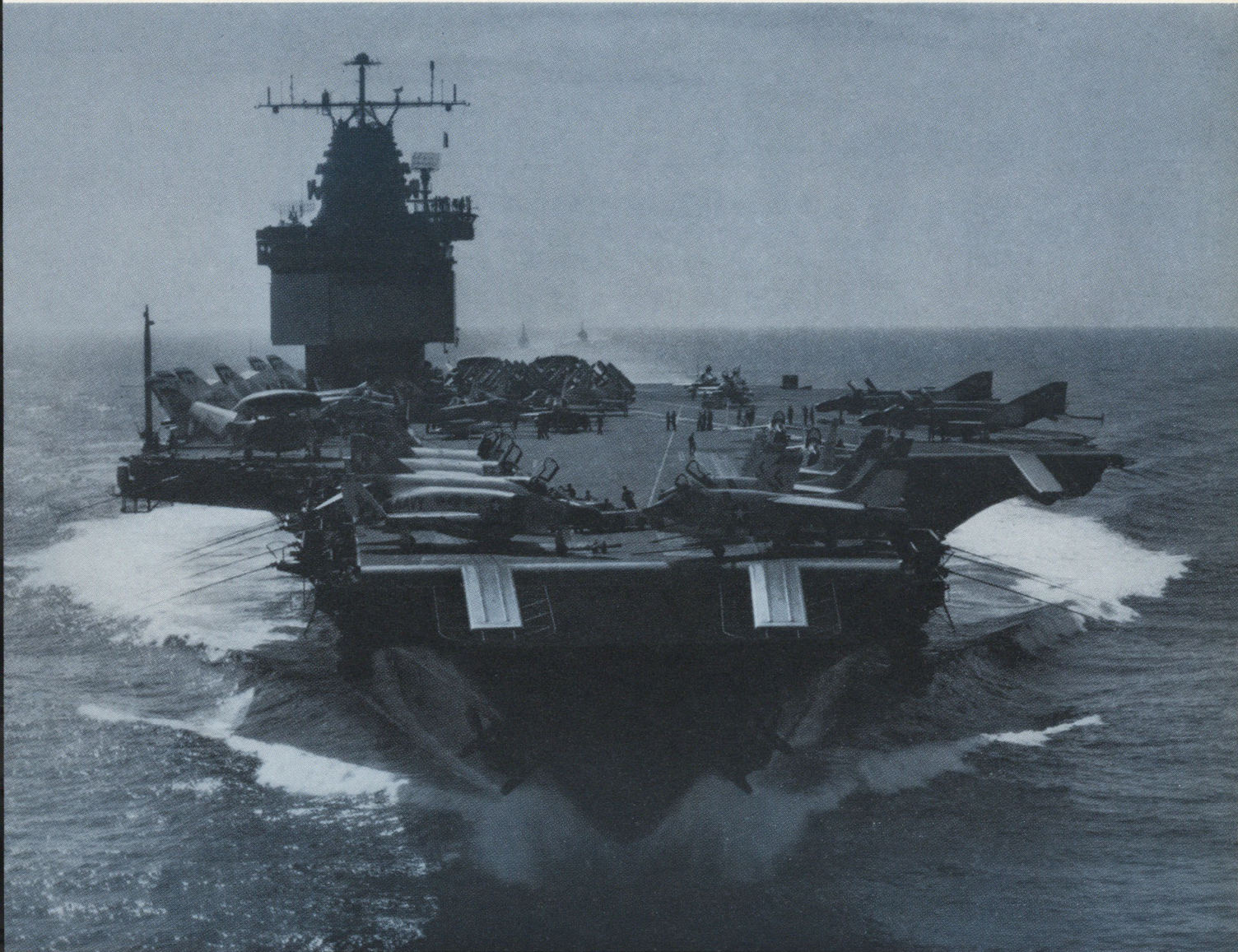


APRIL 1966

Air Force/Space Digest — *International*

PUBLISHED FOR THE LEADERS OF THE FREE WORLD BY THE UNITED STATES AIR FORCE ASSOCIATION



SEAPOWER IN THE SPACE AGE

SPECIAL REPORTS ON: TECHNOLOGY AND MODERN NAVIES

- SEAPOWER IN LIMITED WAR • ANTISUBMARINE WARFARE
- HYDROFOILS • UNDERSEA RESEARCH • NAVAL WEAPONS



This is a horse.

**(It must be a horse.
The First Cavalry rides it.)**

The First Cavalry Division (AirMobile)
calls its mount Chinook.

Chinook takes its riders where the action is.

A whole platoon at once. Or an entire artillery
section. Complete with two howitzers,
gun crews, and ammunition.

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Boeing's CH-47A Chinook is 5,300 of them
rolled into one. That's the combined power
of its twin T55 engines, Avco Lycoming's
most muscular gas turbines.

Behind the T55 stand over 1,700,000
operational hours of gas turbine experience.
Most of them were logged in the skies over
Vietnam, where Avco Lycoming powers nine
out of ten whirlybirds.

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with each new assault mission in Vietnam,
where it's helping the Chinook carry the
First Cavalry's dragoons right into the heart
of battle.

It's something like the old days, when nothing
struck fear into the heart of an enemy like
a cavalry charge.

Only now that charge comes thundering out
of the sky, 5,300 horses strong.



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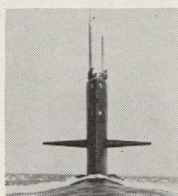
U.S. policy in Southeast Asia is centered around American determination to follow in the pattern of NATO and the programs that checked Russian moves toward aggression in the past. Doing most of the arguing about the U.S. stand in Vietnam are members of Congress, many of whom are seeking reelection this year.

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The "ship of the line," referred to in the 19th century as the most intricate creation of man, today staggers the imagination with its array of radar sensors, electronic equipment, and furnishings ranging from hospital, jail, and fire department to water-desalination plant, air conditioning, and sanitary system. The infinite complexity of a modern navy and its ability to react quickly in any area, as well as remain at sea for extended periods, illustrate the impact of technology.

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In limited-war applications in the past, the U.S. Navy has interdicted arms traffic to forestall subsequent escalation to a land campaign and has confronted naval forces of a potential enemy to bring about his withdrawal. Today, the Navy finds itself controlling the sea lanes in Southeast Asia to deny the enemy access to resupply by sea.

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Despite differences, there are many similarities between space and sea exploration. One man who should know is U.S. Navy Commander Malcolm Scott Carpenter, who has orbited the earth as an astronaut and served as an aquanaut in the Navy's Sealab II undersea research program. He urges much greater efforts to develop the kind of sophisticated equipment that has become routine in manned spaceflight.

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In this day of potential threat from the modern submarine to vital intercontinental sea routes, a requirement rises for a new type of ship—one that can travel at speeds above 60 knots under almost any weather condition.

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By Allan R. Scholin, Associate Editor



The U.S. Navy's aerospace power today resides primarily in its 8,000 aircraft, 27 aircraft carriers, and 32 nuclear-powered Polaris missile submarines. Here is a gallery of its aircraft—attack, fighter, patrol, antisubmarine, early warning, transport, trainer, utility, and helicopter types, many of them in service also in other Free World naval airarms—together with missiles extend combat range of aircraft, ships, and submarines.

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Two astronauts, who were to fly the Gemini-9 mission, have been killed; the Defense Secretary and USAF Chief of Staff differ over need for manned bomber; and a Congressional subcommittee report criticizes Air Force close-support in Vietnam.

Northrop landing systems have brought every astronaut down from space.

It's only a beginning.



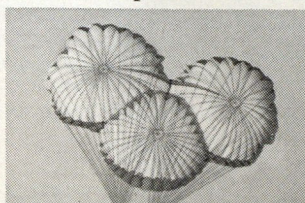
When valuable payloads return from space, Northrop landing systems bring them gently down.

Eleven times, America's astronauts have watched Northrop Ringsail parachutes blossom above their spacecraft.

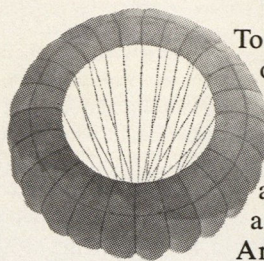
When the Apollo explorers set out on their round trip to the moon, a Northrop landing system will be packed away in their return vehicle.

Future astronauts may not come down in the ocean. They'll glide to landings on airport runways. Northrop built the M2-F2 and HL-10 lifting-body research gliders for NASA.

Northrop is also working on steerable parachutes like



the multi-canopy Cloverleaf. From 10,000 feet up, the Cloverleaf can be steered to any landing spot within an 8-mile circle.



To ease the final bump we're working on devices like the Skirt Jet lander. A ring-shaped rocket fires just above the ground, bringing a heavy vehicle to a stop in midair and letting it settle gently, even on a rough surface.

Another bump-softener is a parachute with a hole in it. Tests of this annular chute indicate higher drag with less weight than even the veteran Ringsail. It looks most promising for aerial recovery—where returning vehicles are snatched by aircraft before they reach the earth.



How will spacecraft land softly on Mars? Its environment poses special problems. High-temperature drogue chutes, very large main parachutes, landing sensors, impact shock absorbers will be required. We're working on all of them.

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Letter from Washington

Most members of the U.S. Congress will seek reelection this year, and the Vietnam argument that is raging among the members more than it is with the President, whose program in Vietnam is certain to win support when it is time to vote. Basic to the whole matter of policy in Southeast Asia is the American determination to follow in the pattern of NATO and the programs that checked Russian moves toward aggression in the past.

The Vietnam Debate: To Stand Firm or Fall Back

By Claude Witze, Senior Editor

Washington, D. C., Feb. 28, 1966

Last week there was a national holiday in the United States, to mark the birthday of George Washington. He was our first President and his name is engraved in history as "The Father of His Country."

Looking back over the years, and particularly through the smoke of this winter's debate about the war in Vietnam, it is easy to see why George Washington had reservations about his elevation to the Presidency.

"My movements to the chair of Government," he wrote in 1789, "will be accompanied by feelings not unlike those of a culprit who is going to the place of his execution. . . . Integrity and firmness are all I can promise."

Washington's current successor, Lyndon B. Johnson, must be credited with similar integrity and firmness, and it is clear he is going to need it all. It is a minority of men in Congress that must take responsibility for the misinformation, passion, and political venom of the Vietnam debate. General Maxwell D. Taylor said in testimony on Capitol Hill that the French lost their Indo-Chinese war in Paris, not at Dien Bien Phu. It does not seem possible that the United States will lose its campaign in Washington instead of Saigon, but the fact remains that some people hope a battle has been joined in the U.S. capital.

George Washington forms part of the background of this situation. When his public service was finished, he had among his parting words a warning that America should avoid foreign entanglements. The first President also was our first isolationist. He is for-

given, because he did not realize how technology and trade would shrink the universe. His words applied to his times, not to ours.

The entire world has watched the

American situation change. For purposes of this discussion, it is not necessary to go back further than World War II. There was heated debate in

(Continued on following page)



—Canfield in The Newark Evening News

"This is what LBJ calls a consensus."

Washington in the early 1940s when President Franklin D. Roosevelt provided some destroyers for Great Britain. The Senate saw, as it is seeing in 1966 over the Vietnam issue, a storm raised about other proposals to aid friends of democracy in Europe. The storm did not abate until the Japanese attacked Pearl Harbor, when the Roosevelt plea to "quarantine the aggressors" became academic, and proved he was right.

Then look at the postwar history. There was the Truman Doctrine, laid down in 1947. President Truman said "it must be the policy of the United States to support free peoples who are resisting attempted subjugation by armed minorities or by outside pressures. I believe that we must assist free peoples to work out their own destinies in their own way."

It was under this doctrine that the United States gave military and economic assistance to Greece and Turkey. Western Europe was given a strong start on the road to recovery and its present prosperity by the Marshall Plan. There was the Berlin Airlift in 1948, that called a halt to an early expression of Russian intransigence. Red Chinese aggression was fought for 3 years in Korea. It was stopped again by the American response to the Formosa Straits incidents. This country was counted against communism again and again—in Lebanon, Berlin, Cuba, and Thailand.

In each case there was an American military display, and in most cases it was a display that featured airpower, either in action or overhead as a persuasive umbrella. In the face of this postwar history, there still is a minority of Americans that ask: "Why are we in South Vietnam?"

There are times when President Johnson could be justifiably provoked by his critics. A prime example came up during the recent hearings of the Senate Foreign Relations Committee, where Chairman J. William Fulbright delivered a solemn soliloquy about atrocities. He recalled that in the waning days of World War II, American B-29 bombers used fire bombs in low-level attacks against Tokyo. The result was fire, of course, to the extent that fire storms were created in the city, killing more people than the nuclear bombs were to annihilate later at Hiroshima and Nagasaki.

Another Senator, Stuart Symington, broke in to tell Mr. Fulbright about a village in Vietnam where the Viet Cong had carried out what, for them, was a routine raid. They called the residents to the center of the village, where they lined up the mayor, his wife, and 4 children. The family

of 6 was disemboweled by Viet Cong soldiers in front of the assembled citizens. Mr. Fulbright's observation was revealing:

"I don't see the moral distinction," he declared, "between killing children and women with bombs and disemboweling with a knife because a knife is all you have."

There are few Americans who share Mr. Fulbright's view. Most of them see a moral distinction between the air raids on Berlin and Hitler's ovens, where the Jews were stripped, killed, and their bodies burned. That Senator Fulbright does not see the distinction is a commentary about the man, not about American policy in Vietnam.

Facing this kind of public debate, it is fortunate that President Johnson, unlike President Washington, has had a long political career with many years of experience in the Congress. This is an election year. All members of the House of Representatives must win the endorsement of their constituents next November. And one-third of the Senators also face a contest for their seats. This is reflected in the argument now raging.

In the heat of the fight a few days ago, a discontented and highly critical Senator—facing a television audience of millions of Americans—said that in his judgment, "the President of the United States is already losing the people of this country by the millions in connection with this war in Southeast Asia."

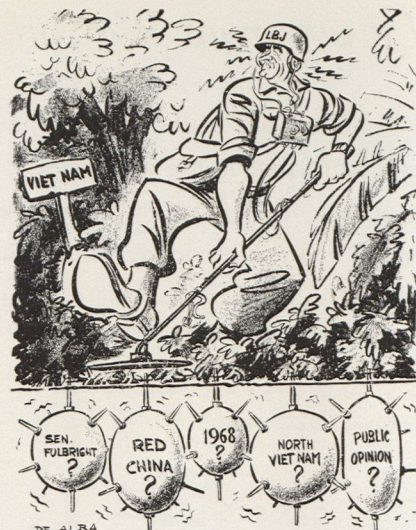
This is an extreme opinion that is not believed in America but will be greeted with cheers in Hanoi and Peking. President Johnson's reaction is that he believes he is weathering the debate. He says that he is pleased that the dissent is not deep or widespread. "I am rather pleased," he told reporters, "that the differences are as minimal as they are."

The President says his Administration is doing everything it can to end the war and to avoid a conflict with Communist China, adding:

"Our measured use of force will and must be continued. But this is prudent firmness under what I believe is careful control. There is not, and there will not be, a mindless escalation."

One result of the debate is that the barometer of public opinion is being swayed. One of the national polls disclosed today that President Johnson's support for his handling of the Vietnam War has dwindled sharply in the last 6 weeks. This, roughly, is the period during which the national argument has increased in intensity.

Support for the President, according to this count, has fallen from 63 to 49 percent of the public. At the



—De Alba in the Washington Daily News

The Minesweeper

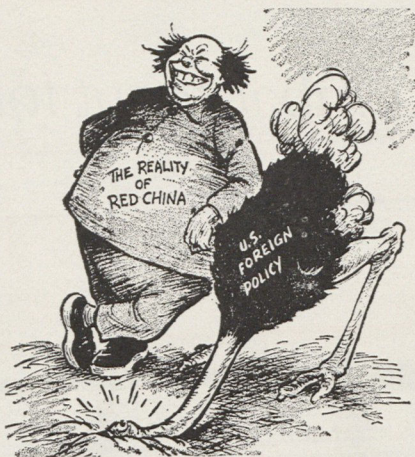
same time, 73 percent of the public approved of his decision to end the pause in the bombing of North Vietnam, which was permitted to last 37 days, while the President tried several doors in his hunt for peace.

