASA cost-saving initiative.

Description: The specific design of the two retrieval vessels reflects the special needs of the SSP for the retrieval of SRBs and, since 1998, the transport of the ETs from their manufacture plant to the stacking site in the Vehicle Assembly Building. The vessels are identical, with each designed to retrieve one expended SRB. Booster retrieval operations were controlled from the aft bridge of the vessel; the forward area of the bridge was for the operation of the vessel itself. Each retrieval vessel held a maximum of twenty-four persons (ten crew and fourteen others), with a thirty-day food and water provision endurance.

Liberty Star and *Freedom Star* are of molded steel hull construction. They measure approximately 176’ in length, 37’ in width, and 72’ in height, from the base to the top of the mast. The depth, from the main deck to the keel, is 15’; the draft, from waterline to keel bottom, is 12’. Each vessel displaces 1,052 tons, with gross and net tonnages of 484 and 329 tons, respectively; has a 30-ton towing pull capability; and has a cruising range of 6,000 miles and a cruising speed of 15 knots, or 17 miles per hour. The

retrieval vessels are similar in overall size and appearance to a medium class cutter.

Each vessel has four enclosed decks: the lower deck, the main deck, the forecastle deck, or Deck 01, and the bridge deck, or Deck 02. The lower deck (Figure No. 1) extends over the entire length and width of the vessel. It is composed of two principal areas: the crew quarters and the engine room, the latter of which also includes the oil and ballast tank areas and the steering compartment. The crew quarters, about 9' above the base, sit towards the forward end of the vessel, beginning approximately 28' from the bow, and extending 66' along the length of the deck. The individual rooms are arranged in a double-loaded corridor layout, with five rooms to either side. On the starboard side, from stern to bow, is the Chief Engineer's cabin, with its own bathroom, the First Mate cabin, the Second Mate cabin, and two crew cabins. The latter four cabins are each equipped with two beds, and have one bathroom per two cabins. On the port side, from stern to bow, is the Engineering Workshop, the Assistant Engineer's cabin, and three crew cabins. Each of the four cabins has two beds and one bathroom per two cabins.[3]

To the stern of the crew quarters is the engine room, which sits roughly 6.5' above the base and extends for 40' along the length of the vessel, and the entire width of the vessel. Within the engine room are the two 12-cylinder main General Motors (EMD 12-645E6A) diesel engines that provide a combined total of 2,900 horsepower. These main engines turn two 7' LIPS propellers[4] with controllable pitch, which provides greater response time and maneuverability. Auxiliary power is provided by stern and bow thrusters that can be steered to move the vessel in any direction, including sideways, without the use of propellers. This dual auxiliary propulsion thruster system was installed to protect endangered manatees, as well as divers working near the vessel. At sea, the water jet thrusters also are used to avoid entangling the main propellers in parachute lines. The stern thruster is a 425-horsepower White Gill[5] water jet system; at the bow is a 425-horsepower Schottel[6] bow thruster. Each is driven by a

[3] Archaeological Consultants, Inc. (ACI), "Survey and Evaluation of NASA-owned Historic Facilities and Properties In the Context of the U.S. Space Shuttle Program, John F. Kennedy Space Center, Brevard County, Florida" (survey report, NASA KSC, 2007).
[4] LIPS, now Wartsila, is a designer and manufacturer of marine propulsion systems; the company is based in Finland.
[5] White Gill is a designer and manufacturer of marine thruster systems. It is now part of Tees Components Limited, which is based in the United Kingdom.
[6] Schottel is a German-based designer and manufacturer of marine propulsion systems.

turbo-intercooled Detroit diesel generator.[7] At the stern of the engine room are the diesel oil and ballast tanks, one to each side, followed by the steering compartment, and two aft peak ballast tanks. Electrical power is supplied by two 166-kilowatt (kw) Kato generators and one 45-kw Kohler emergency generator.[8]

The main deck level of each vessel (Figure No. 2) sits approximately 19.5' above the base at the bow, and slants down to 15' above the base at the stern. Like the lower deck, the main deck can be divided into two distinct areas: the enclosed crew area at the bow of the vessel, and the open deck area at the stern of the vessel. The crew area begins approximately 17.5' from the bow of the vessel, and extends for about 62' along the vessel's length. The layout of the rooms mimics a double-loaded corridor plan; however, it does not have a defined corridor, but rather a small passage. On the starboard side of the vessel, from stern to bow, are the crew lounge, the mess hall, and the laundry facilities. A workshop/locker area, the cook's cabin, the galley, and the galley storage area sit on the port side of the vessel. To the starboard side of the storage room is the chill box and freezer. To the aft end of the crew areas, on the port side of the vessel, are the emergency generator room, the fan room, and the smoke stack. On the starboard side of the vessel, there is a four-person decompression chamber to the aft of the crew lounge.

