WNY Museum
Hydrofoil Exhibit
USN Hydrofoil Development

Draft – 10 November 2017

Objectives

- Summarize significant US Navy hydrofoil development leading to fleet introduction and operation of the 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.

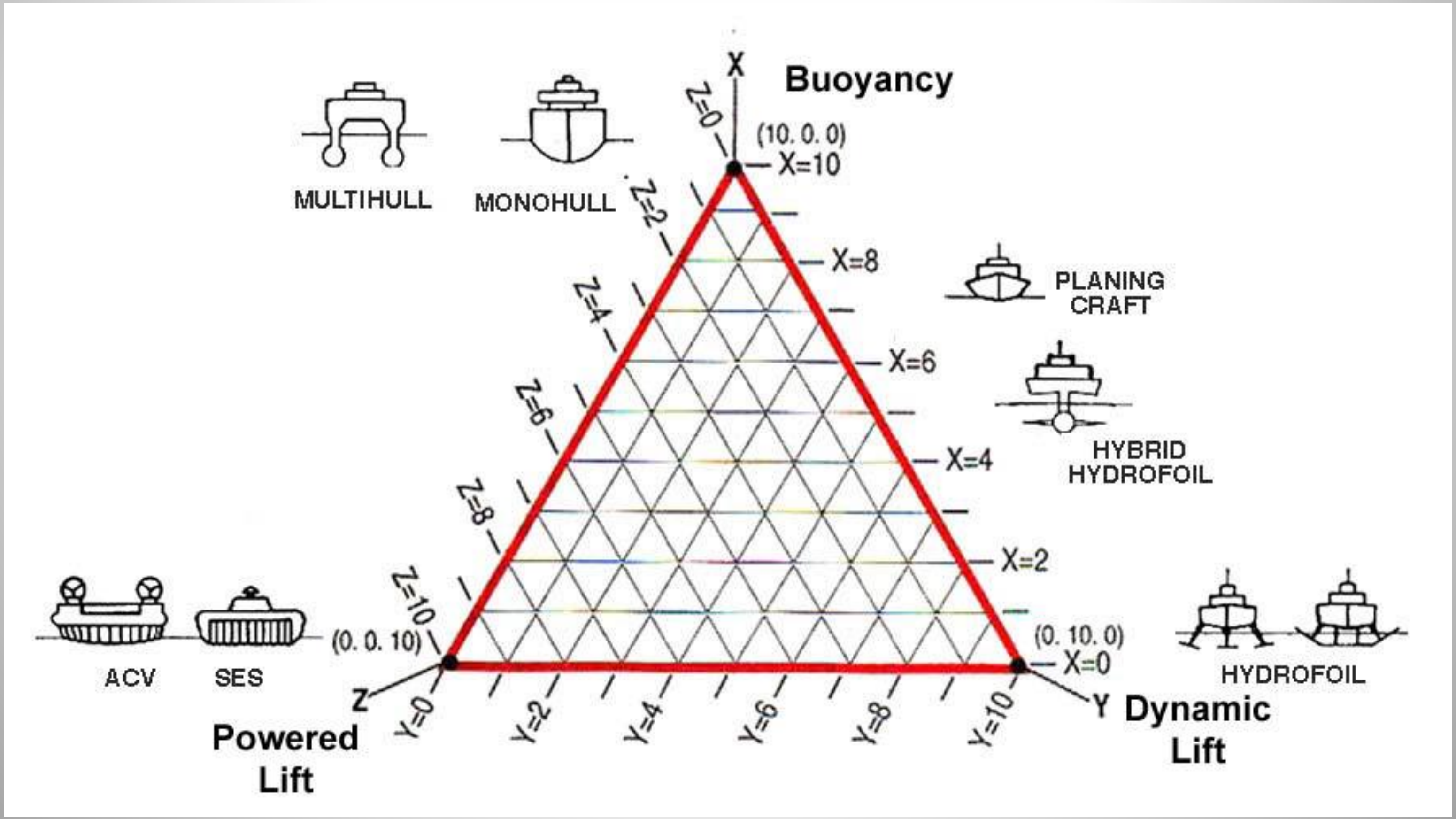
Why Hydrofoils ?

- 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, multihulls, hydrofoil ships and craft, hovercraft, and hybrids.
- 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 !

The Sustension Triangle

- The so-called "Sustension Triangle" shows the lift forces raising the hulls above, or partially above, the water surface.

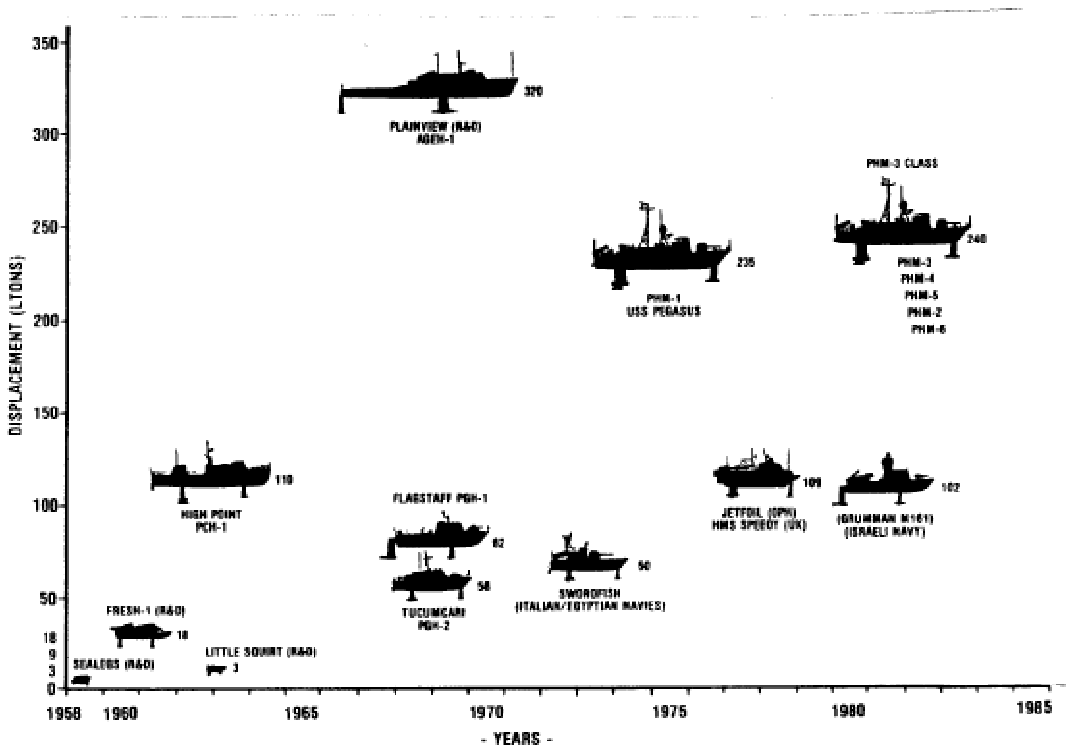


Hydrofoil Ships and Craft

- 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 low pressure on the top surface and high pressure on the bottom surface.
- At a given speed, the forces generated lift the hull out of the water

Introduction

- One of the best ways to see the entire scope of the U.S. Navy hydrofoil development is by way of a plot of ship weight against time over the timeframe of 1958 to 1985.