It is significant that a third of the American people, in reply to more specific questions, appear to agree with the present policy but feel there should be an increased military effort to carry it out. About an equal number agree with the policy, but favor a stronger effort to bring about negotiation.

If there is anything surprising about the polls, it is that only about 8 percent of the people have not made up their minds, and have no opinion on the subject. With the amount of confusion resulting from the debate, and built into it, millions could be excused for not understanding the issues. In the course of the argument, a good deal of misinformation has been bandied about.

There is misinformation about the actual progress of the war, the stability of the Government in Saigon, the role of the sea- and airpower, the amount of control exercised in South Vietnam by the Viet Cong, and the outlook for a Communist victory if an honest election could be held in Vietnam. Even the history of the affair, going back 10 years or more, has been distorted.

Responsibility for this state of affairs can be traced to a number of things, none of them classified as deliberate falsehoods, and some due to a lack of candor on the part of the Administration itself. Most of the blame must be placed on politics. A high official from the White House said the other day that most of the



—Justus in The Minneapolis Star
Bird's-eye view.

discontent here in Washington is between sectors of Congress, not between the Presidency and Congress or between the President and the public.

The Senate Foreign Relations Committee again offers the best illustration. Our military policy in South Vietnam is not the subject of the hearings. The subject is a request for funds, \$275,000,000, for economic aid, not military aid, for South Vietnam.

Yet, with one major exception, all the witnesses heard by the committee have been cross-examined basically on military aspects of the effort in Vietnam. And the exchanges between Senators, those who support the policy and those who are critical of it, have been a major feature of the investigation.

The same is true, to a large extent, in the debate now running on the Senate floor. This involves the entire chamber, not a single committee of Senators. The military costs of the war in Vietnam are the real issue here, where action is needed on a supplemental appropriation of \$4,807,750,000 to support Army, Navy, and Air Force activity in Southeast Asia.

There is no doubt the money will be voted. But the critics are using the platform to air their views, despite the argument that there should be no debate on the military funds. Friends of the Administration hold that the headlines will encourage the Communists to prolong the war. Their opponents plead that they do not intend to cut off funds; they merely want to issue a warning against expansion of the Vietnam conflict into a major war.

It is clear that the result of this approach has, in the past several days,

forced the Johnson Administration to speak up more frankly about its views on Communist China.

In a statement to the Senate Subcommittee on Defense Appropriations, Defense Secretary Robert S. McNamara called the war in Vietnam "a test case of the Chinese Communist version of the so-called 'wars of liberation,' one of a series of conflicts the Chinese hope will sweep the world."

"If it succeeds," Mr. McNamara said, "it will encourage the partisans of violent political change in the Communist world to seek to extend their particular method of installing communism over all of the underdeveloped world. This aggression is a threat not only to the security of the United States and the entire Free World but, interestingly enough, also to the leadership of the Soviet Union in the world Communist movement."

The Defense Secretary cited a policy statement of the Chinese Communist Minister of Defense, Lin Piao. This says that China's long-range objective is to dominate Asia, Africa, and Latin America. They hope to create a new alignment, especially in the eastern and southern hemispheres, in which Communist China is the ideological leader and the most powerful country.

Secretary of State Dean Rusk has said that Lin Piao's outline is "as candid as Hitler's 'Mein Kampf.'"

"Had not the United States and other believers in independence gone to the aid of the people of South Vietnam," Mr. McNamara said, "the Viet Cong, directed by Hanoi and encouraged by Peking, would have, without question, succeeded in overthrowing the Government and seizing control. And, were they to succeed in South Vietnam, there can be no doubt that Communist China's efforts to support such revolutions in Asia and elsewhere would move forward with increased confidence and determination."

A more definitive and powerful statement on the Chinese threat was made by William P. Bundy, an Assistant Secretary of State, in a recent speech.

Mr. Bundy said that Communist China is dedicated to the promotion of communism by violent revolution. And that it is in Asia itself that this force is felt and where it must be countered by China's neighbors. Further, he said America must profit from the experience it had with Russia.

Mr. Bundy sees no hope that China will be diverted from a path of subversion, involving terrorism, selective assassination, guerrilla action, and, finally, conventional military force. He says we must think of these things and deal with them as they are. This means

we must have a basic policy similar to the one we have in Vietnam, of helping free nations save their freedom. Then came the real issue:

"These 2 fundamental elements of our policy have much in common with the policies that we and our NATO allies pursued so successfully in the areas threatened by the Soviet Union after the war. And surely there is, to a very great degree, a valid parallel between the situation we continue to face vis-à-vis Communist China and that we faced with the Soviet Union after the war.

"We have dealt with the Soviet Union fundamentally by assisting in the restoration of the power and strength of Europe so that Soviet ambitions were successfully checked. Since 1955, although Soviet ambitions remain, we have seen a trend toward moderation in Soviet policy and a turning inward by the Soviets to their domestic problems.

"There are, of course, myriad differences between the situation in Asia and that in Europe, in terms of sophistication of economic and political bases, the stability of the societies, and the unity of national cultures.

"But basic to our policy in respect to Communist China, as in the case of our policy toward the Soviet Union, must be our determination to meet with firmness the external pressure of the Communist Chinese."

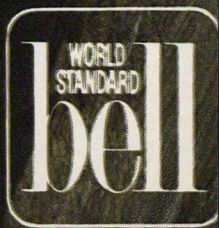
Mr. Bundy's conclusion is that America is Peking's great enemy "because our power is a crucial element in the total balance of power and in the resistance by Asian states to Chinese Communist expansionist designs in Asia."

The White House has offered a minimum of comment about the Chinese threat, but the newspapers are paying more attention to what they call the "ring of steel" around China. One news magazine, reporting on the vast construction program now under way in Southeast Asia, said last week that "the focus of world tensions has shifted in the last few years from Europe to Asia, and the prime threat to peace has become the risk that China will seek to establish dominance over all Southeast Asia. It is the avowed policy of the U.S. to prevent this from happening, and the expanding chain of U.S. bases in Asia puts Peking on notice that the U.S. is prepared to defend what it conceives to be American interests in the area wherever and however they may be threatened."

This is a policy that would make George Washington tremble. But it is an inevitable policy and one that the American people can be expected to support.

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Seapower in the Space Age

**A Message from
Admiral David L. McDonald
Chief of Naval Operations,
United States Navy**

This "Seapower" issue of AF/SD INTERNATIONAL examines important challenges that the United States Navy, and indeed all navies, face in today's environment of technical change. How well these challenges are met will determine the future effectiveness of navies in the military scheme of things.

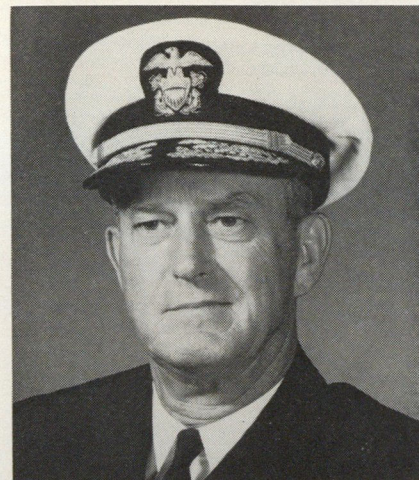
We must be able to operate with increasing effectiveness beneath as well as on and over the seas, and concurrently develop instruments to detect submarines at long range as surely as we now detect surface ships and aircraft.

We must continue to examine technology and tactics which permit navies uniquely to exercise power with restraint and discrimination or with massive force wherever called upon.

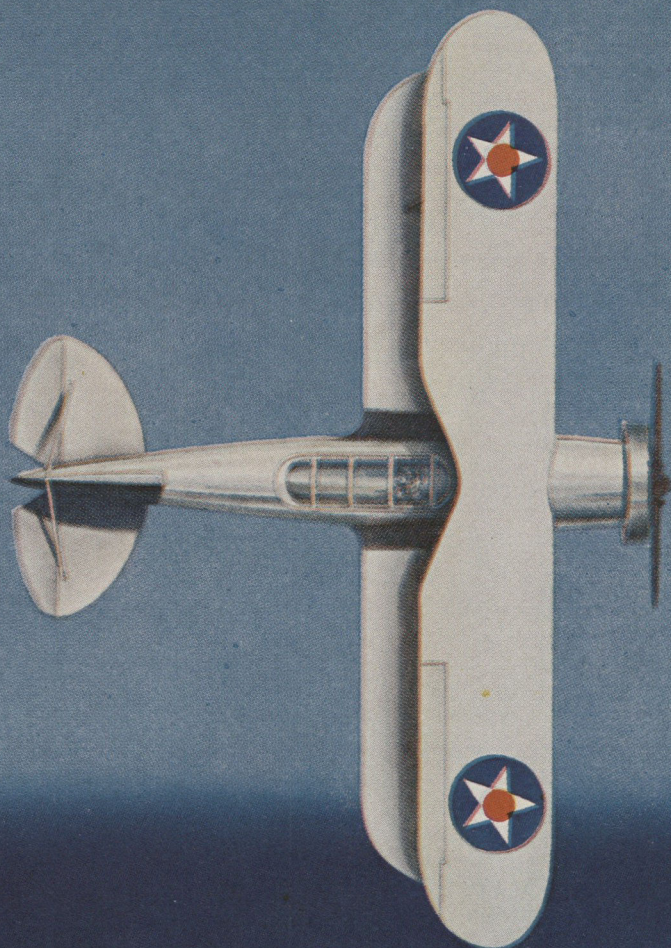
We must acquire and train the best men available to use technology and to apply it well to naval matters—be they missiles, satellites, data systems, nuclear propulsion, or systems still a gleam in someone's eye.

Navies, like other military services, have a tradition of adapting to change in the environment—in this case the sea—and meeting challenges as they come with energy and imagination. Flexibility has been a common characteristic among successful professional fighting men. I am confident that we, too, will employ change to our advantage with determination and wisdom for the preservation of free men everywhere.

After graduation from the U.S. Naval Academy in 1928, Admiral McDonald's career turned toward naval aviation and included command of aircraft carriers and carrier divisions as well as command of the U.S. Sixth Fleet and Naval Striking and Support Forces, Southern Europe. Before becoming Chief of Naval Operations in August 1963, Admiral McDonald was Commander in Chief, U. S. Naval Forces, Europe.



FROM FF-1



**TO F-111... MORE THAN
19,000 FIGHTERS**



GRUMMAN Aircraft Engineering Corp., Bethpage, N.Y.



In the 19th century, John Ruskin described the "ship of the line" as the most intricate creation of man. A modern combat fleet exceeds even that superlative. Today, airpower and missiles, electronics and computers, hydrofoil and air-cushion applications, and nuclear power which enables ships to remain at sea for extended periods, make a modern navy infinitely more complex than those of Ruskin's day . . .

Modern Technology and Naval Power

By Rear Admiral Harold G. Bowen, Jr., USN
Deputy Chief of Naval Operations for Development

The use, or misuse, of advanced technologies has influenced the outcome of many naval battles.

The most imposing assemblies of naval power ever arrayed against each other occurred at the Battle of Jutland during World War I. The entire fleet of the German Imperial Navy was pitted against the mighty Home Fleet of the United Kingdom. Neither force knew the position of its opponent and, except for the chance investigation of a Danish steamer (N.J. FJORD) by a squadron from each fleet, the forces may not have joined in battle at all. One war later, with the advent of naval aviation and radar, such close proximity without position knowledge would be most unlikely. The battles of Guadalcanal, where ship engaged ship

at night, were possible because of the magic of radar. This technology enabled an outnumbered and groggy U.S. force to stave off the efforts of Japan to supply and reinforce their garrisons and denied the Japanese control of seas in the immediate area.

During the same war, but halfway around the world, another battle involving radar and radar jamming (electronic countermeasures) occurred. The inevitable joust between measure and countermeasure was under way. The cream of the German fleet, consisting of the battle cruisers GNEISENAU and SCHARNHORST, cruiser PRINZ EUGEN, and escorts, had been bottled up in Brest, France, for about a year. The ships were continuously bombed and harassed by the RAF, but were

seldom out of commission for very long. A dash to the open ocean or up the English Channel to North Sea Dutch or German ports was expected by the British. The British established detection and attack forces to intercept any move by the German ships. These consisted of visual and radar detection posts on land, sea, and air, and attack forces from the Royal Navy and Royal Air Force.

The German staff decided on the Channel dash and knew they would have to plan well, effect complete surprise, execute precisely, and have good luck. Their planning was excellent; among other things they started jamming the coastal and aircraft radars at a subtle level weeks before the planned dash. The British took this to be "normal disturbances" and when the breakout did occur, radar detection was avoided for the entire Channel passage, and a jamming alarm was not raised because this had become accepted.

Detection finally took place 14 hours after leaving Brest just after the straits at Dover had been passed. Attack was pressed but little significant damage was done. Luck finally ran out when both the GNEISENAU and SCHARNHORST ran into mines in the North Sea and limped to port.

Similar, unpredicted events can be expected to result from the uses of technology in the future.

The design, construction, and maintenance of a modern naval fighting ship is an extremely complex, time-consuming, and costly endeavor. John Ruskin, in the latter part of the 19th century, described the "ship of the line" as the most intricate creation of



Born and raised on U.S. Navy stations as the son of a naval officer who reached the rank of vice admiral, and a 1933 honor graduate of the U.S. Naval Academy, the author, Admiral Bowen, has spent most of his career on sea duty. He served in the South Pacific for 3½ years in World War II. After 2 years with the American Mission for Aid to Turkey in 1947-49, he attended the Naval War College. In the Korean War, he commanded a destroyer division on blockade and patrol missions off Korea, and was twice decorated for actions in which, though outgunned, his division inflicted severe damage on North Korean shore batteries. He returned to Washington in 1958 to become Director of the Navy's Atomic Energy Division. Following another tour of sea duty as Commander of the Operational Test and Evaluation Force, he began his present assignment last June.

man. A modern warship far exceeds this superlative. For example, an aircraft carrier is comparable to a small city, with living quarters, hospital, jail, fire department, powerhouse, warehouses, water desalination plant, air-conditioning and heating systems, water and sanitary systems, etc.

On top of this is an airport, with hangars, runways, repair shops, and fuel supply system. All of this is crammed into a self-propelled fighting vehicle, with sensors to detect the enemy, weapons to destroy him, and facilities for internal and external communications. The structure of the ship must be able to withstand stresses from severe weather. The multitude of parts making up the ship must be designed for the predicted loads, and the many different equipments, with associated wiring or piping, must be fitted into minimum spaces without undue mutual interference with operation and maintenance.

A ship design goes through many cycles before shipyard working plans are produced. The strength of the structure depends partially on the weight of the structure. The propulsion power changes with the weight and volume of the machinery plant. The decision to use a lightweight machinery plant may require radical relocations of equipment and an increase in beam in order to maintain adequate stability, since the center of gravity of the ship would be higher than with heavier machinery. Many iterative design calculations of this type must be made.

In this sort of repetitive, complicated calculation, the mass memory and high calculative speed of modern digital computers may be used to great advantage. A substantial beginning has been made in applying computers to ship design, and it is expected that the design period can be shortened considerably. Beyond the design stage, it is possible to apply computers to produce magnetic tapes from computer-produced working plans. These tapes can control machine tools in the shipyard structural shops, with consequent speeding of ship construction.

Since the advent of steam propulsion for ships, naval tacticians have been able to conduct operations with a greater degree of precision and reliability than when dependent upon the vagaries of the wind. The use of steam required frequent replenishment of fuel and, if widespread operations were necessary, the establishment of a coaling station or an agreement with a friendly port or nation was required. Later, with oil as the prime fuel, resupply at sea became the accepted practice. Today, with nuclear power,



An A-4D Skyhawk approaches deck of nuclear-powered aircraft carrier, USS ENTERPRISE. With BAINBRIDGE and LONG BEACH (background), the carrier completed a 30,000-mile (48,280 km) round-the-world cruise in 60 days without resupply.

