U.S. Navy Hydrofoil Development





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Objectives



- Summarize significant US Navy hydrofoil development leading to fleet introduction and operation of the Patrol Hydrofoil – Missile (PHM-1) Class.
- Highlight key hydrofoil system and sub-system technologies.
- Foster interest in learning more about hydrofoils.
- Encourage students to consider ship design as a career field.



Why Hydrofoils ?



- For more than two hundred years, numerous efforts strove to increase speed of waterborne craft for both military and commercial applications.
- Numerous concepts have been employed in this quest for speed, including planing craft, multi-hulls, hydrofoil ships and craft, hovercraft, surface effect ships and various hybrid hullforms.
- Most efforts to increase speed involve getting the hull out of the water.



Most efforts to increase speed involve getting the hull out of the water !















Hydrofoil Configurations





Figure 1-Surface-Piercing & Fully-Submerged Foil Configurations





Hydrofoil Ships and Craft



- One of the earliest efforts to lift the hull from the water was by use of underwater wing-like lifting surfaces called hydrofoils. These foils, like aircraft wings, follow the "Bernoulli Principle".
- Air and water flowing over the curved upper surface must move faster than that flowing beneath.
- This change in the flow pattern results in <u>low pressure</u> on the top surface and <u>high pressure</u> on the bottom surface.
- At a given speed, the forces generated lift the hull out of the water





Overview



U.S. Navy hydrofoil development – ship weight: 1958 - 1985





SEA LEGS



- Modified Chris Craft with fully-submerged foils and automatic control system
- Gibbs & Cox/USN design, built in 1958









HS DENISON



- Launched by Grumman on 5 June 1962, Oyster Bay, Long Island, New York
- Forward surface-piercing foils carried 85% of its weight, single fully-submerged tail foil aft carried 15%.
- Length: 104.6 ft /Beam: 23 ft/Max draft hullborne foils down: 15 ft/Displacement: 79 LT
- Trials at speeds of 50 60 knots demonstrated stability, maneuverability and good performance in rough water. Many of HS DENISON's subsystems were at the leading edge of the state-of-the-art, knowledge gained was invaluable in further hydrofoil developments by the US Navy.





FRESH-1



- Purpose of the 53-foot, 16.7 ton Foil Research Experimental Supercavitating Hydrofoil, designed and built by Boeing for the US Navy in the 1962-63 time frame, was to evaluate a variety of foil designs and foil system arrangements at high speed.
- Twin-hull catamaran arrangement provided a large clear space between the hulls, within which different foil systems could be mounted.
- FRESH-1 capsized at 70 knots during a high-speed Acceptance Trial on 18 July 1963. The incident strongly influenced the US Navy's decision to abandon its goal of a 100-knot hydrofoil and concentrate instead on achieving reliable 50 knot operations.





PCH-1 USS HIGH POINT



- HIGH POINT, named after a city in North Carolina, was designed by the U.S. Navy Bureau of Ships, built by the Boeing Company under Navy contract, and delivered in August of 1963.
- PCH-1 was 116 feet long, with maximum hull beam of 32 feet (38 feet across its foil guards), a draft of 8.5 feet with foils retracted, 19.0 ft with foils extended, and displaced about 125 long tons.
- Power for foilborne operations was by two British-built Rolls Royce PROTEUS gas turbine engines driving four propellers, two at the bottom of each of two aft struts. A diesel engine powered a steerable outdrive for hullborne operations and low speed maneuvering.



PCH-1 USS HIGH POINT (2)



- Trials and operations led to major modifications starting in 1971.
- Changes included steering and automatic controls, hydraulic system improvements, relocation of the propulsion pods, redesigned gears for the foilborne transmission system, new propellers, and a data gathering systems for ship trials.
- In April 1975, HIGH POINT was turned over to the U.S. Coast Guard for evaluation of the hydrofoil in several coastal roles. The ship was officially commissioned as the Coast Guard vessel WMEH-1, with a new coat of white paint and the conventional red "racing stripes" as shown below.









PCH-1 USS HIGH POINT (3)



- After *HIGH POINT* was decommissioned in 1989, it changed hands several times before coming to Astoria Oregon's North Tongue Point pier in 2000.
- Portland resident and military artifact collector Terence Orme rescued the ship from being scrapped in a 2005 lien sale. He has spent the past 14 years cleaning it out and drumming up support to revive the ship.
- Orme and about a dozen volunteers are working on weekends to restore the High Point and turn it into a floating museum.







LITTLE SQUIRT



- *LITTLE SQUIRT* a 5,500 lb, 20-foot runabout with a stepped W-form hull designed and tested in the early to mid-1960s by Boeing to explore the idea that a waterjet could propel a hydrofoil craft.
- Two foils forward and one aft. Each foil had trailing edge flaps, with lift controlled by changing the angle of each foil. Flaps used for lift augmentation during takeoff and were retracted for the foilborne cruise.
- Automatic control system used an acoustic height sensor to measure the distance between a fixed point on the bow of the boat to the average water surface.
- *LITTLE SQUIRT* is currently located at the USS ARIES (PHM-5) museum in Gasconade, Missouri





PGH-1 USS FLAGSTAFF



- Two hydrofoil patrol gunboats were built for U.S. Navy fleet operational use in the late 1960s. Both were designed and built to the same performance specification
- Configurations were different:
 - PGH-1 was propeller driven with a conventional (airplane) foil configuration
 - TUCUMCARI (PGH-2) was waterjet propelled with a canard foil arrangement.
- Delivered to the Navy in 1968, both operational in Vietnam between Sept 1969 and Feb 1970, making them the first U.S. Navy hydrofoils in combat.
- FLAGSTAFF was designed and built by Grumman Aerospace Corporation.
- Characteristics:
 - Length: 74 feet
 - Maximum beam: 37 feet
 - Draft: 4.2 feet foils up/13.5 feet foils down
 - Displacement: 69 tons.
 - Speed 50 knots foilborne
 - Manning: 4 officers and 12 enlisted men.