U. S. Hydrofoil Military Development: 1958 to 1985

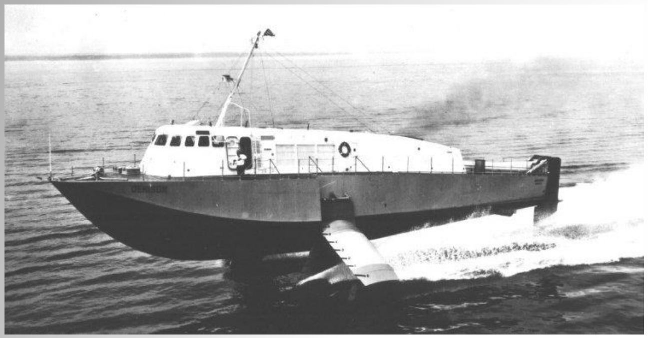
SEA LEGS

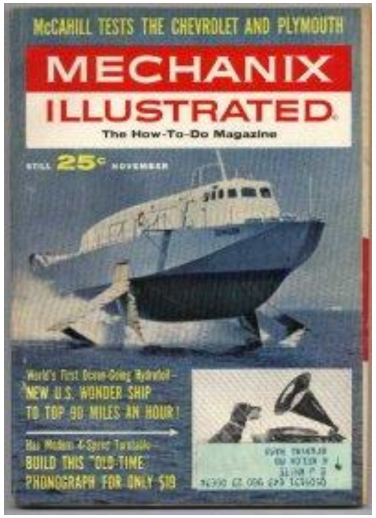
- Modified Chris Craft with fully-submerged foils and automatic control system
- Gibbs & Cox/USN Design, built in 1958

DENISON (1)

- Sparked by the commercial application of hydrofoils in Europe and research sponsored by the USN in the 1950s, the Maritime Administration (MARAD) started a project leading to *HS DENISON*.
- In January 1960, MARAD placed a contract with Dynamic Developments, Inc. to build an experimental hydrofoil capable of speeds up to 60 knots with gas turbine engines. Provision was made for a second phase where sub-cavitating foils would be replaced with super-cavitating foils. Intent was to achieve speeds up to 100 knots with the same power plant.
- Unfortunately, Charles Denison, whose vision and enthusiasm was in great part responsible for the program, suffered an untimely death before the ship got beyond the early design stage. It was in his memory that the ship was later christened *HS DENISON*.
- Although MARAD had contracted with Dynamic Developments, Inc. to build *DENISON*, Grumman Aircraft Engineering Corporation, because of expanding interest in hydrofoils, purchased interest in and eventually acquired all of Dynamic Developments, Inc.
- *DENISON* was launched by Grumman on 5 June 1962 at Oyster Bay, Long Island, and began sea trials only four days later. The 95-ton *DENISON* had a unique foil system. The forward surface-piercing foils carried 85% of its weight, and a single fully-submerged tail foil aft carried the remaining 15%. The ship's length overall was 104.6 feet, maximum hull beam was 23 feet, and maximum draft hullborne with its foils extended was 15.4 feet.

DENISON (2)

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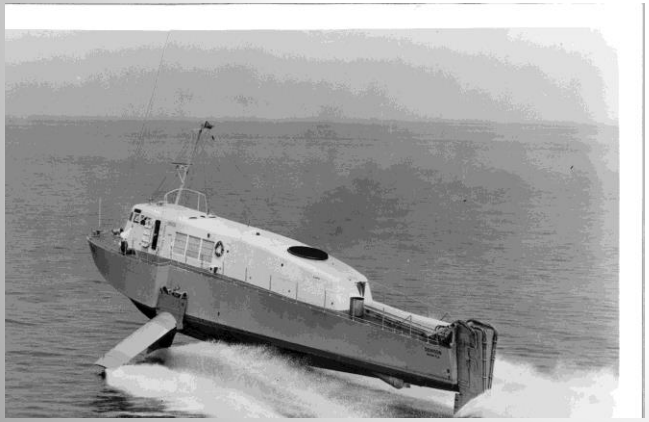


DENISON (3)

- Main propulsion for foilborne operations was provided by a General Electric gas turbine engine rated at 14,000 horsepower. It was a marine version of GE's J-79 aircraft jet engine.

- MARAD obtained two J-79 engines from the Navy and then bailed them to GE who then provided the marine version by the addition of a so-called free power turbine to take energy out of the jet. The arrangement was interesting in that it was accomplished for the <u>total sum of one dollar</u>.

- This proved to be a wise long-term investment on the part of the General Electric Company because it was the basis for their later so-called LM series of marinized gas turbine engines which are extensively used in Navy ships today.

- The design of a propulsion system capable of putting 14,000 hp into the water through a single high speed propeller was a considerable challenge at the time. Power was transmitted from the gas turbine engine through a right-angle bevel-gear drive to a super-cavitating propeller mounted at the bottom of the aft strut. The spiral bevel gears, 20 and 21 inches in diameter and turning at 4,000 rpm, were designed and built by General Electric Company and represented the most stringent requirement of any which previously had been manufactured.

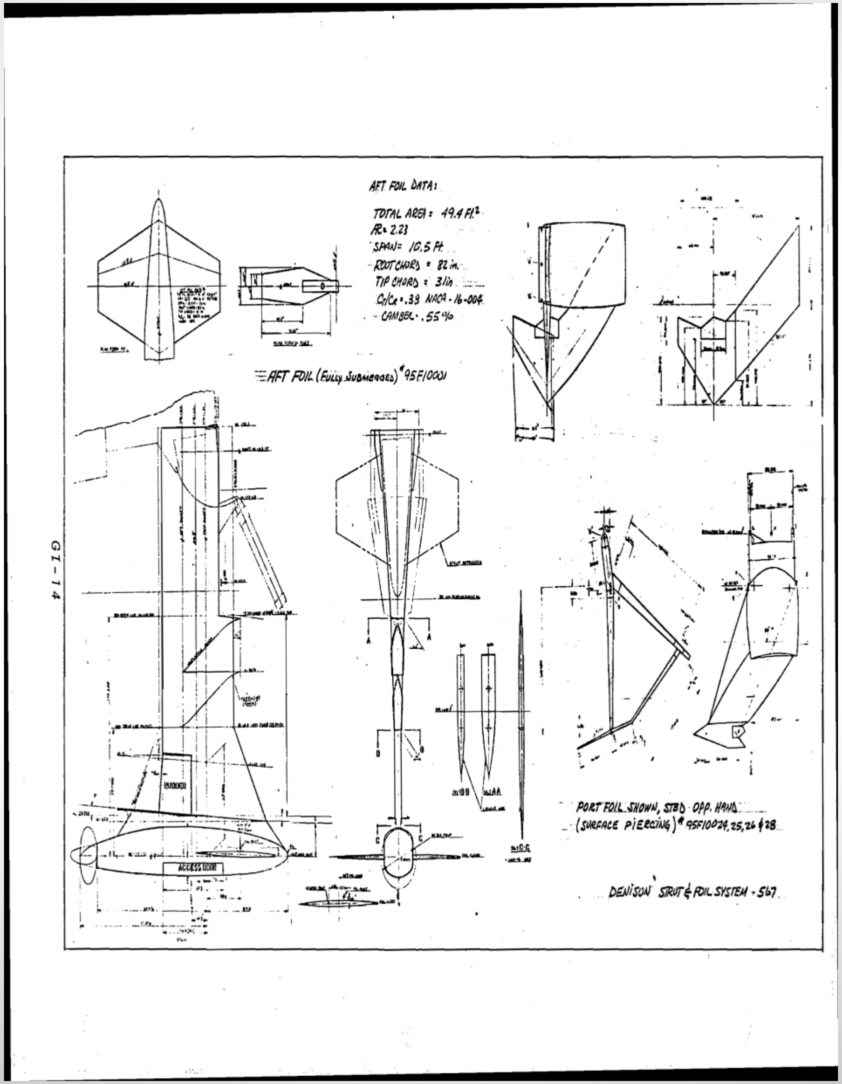
DENISON (4)

- Trials were carried out at speeds of 50 - 60 knots and demonstrated the ability to be stable and highly maneuverable. *DENISON* was also a good performer in rough water under high winds and low temperatures. Temperatures on some tests were below freezing, but no icing problems were encountered during either hullborne or foilborne operations.

- Following the trials, the Navy and MARAD had planned to proceed with the next high-speed phase of the *DENISON* program incorporating a super-cavitating foil system. All seemed to be on track when the Navy decided to change course and proceed with the design of their own high speed foil research craft, designated *FRESH-1*. Since the Navy withdrew their financial support, MARAD terminated the program and did not pursue development of commercial hydrofoils any further.

- The MARAD program, and particularly the *HS DENISON*, contributed in large measure to the growing technology base for the design of hydrofoils. <u>Many of *DENISON's* subsystems were at the leading edge of the state-of-the-art, and knowledge gained was invaluable in further developments by the US Navy</u>. It is unfortunate that it did not also fulfill the bright future originally forecast for the employment of commercial hydrofoils in US service.

