

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.<sup>24</sup> 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.<sup>25</sup>

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.<sup>26</sup> The same year, Weibel Continuous Pulse Doppler X-band radar was installed on both vessels to support radar tracking operations.<sup>27</sup>

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.<sup>28</sup>

## **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.<sup>29</sup> Twenty-four hours prior to launch, the two vessels departed

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<sup>24</sup> Fraine, interview, April 10, 2012, 22.

<sup>25</sup> "New dive boats for SRB vessels," *Spaceport News*, September 26, 1997, 7.

<sup>26</sup> Joseph P. Chaput, interview by Rebecca Wright, *STS Recordation Oral History Project*, July 13, 2011, 12.

<sup>27</sup> 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](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>.

<sup>28</sup> Fraine, interview, July 27, 2006.

<sup>29</sup> *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.<sup>30</sup> They were oriented perpendicular to the flight path of the SRBs and pointing away from the projected splash down location.<sup>31</sup> 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.<sup>32</sup> 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).<sup>33</sup> The frustum and attached drogue chutes were reeled in next.<sup>34</sup> 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.

<sup>30</sup> Joseph Chaput, interview by Joan Deming and Patricia Slovinac, KSC, June 29, 2010.

<sup>31</sup> Fraine, interview, April 10, 2012, 9.

<sup>32</sup> 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.

<sup>33</sup> USA, *Solid Rocket Booster Illustrated Systems Manual*, 33.

<sup>34</sup> 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.<sup>35</sup> 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.<sup>36</sup> 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.<sup>37</sup> *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.<sup>38</sup>

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*

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<sup>35</sup> 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.

<sup>36</sup> 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.

<sup>37</sup> 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](http://blogs.nasa.gov/cm/blog/sailing_with_nasa/posts/post_1255720216729.html).

<sup>38</sup> NASA KSC, “Booster Retrieval Vessels,” 1994.

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was positioned roughly 200 miles east of Nova Scotia to permit radar and special imaging equipment recording.<sup>39</sup>

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<sup>39</sup> Fraine, interview, April 10, 2012, 18.