The stern area of the main deck is open, and contains the auxiliary retrieval and support equipment required to retrieve the booster stacks, frustums, and parachutes. The equipment, which includes cranes and parachute reels, sits in this area. All the equipment on the aft deck, including the crane, parachute reels, tow bits, and the boat cradles is bolt-on, bolt-off, allowing the equipment layout to be reconfigured in a few hours to support a specific mission.[9]

Each retrieval vessel carried the equipment necessary to deploy a crew to plug the aft-end nozzle of the booster stacks, pump out water, bring the spent vertically-oriented (spar buoy mode) booster stacks into the horizontal position (log mode), and tow them back to the Hangar AF SRB

[7] ACI, "Kennedy Space Center."
[8] NASA, KSC, *Space Shuttle Solid Rocket Booster Retrieval Vessels*, NASA Facts (Florida: Kennedy Space Center, 2006), http://www.nasa.gov/centers/kennedy/pdf/167446main_SRBvessels06.pdf.
[9] Steve Roy, "Welcome Aboard Liberty Star," NASA Blogs, October 19, 2009, accessed at html:file://D:\resources-vessel\Blog with Pegasus\SRB Welcome Aboard Liberty Star_.mht; David S. Fraine, interview by Rebecca Wright, *SRB Recovery Vessels Oral History Project*, April 10, 2012, 14-15, on file, Johnson Space Center History Office, Houston, Texas; ACI, "Kennedy Space Center."

Disassembly Facility at CCAFS. For the aft-end nozzle orifice plug operation, the support equipment included an Enhanced Diver Operated Plug, one 60-kw 400-cycle generator and a Quincy QR100 air-cooled, two-stage air compressor for dewatering the boosters. Four parachute reels (rollers) on each vessel were used to retrieve the three main parachutes and single drogue parachute (and pilot parachute, if recovered) on each booster. Each 5.5'-diameter reel has 8,000 pounds pull capability. A Model 410 Hallmark-Prentice 7,500-pound capability articulated deck crane with a power block was used for frustum retrieval. Each vessel also was equipped with one capstan (winch), one H-bit for towing the SRB, and a 1,200' air hose for booster dewatering. A conventional and a Nitrox compressor for diver breathing air and a hyperbaric chamber for diver emergencies were also provided.

The forecastle deck, or Deck 01 (Figure No. 3), sits within the forward 100' of the vessel, slanting from approximately 29' above the base at the forward end to 23' above the base at the aft end. It consists of an enclosed area surrounded by an open deck area. The enclosed portion of the deck begins 40' from the bow of the vessel, and has approximate overall dimensions of 36' in length and 26' in width. Its layout is based on a double-loaded corridor plan, with the Chief Scientist's (or NASA Operations) cabin and the Captain's cabin on the starboard side, and the vessel's office (or Owner's Study Room) and Captain's office on the port side. On the aft end of the deck, along the starboard side, is the boat deck. The smoke stack pierces through this deck on the aft end of the port side.

The bridge deck, or Deck 02 (Figure No. 4), sits directly over the enclosed area of Deck 01, slanting from approximately 33' above the base at the forward end to 31' above the base at the aft end. It is comprised of a single room, which measures roughly 34' in length and 17' in width, and as the name suggests, it contains the equipment necessary for the vessel's operations, including the wheel, engine controls, and electronic chart plotters table. Each vessel has consoles for a Kongsberg dynamic position system with joystick control, X-band and S-band radars with integrated automatic radar plotting aid and automatic identification systems, wide area surveillance system global positioning navigation systems, differential global positioning systems (GPS), handheld very high frequency (VHF) radios, tow wire monitoring and tension digital video and recording systems, voice and broadband satellite communication capability, VHF automatic direction finding, high frequency (HF) single-side band radios, night vision scope, collision-avoidance sonar, underwater communication unit, electronic chart plotter, direction finders,

fathometers, gyro compasses, and Sea Area-3 Global Maritime Distress Safety and System consoles. It is the only deck that contains large, fixed windows on all sides, and is surrounded on all four sides by an open walkway, which measures approximately 3' in width.[10]

History:

In December 1976, NASA awarded the contract for the checkout and assembly of SRBs, at both KSC and MSFC, to USBI of Huntsville, Alabama.[11] A supplement to this parent contract gave USBI the responsibility for the location and retrieval of expended SRB casings, parachutes, and other flight elements from the Atlantic Ocean, and delivery to the Hangar AF SRB Disassembly Facility located on the eastern shore of the Banana River at CCAFS. On July 13, 1979, NASA signed a letter contract with USBI, allowing the company to establish and operate a two-vessel SRB recovery force; the contract was managed by KSC. The letter was formalized in June 1980, through a contract that amounted to $7,230,976, and covered the period through February 28, 1982, with the option of extension through February 28, 1995.[12]

In 1977, the Naval Undersea Center, San Diego, and the U.S. Navy Supervisor of Salvage, under contract with NASA, formulated and developed the final operational scheme and retrieval vessel specifications for the SRB Retrieval System.[13] NASA specified that the at-sea recovery operations be developed around using commercially available oilfield tug/supply vessels measuring at least 170 feet long. The design task was first to investigate the availability of such vessels suited to SRB recovery,