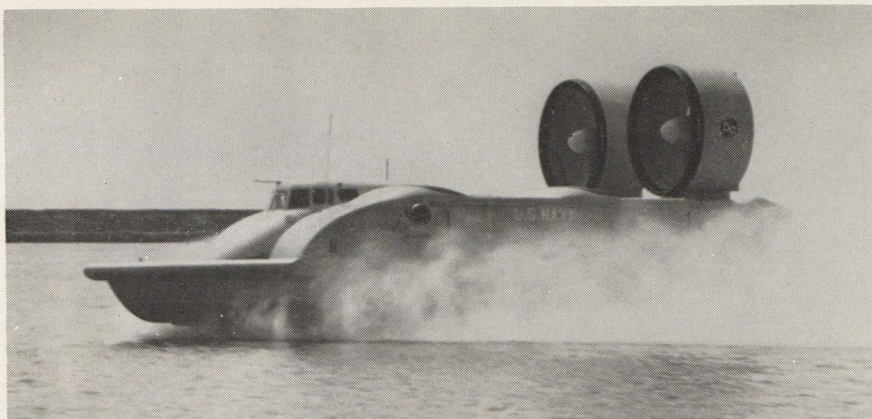
a source of energy is available that does not need replenishment for many thousands of miles.

A naval force utilizing nuclear propulsion is free to react quickly in any area and to remain at sea or on station for a long period of time. Nuclear power does not by any means solve the complete problem of resupply, but it does eliminate a major deterrent to sustained operations and tactical freedom. A show of force can be imple-

mented more quickly, over greater distances, without prior logistics moves, than ever before.

The 30,000-mile (48,280 km) round-the-world cruise of the U.S. Navy nuclear ships ENTERPRISE, LONG BEACH, and BAINBRIDGE is an example of what is possible. These ships completed the world cruise in 60 days, visited 18 ports in 10 countries, and no resupply of any kind was made except

(Continued on following page)



Largest air-cushion craft built in U.S., the hydroskimmer, can attain over-water speeds of more than 40 knots. Built by Textron's Bell Aerosystems Company, the craft, pushed by 2 10-foot (3 m) propellers, has 4 air-cushion fans in hull to lift it from the surface.

for occasional mail deliveries. Full employment of nuclear power would result in a capability that could be used to project the force of seapower to any area in the world on very short notice.

The ships and boats of most navies are displacement craft. That is, they are based on the principle of Archimedes, which states that a fluid acts on a body immersed in it with a net force (buoyancy) that is vertically upward and equal in magnitude to the weight of the fluid displaced by the body. Ships and boats, running at the waterline corresponding to their displacement, utilize much of their propulsive power in creating waves.

At high speeds, these waves become very large and reduce efficiency to a low level. Planing boats, such as PT boats, have relatively less resistance at high speeds because dynamic lift raises them out of the water and they lose less energy in wave making. Other technologies are used to reduce the drag for high-speed operation.

Hydrofoil ships use a foil section, similar to an aircraft wing, to create lift and essentially fly the ship almost entirely out of water. The air-cushion and the captured-air-bubble ships use fan-generated cushions of air to support the entire ship above the water; forward motion can be accomplished by an air propeller. These techniques have been successfully demonstrated. Improvement in various engineering aspects will provide usable vehicles with a significant increase in speed over displacement ships.

Naval aviation is essential for the modern navy unless operations are limited to very restricted waters. In the history of navies, the introduction of aircraft is comparatively recent. The British introduced the concept of the carrier after World War I. Until World

War II the aircraft carrier and aircraft were employed in a supporting role to the fleet. Today the carrier is the keystone of most types of naval forces engaged in the major functions of ocean control. Aircraft of various types and configurations enable the modern navy to project its strike, surveillance, and control functions over a large area of influence.

Two new developments that may have considerable impact on naval operations and Task-Force composition are the application of the variable-sweep wing and vertical/short takeoff and landing (V/STOL) technologies. The first of these, variable-sweep wing, makes multimission aircraft a real possibility. This will allow greater flexibility in selecting aircraft complements for the aircraft carrier and will increase Task-Force flexibility and efficiency. Aircraft incorporating variable sweep will be more efficient since fewer design compromises are required to provide supersonic speed,

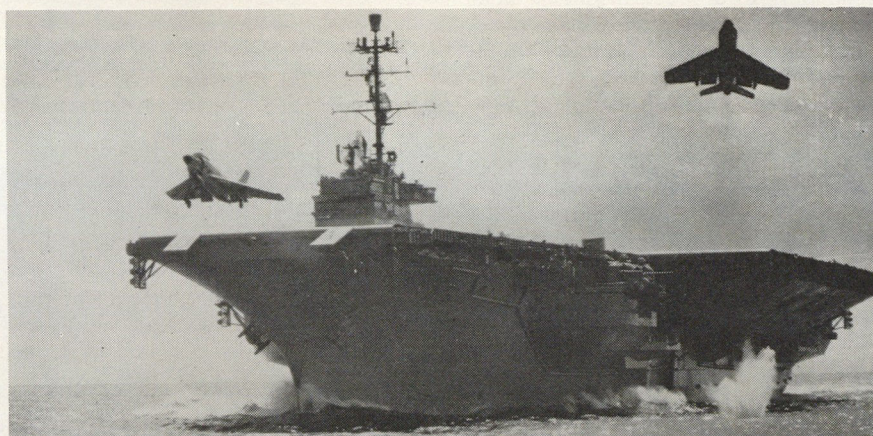
good loiter endurance, and lower landing speed. Lower landing speed will certainly reduce landing accidents and should reduce repair and logistics requirements. Similarly, the introduction of V/STOL technology for naval use will be significant. The elimination of, or reduction in capacity of, catapults and arresting gears is a distinct possibility. The use of V/STOL aircraft suggests the possibility of multiple simultaneous launching and landing operations. This could improve attack efficiency and reduce defense reaction time. V/STOL techniques may enable navies to utilize aircraft from small carriers or a multipurpose-type ship.

The use of magnetics in naval applications dates back to the 12th and 13th century A.D., with the introduction of the magnetic compass. Magnetics today has a much wider application, although the compass is still used universally. Magnetic mines are a potent weapon for all navies, but are particularly useful to the smaller navy in the defense of home waters and strategic approaches. The application of magnetics to submarine detection led to development of the Magnetic Anomaly Detector (MAD) in the early 1940s.

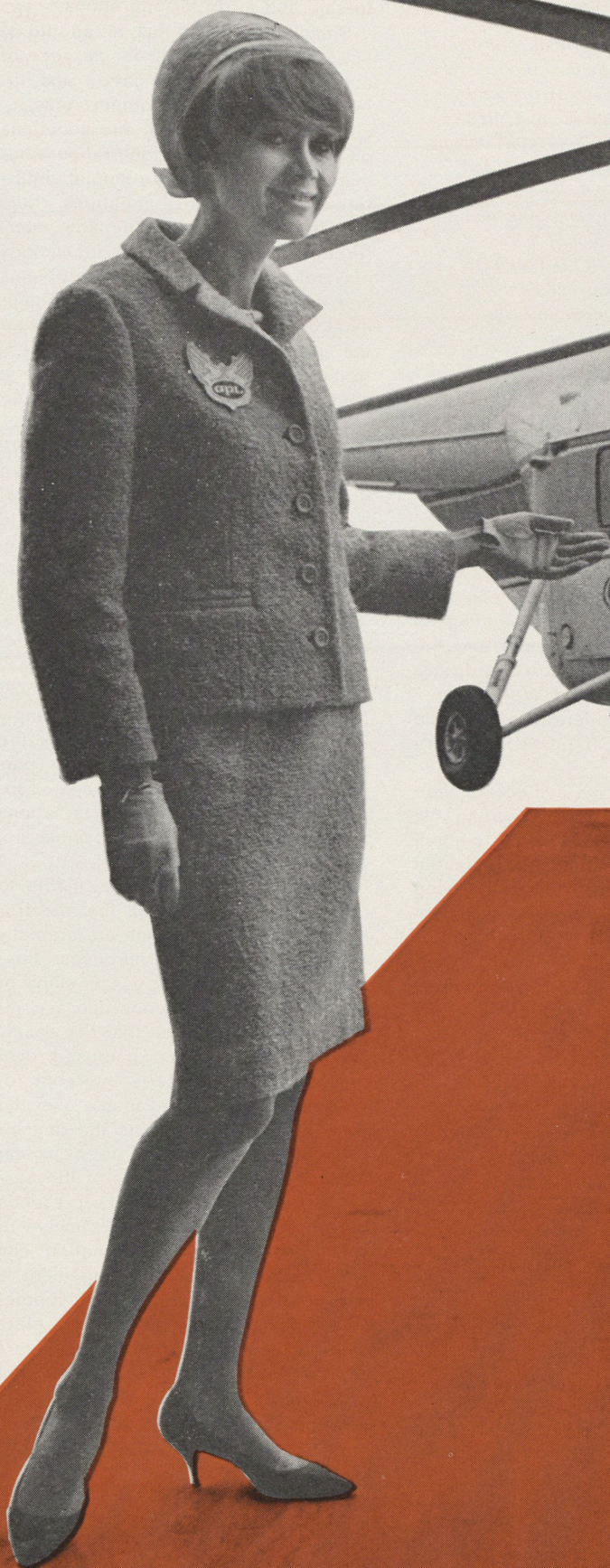
This instrument is used widely in exploration for petroleum deposits as well as in military detection. MAD is one of the standard sensors in ASW aircraft of the modern navy. Magnetic degaussing of ships and submarines is a countermeasure to the effectiveness of magnetic mines and to the range of airborne MAD.

Electronics has shown one of the most prolific increases of any technology. Prior to World War II, electronics, as used in naval ships, consisted of radio and internal communications, sonar acoustic detection equipment, and direction-finder equipment used for

(Continued on page 14)



USS SARATOGA simultaneously catapults 2 F-3H fighter aircraft from its deck during carrier-qualification operations near Guantanamo Bay, Cuba. The introduction of V/STOL technology may eliminate or reduce the need for catapults altogether.



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Modern ships utilize radar for almost every aspect of operation, from air and surface search to gun and air traffic control and missile guidance. At left, air controller on board USS NORTHAMPTON scans screen in combat information center.

navigation. Today, electronic devices are used in almost every aspect of a modern navy from weapon control to ship navigation and from food preparation (radar stove) to tracking of distant targets. Radar, sonar, communications, electronic countermeasures, digital computers, and navigation systems are examples of electronic technology which are extensively used by modern navies.

Several examples have already been noted regarding the role radar played in World War II. Since the end of that war radars have been developed to perform many diverse functions. A modern ship bristles with radars as well as guns and missiles. Individual radars exist for air search, surface search, gun control, missile guidance, air traffic control, aircraft landing, and other special purposes.

Aircraft are limited as to weight and size of equipment and usually carry only a single radar. The aircraft itself is designed for a special function and carries a radar for that purpose. A typical air group on a carrier might have an early-warning aircraft with a suitable radar to give maximum warning on targets that are below the radar horizon of the surface ship. Similarly, air-to-air radars exist in fighter aircraft, surface-search radars in patrol aircraft, and high-resolution mapping radars in reconnaissance aircraft. The future trend in radar design is toward a combination of functions in a single equipment. Technological advances which will make this possible are microelectronics and electronic scanning of the antenna beam in place of mechanical rotation.

Sonar is the major sensor used to detect submarines. It will only be covered briefly here because a more com-

plete coverage will be found in an article on antisubmarine warfare on page 16. Sonar, like radar, can take many forms and shapes depending on the platform which carries it and the function it is to perform. Its progress since the latter days of World War I, when it was used operationally by the British (called ASDIC), has been considerable.

It has evolved from a piece of incidental instrumentation, requiring its parent ship to stop to take a reading, to a major installation with substantial impact on the design of the carrying vehicle. Fixed installations, sonobuoys, and dipped sonar have extended operations to the shore and to the air. Technology offers great possibilities for continued sonar improvements; this includes detection and classification and the development of sonars as an integral part of the ship or submarine design.

Radio communications is the oldest user of electronic technology in all navies and still ranks as a most critical and important function. The use of radio (wireless telegraphy) was demonstrated for naval use before the turn of the century. Between 1900 and World War II the major navies of the world were instrumental in developing worldwide communications systems to direct their extended operations. Today, naval communications requires a remarkable number of circuits to handle the complex flow of information necessary for fleet operations.

Many aspects of electronic technology are used to provide reliable circuits with high data rates and error-free information content. A naval force flagship may have several scores of separate circuits to handle the maze of data necessary for tactical, stra-

tegic, and logistic operations. A relatively simple fighter aircraft may require several tactical circuits for air-to-ship and air-to-air operations.

Simultaneous with this, an additional link is often maintained for passage of automatic-control information and directions. Continuing problem areas include: antenna design and locations on aircraft and ships, long-range communications reliability, mutual interference, spectrum limitations, and countermeasures to man-made interference. Two aspects of technology may solve more of the above problems and expand the capability of communications at the same time. These are the use of fixed antennas with electronic scanning for all short-range communications and the use of satellites for longer-range circuits.

All users of electronic devices have enough problems in trying to keep equipment working and combating natural phenomena without having to contend with purposeful interference. But contend with this they must. It was illustrated early in this article, in the GNEISENAU-SCHARNHORST dash, that electronic countermeasures (ECM) are a vital tool that a modern navy must employ. A modern navy must conduct electronic warfare. Simply stated, this is to deny the enemy the use of electronics for whatever purpose he may be using it and, conversely, to utilize electronic radiations to the best advantage possible for your own forces.

Electronic jammers are available to cover most portions of the electromagnetic spectrum which are normally employed for military purposes. Jammers are designed for use in ships or aircraft so that protection can accompany the mission or so that the enemy can be harassed and confused over the widest area. Passive intercept receivers are generally available over the same frequency range as the jammer and they are deployed in a similar manner. The main purpose of the passive receiver is to detect the presence of an opponent before he is aware of your presence. This information can shape tactics if actual engagement is imminent or can be used to supplement your information regarding electronic activity and ability, if this is desired. Both jammers and intercept receivers have design problems. Some of these limitations are due to natural laws; others are due to the counter-countermeasure design of opposing equipment.

High-speed electronic digital computing is the most recent technology which has evolved from an electronic background. This technology has very significant impact on all electronic equipment in that the repetitious high-

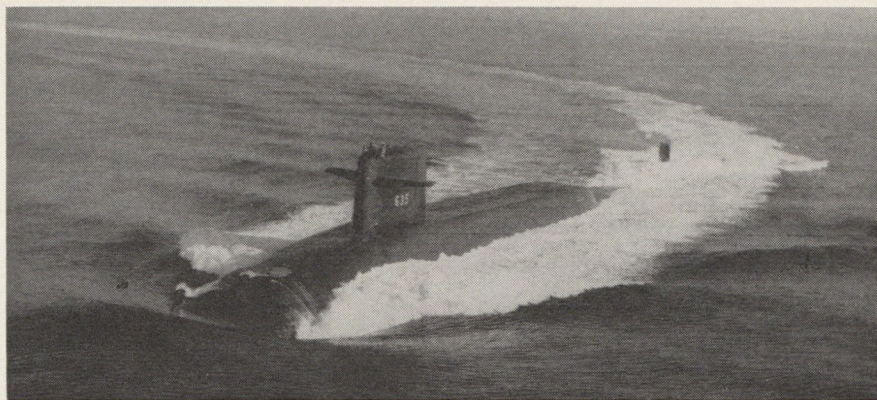
speed handling of tremendous quantities of information of all types is now possible in a form that can be packaged for almost any conceivable use. Computers are now solving problems involving mass data handling, target sorting and comparison, signal processing and correlation, antenna beam stabilization and control, and many others. The computer is utilized in all phases of naval operations—from ship-board payroll and accounts handling, supply inventory, and replenishment at sea, to the design and construction of ships and aircraft.