DENISON (5)
Strut & Foil System



FRESH-1

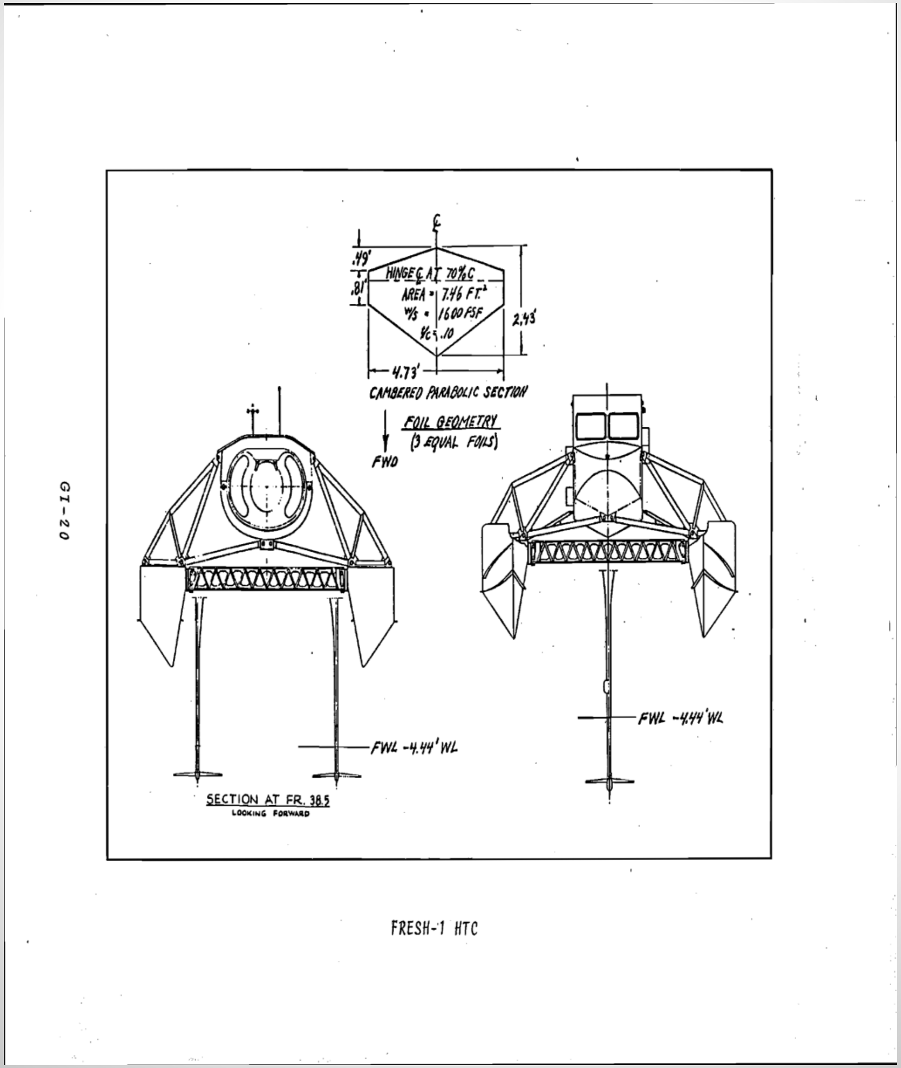
- The purpose of the 53-foot, 16.7 ton Foil Research Experimental Supercavitating Hydrofoil, designed and built by Boeing for the US Navy in the 1962-63 time frame was to evaluate a variety of foil designs and foil system arrangements at high speed.

- Twin-hull catamaran arrangement provided a large clear space between the hulls, within which different foil systems could be mounted. There was complete freedom for the arrangement and location of foils relative to each other. *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.

FRESH-1(2)

Strut & Foil System



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 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 power a steerable outdrive for hullborne ops and low speed maneuvering.

PCH-1 USS HIGH POINT (2)

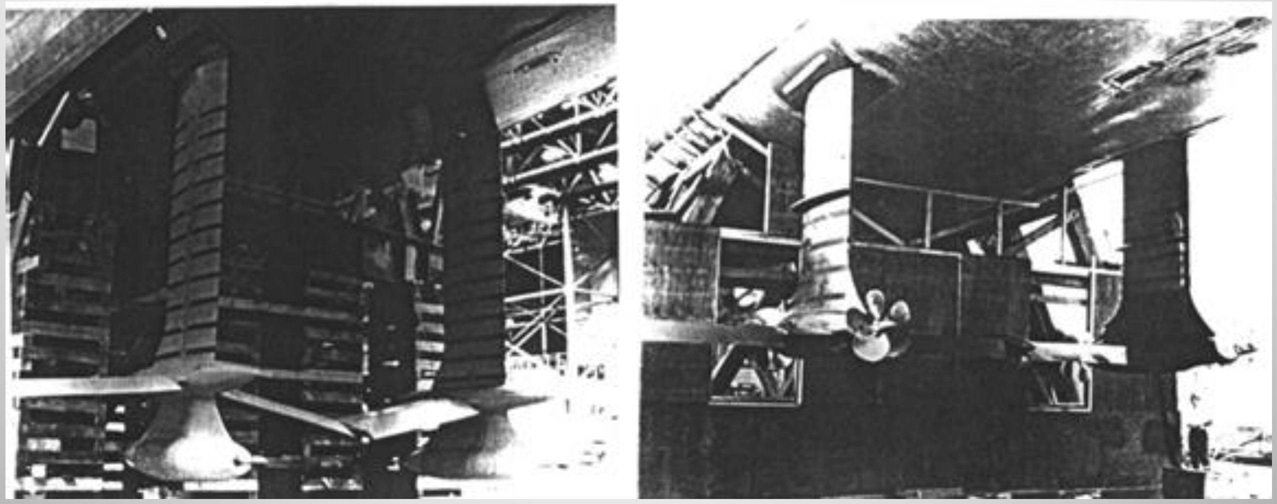
- HIGH POINT was originally intended for off-shore Anti-Submarine Warfare (ASW). The concept was to use the PCH-I as a small, high-speed sonar platform with ASW torpedoes to sortie from harbors in advance of a convoy. Using its speed to move quickly over a larger area, the PCH-I could protect the departing convoy and its ASW escorts at its origin when they are most vulnerable.
- In this connection the ship was to be delivered to the Pacific Fleet for operation by the Mine Force. However, development of a sonar suitable for effective utilization of the ship's unique capabilities was never prosecuted. But instead, HIGH POINT underwent Navy tests immediately after construction during which time numerous technical problems were uncovered.

PCH-1 USS HIGH POINT (3)

- Delivery to the Pacific Fleet was postponed because it was recognized that the hydrofoil state-of-the art was not adequate to produce a fleet hydrofoil with acceptable operational reliability. In spite of this, the initial version of HIGH POINT underwent extensive calm and rough-water trials.
- Because the ship still displayed some shortcomings, a decision was made in October of 1964 to perform extensive repairs and refurbishment. Much was learned during subsequent trials and operations which lead to major modifications proposed and made by The Boeing Company starting in l97l under the "MOD-l" (modification) program.
- Among the many changes, the major ones included steering and automatic controls, hydraulic system improvements, relocation of the propulsion pods, redesigned gears for the foilborne transmission system, new propellers, and the incorporation of strain gauges and video cameras at critical locations for gathering data during trials.