[10] ACI, "Kennedy Space Center."
[11] USBI was a subsidiary of United Technologies Corporation (UTC) of Sunnyvale, California. Eleanor H. Ritchie, *Astronautics and Aeronautics, 1976, A Chronology* (Washington, DC: NASA, Office of Scientific and Technical Information, 1984), 300, http://history.nasa.gov/AAchronologies/1976.pdf.
[12] NASA KSC, "Alabama Firm To Conduct Shuttle Booster Retrieval Operations," News Release No: KSC 101-80, June 10, 1980, Sweetsir Collection, File No. ARCH00009097, Kennedy Space Center Archives Department, Florida. A third retrieval vessel, *Independence*, was built in 1985 by Halter Marine in Moss Point, Mississippi to support shuttle launch operations at Vandenberg Air Force Base in California. It was owned by the U.S. Air Force. After construction, she spent time at KSC getting ready for service. *Independence*, along with *Freedom Star* and *Liberty Star*, also was used in the salvage and recovery operations following the *Challenger* accident. On August 22, 1987, *Independence* left KSC for Port Hueneme, California, where the Air Force turned the vessel over to the Navy. "Photo caption," *Spaceport News*, September 11, 1987, 8; "KSC Welcomes VAFB's "Independence," *Spaceport News*, June 7, 1985, 3.
[13] The Technical Report for the SRB Retrieval System Final Design Concept was prepared in 1977 by the Naval Undersea Center (NUC TN 1822). Anker M. Rasmussen, "Solid Rocket Booster Retrieval Operations," in *Space Shuttle Technical Conference, Part 1*, ed. Norman Chaffee (Springfield, VA: National Technical Information Service, U.S. Department of Commerce, 1985), 505.

and then to adopt and modify them.[14] David Fraine, Captain of the *Freedom Star* from 1992 until 2007, noted that USBI became involved in the recovery plan development process, and, using some of the Navy's recommendations, and "based on their own insight, developed some ideas and a plan for SRB recovery that wouldn't cost NASA as much money."[15]

In 1979, USBI hired Rudolph F. Matzer & Associates, Inc., of Jacksonville, Florida, to design the special retrieval vessels, based on the Naval Undersea Center specifications. The vessels, which were originally named *UTC Liberty* and *UTC Freedom*, were built at the Atlantic Marine Shipyard, Fort George Island, Florida.[16] Since NASA did not have the money to buy or build their own vessels, UTC paid for the vessels' construction, and in turn, NASA paid the lease cost of the vessels. *UTC Liberty* was delivered to KSC in October 1980, and the *UTC Freedom* followed in January 1981.

In December 1980, several months prior to the first launch of the SSP (STS-1), *Liberty Star* underwent at-sea training (Figure No. 5) while *Freedom Star* was still at the Fort George Island shipyard. The tests of the final design concepts, conducted in an area located approximately thirty miles east of Cape Canaveral, utilized a full-scale Ocean Test Fixture simulating the booster stack, a full-scale model frustum, and full-sized parachutes.[17]

Beginning with STS-1, which launched April 12, 1981, the two booster stack retrieval vessels supported all 135 SSP missions (Figure Nos. 6, 7, 8). During STS-1 operations, the nozzle plug failed to operate satisfactorily. As a result, the Ballast Aerating Retrieval Boom (BARB), a device constructed from aluminum pipe and tubing, and divers were baselined for booster stack dewatering; an in-port Diver Operated Plug was developed and brought into service to provide final booster stack dewatering at Port Canaveral. Prior to STS-4, a recompression chamber obtained from the Navy was installed on-board one retrieval vessel, and

[14] Robert L. Watts, "The SRB Retrieval Support Craft," in *Oceans '79, Fifth Annual Combined Conference* (New York, NY: The Institute of Electrical and Electronics Engineers, Inc., 1979), 691.
[15] Fraine, interview, April 10, 2012, 18.
[16] After Lockheed replaced USBI as the KSC base operations contractor, Lockheed changed the name of the vessels to *Liberty Star* and *Freedom Star* after their company symbol, the flying star. David S. Fraine, interview by Joan Deming and Patricia Slovinac, July 27, 2006, notes on file, ACI, Sarasota, Florida.
[17] NASA KSC, "Flight Simulations Conducted as Shuttle Interface Test Nears End," KSC News Release No. 268-80, 1980, Sweetsir Collection, File No. ARCH 00009192, Kennedy Space Center Archives Department, Florida; Rasmussen, "Solid Rocket Booster Retrieval Operations," 506.

before STS-5, an at-sea prototype Diver Operated Plug was designed and constructed. Other equipment changes followed in parallel with the evolution of retrieval techniques.[18]

Beginning on January 28, 1986, immediately following the *Challenger* accident (STS-51-L), and ending on August 28, 1986, both *Freedom Star* and *Liberty Star* were among thirty-eight surface vessels and approximately 6,000 NASA, Air Force, Navy, Coast Guard, and contractor personnel participating in marine search and salvage operations.[19] As a result, about forty-five percent of the orbiter, fifty percent of the ET and booster stacks, and other flight systems were recovered.[20] This effort was characterized as the largest ocean recovery operation in history.