Naval applications of this advancing technology will continue to grow. The new microminiaturization and integrated-circuit techniques are being applied to computers and peripheral equipment to provide greatly increased capability, reduced size, and better reliability. In the future, navy ships, aircraft, and submarines may be significantly automated through integrated computer complexes.

Personnel to monitor and direct system operation will be required, but large numbers of individual device operators will be eliminated. Self-checking and automatic fault correction of system operation through redundant or alternate circuitry will be commonplace in all computing equipment. Through imaginative application of data-processing technology, navies of the future will reach a level of effectiveness enabling them to better cope with threats under all degrees of conflict. Computer-aided decision-making will become an everyday reality. The machine will work for the naval operator, when he has become conversant with the vast potential such systems hold for Navy operations.

The major result of naval weapon technology in the past 15 years has been the development of guided missiles. Functionally, these fall into the following categories: air-to-surface, surface-to-air, air-to-air, and surface-to-surface. Subsurface operations open up another group of categories, but these employ the same basic techniques. Depending on the size, scope, and mission of a modern navy, 1 or more of the above types of missiles are essential.

The surface-to-air missile (SAM) is the most universally required. Air defense against modern aircraft with guns alone is not adequate. SAM missiles are able to reach out to long ranges and high altitudes and destroy attacking aircraft before they penetrate to a dangerous distance. A SAM system on a ship is a very complicated ensemble and requires precise inputs from related systems such as radars, computers, and data links. Improvements in missile technology will pro-



The nuclear submarine is significant technological achievement of the modern U.S. Navy, which today operates 32 Polaris-bearing subs, plus others for ASW missions.

vide smaller missiles for the same range and missiles with greater speed and acceleration. Improvements in the related technologies have been discussed and will provide better guidance, improved electronic countermeasures, longer ranges, and higher speed data handling and computation.

The importance of the oceanographic and atmospheric environment to the effective use of modern complex detection and weapon systems has resulted in increased efforts to better understand the physical environment and to develop the methodology to accurately predict its variability in time and space. Techniques have been developed which enable the forecaster to successfully route ships to avoid storm centers with the accompanying high seas. This has resulted in great savings in time, cargo and ship damage, and in comfort (in the case of passenger ships).

Increased knowledge of the vertical water-column structure, coupled with the ship-routing techniques, makes it possible to select "good" sonar water for the routing of convoys in an effort to maximize detection of enemy submarines and thus provide safer conduct. This better understanding of the physical behavior of the ocean has led to the development of new tactics for naval forces to take advantage of environmental conditions.

Man has conquered land, learned to cope with the problems of the sea, and is learning how to live and operate in outer space. Recent efforts to extend man's capability to live and work in the sea ("inner space") have been encouraging. The success of such efforts as those of Jacques Cousteau, the U.S. Navy Sealab project, and others, is positive evidence that a deep-ocean technology may be attainable in the foreseeable future. From these efforts, we may anticipate important contributions to more rapid and efficient submarine rescue and escape, improved underwater salvage and construction, and

increased knowledge and potential exploitation of large mineral and food resources.

The impact of technology on a modern navy has been covered in most of the important areas. The impact of this technology on man has not been mentioned. Man is a key link in many of the complex systems discussed. Progress in the behavioral and social sciences continues to be slow and difficult. Deficiencies in knowledge about human motivation and performance in highly complex weapon systems have adversely affected systems effectiveness. Small but continuous investment in basic and applied research has produced a series of isolated advances which now appear to warrant synthesis and integration.

The coupling of these sciences with military operations into a new technology is beginning to take form as we implement programs to move these research advances into development. For example, new techniques of operations research and management sciences are being tested for improving manpower planning and utilization.

The areas of training and education are of central importance in military readiness and effectiveness. The combining of computer technology and theories of learning and education is providing the vehicle, computer-aided instruction, for a significant advance in military education and training, which should far surpass the impact of the earlier programmed instruction techniques. Although the past and present provide strong bases for optimism as we intensify our development effort for dealing more effectively with the operational and personal problems of military personnel, the significant progress remains in the future.

In summary, it is obvious that a modern navy must rely on technology for many vital functions. Technology will advance and a navy, to remain modern, must continue to apply those technologies that will keep it effective in carrying out its mission. ☆☆☆

The United States today faces a potential enemy submarine fleet 9 times the size of the one Germany had at the start of the second World War. In an era when submarines can not only inflict catastrophic losses on shipping and naval craft but also threaten cities, it is vital that the most effective and reliable weapons that technology can devise be deployed. But the problems of antisubmarine warfare are formidable.

Antisubmarine Warfare: Pushing the State of the Art

By Vice Admiral Charles B. Martell, USN
Director, Antisubmarine Warfare Programs
Office of the Chief of Naval Operations

(The following article is adapted from a recent address by Admiral Martell to the national convention of the Navy League of the United States in Washington, D.C.)

The submarine is an ideal weapon for a land power to use against a sea-power. It can harass and strangle a nation like the U.S. that depends upon the sea, making it necessary to maintain an effective, credible antisubmarine warfare (ASW) capability. Today the U.S. is faced with a submarine fleet that is 9 times the size of the one

which Germany had at the start of World War II. This force could have quick effect.

In former conflicts the allies have been able to absorb losses and gradually come back. But now the sheer numbers of our opponent's submarines could effect catastrophic losses in time of war unless we ensure that he will

not attempt this course of action because he recognizes that the cost to him would be too high.

The Soviets have shown foresight in their choice of this weapon—the submarine. Armed with torpedoes it could menace every naval task force and every merchant ship. It has a meaning in all shades of war—from cold war to thermonuclear exchange. Armed with missiles it could threaten U.S. strategic military installations, industrial complexes, centers of governmental control, and population centers.

Of course, missile submarines are not new to the U.S. The first missile was launched from a United States submarine in 1946, and the U.S. Navy fleet ballistic missile submarine represents the culmination of that effort.

There is an important consideration to remember, however, when discussing the potential threat from inner space. Although the selection of priorities in ASW must begin with a careful appraisal of an enemy's capabilities, it is sound philosophy to assign your potential enemy a future capability at least akin to your own. The Soviets have demonstrated that they have the technical base that can provide exceptional hardware if they choose to exert still heavier emphasis on their submarine program.

The U.S. Navy basically views ASW, in the positive and total sense, as

The author, Admiral Martell, a graduate of the U.S. Naval Academy, class of 1930, is a veteran sea officer who has seen extensive service as an ordnance development expert, and has received the U.S. Legion of Merit for his work in development of defensive warfare tactics for the U.S. Fleet. In recent years he has served as principal executive to the Deputy Chief of Naval Operations, Development, and Deputy Director of Defense Research and Engineering for Administration and Management in the Office of the Secretary of Defense. He became commander of the U.S. Second Fleet in 1963 and in 1964 was named Director of Antisubmarine Warfare Programs, a new top-level post in the Navy set up to meet the growing submarine threat.



being the measures taken by the aggressive, offensively oriented team of aircraft, destroyers, and submarines, operating with an offensive spirit and intent in all areas of actual or potential submarine concentrations.

This is true of all naval formations and convoys:

- In ocean areas from which submarine missiles can reach U.S. coasts,
- In the vicinity of potential enemy bases and support forces,
- And along transit paths between the submarines' bases and their objective areas.

Today, the U.S. Navy stands first in the world in ASW capability. Our superior aircraft, ships, and weapon systems with their skilled operators, backed by a strong ASW research-and-development program, are insurance that the U.S. will remain first.

Our greatest strength in ASW is in the teamwork of our highly trained forces, in the excellence of our command-and-control system, and in co-operating with our allies in ASW operations.

Thus, against the present assessment of the ASW problem, steady progress is being made. The rate at which we progress depends on the speed with which we can transform new ideas or new techniques into improved capabilities. These ideas and techniques come to the Navy from U.S. industry, laboratories, research centers, and individuals.

Effective ASW requires adequate numbers of trained and ready forces, technical superiority, and excellent intelligence. These are available to the Navy in varying degrees today. We intend to maintain and improve them in the future.

The requirement for well-trained technical personnel increases daily. This is a direct result of past investments in research and development now reaching fruition. This new equipment now entering the U.S. Fleet is demanding in numbers of skilled personnel. For example, more than 15 sonarmen are required in each ship which is receiving the new long-range sonar, the SQS-26.

However, this new equipment is greatly increasing our current ASW capabilities. Our new sonars have increased ranges. We have achieved better classification and better kill capability and attack response with ASROC, SUBROC, DASH, and the new lightweight torpedo, the MK 46.

In the case of DASH, the drone ASW helicopter has lived up to expectations and, in fact, has exceeded them in reliability.

We are engaged in the transition to the new maritime patrol aircraft, the (Continued on following page)

ASW: MEETING A DIFFICULT CHALLENGE

By Paul H. Nitze, Secretary of the Navy

(Excerpted from an address by Mr. Nitze to the American Ordnance Association in Chicago, Illinois.)

With regard to our ASW ships and submarines, the U.S. Navy Bureau of Ships, with its laboratories and contractors, has made herculean efforts to increase the ranges of detection and the depth of penetration of shipboard sonar sensors and to improve techniques of localization, classification, identification, and fire control. At least 2 complete generations of such sensors have been brought into the U.S. Fleet since World War II.

This has not been done without difficulty. The urgency of installing the most modern equipment in the Fleet at the earliest possible date has resulted in entering the production phase prior to the completion of the normally prescribed research, development, test, and evaluation processes. However, the incentives were considered sufficiently significant to accept the risks associated with this procedure.

For example, in the cases of the second-generation sonars, the SQS-26 for surface ships and the BQQ-2 for submarines, greatly increased power gave the possibility of significantly increased ranges. We sought here to capitalize on the phenomenon of bouncing the sound signal off the ocean bottom and [using] the layer characteristics of the ocean to propagate the sound wave.

At the same time, equally strong efforts were made to develop a capability for surface ships to penetrate mechanically below the surface thermal layer by the use of variable-depth sonar equipment. Through many different programs, the U.S. Navy sought to develop and place into production a device capable of being carried aboard ship, lowered to, and towed at such depths as to be able to penetrate that elusive thermal layer below which the enemy submarine can lurk. In the same fashion, the Bureau of Weapons has developed acoustic and homing ASW torpedoes and married them with the antisubmarine rockets, ASROC and SUBROC, and the antisubmarine drone helicopter, DASH, to provide greatly extended kill ranges.

But here again, the significant technological advances were not sufficient to outdistance the rapidly increasing threat. The sophisticated design concepts of the weapon systems demanded more intensified and disciplined development and production programs in order to realize their full potential.

The exploitation of ASW aircraft became more difficult as the newer submarines became less dependent upon operations near the ocean surface. However, there are a number of phenomena which appear to offer promise of helping to maintain this airborne ASW advantage. It is important to attempt to exploit these, since rapid response time can be realized with aircraft, and large ocean areas can be searched economically. In addition, we are learning a great deal about the utilization of ASW helicopters with their dunking sonars to help converge on areas of known submarine threats. In so doing, we are aware of the environmental limitations on the smaller and less powerful sensing devices carried by aircraft and helicopters—the same environmental limitations affecting the operation of shipboard sensors.

The requirement to exploit every potential advantage in technology, as well as to extract the maximum capability from each and every piece of ASW equipment and system, is increasingly apparent. Furthermore, operating the individual ASW platforms—the ship, the sub, and the aircraft—in antisubmarine attacks imposes additional problems that transcend those associated with the individual ship, submarine, or aircraft systems. Contributing problems are: underwater communications, including those between the submarine and other nonsubmarine units; mutual interference between various sensors and weapon delivery systems; masking of the detection of enemy submarines by the noise of machinery and propellers of the searching ships. All of these problems require further intensified investigations.

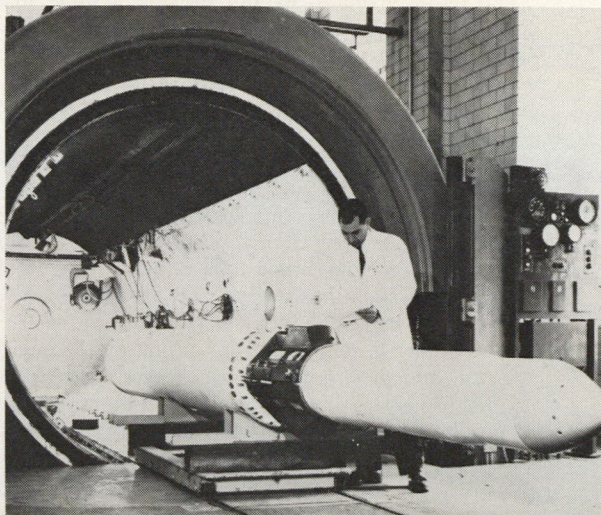
As we delve deeper into each of these areas in a more sophisticated manner, we are learning that the ocean is a peculiarly intractable medium for search and detection. We are not removing from the enemy submarines the protective mantle of the unpredictable ocean as quickly as we had anticipated. The need is apparent for a better understanding of the ocean sciences and the detailed influences of these sciences on our ASW systems designs and operations.

Simple rocket-powered device to project depth bombs beyond normal wake of destroyer is this Weapon Alpha, fired from a launcher resembling conventional gun turret. Built by U.S. Navy specialists, it weighs about 500 pounds (227 kg) and has a range of 1,000 yards (915 m).



This brightly lit "threat-evaluator" console is part of the electronic data display system developed by Hughes Aircraft Company as a portion of an over-all system designed to locate aerial, sea-surface, and submarine targets, then indicate their identity, and establish defensive operations for ships in a naval task force.

An important phase of the prefiring program for the Navy's SUBROC ASW missiles was the underwater pressure testing, conducted in this pressure chamber at the U.S. Naval Ordnance Laboratory, Silver Spring, Maryland. The missile, in action, is fired from a submerged submarine, surfaces, travels through air, and reenters water to hit enemy with nuclear warhead.



P-3A Orion, which increases ocean area surveillance capability markedly.

Most carrier-based, fixed-wing squadrons have the improved S-2 tracker aircraft, and the helicopter ASW squadrons are now employing the Sea King.

None of these new equipments, however, represents the final answer. The research-and-development effort must continue to explore all possible avenues for detection, classification, localization, and destruction of quiet nuclear submarines. We cannot afford to put all our eggs into one basket, but must make simultaneous approaches at a number of points along a broad scientific front. There is much fundamental work to be done. Meanwhile, we are seeking to utilize the full potential of underwater sound, through passive and active techniques. We are learning more about the propagation of this sound in the complex ocean environment and about the many paths it may take. We are investigating non-acoustic means as well, and experimenting with all possible phenomena which may help us.

We are pushing the state of the art in the development of weapons, torpedoes, rockets, missiles, and mines, and are embarked on a major program seeking to solve the new problems of ocean surveillance. We are supporting a large amount of research, particularly in the field of oceanography. The importance of this area to ASW is so great that 50 percent of the total U.S. oceanographic program derives from the Navy, and over 80 percent of the budget for private oceanographic laboratories is provided from Navy funds.

ASW is not an exact science. It is extremely complex—involving surface ships, aircraft, submarines, and fixed systems. Nearly all scientific disciplines and most engineering fields are involved in antisubmarine warfare. The ocean is a vast, intractable medium—dense and impenetrable. The only important means we have found of searching its depths is with sound waves, and these provide us with information normally limited in range to a few miles, compared with the hundreds of miles provided by radar in the air. Unstable temperature layers in the ocean delay, distort, and misdirect sound waves, so that expensive, complex equipment and highly trained operators are needed to interpret submarine noises and sonar echoes.