PCH-1 USS HIGH POINT (4)

- Shown below are comparison photographs of HIGH POINT on blocks before and after major modification of the propulsion pod and foil to strut intersection arrangement.
- These changes were made because of unforeseen effects of cavitation on the foils, transmission pods and propellers.
- Subsequent to MOD-I, HIGH POINT attained a level of availability that was significantly higher than that previously experienced



PCH-1 USS HIGH POINT (5)

- 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 (6)

- Ship's legacy could rise again - after it was decommissioned in 1989, it quietly changed hands several times before coming to languish at Astoria Oregon's North Tongue Point around 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 eight 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

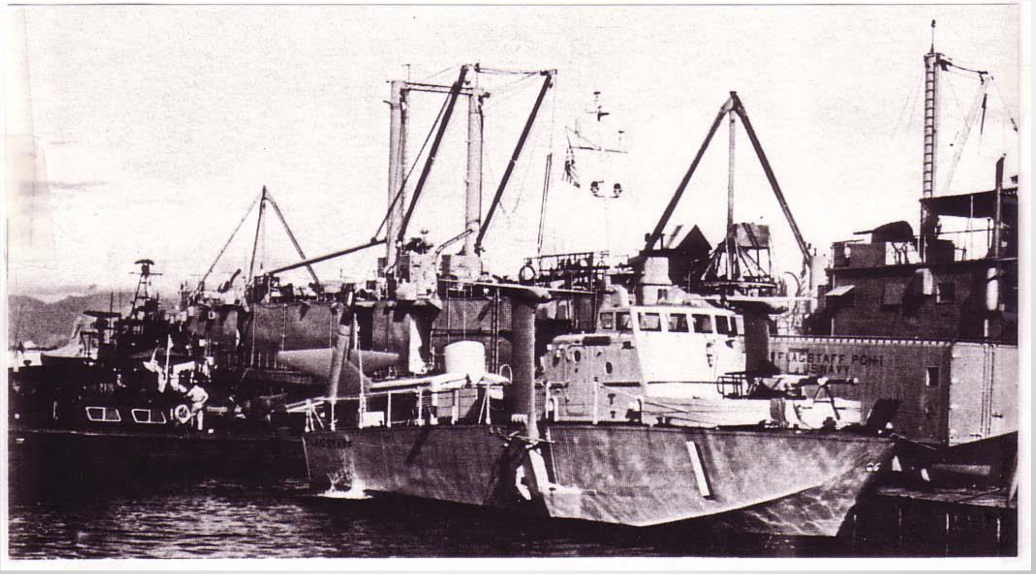
- *LITTLE SQUIRT* a 5,500 lb, 20-foot runabout with a stepped W-form hull designed and tested in the early to mid-1960s by Boeing to explore the idea that a waterjet could propel a hydrofoil craft.
- Boat used a centrifugal pump producing a flow rate of 3,600 gallons of water per minute out the stern; hence its name. The pump was powered through a reduction gear by a 425 HP Boeing gas turbine engine (at that time Boeing had such a small gas turbine as one of their product lines and anticipated wide use on trucks and small craft).
- Two foils were placed forward and one aft. Each foil had trailing edge flaps, but in addition, lift was controlled by changing the incidence of each foil. The flaps were 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 mean, or average water surface.

PGH-1 USS FLAGSTAFF

- Two hydrofoil patrol gunboats were built for U.S. Navy fleet operational evaluation in the late 1960s.
- Although they were designed and built to the same performance specification, their configurations were different. PGH-1 was propeller driven and had a conventional (airplane) foil configuration, whereas TUCUMCARI (PGH-2) was waterjet propelled and had a canard foil arrangement. Delivered to the Navy in 1968, they both saw service in Vietnam between September 1969 and February 1970, making them the first U.S. Navy hydrofoils in combat.
- FLAGSTAFF, named after a city in Arizona, was designed and built by Grumman Aerospace Corporation.
- The ship was 74 feet long with a maximum beam of 37 feet and a displacement of about 69 tons. Draft was 4.2 feet with foils retracted, and 13.5 feet with foils extended. This 69-ton hydrofoil, with its airplane foil configuration, carried 70% of the lift on the forward, main foils and 30% of the lift on the aft foil. Manning was 4 officers and 12 enlisted men

PGH-1 USS FLAGSTAFF (2)

After completion of performance trials, FLAGSTAFF was transported to Vietnam for riverine operations. The 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

- A Proteus gas turbine engine gave this 57-ton hydrofoil a speed in excess of 40 knots. The ship was 72 feet long, had a beam of 35.3 feet, and had a draft of 4.5 feet (foils retracted) or 13.9 feet (foils extended). The crew consisted of one officer and 12 enlisted personnel.
- Design of *TUCUMCARI* started with a contract award to Boeing in 1966. By July 1967, the hull of PGH-2 was built in Portland OR and transported to one of Boeing's plants in Seattle WA for completion and outfitting. Delivery of the ship to the US Navy took place on 8 Mar 68 at a cost of US$ 4M.
- *TUCUMCARI* was deployed to Vietnam with *FLAGSTAFF* in Nov 1969 for riverine operations near Danang and evaluation in a wartime environment.
- Following her tour of duty in Vietnam, *TUCUMCARI* was deck-loaded on *USS WOOD COUNTY* and transported to Europe for a NATO tour and demonstrations. From Apr – Oct 1971, she operated in European waters, while performing numerous demonstrations and combat exercises.
- Upon returning from Europe, *TUCUMCARI* was assigned to the Amphibious Force in the Atlantic Fleet. However, it was a sad ending to a distinguished period of performance when -- in Nov 1972 -- she ran onto a coral reef at Caballo Blanco, Vieques Island, Puerto Rico. Fortunately there were no serious injuries to the crew. The ship was salvaged and transported to Norfolk VA, where it was decided not to attempt repair of the extensive damage.

PGH-2 USS TUCUMCARI (2)

AGEH-1 USS PLAINVIEW

- Initial design by Grumman Aircraft Engineering Corporation. Detail design and construction by Lockheed Shipbuilding and Construction Co. (formerly Puget sound Bridge and Drydock Co.), Seattle WA teamed with W. C. Nickum & Sons, Ruker, General Electric, Hamilton Standard, and Lockheed California.
- Keel was 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 and an extreme beam with foils down of 70.8 feet. It attained foilborne speeds of over 50 knots from two General Electric LM-1500 gas turbine engines driving two supercavitating propellers. Two Packard diesel engines drove propellers for low-speed hullborne operations. The large foils were forward, and a smaller foil was located aft, which puts the foil arrangement in the conventional, or airplane category.
- PLAINVIEW made its first foilborne flight of 11-1/2 minutes on 21 March 1968, but it was nearly a year later, 3 February 1969, that it began Preliminary Acceptance Trials.
- On 1 March 1969, the Navy reluctantly took delivery and assigned the ship to the Navy Hydrofoil Special Trials Unit (HYSTU) located at the Puget Sound Naval Shipyard in Bremerton, Washington for administrative and technical control.
- This was nearly 3-1/2 years later than the originally projected delivery date. Much of this delay was due to 3 major strikes during the construction period. *PLAINVIEW* was far from problem free at time of delivery.
- 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 (2)

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 supercavitating propellers with a diameter of 5.2 feet and a design rotational speed of 1,700 rpm. A visitor to the David Taylor Research Center in Annapolis MD will see one of these propellers mounted on a pedestal near the Center's main entrance. The propeller's titanium structure remains sparkling bright through all the elements wrought by the Washington DC weather!
- 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 (3)

- One of the objectives of the ship was to demonstrate the applicability of hydrofoils to Navy missions. Several operations included launching of torpedoes, the firing of missiles such as the Sea Sparrow, launching and retrieval of remotely piloted vehicles (RPVs), underway replenishment / personnel transfer, and multiple ship close formation flying.
- Unfortunately, soon after emerging from a program of deficiencies correction and returning to the trials program with many successful operations in its log, *PLAINVIEW* fell victim to the Congressional budget knife. She made her 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.
- The ship was officially inactivated on 22 September 1978 and towed to the inactive fleet at Bremerton WA. In May of 1979, the hull (less the struts and foils, gas turbines, and other special equipment) was sold to a private party for the sum of $128,000.
- Engines, foils, and transmissions were retained by the Navy for possible use on another prototype hydrofoil or another advanced naval vehicle. The final indignity for this once proud and beautiful ship was being relegated to resting on a mud flat near Astoria Oregon.

PHM-1 USS PEGASUS

USS PEGASUS (PHM-1) **- US Navy Patrol Combatant Hydrofoil - Missile**
Built by Boeing Marine Systems (BMS), launched June 1974; first foilborne flight February 1975; commissioned into service July 1977.

PHM Beginnings

- The U.S. Navy ship acquisition process historically requires approximately a 7-year development cycle for the definition, design and first unit construction of a new ship platform. As the schedule of major events on the next slide shows, about six years elapsed from the signing of the contract for the design and construction of the lead ship and its commissioning and delivery to SURFPAC (Surface Forces, Pacific).

- The NATO PHM was the first U.S. Navy ship program to complete all aspects of the design, construction, technical evaluation, and independent operational evaluation as required by Department of Defense "fly-before-buy" policies required of selected DOD system acquisition programs. The extensive pre-delivery test and evaluation program, including problem resolution and corrective actions, accounted for more than a 2.5 year time span from launch to delivery.

PHM Beginnings (2)

- The need for a relatively small, fast ship to counter the proliferation of Soviet and Warsaw Pact missile boats, such as this Soviet hydrofoil, *BABOCHKA* (shown here) was articulated in the late 1960s by the NATO Commander-in-Chief of its Southern Command.