In 1993, NASA officially purchased *Freedom Star* and *Liberty Star* from USBI. As a result, at this time, the vessels went from being privately-owned and operated commercial vessels to government-owned and contractor-operated.[21] To commemorate NASA's purchase of the two vessels, four aluminum "meatball" emblems fabricated by EG&G were attached to the smoke stack port and starboard sides of both vessels.[22]

Permanent structural changes were made to the vessels ca. 1997 and 1998 by Dentyen's Shipyard in Charleston, South Carolina, in order to tow the NASA ET barge from MAF to KSC (Figure No. 9). These modifications were designed by Rodney E. Lay & Associates, Naval Architects, in Jacksonville. Changes included strengthening of the stern with reinforced plating, as well as installation of new bulwark fairings and a new H-bit on the back deck through which cabling will be threaded to keep it centered during towing operations. In addition, the hydraulic tow winch was replaced with a stronger and more powerful double-drum waterfall tow winch. One reel of the winch was dedicated to booster stack towing; the other supported ET towing operations.[23]

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[18] Rasmussen, "Solid Rocket Booster Retrieval Operations," 507.
[19] Joel W. Powell, "Challenger search and salvage," *Spaceflight* (29), April 1987, 154-159.
[20] "51-L salvage operation ends," *Space News Roundup*, September 5, 1986, 1.
[21] Fraine, interview, April 10, 2012, 19.
[22] "Retrieval vessels exhibit NASA emblem," *Spaceport News*, January 15, 1993, 8. Previously, in 1992, the NASA "meatball" insignia had been painted on the stack of each vessel. NASA KSC, *Space Shuttle Solid Rocket Booster Retrieval Vessels*, NASA Facts (Florida: Kennedy Space Center, 1994), Sweetsir Collection, File No. ARCH00019061, Kennedy Space Center Archives Department, Florida.
[23] "SRB retrieval vessels to begin towing external tank," *Spaceport News*, August 29, 1997, 1 and 8.

Other vessel improvements included Differential and WAAS GPS navigational equipment, a flume tank system for increased stability, state-of-the-art communication systems, and man-rated boat davits. The Welin davit system, installed circa 2001, was a safety enhancement that, in addition to new Ambar boats, made it possible to work under rougher conditions.[24] The new dive boats, unlike their predecessors, were safer and more efficient, and could be hoisted fully loaded over the side of the retrieval vessels. Previously, equipment had to be handed down to the divers.[25]

The dynamic positioning system was installed in 2002. A Genset Seachest, designed by Rodney E. Lay & Associates, was installed on each vessel in 2003. The following year, each vessel received a new emergency generator. In 2006, both retrieval vessels were modified with the installation of a mount on the back deck to support the power supply for the debris detecting Doppler radar system.[26] The same year, Weibel Continuous Pulse Doppler X-band radar was installed on both vessels to support radar tracking operations.[27]

Twice every five years, the vessels were placed in drydock at a vesselyard for scheduled repairs and modifications. Both *Liberty Star* and *Freedom Star* were taken out of service at the same time, and were down for three to six weeks.[28]

Functions: SRB Recovery at Sea

Both *Liberty Star* and *Freedom Star* were used for every Shuttle mission; each vessel retrieved one booster stack, as well as its corresponding frustum, three main parachutes, drogue parachute, and if found, its pilot parachute.[29] Twenty-four hours prior to launch, the two vessels departed

[24] Fraine, interview, April 10, 2012, 22.
[25] "New dive boats for SRB vessels," *Spaceport News*, September 26, 1997, 7.
[26] Joseph P. Chaput, interview by Rebecca Wright, *STS Recordation Oral History Project*, July 13, 2011, 12.
[27] Cheryl L. Mansfield, "Freedom and Liberty Go to Sea," April 26, 2006, accessed at http://www.nasa.gov/mission_pages/shuttle/behindscenes/recovery_vessels.html. Working with the land-based C-band radar, the X-band radar provided velocity and differential shuttle/debris motion information during launch. The radar data were sent from the vessels via a satellite link and analyzed at the C-band radar site located on north KSC. NASA, KSC, "Media Detail," Photo No: KSC-06PD-2648, Released December 1, 2006, accessed at http://mediaarchive.ksc.nasa.gov/detail.cfm?mediaid=30622.
[28] Fraine, interview, July 27, 2006.
[29] *Liberty Star* typically retrieved the right-hand booster and *Freedom Star* the left-hand booster as part of two independent operations. Chaput, interview, 20. Features on the exterior of the SRB, such as the ET attach struts, required that the right-hand SRB be hipped on the starboard side of the towing vessel, and the left-hand SRB on the

the CCAFS Hanger AF Wharf and proceeded to their stations in international waters approximately 160 miles downrange of the launch site. The vessels reached the predicted impact area in approximately ten hours. In the hours prior to liftoff, visual and electronic sweeps of the site were conducted ensure clearance from other vessels. Splashdown weather data were provided to the launch and retrieval director at two hours before launch. The splashdown footprint was an area approximately seven mile wide and ten miles long. At the time of SRB splashdown, the vessels were positioned about eight to ten nautical miles from the impact area, and approximately one mile apart.[30] They were oriented perpendicular to the flight path of the SRBs and pointing away from the projected splash down location.[31] The typical flight trajectory took the vehicle away from the continental United States.