In antisubmarine warfare we face a problem of continuing and probably increasing difficulty. The office of which I am head represents a step forward in providing U.S. Fleets with steadily improving means of coping with the potential threat. It provides a focal point for new ideas and concepts from whatever source. ☆☆☆

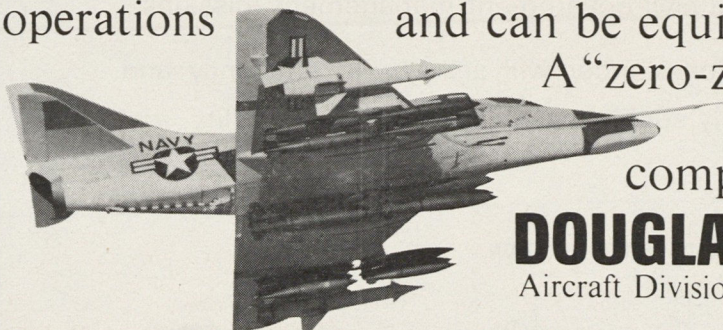


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DOUGLAS SKYHAWK

Aircraft Division, Long Beach, California, U.S.A.

In civvies or in uniform . . .

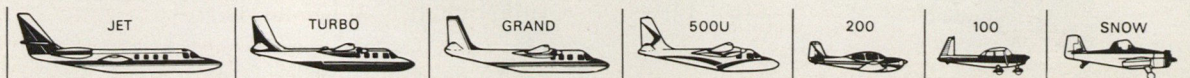
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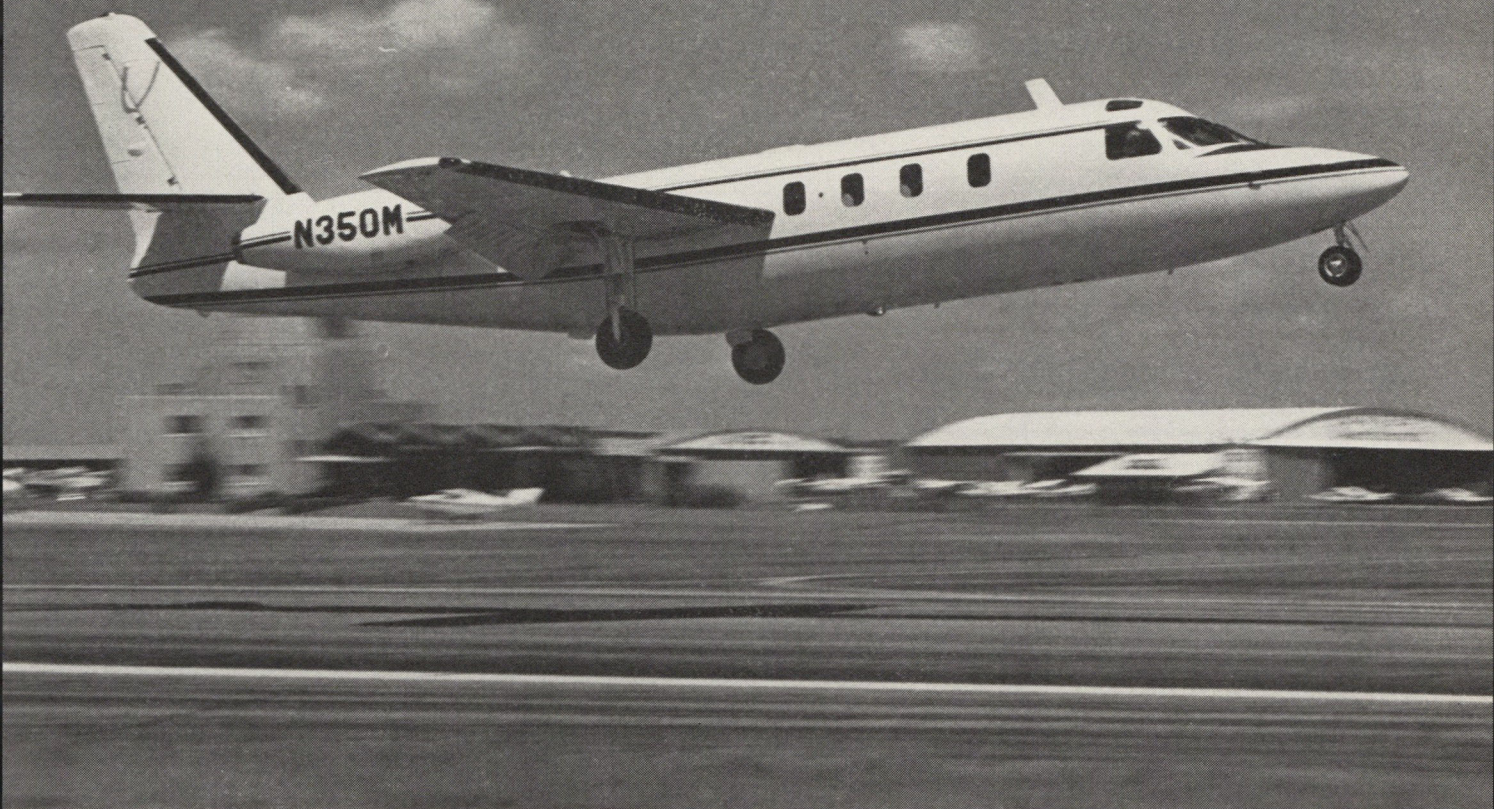
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JET COMMANDER

There are three sets of conditions under which a navy may function in limited war—interdiction of arms traffic to forestall subsequent escalation to a land campaign, confrontation with naval forces of a potential enemy to bring about his withdrawal, and control of sea lanes to support friendly forces overseas and deny the enemy access to reinforcement by sea. In past years the U.S. Navy has applied the first 2; it is carrying out the third today in Southeast Asia . . .

The Navy and Limited Warfare

By Rear Admiral Gerald H. Miller, USN
Director, Long Range Objectives Group, OCNO

A nation maintains a navy to enable its people and government to use the seas, and to provide the capability to prevent their use by others in ways contrary to its interests.

Some have had the impression in recent years that the control-of-the-sea function is applicable only to those periods covered by a formal declaration of war. However, many sea-control actions on record have taken place while diplomats and armies of the powers involved remained at peace ashore. These days, there seems even less reason to suggest that time-

ly measures taken at sea to prevent or control aggression must await some kind of formal declaration before they are undertaken.

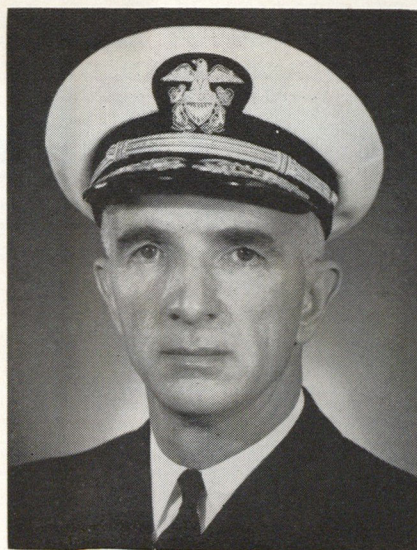
Examples of the use of naval options by governments to prevent and control armed conflict cover a range of actions limited only by the resourcefulness, foresight, and maritime comprehension of the leaders of the time.

In the Cuban crisis in the fall of 1962, the United States became concerned about the buildup of offensive ballistic missiles on Cuban soil. The basis for this concern was twofold—

ballistic missiles in Cuba constituted a clear and present danger to the U.S. homeland, and delay in halting the missile buildup probably would have necessitated the later commitment to battle of large contingents of U.S. troops, after the Cuban forces had been armed and trained with Communist weapons.

The decision to turn back ships carrying missiles to Cuba was executed with great care. The procedure was supervised in detail at the highest level of government, and the great U.S. military power, though fully alert against surprise attack, was kept under tight rein. In this case, controlled, limited action at sea was used to prevent escalation of a military threat in a strategically important area, without declaration of war and without damage or casualties to either side.

The geographical site of a limited naval confrontation need not necessarily be adjacent to one's own shores to ensure success. In the years following World War II, differences of opinion existed between the Communist-oriented elements and government forces as to their relative strength—in Malaya, the Philippines, and Korea. Armed conflict resulted. While these areas are relatively close to the main sources of Communist strength, help from friendly Free World nations was more accessible by sea. With the superior allied sea communications tilting the logistic scales against them, the Communist-oriented elements were eventually brought under control.



The author, Admiral Miller, is one of a relatively small group of U.S. naval officers to rise from enlisted seaman to his present rank. Selected by competitive examination for the U.S. Naval Academy, he graduated in December 1941. After 2 years aboard a cruiser, he entered pilot training. At the outbreak of the Korean War, he was assigned as Flag Secretary and Aide to a carrier division commander in Korean waters. He returned to the Korean campaign in May 1952 as a fighter squadron commander, earning the Distinguished Flying Cross and the Air Medal with 5 gold stars. Subsequently, he led a carrier air group and in 1963-64 commanded the USS FRANKLIN D. ROOSEVELT. In July 1964 he returned to Washington as Administrative Assistant to the Vice Chief of Naval Operations before moving to his present assignment.



Aircraft carriers are invaluable in all phases of limited warfare. Operating in South China Sea, they launch air strikes against supply routes in North Vietnam, provide air support against Viet Cong in South, and patrol sea lanes to interdict enemy shipping.

There are 3 general sets of conditions under which a navy can be employed in a controlled, limited-war environment:

- Naval interdiction and control of arms traffic to forestall subsequent escalation to a land campaign. The Cuba quarantine was instituted to control the nature and scope of the build-up of Communist military power in an area directly threatening the safety of the United States itself. If the quarantine had been imposed at a later time, or if it had been delayed indefinitely, remedial action probably would have required involvement of U.S. ground and air forces against a Communist-equipped army, and employment of Cuba-based missiles may have made ensuing operations difficult to control. Naval power was used to arrest the buildup before land escalation was required.

- Initiation, or acceptance, of naval war at sea, as an alternative or prelude to conflict involving the land. President Roosevelt's announcement in 1941 that the "very presence [of German submarines] in any waters which America deems vital to its defense constitutes an attack" is an illustration of how the exercise of naval options can take place without simultaneously involving land forces, or even without involving armed conflict. Whether Roosevelt would have made good his threat of counteraction in any significant strategic way is an unanswerable question. Presumably Germany made its decision to withdraw

its submarines from the waters in question on the basis of not only a suspicion that he would, but also on the basis of the political results—growing enmity with the United States Government, alienation of pro-German or isolationist elements within the United States, etc.

- Use of naval forces to supply, support, and protect an overseas land campaign and to deny enemy access to the sea and land areas under contention. Of the 3 general conditions discussed, naval support of an overseas land campaign is the most familiar to Americans generally. It is the

naval option most generally employed in unified operations of the past 2 decades. It is being employed today in South Vietnam.

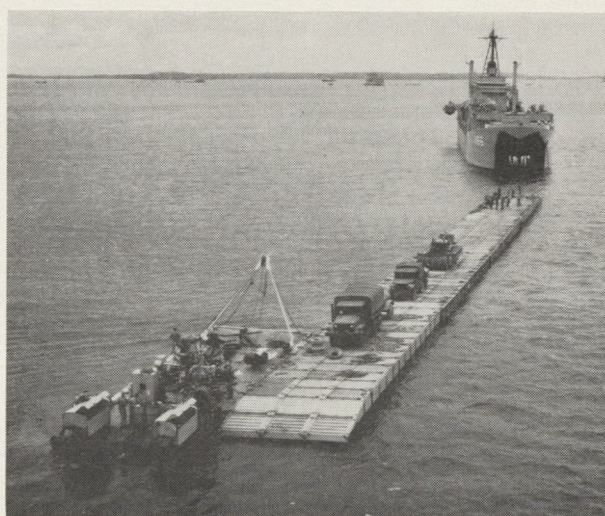
As an example of this kind of naval employment, let us examine the Korean invasion of 1950. The Communists' sudden invasion of South Korea went smoothly until they reached the outskirts of Pusan in the extreme south. Meanwhile, United Nations naval forces in the vicinity were able to take control of adjacent sea areas and to deny their use to hostile forces.

Naval forces brought seaborne offensive weapons into play to support and protect the beleaguered land forces, and assisted in preventing the Communists from reinforcing their armies by land, sea, or air. At the same time, United Nations forces ashore were reinforced and supported by an uninterrupted flow of men and equipment via overseas air- and sealift. As a result, the logistic balance began to move slowly but relentlessly in favor of United Nations forces.

In Korea, as is usually the case with limited, controlled-response situations, one of the most important factors was time. Time was needed to tip the scales in favor of the maritime powers, time to evaluate the situation and select the appropriate response, time to strangle the aggressor's logistic supply lines, time to build up the strength and supplies of friendly forces, and time for sufficient data and experience to accumulate in the hands of the aggressor to convince him that his adventure was costing him more than it was worth.

Along with the time requirement, the nuclear era adds to the requirement for more direct governmental control over actions at the scene of a limited

(Continued on following page)



Landing craft unloads vehicles and construction equipment onto pontoon causeway at Chu Lai in South Vietnam. Despite lack of normal port facilities, U.S. Marines and Navy construction battalions built airstrip at Chu Lai from which fighter planes began combat operations in less than a month.

confrontation. In the Cuban crisis, close control of the actions of ships at sea was exercised by the constitutionally responsible head of the government, and peoples and governments everywhere followed developments with concern. This kind of direct use of the Navy by the head of government was new to many people of this generation, even some in uniform, although the concept itself is not new.

Nuclear arms, better command communications, and modern means of keeping the public informed have just about ended the days when the military man at the scene can have complete freedom, particularly in limited situations, to conduct operations as he sees fit.

The future prospect and scope of limited-war actions at sea will depend very much on how and by whom the seas are being used, commercially as well as militarily. All available evidence points to the fact that man's utilization of the seas is continuing to expand in scope, a good indication that the threats and opportunities arising from conflicting maritime activities will also increase.

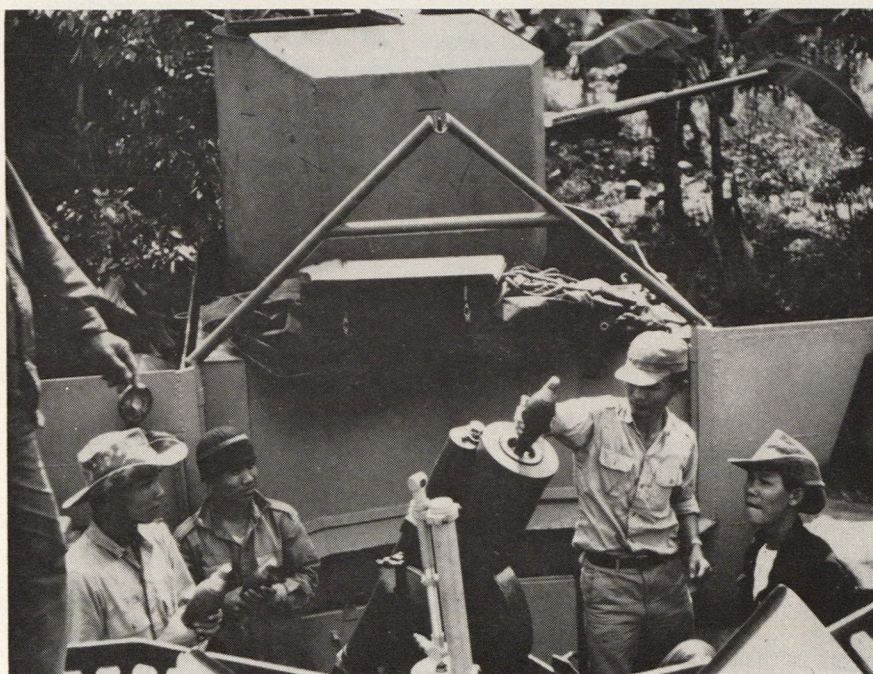
In seaborne commerce, the value of world trade has increased from \$194,800,000,000 in 1958 to \$329,400,000,000 in 1965. U.S. seaborne trade alone expanded from \$32,600,000,000 in 1958 to \$48,700,000,000 in 1965. Seaborne trade of Soviet bloc countries expanded from \$20,500,000,000 in 1958 to over \$28,000,000,000 in 1965, with the Soviet share expanding from \$8,600,000,000 in 1958 to over \$15,500,000,000 in 1965.