- This requirement was researched by the appropriate groups within the NATO Naval Armaments Group, ultimately leading to a tripartite agreement between United States , the Federal Republic of Germany and Italy in 1972 , for the design, development and acquisition of the NATO PHM . This program was strongly supported by Admiral Elmo Zumwalt, who was then the U.S. Navy's Chief of Naval Operations (CNO). This hydrofoil craft was to play a major role in his new "high-low mix" vision for the U.S. Navy's shipbuilding program.
- In November 1972, the NATO PHM Project Office and Steering Committee were formed. The USA was the lead nation for design, development, and acquisition and chaired the three-nation steering Committee.

PHM Beginnings (3)

- NATO-agreed basic operational characteristics for the PHM are shown here.

PHM Characteristics

- Displacement: 250 Metric Tons
- Length: 132.9 ft
- Beam: 28.2 ft (hull) 47.5 ft. (foils)
- Propulsion: 1- LM-2500 gas turbine (Foilborne) w/waterjet pump
  2- MTU diesels (1630 hp) (Hullborne) w/WJ pumps
- Crew: 4 Officers / 19 Enlisted
- Foilborne Speed : 40+ knots/Sea State 0; 40 knots/Sea State 5
- Hullborne Speed : 11 knots/Sea State 0
- Range: 750 nautical miles foilborne/1200 nautical miles hullborne
- Draft: 7.5 ft (foils raised) / 23ft (foils lowered)

PHM Beginnings (4)

- The two NATO production variants were to be very similar, the primary differences being in combat suites and certain internal arrangements.
- The US Variant was to be outfitted with the US Harpoon Surface-to – surface missile, mounted on the fantail, as shown here.

- The German Variant would mount French Exocet missiles in a similar configuration.

PHM Beginnings (5)

NATO PHM MILESTONES

- Nov 72: NATO PHM Program Office and Steering Committee Formed (US, FRG and Italy)
- Contract Let to Boeing Marine Systems for Two Lead PHMs
- Nov 74 PEGASUS (PHM-1) Launched
- 1975: Funds to Build PHM 3-6 Appropriated.
- 1976/1977: Funds to Complete PHM 2 Appropriated

PHM Beginnings (6)

- Later in 1972, the US Navy awarded a contract to Boeing for construction of two “lead ships” (actually prototypes, though the USA avoided use of this term in order to emphasize the maturity of hydrofoil technology to Congress).
- The PHM was to be a minimally manned ship, with only minor repairs to be accomplished aboard. For the US, prior experience with the similar Patrol Gunboat (PG) class suggested that a Logistics Support Ship to provide alongside berthing, routine upkeep and maintenance, fuel, and crew rest and messing facilities, should be included in the PHM program.
- This would be accomplished by conversion of the USS WOOD COUNTY (LST 1178) shown here.

PHM Beginnings (7)

- The decade of the 1970s were formative years for this new class of warship. As might be expected, the program experienced early difficulties, all of which were overcome, but not without effort and some cost growth.

- The initial USA planning figure for acquisition was 30 PHMs; this was reduced to 25 in 1974, and further reduced to 6 in 1975.

- Italy announced in 1974 that they would not enter PHM production; they would, however, continue to participate in design/development. That was the same year in which the USA reduced its intended "buy" to 25 ships.

- Germany remained a full partner in development, as well, but deferred any production decision until the US decision would be made.

PHM Production

- In 1972-73 Boeing experienced a variety of manufacturing problems including substandard aluminum welding, foil and waterjet propulsor cracking, foilborne gearbox design, and outfit sequencing.
- As a result of cost growth resulting from the reduction in the buy and deficiency correction , the U.S. Navy issued a “stop work” order on *HERCULES* (PHM-2), and applied the funding saved by this action to the successful completion of *PEGASUS (PHM-1)*. First PHM production buy was reduced to an initial procurement of six ships.
- PHM-1 was launched in November 1974, and soon began the most extensive technical and operational evaluation (TECHEVAL and OPEVAL) that had been conducted on any US Navy ship at that time. She is shown here in OPEVAL successfully launching a HARPOON missile in Sea State 3.

PHM-1 USS PEGASUS



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Built by Boeing Marine Systems (BMS), launched June 1974; first foilborne flight February 1975; commissioned into service July 1977.

PHM-1 USS PEGASUS

PHM Class Characteristics

Displacement	241 metric tons maximum
Length	40.5m foils down 44.3m foils up
Beam	14.5m
Draught	7.1m foils down 1.5m foils up
Maximum speed	48 kt foilborne 12 kt hullborne
Range	1300 km at 40 kt foilborne 3150 km at 9 kt hullborne
Foilborne propulsion	GE LM2500 gas turbine 13,400 kw 2 waterjets
Hullborne propulsion	Two MTU 8V 331 TC81 diesels 1220 kw 2 waterjets