Booster stack splashdown range was approximately 140 miles off-shore the eastern coast of the Florida peninsula. The main parachutes provided a nozzle-first water impact and air was trapped in the burned out reusable solid rocket motor casings causing the booster stack to float with the forward-end approximately 30 feet out of the water (vertical orientation position or spar buoy mode).

Ambar utility boats were deployed from the vessels and retrieval operations crews arrived at the booster stack sites. Prior to retrieval, the dive team conducted a search and recovery (if found) of the pilot parachutes and drogue bags, and an above water and below water visual/photographic damage assessment.[32] Divers installed flotation devices on the main parachutes for reeling in and cut the riser extensions for the main parachutes, which were subsequently wound onto three of the four powered reels on the vessel's deck (Figure No. 10).[33] The frustum and attached drogue chutes were reeled in next.[34] The frustum was lifted from the water by the vessel's 10-ton crane (Figure No. 11).

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port side. USA, *Solid Rocket Booster Illustrated Systems Manual* (Huntsville: United Space Alliance, May 2005), 119.

[30] Joseph Chaput, interview by Joan Deming and Patricia Slovinac, KSC, June 29, 2010.

[31] Fraine, interview, April 10, 2012, 9.

[32] Chaput, interview, June 29, 2010. The dive team for each vessel consisted of four lead divers and a dive supervisor; all were trained as diver medical technicians. Each dive team was part of a ten-person crew, permanently assigned to the vessel. These personnel included the Captain, the Chief Mate, the Second Mate, the Lead Seaman, to Able Bodied Seamen, one Ordinary Seaman, a cook, and two engineers. John C. Fischbeck, interview by Rebecca Wright, *SRB Recovery Vessel Oral History Project*, April 11, 2012, 54.

[33] USA, *Solid Rocket Booster Illustrated Systems Manual*, 33.

[34] The pilot/drogue chute deployment bag assemblies were not always recovered. Replacements were fabricated at KSC's Parachute Refurbishment Facility. ACI, *Survey and Evaluation. Kennedy Space Center*, Appendix C.

The booster stacks were recovered last. Two dive teams were deployed in two Ambar utility boats to recover the booster stacks (Figure No. 12). The boats were affixed to the booster stacks and the air hoses were positioned. An Enhanced Diver-Operated Plug was launched from the vessel and towed to the booster stack by an Ambar utility boat. The first team, comprised of five divers, inserted the plug into the reusable solid rocket motor aft nozzle orifice, and the hoses were connected to the plug, which pumped air from the vessel into the booster stack to displace the seawater in the cavities. The second team verified the aft skirt and plug installation to ensure proper fit. After inspection, the dewatering process began (Figure No. 13). This operation, which took approximately twenty minutes, forced out all the water, causing the booster stack to shift position from vertical (spar buoy mode) to horizontal (log mode) in preparation for towback to CCAFS Hangar AF. Towback was accomplished in approximately 26 hours. During the final step, a tow line from each vessel was connected to the booster stack, and each booster stack was towed about 800’ (long tow configuration) behind the vessel. The tow was shortened to 200’ (short tow configuration) and a final booster stack dewater was performed prior to entering Port Canaveral. At Port Canaveral, each booster stack was repositioned from the stern tow configuration to the hip tow configuration alongside the vessel for the remainder of the trip to the Wharf at Hangar AF for better control of the structures in the shallow inland waters during navigation through Port Canaveral and Port Canaveral Locks into the Banana River (Figure No. 14). The stern thruster, installed for manatee protection, was used during transit from Port Canaveral to Hangar AF.

Upon arrival at the CCAFS Hangar AF Wharf, the booster stacks were placed in the hoisting slip for lift by the mobile gantry crane and offload onto tracked dollies for safing and to perform subsequent open assessment, inspections, and disassembly operations. The frustums and parachute reels were also offloaded at Hangar AF for processing. The parachutes were delivered on reels to the Parachute Refurbishment Facility for processing (untangle, in-line wash and dry, refurbishment, inspection, assembly, and storage). The eight reusable solid rocket motor case segments were final-cleaned prior to truck delivery to the Launch Complex 39 rail yard for shipment to the Alliant Techsystems facility in Promontory, Utah, for refurbishment and propellant reloading for reuse.