As a general rule, navies and merchant marines have tended to lag behind their land-based counterparts in utilization of latest technologies. Comparatively little research-and-development effort has been expended for marine hull and propulsion advancement, and relatively few people have seen the need for it. Recently, however, a number of nations have begun to examine new hull and propulsion technologies which show promise of producing transoceanic ship speeds in the 100-knot bracket.

In weapons also, navies have tended to lag behind their land-based counterparts. The gun and the military aircraft, for example, were in general use by the land forces for some years before they were adapted to use aboard ship. In ballistic-missile development, the emphasis up to now has been mainly on land-based systems, where both strategic and tactical missiles are becoming operational in increasing numbers, and nonnuclear as well as nuclear payloads are becoming available.

Wider naval use of offensive mis-

U. S. Navy personnel serve as advisers to gunboat crews of the South Vietnamese Navy. Gunboats patrol coastal and inland waterways to inspect cargo aboard sampans and other light vessels and intercept shipments intended for the Viet Cong.



A mortar weapon has been rigged aboard this South Vietnamese patrol boat to attack vessels refusing to submit to search. Destruction of bridges and roads in North Vietnam by air strikes has resulted in increased efforts to resupply the Viet Cong by water.

siles can be anticipated, and, as in the case of the gun and the military aircraft, they are expected to become, in a relatively few years, a standard ship-board weapon. More compact missiles now in prospect will enable them to be mounted and serviced aboard many types of ships. As in the case of guns and aircraft, many types of warheads will be available, which can be interchanged at sea, for use as strategic, tactical, nuclear, or nonnuclear weapons. Offensive missiles are destined to take their place alongside the gun and the aircraft as standard naval weapons for limited as well as general nuclear war purposes.

A perusal of "Jane's Fighting Ships" yearbook shows that at the present time the United States is leading in utilization of offensive missiles for strategic purposes, while the Soviet Navy is leading in their utilization for tactical purposes.

At the present time, the United States Navy is ready and sufficiently adaptable to serve the nation in a spectrum of limited and controlled-response options. But the road ahead is long, and the mantle of naval supremacy has been known to pass quickly, and in some instances quietly, from one nation to another—invariably with far-reaching consequences. ☆☆☆

Speaking of Space

Despite obvious differences, there are many important similarities between manned space exploration and manned undersea research. One man who knows both environments is the world's only astronaut-aquanaut, U.S. Navy Commander Malcolm Scott Carpenter. Having both flown in space as a Mercury pilot and served in the Navy's Sealab undersea research program, he argues vigorously for better equipment and greater support for ocean studies . . .

Space-Age Support For Man in the Sea

By William Leavitt

Senior Editor, Science and Education

To a casual observer, no 2 environments could be less alike than space and the sea. Space is virtually empty, pressure is absent, weight zero. The ocean is thickly fluid, pressures are massive and increase with depth.

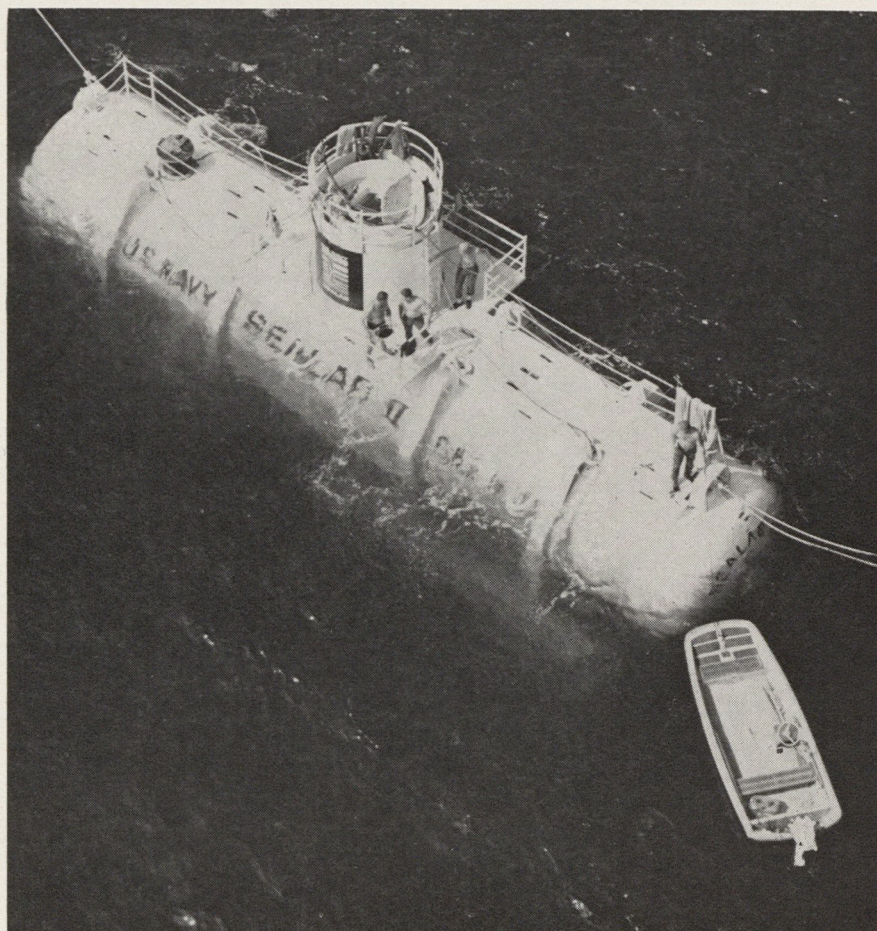
Yet, outer space and the "inner space" of the sea have much in common for the man exploring them. They are both hostile environments and challenge man's technology, his personal skills, and, certainly, his courage.

One American, U.S. Navy Commander Malcolm Scott Carpenter, who as one of the original astronauts flew the second Mercury mission, holds the unique distinction of having flown in space and also having operated for a month in the depths of the sea—in the Navy's Sealab II project off the coast of California, near the town of La Jolla. Carpenter spent 30 days in Sealab. The total submergence time for the research craft was 45 days.

Astronaut-Aquanaut Carpenter sees many parallels between man in space and man in the sea. Not long ago he reported publicly in Washington on his exploits and his views.

"There is a small but expanding group which believes that it is imperative for this nation to develop a broad capability for exploring the ocean floor," he said. "There is a larger group which believes it is mandatory to explore the outer reaches of space," he added. "I belong to both, and my experience with the 2 . . .

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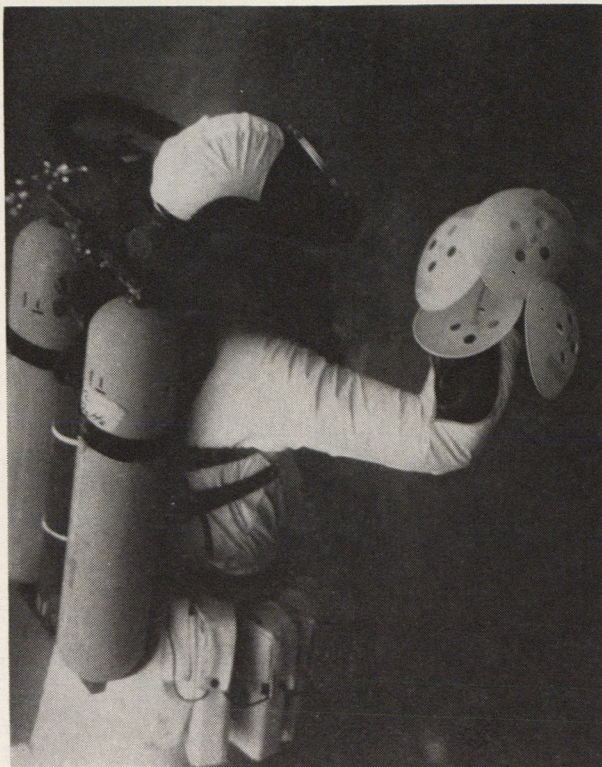
U.S. Navy's Sealab II research craft submerges off La Jolla, California. Rotated crews spent a total of 45 days at depth of some 200 feet (61 m). Astronaut Carpenter stayed on undersea job for 30 days. Predecessor Sealab I had spent 10 days at similar depth off Bermuda. Navy hopes to send a successor Sealab III to 600 feet (183 m).

Undersea Research Vehicles in Operation or Under Construction

Name of Vehicle	Owner/Operator	Operating Depth Feet (Meters)	Speed (knots)		Propulsion Endurance	No. of Propulsion Units	Energy Source	Dimensions Feet (Meters)			Dry Weight	Displacement Submerged
			Cruise	Max.				Length (ft)	Beam	Height		
ALUMINAUT	Reynolds International, Inc.; Reynolds Submarine Services Corp. (1965)	15,000 (4,600)	3	3.8	32 hrs at 3 kts	2 5-hp horiz (tailplane) 1 5-hp vert (amidships)	4 77-cell, 32,500 amp-hr, silver-zinc (internal)	51 (15.5)	8 (2.4)	14.25 (4.3)	73.2 T (74.3 mt)	81.1 T (82.4 mt)
ALVIN I	Office of Naval Research, Woods Hole Oceanographic Institution (1965)	6,000 (1,800)	2.5	4	8 hrs at 2 kts	2 5-hp hydraulic motors powered by pumps driven by 2 oil-encased elec motors	3 external, oil-encased, lead-acid, pressure comp.	22 (6.7)	8 (2.4)	13 (4)	13 T (13.2 mt)	—
AMERICAN SUBMARINE MODEL 300	American Submarine Co. (1961)	300 (90)	1	6	3 hrs at 3 kts	1 3-hp, 12- to 24-v	4 6-v, lead-acid	13 (4)	4.2 (1.3)	4.75 (1.4)	2,200 lbs (1,000 kg)	—
AMERICAN SUBMARINE MODEL 600	American Submarine Co. (1963)	600 (180)	1	6	6 hrs at 3 kts	1 3.5-hp oil-immersed	4 6-v, nickel-cadmium	13 (4)	5.5 (1.7)	5.2 (1.6)	3,500 lbs (1,600 kg)	—
ARCHIMEDE	French Navy (1961)	36,000 (11,000)	1	2	12 hrs at 1 kt	1 20-hp, 110-v (horiz), 1 5-hp (vert), 1 6-hp (direction control)	2 110-v, 860-amp-hrs, oil-encased, alkaline batteries (outside pressure hull)	69 (21)	13 (4)	26.5 (8.1)	61 T (less ballast and hexane) (62 mt)	195.9 T (199 mt)
AUGUSTE PICCARD	Swiss National Exposition Corp. (1964)	2,500 (760)	1-2	6	8 hrs at 6 kts	1 80-hp	2 2,000-amp-hr, 110-v, lead-acid batteries	93.5 (38.1)	19.7 (6)	24 (7.3)	164.37 T (167 mt)	218.5 T (222 mt)
BENTHOS V	Lear Siegler, Inc. (1963)	600 (180)	1	3	2 hrs at 2 kts	2 1-hp, 24-v	3 120-amp-hr, nickel-cadmium (internal)	11.3 (34.4)	6.1 (1.8)	6 (1.8)	4,200 lbs (1,900 kg)	—
CUBMARINE PC3A	Perry Submarine Builders, Inc.; Ocean Systems, Inc. (1965)	300 (90)	2.5	4	8 hrs at 2 kts 3 hrs at 3.5 kts	1 7-hp, 36-v	6 6-v, 210-amp-hr, lead-acid	19 (5.8)	3.5 (1.1)	6 (1.8)	4,790 lbs (2,170 kg)	6,580 lbs (2,980 kg)
CUBMARINE PC3B	Perry Submarine Builders, Inc.; Ocean Systems, Inc. (1964)	600 (180)	2.5	4	2 hrs at 3.5 kts 6 hrs at 2 kts	1 7-hp, 60-v/120-v	50 1.5-v, 250-amp-hr, silver-zinc	22 (6.7)	3.5 (1.1)	6 (1.8)	6,350 lbs (2,880 kg)	7,750 lbs (3,515 kg)
CUBMARINE PLC4	Perry Submarine Builders, Inc.; Ocean Systems, Inc. (under construction)	1,500 (450)	2	4	8 hrs at 2 kts	1 7.5-hp; 2 2-hp for hovering and maneuvering	Silver-zinc batteries	24 (7.3)	4.5 (1.4)	8.7 (2.6)	8 T (8.1 mt)	8.8 T (8.9 mt)
DEEP JEEP	Naval Ordnance Test Station, China Lake, California (1964)	2,000 (600)	2	2	4-6 hrs at 2 kts	2. 75-hp, 24-v (variable), oil-immersed	8 6,900-watt-hr, lead-acid	10 (3)	8.5 (2.6)	8 (2.4)	8,000 lbs (3,600 kg)	—
DEEP QUEST	Lockheed Aircraft Corp., Lockheed Missiles and Space Co. (under construction)	6,000 (1,800)	4.5	—	24 hrs at 2 kts	2 7.5-hp AC main propulsion; 2 7.5 hp AC vertical thrusters	Lead-acid batteries (main), silver-zinc (emergency)	39.1 (11.9)	19 (5.8)	13.3 (4.1)	56 short tons (50.8 mt)	53.7 short tons (48.7 mt)
DEEPSTAR 2000	Westinghouse Electric Corp. (under construction)	2,000 (600)	2	4	8 hrs at 2 kts	Single propeller provides main thrust; 2 water jets provide auxiliary thrust for controlling and maneuvering	Lead-acid batteries	14 (4.3)	7 (2.1)	5 (1.5)	8,000 lbs dry (3,600 kg)	—
DEEPSTAR 4000	Westinghouse Electric Corp.	4,000 (1,200)	1	3	6 hrs at 3 kts 12 hrs at 1 kt	2 4.5-hp/AC free-flooded	3 lead-acid, 400 amp-hr in 62 2-v cells (inverter)	18 (5.5)	10 (3)	7 (2.1)	19,000 lbs (8,600 kg)	—
DIVING SAUCER	OFRS-J.Y. Cousteau Westinghouse Electric Corp. (1959)	1,000 (300)	1	1	4 hrs at 1 kt	1 2-hp motor driving centrifugal water pump; 2 jets provide thrust	3 104-amp-hr, lead-acid batteries	9.5 (2.9)	9.5 (2.9)	5.5 (1.7)	8,500 lbs (3,850 kg)	—
DOLPHIN AG(SS) 555	U.S. Navy (under construction)	—	—	—	—	1 diesel/electric	3 silver-zinc batteries; 2 diesel/electric generators	152 (46.3)	19 (5.8)	20 (6)	700 T (711 mt)	925 T (940 mt)
DOWB	General Motors Defense Research Lab. (under construction)	6,500 (2,000)	2	5	8.1 hrs at 5 kts 36 hrs at 2 kts 58 hrs at 1/2 kt	2 2-hp horiz plus 2 2-hp vert	120 outboard, Delco-type cells producing total of 43.2 KWH	16 (4.9)	8.5 (2.6)	6 (1.8)	14,274 lbs (6,474 mt)	—
KUROSHIO II	Hokkaido University, Japan (1960)	650 (200)	2	—	Tethered to surface power source	1 440-v AC motor	Surface electric power through cable	36.7 (11.2)	7.15 (2.2)	10.4 (3.2)	11.5 T (11.7 mt)	—
MORAY (TV-1A)	U.S. Naval Ordnance Test Station, China Lake, California (1964)	6,000 (1,800)	6	15	3.6 hrs at 6 kts	1 90-hp battery-operated torpedo motor; counter-rotating propellers	Bank of 240 silver-zinc secondary cells	33 (10)	5.3 (1.6)	5.3 (1.6)	10 T (10.2 mt)	16 T (16.25 mt)
NR-1	U.S. Navy/Special Projects Office (under construction)	—	—	—	—	2 aft-located propellers	Small nuclear reactor of pressurized water type	—	—	—	—	—
PISCES	International Hydrodynamics Co. Ltd., Vancouver, B.C., Canada	5,000 (1,500)	1	6	7 hrs at 6 kts 24 hrs at 1 kt	2 oil-immersed DC motors; 2 variable-pitch propellers	60 120-v oil-immersed, lead-acid cells, 550 amp-hrs	16 (4.9)	11.5 (3.5)	9 (2.7)	6.5 T (6.6 mt)	—
SEVERYANKA	U.S.S.R./All-Union Institute of Marine Fishery and Oceanography (VNRI) (1958)	550 (170)	15	—	16,500-mile (26,550 km) range at snorkel speed	Diesel/electric	Diesel-snorkel, lead-acid batteries	240 (73.1)	22 (6.7)	15 (4.6)	—	1,180 T (1,199 mt)
STAR I	Electric Boat Co., General Dynamics Corp. (1963)	200 (60)	.75	1	3 hrs at .75 kt	2 side-mounted, .25-hp, 18-v	2 external, 18-v, DC, lead-acid (fuel cell was used, 1964)	10.1 (3.1)	6 (1.8)	5.8 (1.7)	2,750 lbs (1,250 kg)	—
STAR II (ASHERAH)	Electric Boat Co., General Dynamics Corp./University of Pennsylvania Museum (1964)	600 (180)	1	4	8 hrs at 1 kt 2 hrs at 4 kts	2 side-mounted 2-hp, 24-v	External, 24-v, lead-acid	17 (5.2)	7.7 (2.34)	7.6 (2.31)	8,600 lbs (3,900 kg)	9,900 lbs (4,490 kg)
STAR III	Electric Boat Co., General Dynamics Corp. (under construction)	2,000 (600)	1	4	10 hrs at 1 kt 2 hrs at 4 kts	7.5-hp, single-screw, stern-drive; 1 2-hp bow thruster; 1 2-hp, vertical hovering motor	115-v, 30-KWH, oil-immersed, lead-acid	24.5 (7.5)	6.5 (2)	9 (2.7)	18,300 lbs (8,300 kg)	20,800 lbs (9,400 kg)
TRIESTE II	U.S. Navy/COMSUBPAC (1964)	20,000 (6,000) (Terini) 36,000 (11,000) (Krupp)	2	—	5 hrs at 2 kts	2 10-hp aft; 1 2-hp bow thruster	External, 145-KWH, lead-acid	67 (20.4)	15 (4.6)	18 (5.5)	50 T (less ballast and avgas) (50.8 mt)	220 T (223.5 mt)
YOMIURI	Mitsubishi/Yomiuri, Shimbun Newspaper, Tokyo, Japan (1964)	1,000 (300)	4	—	6 hrs at 4 kts	1 electric, AC 2 diesel	Diesel/electric; auxiliary diesel for battery charging; alternator for AC pwr	48 (14.6)	8.2 (2.5)	9.2 (2.8)	—	35 T (35.5 mt)