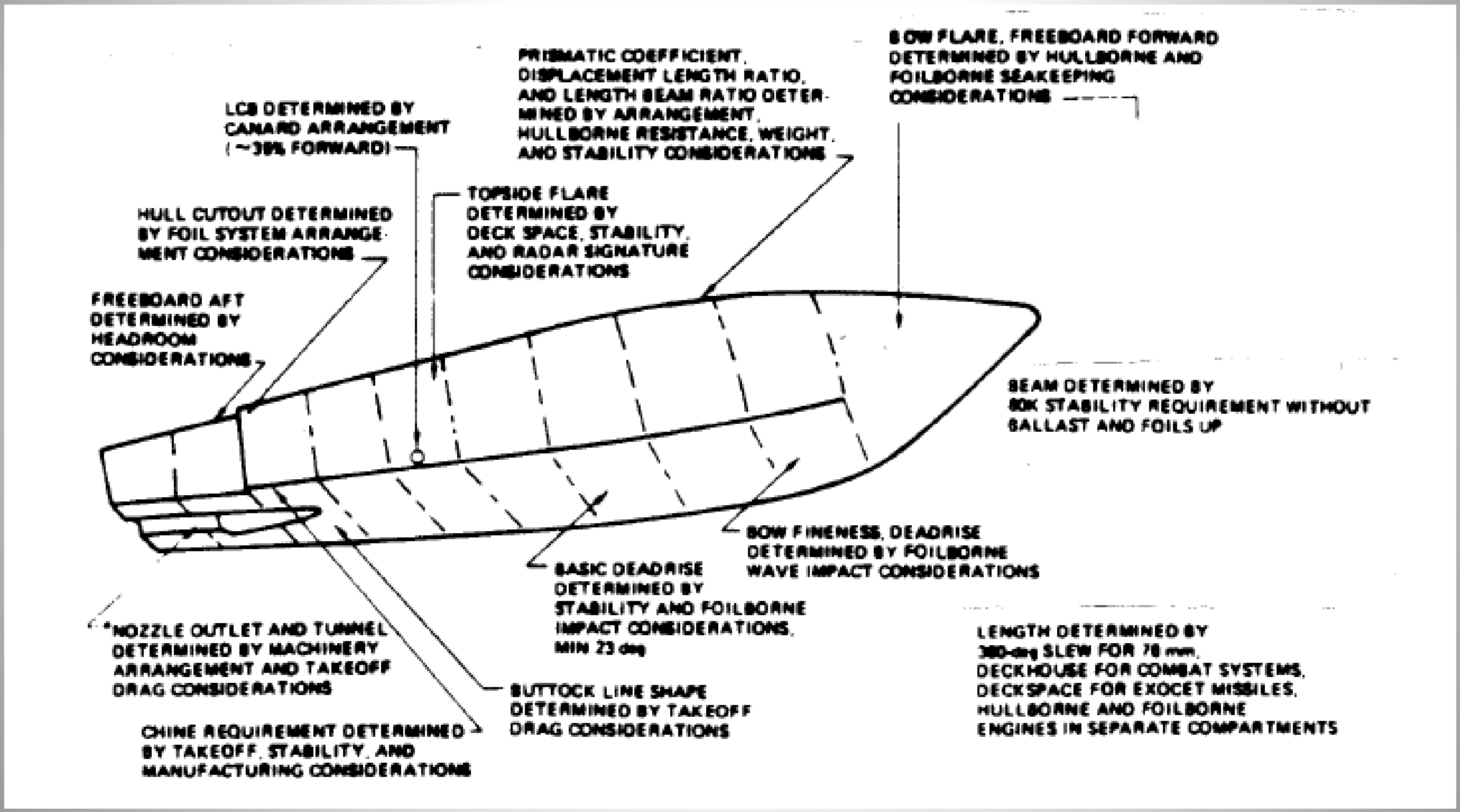
PHM-1 Launch

USS PEGASUS on Cradle

USS PEGASUS Launching

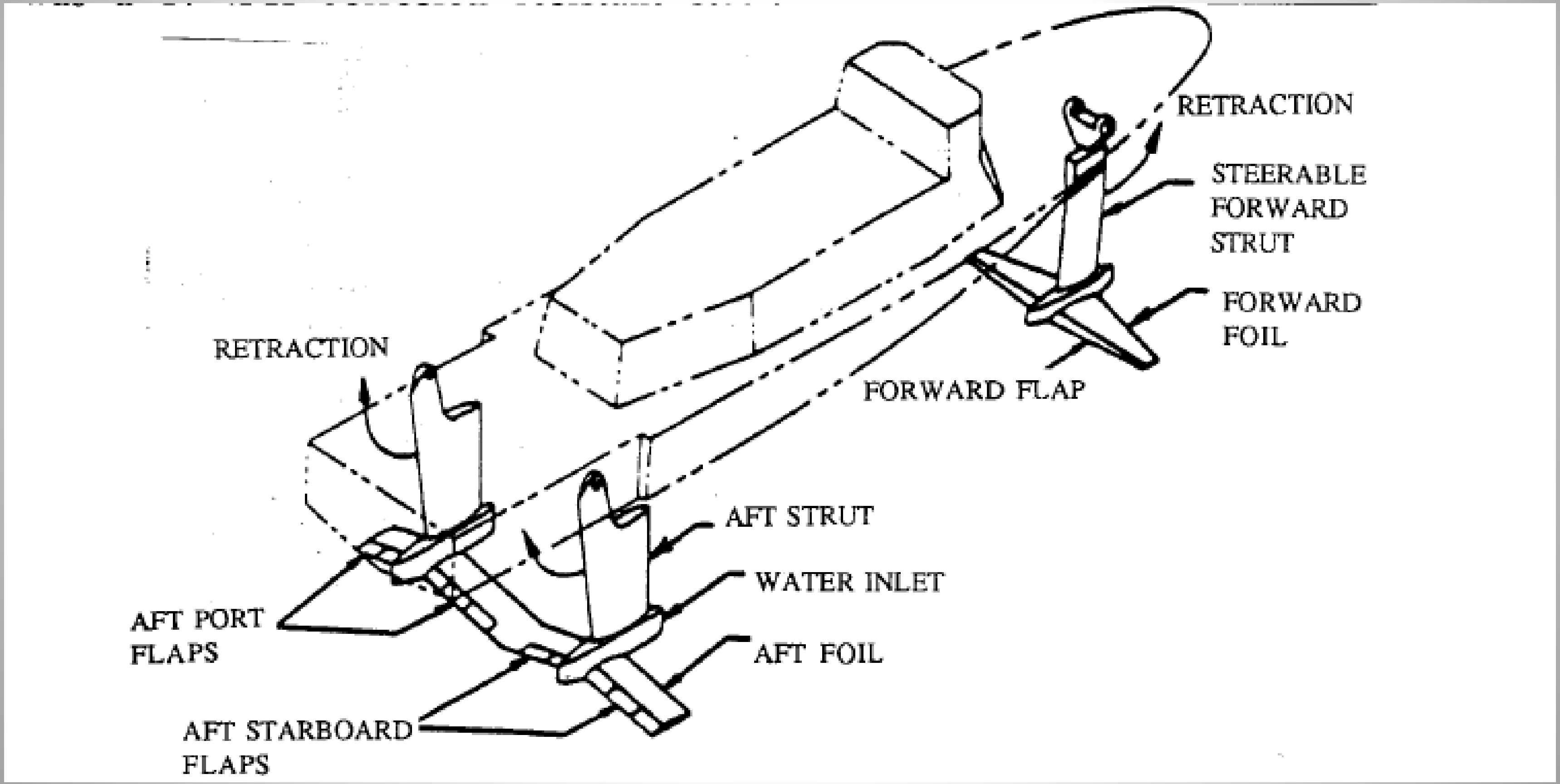
PHM Design

- *Hullform Design Considerations*



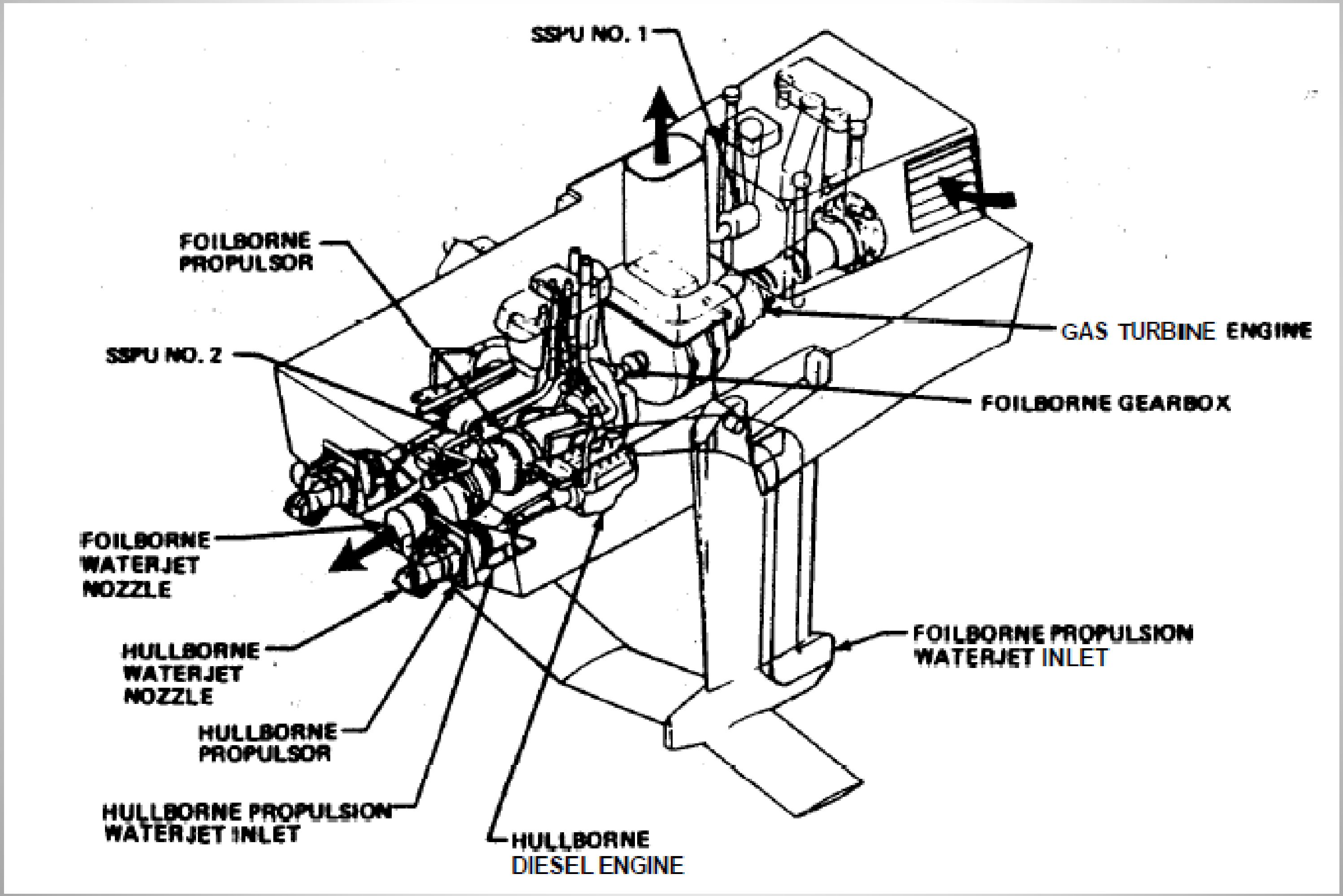
PHM Design (2)