ET Towing

On June 16, 1998, a new milestone for the SSP was reached when NASA motor vessel *Freedom Star* arrived at KSC towing a barge carrying an ET.[35] Prior to this time, NASA had used an external contractor to provide towing services, at a cost of approximately $120,000 per trip. Using the retrieval vessels to provide the same service during their downtime between Shuttle launches yielded a savings of about $50,000 per trip.[36] Commercial tugboats were still used to tow the barge between Gulfport, Mississippi, and MAF near New Orleans, Louisiana, at the beginning of the trip, and during the final miles in a shallow and narrow channel to the turn basin in front of the Vehicle Assembly Building at KSC.[37] *Freedom Star* made the first four tows. Subsequently, towing duty alternated between the two vessels. The barge tow journey took four to five days.

Other Functions

When not required for NASA missions, the retrieval vessels were used for other purposes, including mapping the ocean floor with side scan sonar; seismographic studies; marine life and marine fisheries studies; National Oceanic and Atmospheric Administration (NOAA) weather buoy deployment and recoveries; cable-laying; underwater search and salvage; Air Force drone aircraft recovery; robotic submarine operations; and numerous support roles for other government agencies, including the Navy.[38]

Once the SSP ended, *Liberty Star* and *Freedom Star* began to provide X-band radar tracking services in support of COTS (Commercial Orbital Transportation Services) 2/3, Falcon 9, and the Dragon capsule – all delivering cargo to the International Space Station. *Liberty Star* was positioned approximately 200 miles east of Cape Cod and *Freedom Star*

[35] The NASA barge Orion, built in 1945 and modified and upgraded in 1965, carried the ET until 1999, when it was replaced by the newly constructed barge Pegasus. "Ready for action," *Marshall Star*, June 24, 1999, 4.
[36] Joel Wells, "Solid Rocket Booster Recovery Vessels 'Pull' Double Duty," KSC Press Release No. 81-98, June 15, 1998, accessed at http://www-pao.ksc.nasa.gov/kscpao/release/1998/81-98.html; Photo caption, *Spaceport News*, July 3, 1998, 8.
[37] The original route of the barge towed by the retrieval vessels was through the Mississippi River – Gulf Outlet out to the Gulf of Mexico. However, due to significant shoaling and severe erosion caused by Hurricane Katrina, this route was closed to larger vessels. Subsequently, the barge was towed by commercial tug boats to Gulfport, Mississippi, where it was met by *Liberty Star* or *Freedom Star*, and taken in tow. Steven Roy, "Pegasus: The 'Winged Horse' of the Space Program," *NASA Blogs*, October 16, 2009, http://blogs.nasa.gov/cm/blog/sailing_with_nasa/posts/post_1255720216729.html.
[38] NASA KSC, "Booster Retrieval Vessels," 1994.

was positioned roughly 200 miles east of Nova Scotia to permit radar and special imaging equipment recording.[39]

[39] Fraine, interview, April 10, 2012, 18.

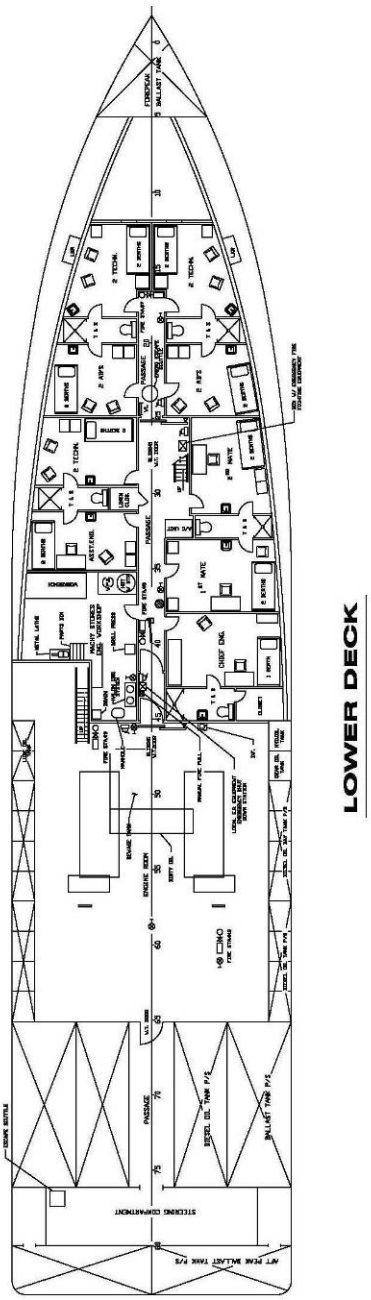

Figure 1. Layout of lower deck.
Source: United Space Alliance, *Drawing No. 1547-1401*, Sheet 1.