PGH-1 USS FLAGSTAFF (2)



- After completion of performance trials, *FLAGSTAFF* was transported to Vietnam for riverine operations.
- Photo below shows the ship at a pier in Danang. Note the support vans in the background which were transported along with FLAGSTAFF to provide the crew with spare parts and maintenance equipment.
- Operations in the area were very successful. The crew was particularly impressed with the ship's ability to operate under adverse conditions and had occasion to fly through many monsoons near South Vietnam's Demilitarized Zone.





PGH-2 USS TUCUMCARI



- Contract award to Boeing in 1966.
- Delivered to the US Navy on 8 Mar 1968 at a cost of US\$ 4M.
- Characteristics:
 - Displacement: 57 tons
 - Length:72 feet
 - Beam:35.3 feet
 - Draft: 4.5 feet (foils up)/13.9 feet (foils down).
 - Speed: in excess of 40 knots.
 - Manning: 1 officer and 12 enlisted personnel.
- *TUCUMCARI* was deployed to Vietnam with *FLAGSTAFF* in Nov 1969 for riverine operations near Danang and evaluation in a wartime environment.



PGH-2 USSTUCUMCARI (2)



- Following her mission in Vietnam, *TUCUMCARI* was transported to Europe for a NATO tour, demonstrations and combat exercises from Apr – Oct 1971.
- Upon returning from Europe, *TUCUMCARI* was assigned to the Amphibious Force in the Atlantic Fleet.
- In Nov 1972 -- she ran onto a coral reef at Caballo Blanco, Vieques Island, Puerto Rico. There were no serious injuries to the crew. The ship was salvaged and transported to Norfolk VA, but it was decided not to attempt repair of the extensive damage.
- PGH-2 foil system configuration, propulsion system (GT/waterjet) and excellent operational capabilities heavily influenced the design of the Patrol Hydrofoil – Missile (PHM) Class, also built by Boeing.









AGEH-1 USS PLAINVIEW



- Initial design by Grumman Aircraft Engineering Corporation and detail design and construction by Lockheed Shipbuilding and Construction Co.
- Keel laid on 8 May 1964 and the ship was launched on 28 June 1965. It was christened *PLAINVIEW* in honor of Plainview, New York and Texas.
- 320-ton ship had a length of 212 feet, extreme beam with foils down of 70.8 feet.
- Foilborne speeds of over 50 knots from two General Electric LM-1500 gas turbine engines driving two super-cavitating propellers. Two Packard diesel engines drove propellers for low-speed hullborne operations.
- Two large foils forward, smaller foil aft, in an airplane configuration.





AGEH-1 USS PLAINVIEW (2)



- PLAINVIEW first foilborne flight: 11.5 minutes on 21 March 1968
- 3 February 1969: start of Preliminary Acceptance Trials.
- 1 March 1969: U.S. Navy took delivery and assigned the ship to the Hydrofoil Special Trials Unit (HYSTU) located at the Puget Sound Naval Shipyard in Bremerton, Washington for administrative and technical control.
- The Navy decided that its best course of action was to undertake its own program of deficiency correction if the ship was every to become fully operational. Final Contract Trials were begun on 21 January 1970, and on 2 March 1970, the Navy accepted the ship.





AGEH-1 USS PLAINVIEW (3)



PLAINVIEW possessed many unusual characteristics, including:

- Largest hydrofoil ship in the world at that time. It was subsequently surpassed by the Soviet BABUCHKA hydrofoil at about 400 tons.
- Largest high-speed aluminum hull.
- Highest sub-cavitating foil loading at 1460 pounds per square foot.
- Largest vehicular hydraulic system with a pressure of 3,600 pounds per square inch at 1,000 gallons per minute.
- Highest power Zee-drive transmission incorporating two 15,000 HP units.
- Largest high-speed super-cavitating propellers with a diameter of 5.2 feet and a design rotational speed of 1,700 rpm.
- Highest design sea state capability at high speed. PLAINVIEW could essentially maintain its design speed through ten-foot waves with little difficulty.



AGEH-1 USS PLAINVIEW (4)



- One objective: demonstrate applicability of hydrofoils to Navy missions. Operations included launching of torpedoes, firing of missiles, launching and retrieval of remotely piloted vehicles (RPVs), underway replenishment/personnel transfer, and multiple ship close formation flying.
- Soon after emerging from deficiencies correction and returning to the trials
 program with many successful operations in its log, *PLAINVIEW* fell victim to the
 Congressional budget knife.
- Last foilborne flight on 17 July 1978, ending with a total of 268 foilborne hours and without ever being tested to the limits of her rough water capability.
- Ship was inactivated on 22 September 1978 and towed to the inactive fleet at Bremerton WA. In May of 1979, the hull (without struts and foils, gas turbines, and other equipment) was sold to a private party for \$128,000.
- Engines, foils, and transmissions were retained by the Navy for possible use on another prototype hydrofoil or another advanced naval vehicle. This once proud and beautiful ship is now resting on a mud flat near Astoria Oregon.







Backup Slides





U.S. Navy Hydrofoil Video

https://www.youtube.com/watch?v=6SRxgbHsHdQ&t=48s