Crew	Life Support Endurance (Hours)		Payload Pounds (Kilograms)	Pressure Hull Type	Maneuvering Control	Remarks
	Normal	Maximum				
4-6	32	72	6,000 (2,700)	11 forged cylindrical sections, 40 in (1 m) long and 8 ft (2.4) in diameter, 2 hemispherical heads of aluminum 7079-T6, 6.5 in (.165 m) thick. Bolted construction.	Vertical motor, rudder and control planes, variable H ₂ O trim tanks, puller-type propellers.	Oceanography, mineral and oil survey; 2 mechanical arms capable of taking 4-ft (1.2 m) core samples and 1-cubic-foot (.3 m ³) grab; 2 trainable TV, extendable boom, lifting ability of 4,400 lbs (1,990 kg).
2	10	24	1,200 (540)	7-ft (2.1 m) (o.d.) sphere HY-100 steel, 1.33 in (.033 m) thick.	1 trainable stern and 2 rotatable reversible propellers, mercury trim systems, variable ballast system.	Designed to support multipurpose scientific program; mechanical arm, sample trays and jars; 2 additional ALVIN-type vehicles in planning stage.
2	8	8	450 (200)	Welded dimetacoted A-36 steel, .375 in (.099 m) thick.	Stick-type diving planes and rudder, H ₂ O trim tank.	2 conning towers with wrap-around plexiglass windows.
2	8	16	750 (340)	Welded dimetacoted A-36 steel, .5 in (.012 m) thick.	Stick-type diving planes and rudder, mercury trim system, mineral oil trim tanks for vernier weight control.	Single conning tower with wrap-around window, 8-in (.2 m) port in bottom forward.
3	12	32	4,000 (1,810)	Ni-Cr-Mo forged steel sphere, 7.87 ft (2.39 m) (o.d.), 6.9 ft (2.1 m) (i.d.), 5.9 in (.149 m) thick.	2 motors provide vertical movement and direction control, trailing rope for near-bottom control.	Has explored Kuriles Trench (31,320 ft; 9,550 m), Puerto Rican Trench and Tyrrhenian Sea; uses hexane (45,173 gal; 170,995 L) for buoyancy.
40 (passengers and crew)	8	48 (without pass)	20,000 (9,070)	Steel cylinder, capped by steel hemispheres.	Forward and stern planes, kurt tureye, variable H ₂ O trim system.	Tourist version used to transport passengers to 300 ft (91 m) in Lake Geneva during 1964 Swiss National Exposition at Lausanne; has scientific capability.
2	8	16	400 (180)	5-ft (1.5 m) (o.d.) mild steel sphere, .625 in (.015 m) thick, fiberglass fairing.	Reversible propulsion motors trainable 180° from horizon, variable H ₂ O trim system.	6 viewing ports.
2	12	20	750 (340)	A285 steel.	Rudder and bow planes, variable H ₂ O trim system.	Propulsion endurance may be increased with optional silver-cadmium or silver-zinc batteries; hovering motors available; lifting capacity of 2,100 lbs (950 kg).
2	12	20	950 (430)	.5 in (.012 m)—A212 steel.	Rudder and bow planes, variable H ₂ O trim system.	Lifting capacity of 2,200 lbs (998 kg).
2 (plus 2 divers)	5 at 1,000 feet (300 m) of depth	36	1,500 (680)	T-1 steel.	1 vertical motor aft, main propulsion motor on 180° swivel, 1 360° thruster motor forward.	Diver support vehicle; operators compt. forward, diver decompression chamber aft; diver lockout depth —1,250 ft (380 m).
2	6	48	200 (90)	5-ft (1.5 m) (o.d.) HY-50 sphere.	Rotatable motors aft.	Neutrally buoyant vehicle; underwater range tool and oc. research instrument; single viewpoint and fixed periscope.
2 operators 2 scientist/observers	24	48	3,400 (1,540)	2 intersecting maraging steel spheres.	Integrated system—50° of freedom.	Designed for deep ocean exploration, mineral surveys, and support of ocean engineering operations.
2	8	48	400-1,000 (180-450)	HY 80 steel 2 hemi heads welded to end—75-in (1.9 m) wide cylinder.	Rotatable jets, mercury trim system, reversible main thrust motor—60-lb (27 kg) weight for descent, high-pressure air-blown tank for ascent.	2 external manipulators, motion-picture camera, 2-way underwater telephone and surface radio communication.
3	12	48	100 (min) (450)	6.5 ft (1.98 m) (o.d.), 1.2-in (.03 m) HY-80 sphere.	8 small, floodable bottles outside hull; mercury trim system; reversible, variable speed motors; 2 weights: 231 lb (105 kg) for descent; 187 lb (85 kg) for ascent.	Helicoidal operating pattern permits 60° ascent and 50° descent; hydraulically controlled arm and specimen basket; 12,000- and 20,000-ft (3,660 and 6,100 m) vehicles of similar design but stronger pressure hull planned.
2	4	24	100 (min) (450)	.75-in (.019 m) thick mild steel ellipsoidal, 6.5 ft (1.98 m) (major d.), 4.9 ft (1.49 m) (min d.).	Rotatable jets; 2 55-lb (25 kg) weights for ascent and descent; fine buoyancy control by internal ballast tank; mercury trim system.	Hydraulically controlled arm, specimen basket; excellent maneuverability.
22	—	—	—	HY-80 cylinder, hemispheric ends.	Water ballast, rudder and diving planes, hovering control.	This deep-diving submarine will be operated in support of naval oceanographic research requirements.
2	—	40	1,021 (460)	HY-100 steel sphere, .915 in (.023 m) thick 80.16 in (2.036 m) (i.d.).	2 vertical motors, 2 horiz motors.	Optical ports at north and south poles of sphere; out-board system below for full hemisphere visibility; TV cameras may be mounted fore or aft; will be used for research and deep ocean engineering applications.
4-6	24	—	—	Mild steel plate.	Rudder, water ballast system.	Vehicle tethered to surface by 1,900-ft (580 m) (35 mm diam.) cable, 16 viewing ports, 5 exterior lights; manipulator, btm. sampler; TV, phone to surface.
2	24	—	150-200 (70-90)	2.5 ft (.6-1.5 m) (o.d.) cast aluminum A-356-T6 bolted spheres (1 for crew, 1 for inst.).	Tail-mounted control surfaces, mercury trim system, autopilot.	Ring stiffened fiberglass hull contains syntactic foam; first vehicle to demonstrate feasibility of positively buoyant URV design; MORAY is "flown" through water; oceano-acoustic research; no viewports, 2 TV cameras.
—	Periods compatible with personnel endurance and food supply.	—	—	HY-80 steel.	Internal thruster tubes located fore and aft.	First nuclear-powered deep-submergence vehicle for detailed studies and mapping of ocean floor for scientific and commercial purposes, and for retrieval of objects on the seabed; small onboard laboratory.
2	24	72	1,500 (680)	2 spherical Algoma 44 steel sections.	Motor-drive, ballast—fore and aft inclination.	Sonar systems scannable through 180° and tiltable 90°; 2 manipulators and clamping arm for holding vehicle to floor; for charter to oil industry, underseas mining, geology, and geophysics.
60 (6-8 sci. party)	—	—	—	—	Rudder, diving planes, and water ballast.	Converted WHISKEY-class submarine for fisheries oceanography; forward torpedo room converted into scientific lab; 3 observation stations with viewing ports on each side of hull and overhead; TV in bow; exterior illumination; bottom sampler extendable through hull.
1	4	18	200 (90)	A212 grade B steel, .375 in (.009 m) thick.	Differential operation or rotatable motors with planes attached, water ballast.	First URV to test fuel-cell propulsion.
2	10	24	250 (110)	A212 grade B steel, .625 in (.015 m) thick.	Variable-speed rotatable propulsion motors, water ballast, fixed stern stabilizers.	6 viewports forward, downward on both sides. Highly maneuverable.
2	12	24	1,000 (450)	5.5 ft (1.676 m) HY-100, .5-in (.127 m) thick.	Hovering and bow thrust motors, servo-powered rudder, mercury trim system, variable ballast tanks.	Retractable mechanical arm, 5 viewports, 2 TV cameras; high payload to displacement ratio and maneuverability.
3	10	24	20,000 (9,070) (with Terni-sphere)	Terni-sphere, 7 ft (2.1 m) (o.d.), 3.5 in (.088 m) thick, Ni-Cr-Mo forged steel. Krupp sphere, 7.2 ft (2.193 m) (o.d.), 4.72-in (.145 m) thick forged steel.	2 shot-ballast silos, 47,000-gal (178,000 l avgas floatation, drag rope, gas maneuvering tank amidships.	Vehicle presently equipped with Terni-sphere; Krupp-sphere interchangeable; mechanical arms, 3 TV cameras, high payload capacity. An evolutionary improvement over T-II will be built in FY 1966 at Mare Island Naval Shipyard for naval research; currently operated in support of DSSP Project.
6	—	—	—	High tensile strength steel cylinder.	Manual control of rudder and diving planes, H ₂ O trim, buoyancy tanks.	Miniature submarine for fisheries oceanography and seafloor investigation; mechanical arm, 4 floodlights, 7 optical glass windows, TV cameras, net and pressure tank for specimen preservation.

Sealab II aquanaut, working in the vicinity of undersea research vehicle, moves mushroom-shaped current monitor designed to check direction of ocean flow in study area off California coast. Some 47 experiments were undertaken, ranging from examination of human performance to analysis of contributions to research by porpoises, during Sealab effort.



allows me to make some comparisons and draw some conclusions which are pertinent to the safe, expedient, and successful conduct of our man-in-the-sea programs. The comparisons reveal . . . some similarities. . . ."

Many of the same problems are encountered, Commander Carpenter said, in designing and fabricating the machines and especially the environmental control systems required for space and sea operations. There are also many problems in common in the selection and training of crews, including the physiological and psychological studies that have to be conducted before, during, and after the experiments. And there are similarities in the problems of suit design, manufacture, and fitting.

A "vast array of talent and equipment" is needed for both space and sea operations, Carpenter said, lamenting the fact that the sea-research community is so much smaller than the space-research team, when both are needed in large numbers.

What was it like for 30 days in a cramped, 10-man vessel, some 200 feet (61 m) below the surface? Carpenter's description was vivid:

"First, forget all you've seen of [television stories about underwater operations]. Sealab waters are not like that. They are dark, and dirty, and cold. We don't relish these conditions, but we realize that most of the waters of the world are not warm, clear, and inviting. And we know that

these are the surroundings to which man must adapt himself and his equipment if he is to prove he can live and work in the sea.

"Preparation for a dive is a lengthy process. To don the easily torn sponge-rubber wet suit, the knife, the watch, compass, depth gauge, weight belt, helmet, face mask, flippers, and breathing apparatus requires perhaps 45 minutes. More time is required to assemble tools and equipment he will use. Still more is required for a last-minute recapitulation of the dive plan. It is necessary to do this because as soon as a diver and his [comrade] . . . step through the hatch and enter the water world they become mute and essentially deaf. Their vocabularies are reduced to less than a dozen words, spoken only with raised fingers or the rap of a knife hilt against a gas bottle.

"A diver's most urgent cry—M'aidez!—can be uttered only with 4 fingers or 4 raps, and the raps don't carry very far," Carpenter added.

To overcome such undersea operational problems he urged a "desperately needed" research program to develop a reliable diver-to-diver communications system that does not encumber aquanauts with wires or compromise the performance of their breathing apparatus.

"The divers will spend their first 10 to 15 minutes in the water working against the clock on delicate assembly tasks and intricate 2-hand coordi-

nation tests," Carpenter continued. "These, as well as measures of whole-body strength, are done pre- and post-dive, in the water, in an attempt to measure the degradation of man's performance during long exposure to cold water.

"Once these tests have been accomplished, they can get on with their work. This can consist of any number of tasks related to the ocean sciences; salvage; rescue; marine biology; geology; sound and light propagation; installation of marine weather instrumentation; logistics; and maintenance of underwater equipment. By and large this work is done with ordinary tools that can be found in any mechanic's toolbox and with equipment that works well on dry land, but invariably develops some ailment after immersion in salt water. We need to devote more human engineering talent to the development of special equipment and tools for use in this dim, . . . corrosive void."

Suit equipment is a special problem because of pressure, Carpenter stressed.

"If the diver's work carries him into water much deeper than his habitat, his suit is compressed by the increased pressure until it becomes paper-thin and loses nearly all its thermal-insulation properties, and he gets cold faster."

Carpenter said that a suit must be developed that does not tear easily, yet still provides a good thermal barrier regardless of depth. This means a reliable, thermostatically heated suit. He believes that eventually it will be necessary for successful sea operations to adapt something like the Apollo liquid-cooled spacesuit to ocean use. "The liquid flowing through the garment could be heated with a small radioisotope package that will replace one weight on a diver's belt," he said.