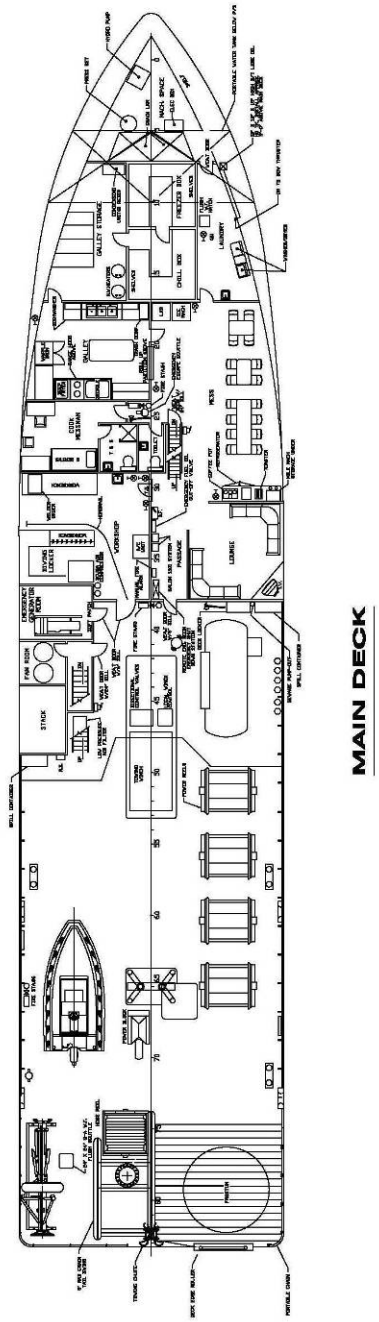

Figure 2. Layout of main deck.
Source: United Space Alliance, *Drawing No. 1547-1401*, Sheet 1.

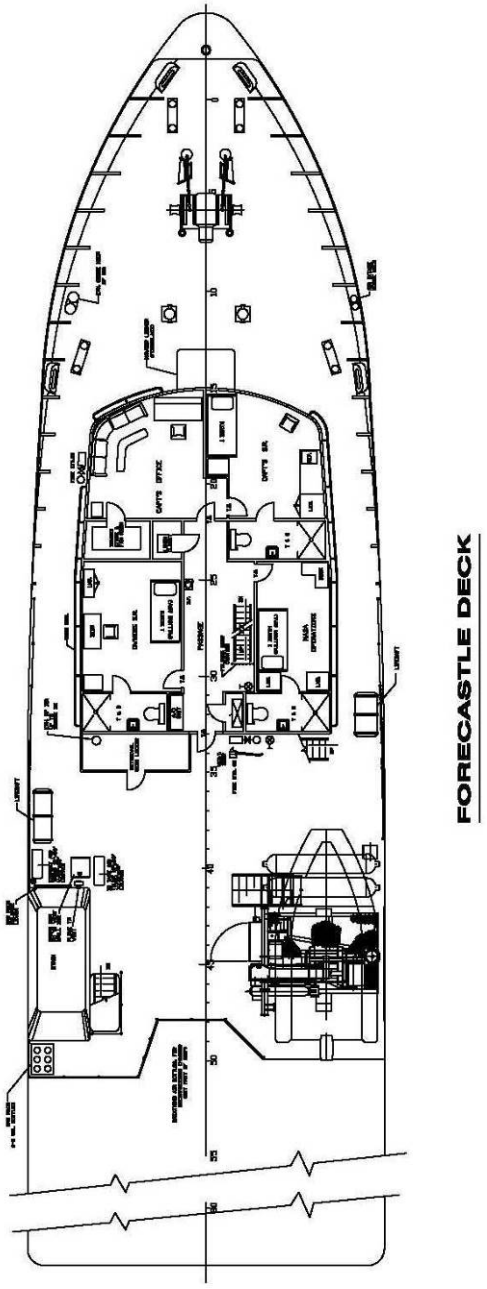

Figure 3. Layout of forecastle deck.
Source: United Space Alliance, *Drawing No. 1547-1401*, Sheet 2.