- *Foil System Configuration*



PHM Design (3)

- *Propulsion System Arrangement*



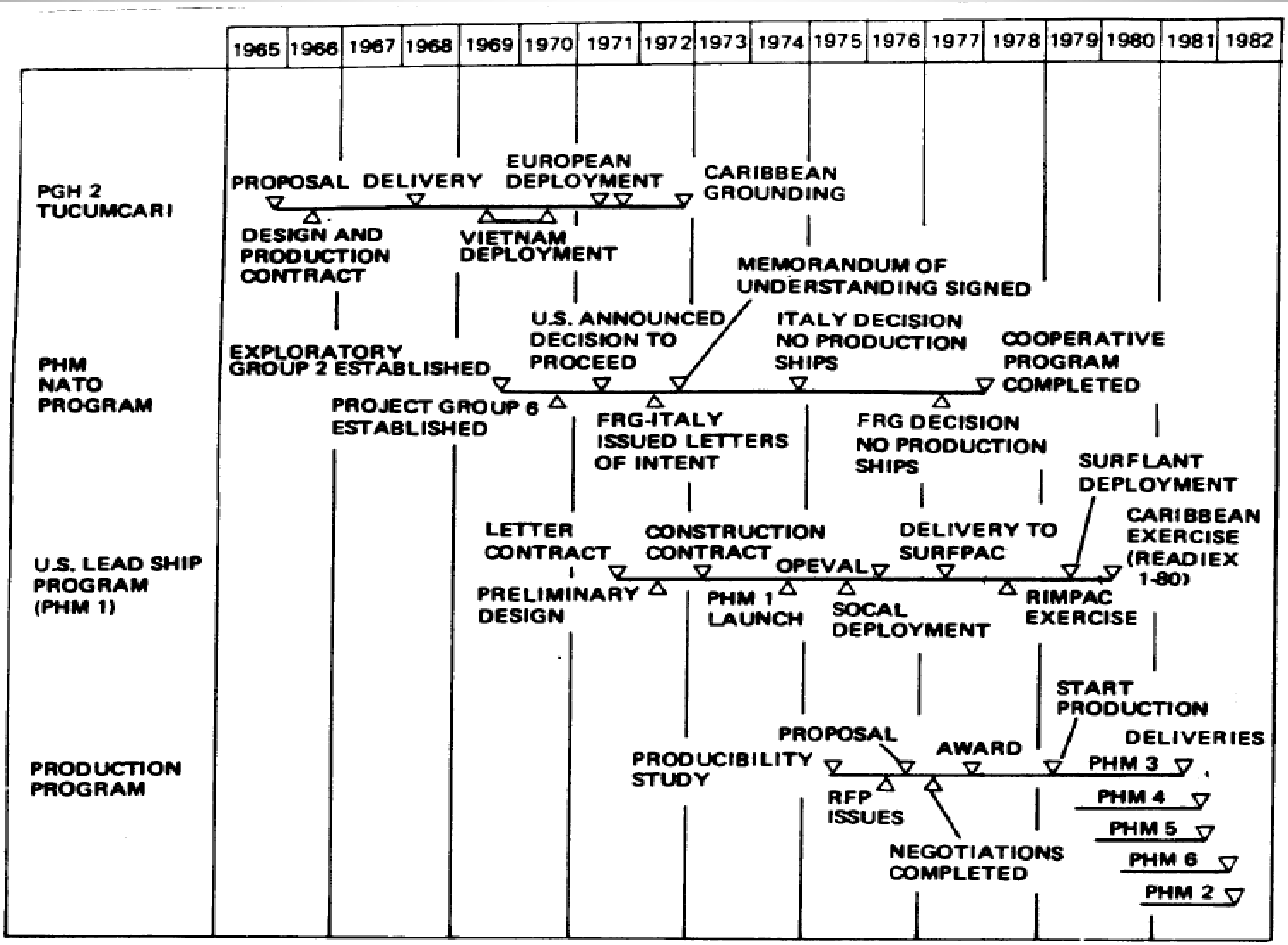
PHM Program Evolution

- By the completion of OPEVAL in the summer of 1976, PHM-1 had traveled over 25,000 miles - essentially once around the world.

- In 1975 the US Navy's program was reduced to a total of six ships; *PEGASUS*, plus four ships for which funding had been appropriated in 1975, plus completion of *HERCULES* (to be appropriated in 1976).

- In May 1977, two months before the Congress reinstated the program, the German Navy announced its decision not to procure PHMs, effectively ending the NATO aspect of the program. Germany maintained that their decision was based on cost. The impact, if any, of the off-again on-again decision process in the US on the German Navy, is not known.

PHM Program Evolution (2)



Major Events Leading to the Operational PHM Squadron

PHM-3 Series Follow Ships

- *USS HERCULES PHM-2*: Commissioned July 1982

- *USS TAURUS PHM-3*: Commissioned October 1981

PHM-3 Series Follow Ships

- *USS AQUILA PHM-4*: Commissioned December 1981

- *USS ARIES PHM-5*: Commissioned April 1982

PHM-3 Series Follow Ships

- *USS GEMINI PHM-6*: Commissioned June 1982

PHM Operations

- Since the earliest days of planning, it had been expected that the ships would be utilized in the NATO Areas of Operations, primarily the Mediterranean, with occasional excursions into the North Sea and the Baltic. This planning was consistent with and responsive to the original requirement enunciated by NATO in the early '60s.

- Absence of a dedicated support ship (among other things) to accompany the PHMs on long open ocean transits, made the concept of overseas home-porting an attractive one compared to relatively frequent transits from the US to the European theater. The US Commander in Europe agreed and plans were made to homeport the ships at Augusta Bay, Sicily, which was centrally located for employment and close to NATO and US national support.
- Delays in delivery of the production PHMs and concern about Pegasus' material condition resulted in several cancelled trial deployments. PEGASUS was home-ported initially at Little Creek, VA in 1979, awaiting the arrival of her sister ships.

PHM Operations (2)

- In 1980, PHM-1 homeport was shifted to Key West Florida where she could participate in the US Navy's contribution to the "War on Drugs" while awaiting delivery of PHMs 2-6.
- The production ships and the shore-based, but transportable PHM Mobile Logistic Support Group were delivered to Key West over the next three years, with the full squadron (PHMRON TWO) constituted in Spring 1983.

PHM Operations (3)

- The Navy put the overseas home-porting plan on indefinite hold, citing the need to refine the PHM logistic concept, to develop tactics and generally gain more experience with the ships. This plan was never revisited, and for the next ten years PHMs operated solely in the Caribbean, western Atlantic and Gulf of Mexico. The ships' operational employment was similar to other USN ships operating in those areas.

- **WAR - Grenada**
- **Battle Group Workups**
  - **Usually "Orange Force"**
- **Port Visits**
  - **East Coast/Carib/GOM Ports**
- **Developed Fast Ship Tactics**
  - **With USN and Foreign Navies**
- **Trial Deployments**

PHM Operations (4)

- PHMs excelled in counter-drug operations and were able to perform missions that USCG WSES (surface effect ship) cutters could not. This was because of PHM superior speed/sea state operational envelope.
- Counter-drug operations were very successful:

- **3% of Navy Ships Accounted for 30% of Navy-assisted "Busts"**
- **225,000 Lb MJ, 12,000 Lb Cocaine**
  - **Street Value $1.2 Billion**
- **Received 22 Unit Awards from USCG**
- **PHM is: "Superior Platform, . . . The Most Effective Surface Asset . . ." (in Many Counter Drug Scenarios)**
  -- Commander USCG District 7 (AUG '92)

PHM Operations (5)

Why Was the PHM So Effective?