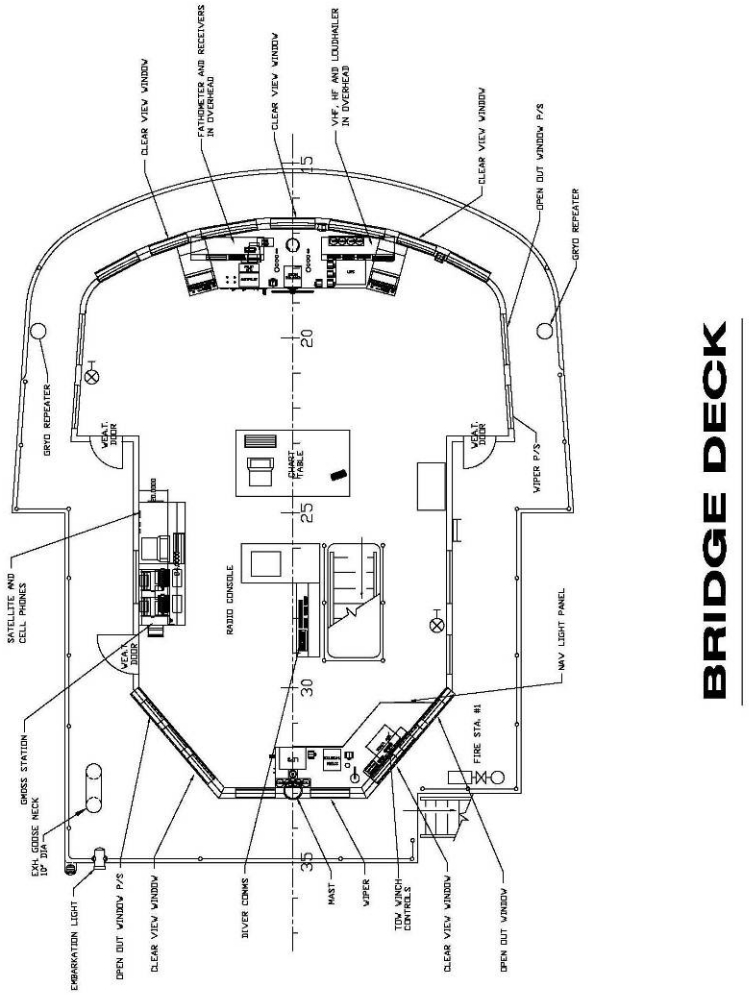

Figure 4. Layout of bridge deck.
Source: United Space Alliance, *Drawing No. 1547-1401*, Sheet 2.

Figure 5. SRB Retrieval Ship acceptance testing, 1980.
Source: John F. Kennedy Space Center Online Multimedia Gallery, KSC-80PC-0292, http://mediaarchive.ksc.nasa.gov/search.cfm.

Figure 6. Dewatering of one of the SRB casings following STS-1, April 13, 1981. Source: John F. Kennedy Space Center Online Multimedia Gallery, KSC-81PC-0399, http://mediaarchive.ksc.nasa.gov/search.cfm.

Figure 7. *Liberty Star* arriving at Hangar AF with spent SRB, following launch of STS-87. Source: NASA John F. Kennedy Space Center, KSC-97PC-1725.

Figure 8. *Freedom Star* towing SRB, July 27, 2005.
Source: NASA John F. Kennedy Space Center, KSC-05PD-1791.

Figure 9. *Freedom Star* towing a barge with an external tank, June 16, 1998.
Source: John F. Kennedy Space Center Online Multimedia Gallery, KSC-98PC-0753,
http://mediaarchive.ksc.nasa.gov/search.cfm.

Figure 10. Crew of *Freedom Star* reeling in parachutes following STS-133, February 25, 2011. Source: John F. Kennedy Space Center Online Multimedia Gallery, KSC-2011-1832, http://mediaarchive.ksc.nasa.gov/search.cfm.

Figure 11. *Freedom Star's* crane lifting SRB frustum from water following launch of STS-135, February 25, 2011.
Source: John F. Kennedy Space Center Online Multimedia Gallery, KSC-2011-1820, http://mediaarchive.ksc.nasa.gov/search.cfm.

Figure 12. Dive team from *Freedom Star* approaching SRB casing, February 25, 2011. Source: John F. Kennedy Space Center Online Multimedia Gallery, KSC-2011-1823, http://mediaarchive.ksc.nasa.gov/search.cfm.

Figure 13. Water being pumped from SRB casing, February 25, 2011.
Source: John F. Kennedy Space Center Online Multimedia Gallery, KSC-2011-1844, http://mediaarchive.ksc.nasa.gov/search.cfm.

Figure 14. Crew of *Liberty Star* maneuvering SRB casing into hip tow position, February 27, 2011.
Source: John F. Kennedy Space Center Online Multimedia Gallery, KSC-2011-1850, http://mediaarchive.ksc.nasa.gov/search.cfm.

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Historians: Joan Deming and Patricia Slovinac, Archaeological Consultants, Inc. (ACI), Sarasota, Florida, August 2013

Project Information: The documentation of the Motor Vessels *Liberty Star* and *Freedom Star* was conducted in 2012 for NASA's Lyndon B. Johnson Space Center (JSC) by Archaeological Consultants, Inc. (ACI), under contract to Earth Resources Technology, Inc. (ERT). It was based upon research originated in 2006 as part of a nationwide assessment of NASA's Space Shuttle Program assets, conducted by ACI, and between 2009 and 2011 incident to the preparation of HAER Level II documentation of NASA's Space Transportation System (STS). The project team consisted of architectural historian, Patricia Slovinac and project manager, Joan Deming (both with ACI). Assistance was provided by Sandra J. Tetley, JSC Historic

Preservation Officer and Real Property Officer. The written narrative was prepared by Ms. Slovinac and Ms. Deming; it was edited by Ms. Tetley and Art Morales, formerly of the Office of the Director, Shuttle-ARES Transition Office. The 4x5 negatives were taken by the JSC Photo Operations Group, under the direction of Maura White, JSC Photographer.

The Scope of Services for the project specifies a documentation effort following HAER Level III Standards. Information for the written narrative was primarily gathered through informal interviews with NASA and contractor personnel, research materials housed at the KSC Archives, and oral histories provided by Dr. Jennifer Ross-Nazzal, JSC Historian. Dr. Ross-Nazzal also provided research materials from the KSC Archives, with the assistance of archivist Elaine Liston.