SPEED

- Could Cover Larger Areas in Shorter time
- Faster Turnaround Between Station and "Home Plate"
- Could Intercept Other High Speed Craft

Intercept Problem:

- Target Heading North at High Speed
- Can Patrol Intercept?
- "Limiting Lines of Approach Solution"

THIS REPRESENTS A PATROL CRAFT (BLACK TRIANGLE ON THE LEFT) OPERATING OFF THE COASTLINE. ON THE LEFT

PHM Operations

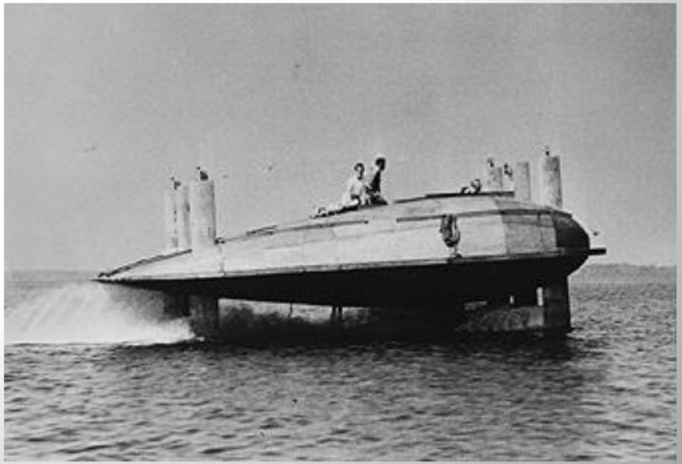
- Continue with more slides on operations.

- Wrap up with reasons for early DECOMM

- *Early Hydrofoil Development*

LANTERN (HC-4)

- Designed and built by the Hydrofoil Corporation, Annapolis MD, USA, one of the earliest hydrofoils to use electronic controls.
- First flew in 1953, had tandem submerged foils, displaced about 10 tons, 35 feet long with a beam of 22 feet. The control system was a straight adaptation of an aircraft automatic control system.
- The craft was unusual from another point of view: the foils, struts and hull were all the same shaped section, namely a symmetrical 24% thickness ratio NACA airfoil section. *LANTERN* was powered by a 200 hp Chrysler marine engine, had a takeoff speed of 14 knots, and a maximum speed in calm water of only 18 knots.

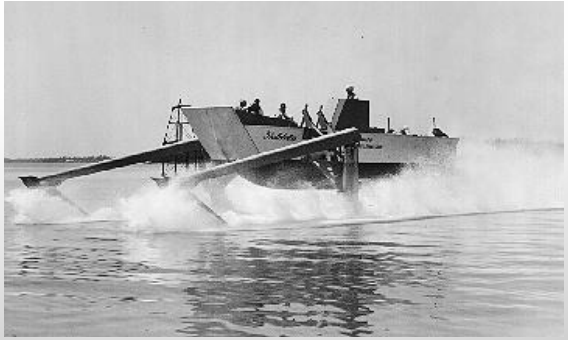


MASSAWIPPI

45-foot hydrofoil craft also known as R-100 or KC-B, during 1953 trials. First of four experimental hydrofoils that Canada's DREA (Defense Research Establishment Atlantic) operated between 1950 and 1979.

HALOBATES

- Program initiated in 1954 and completed in 1957 by Miami Shipbuilding Corp. for USMC, to evaluate a hydrofoil-supported landing craft designated LCVP. The craft is shown here with "feeler" arms adapted from the Hook system.
- Modified small landing craft was 35.5 feet long with a beam of 11.7 feet and displacement of 31,000 pounds. A 630 hp gasoline engine enabled speeds up to 34 knots in 5-foot waves.
- Design complicated by the use of many ball and screw actuators necessary to provide retraction of the foil and propulsion system for the landing craft. In spite of relative success, this configuration led to the observation that if this is the way hydrofoils are to be built, the US Navy has no use for them! The feeler concept was certainly objectionable, and was abandoned.



HIGH POCKETS

- In 1951, the US Navy contracted with Baker Manufacturing Co. of Evansville WI for two 24 ft. hydrofoils. These projects were directed by Gordon Baker, who has been described as a mechanical genius.
- First of these craft, *HIGH POCKETS* had a surface-piercing foil configuration, i.e. four retractable "V"-foils that could be steered and rotated to allow banking into a turn. *HIGH POCKETS* was the first hydrofoil to embark the then Chief of Naval Operations, Admiral Carney, in the summer of 1953.

HIGH TAIL

- Second Baker hydrofoil had a controllable, fully submerged foil system. The 3-foil system, one forward & two aft, had three mechanical sensors touching the water ahead of each foil. Sensors provided input for controlling foil lift. Propeller driven by an inboard marine engine through an angled shaft.
- Forward foil and struts were mounted on a vertical axis to provide steering while flying. Foils, sensors, & propeller were hydraulically retractable for operating in shallow water. Foils were quite small and lift control was obtained by changing foil incidence relative to a fixed reference using a mechanical/hydraulic autopilot.
- Conclusion was that future autopilots should be electro-hydraulic. Baker's contributions during this experimental stage of hydrofoil development were significant and helpful for future design.

CARL XCH-4

- 16,500 lb, 53-foot craft known officially as "Experimental Craft Hydrofoil No. 4," unofficially as "The Carl Boat" after its principal designer, William P. Carl.
- Seaplane type hull supported by two sets of foils forward, and a single strut and foil aft. Two 250HP Pratt and Whitney R-985 aircraft engines with two-bladed 8-ft diameter controllable pitch propellers provided thrust to carry this craft to the highest speed attained since those achieved by Alexander Graham Bell's *HD-4*.
- During trials of the *CARL XCH-4* in 1953, the design speed of 65 mph was exceeded in 3 to 4 foot waves. In USN tests off Long Island NY, someone called the US Coast Guard to report that "A seaplane had been trying unsuccessfully to take off and undoubtedly needed help", an understandable error in view of the craft's appearance!

CARL XCH-6

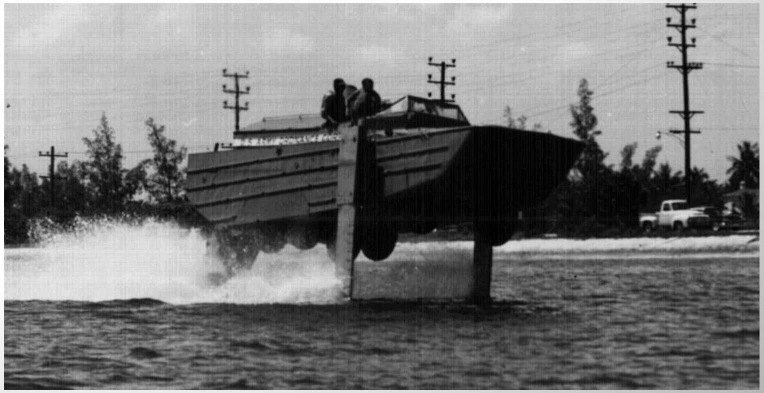
- *XCH-6* built by Dynamic Developments, the joint venture by Carl and Son, and Grumman. *XCH-6* first flew in August/September time frame of 1959.

- *XCH-6* had a 19 foot aluminum hull built by Grumman with similar lines to the popular Grumman 16 foot runabout. The *XCH-6* however had a step, which was a holdover from Grumman's experience on seaplanes.

- *XCH-6* propulsion was a General Electric gas turbine greatly de-rated to about 250-300 HP. The hull had a 4 foot stern extension to accommodate the gas turbine. Main foils and struts were patterned after those eventually used on the MARAD *Denison*.

FLYING DUKW

- Colonel Frank Speir, Project Engineer of the Army's Amphibious Warfare Program until the time of his death on 8 July 1956, one of the fathers of the US Army's DUKW, thought that foils could increase the sea speed of this vehicle.
- He initiated a contract with Lycoming Division of AVCO and Miami Shipbuilding Corp to build a prototype. Adapting data from *HALOBATES*, including its autopilot, and using a Lycoming T-53 gas turbine for main propulsion, a flying DUKW was designed, and successful demonstration trials were conducted in Miami waters. Speeds in excess of 30 knots were demonstrated (compared with the 5 knots of the conventional DUKW).



LVHX-1 and *LVHX-2*

- Following successful trials of *HALOBATES* in the late 1950s, Lycoming Division of AVCO built *LVHX-l* based on the *Flying DUKW* design. *LVHX-2*, a competing version of the same craft, was built by Food Machinery Corp.
- Both craft were built to meet the same requirement, with aluminum hulls 38 feet long and a capability of carrying a 5-ton payload at a speed of 35 knots. *LVHX-1* had a submerged foil system, and *LVHX-2* employed surface-piercing foils forward with a single submerged foil aft.
- During the trials program that followed, it finally became clear that the complexities and costs of such features a foil retraction and high speed gas turbine propulsion presented too great a penalty to pay for the increased water speed. As a result, further pursuit of hydrofoil landing craft was terminated.