As to breathing apparatus used for astronautics and sea work, they are a study in contrasts between the primitive and sophisticated. Carpenter reported: "Monitoring the satisfactory performance of the [diver's] lung currently in use is purely subjective, is done mainly by the diver's companion, and is limited to watching whether bubbles are coming from the right place or the wrong place. It is both difficult and time-consuming to set up the control element properly. It gets out of calibration easily, and is not as reliable as it can be made. It has many design defects and reflects very little of the tremendous advances recently made in the field of human engineering that are so evident in aircraft, spacecraft, and space-age personal equipment."

In contrast, Carpenter said, "the



Astronaut Carpenter, shown in space garb, says sea research equipment must be improved sharply to assure program progress.

astronaut in flight faces a splendid panel of instruments, which provide immediate and continuous evaluation of all the components and systems upon which his security depends. In addition, he has 3 shifts of eyes and ears around the world helping him, through telemetry, to check his equipment. The diver . . . has little or no instrumentation in or out of his habitat. And when he is in the water, he is alone. He and his companion are completely beyond the help of any man."

What is lacking in sophistication of equipment has to be compensated for in personal skill and imagination, Carpenter emphasized. "We do have some

safeguards. For instance, a man can help his [comrade] get back home with an extra mouthpiece on his own equipment, but the need to give the diver better equipment, more instrumentation, and longer and deeper excursion times still exists," he said.

Carpenter summed up the requirements for important progress in man-in-the-sea operations in these words:

"Our most imaginative thought must focus on the design of the habitat and the whole concept of undersea living. Man must be able to sever his psychological as well as his physical ties to the surface. Adaptation of nuclear power would give us a completely autonomous, self-propelled research vehicle. It would avoid the many problems we face trying to handle a sub-surface object with a surface vessel and would open up unprecedented depth and endurance capabilities.

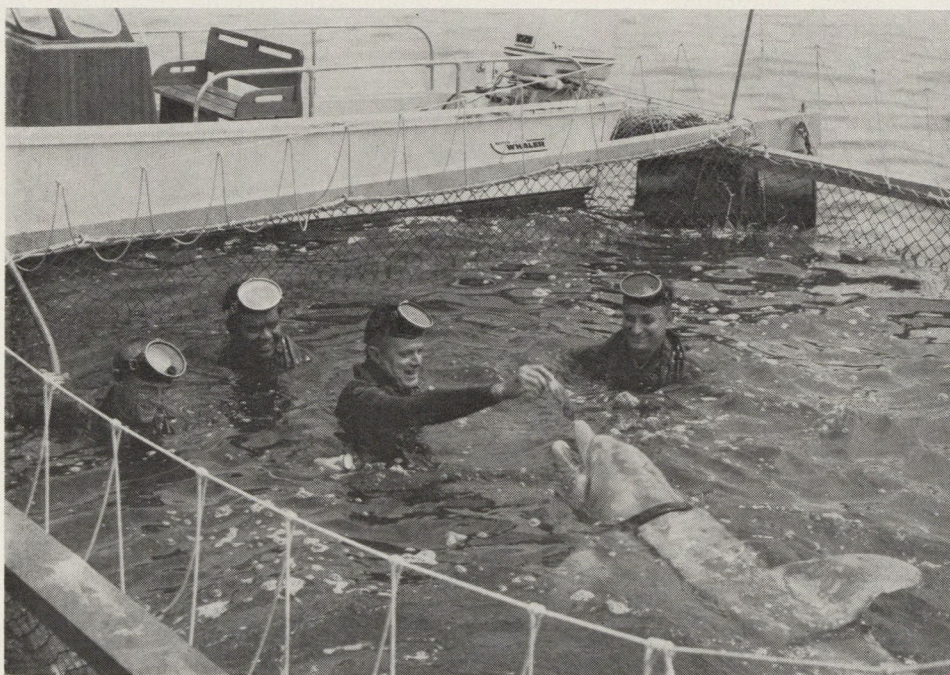
"The Sealab II habitat was luxurious in many respects, with larger portholes [than its predecessor Sealab I] and wall-to-wall carpeting, but we are not served well by a cylindrical design. We need more room in the diving station. This was our worst bottleneck. We need telescoping legs to help us level [out] on uneven terrain, and separate laboratory areas away from traffic, and . . . oxygen storage. . . .

"For undersea work we have a scattering of small pressure chambers around the country. One goes [down to] 800 feet [244 m]. We need a 2,000-foot [610 m] capability now with a large water-filled compartment which will allow us to evaluate the immovable equipment. It must be capable of being pressurized with helium,

argon, or other rare gases as the need arises, and in it we need to study the effects on man of very high pressures. Does he slow down, become sluggish? What cellular changes occur? How are his organic functions altered? A marriage of cellular chemistry and definitive physiological and psychological studies, which is so badly needed, could center around a deep-submergence center with a high-pressure facility such as this. Accurate measures of caloric intake and metabolic rates could be made and valuable information can be gained by . . . hyperbaric medicine. Perhaps the chamber's most important use would be in the study of inert gas uptake and elimination by the human body. We must have a better understanding of this before we really begin to understand the decompression and narcosis problems. . . .

"I'm convinced the press and television sold the space program to the world. One of my chief regrets is that we could not bring back better photographic documentation. . . . These pictures would have been of great value in attracting young, intelligent, hard-driving men into [our program]. . . .

"The disparity between the equipment used by aviators and divers is incredible. . . . [Pilots] have complained and fought for the innovations and safety precautions that [man in the sea] needs. . . . We cry to industry: Make it better, make it last longer, make it easier to operate. After the feeble beginnings of pushing body and mind—figuring out a way to beat the odds, we . . . want more. It is not an uncommon trait among men." ☆☆☆



Prior to Sealab II submergence, crew trained porpoise named Tuffy in a floating tank. Porpoises, known to be extremely intelligent sea mammals, have been object of research interest to U.S. Navy for several years. Tuffy was a member of Sealab II's ship's complement. The idea was to see how a porpoise might be able to aid an aquanaut in undersea operations. Left, he gets a fish for a snack.



ITT—the place to go for the latest in AVIONICS

ITT—International Telephone and Telegraph Corporation—is displaying its advanced avionics capabilities at the West German Air Show in Langenhagen, April 29 to May 8.

Companies* who have helped make ITT the world's largest international supplier in electronics and telecommunications, are featuring equipment and displays covering some of the most up-to-date techniques and systems for ground-based and airborne applications.

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Instrument Landing Systems accurate within inches; Radio Altimeters flight-tested in 15,000 blind landings.

Flight Simulators for aircraft and for flight behaviour study of "Concorde".

DME Ground Beacons giving pilots reliable distance readings.

TACAN for accurate bearing indication and continuous position information.

LORAN-C, airborne version.

VOR and D-VOR comply with ICAO standards.

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In addition, a special section of the exhibit is devoted to ITT's growing contribution to space technology, featuring satellites, programming systems and

tracking equipment.

When visiting the West German Air Show at Langenhagen, be sure to see **ITT—HALL B, STAND 1204/1304.**

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Seapower

Maneuverability and speed on the high seas are vital to successful antisubmarine warfare, and the task of attaining these capabilities in an era of extremely high-performance submarines is a difficult assignment for technology. There is a good deal of promise that these requirements can be met to a significant degree by . . .

Hydrofoils: Fast, New Sea Legs for Antisubmarine Warfare

By Stefan Geisenheyner, Editor for Europe

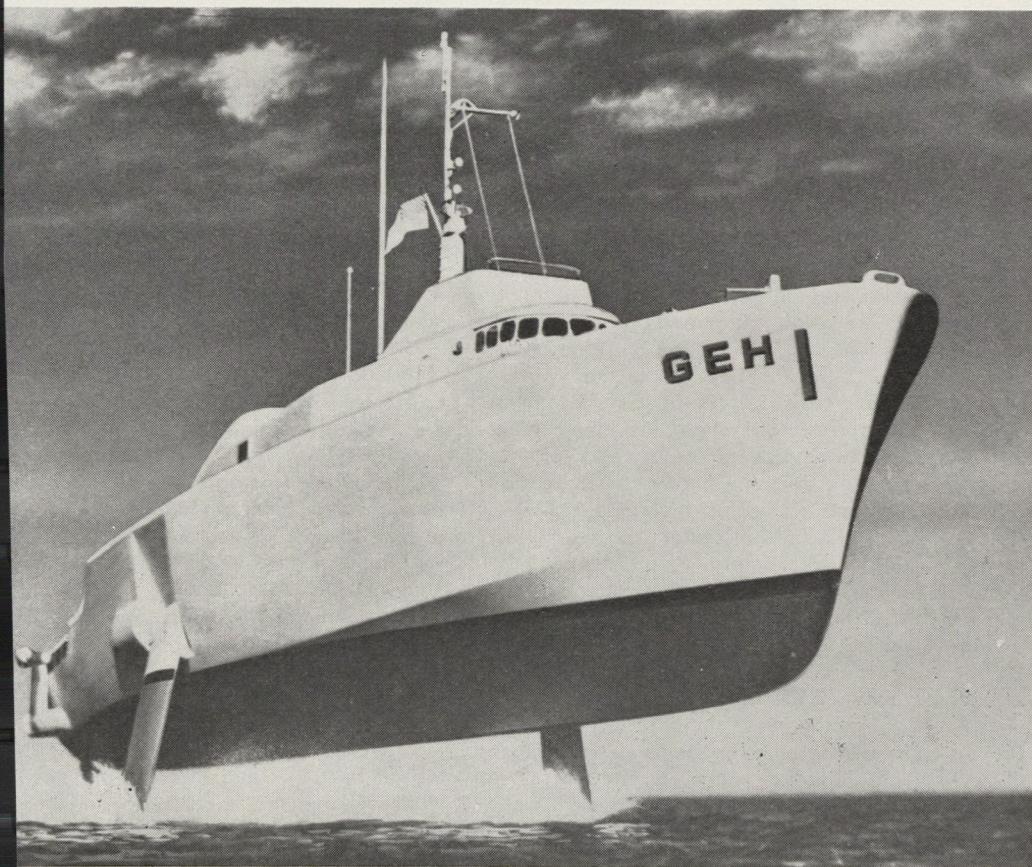
Proportionally with the steadily increasing threat of the modern submarine to vital intercontinental sea routes rises the interest in finding new methods for combating this menace. The only modern antisubmarine warfare (ASW) weapons available today are the hunter-killer teams consisting of appropriately armed, long-range patrol aircraft, and helicopters working

in combination with small, very fast, attack submarines. These teams are able to cope with present-day submarines, but due to the high costs it is impossible to put enough of them into service to cover even the barest wartime requirements. The teams will be protecting the carrier task forces and hunting ballistic-missile submarines.

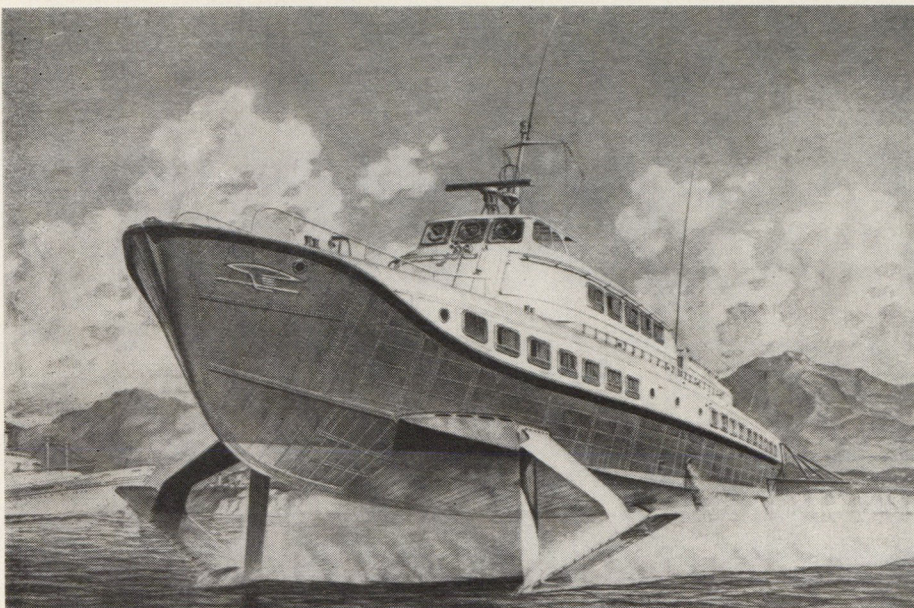
Nonetheless, supply convoys must

also be protected. At present, this task still falls to the destroyers, frigates, and corvettes of yesteryear, which, due to their speed limitations, are unable to fight efficiently, let alone protect the convoy they are entrusted with. The nuclear submarine can cruise submerged at speeds above 40 knots, whereas the surface-bound displace-

(Continued on following page)



Lockheed Shipbuilding and Construction Company has built for the U.S. Navy this experimental hydrofoil ship, described as the world's largest. Named the PLAINVIEW, it has a fully submerged hydrofoil system controllable by an electronic autopilot. Two General Electric J79 gas-turbine engines, modified for marine use, power the craft during high-speed operation, each developing 15,000 horsepower transmitted to 2 super-cavitating props.



An example of the surface-piercing approach to hydrofoil design is the Swiss-designed Supramar boat, used commercially, and powered by Bristol Siddeley gas-turbine engines. Although there are some operational disadvantages, such as a built-in wave-following tendency, the system's simplicity makes it attractive.

ment-type ship cannot go faster than 35-40 knots under the most favorable weather conditions. Rough seas limit the speed severely, whereas the submarine remains unaffected.

Out of this militarily uncomfortable background rises a requirement for a new type of ship, capable of top speeds above 60 knots under almost any weather condition, carrying extensive ASW armament, and having enough range for convoy duties. Moreover, the ship should not be too expensive or too sophisticated so that it can be built quickly in great numbers should the need arise.

The speed requirement cannot be filled by any type of conventional ship due to the inflexible laws of hydrodynamics. Neither a displacement-type hull, which encounters speed-limiting drag problems, nor the planing-type hull, which skims the surface during high-speed operations, is suitable. The high-speed planing ship is an unstable weapon platform even in moderately agitated seas where the equipment and crew have to stand G-loads varying between zero and 3 Gs as the bow hits the oncoming waves. A solution to the requirement has appeared in the form of the hydrofoil—a ship “flying” on wings immersed in the water.

The essential feature of a hydrofoil is its 2 or more lifting surfaces, so-called foils, mounted beneath the hull. The foils generate enough lift to raise the hull above the waves, thus reducing water resistance so that less power is required for any given speed. Since the drag of the foils is minimal, speeds above 60 knots can be attained easily. At low speeds a hydrofoil vessel functions as a standard displacement ship. At higher speeds the forward movement causes the foils to

rise, enabling the vessel to “fly” with the hull clear of the water. Hydrofoil craft, similar to aircraft, can be configured in many different ways, and several basic types of foil systems have been evolved according to the type of operational environment expected. Mainly, these fall into 2 general types—surface piercing and fully submerged.

In the surface-piercing system, part of the foil extends above the water surface. Since the amount of foil which is submerged tends to remain constant for a given speed or load, the system has inherent stabilizing forces, which keep the ship upright in the “flying” state. A typical example of the surface-piercing approach is the Swiss-designed Supramar boats where the forward and aft foils are attached to the hull in V-form, with the tip of the V pointing downward. This simple method has its drawbacks. The surface-piercing foil has a built-in wave-following tendency which will produce a rough ride in high seas. Still, the simplicity of the system makes it attractive for use in similar hydrofoil craft, where the employment of an automatic pilot and control needed for the fully submerged foil systems would be uneconomical.

In the flat-foil system the foils operate fully submerged and it lacks the inherent stability of the other system. The fully submerged system, however, will give a smooth and level ride even in rough seas, as the foils never break above the surface of the water. Provided the wave height does not exceed the length of the struts on which the foils are mounted, the vessel is capable of smooth motion in any weather.

To keep such a ship on an even

keel, control surfaces similar to aircraft flaps or ailerons must be built into the foils or else the incidence of the foils (the angle at which they move through the water) has to be made variable. This can be done by an automatic stabilization and control system which receives its input from electronic surface sensing equipment. Any deviation from a preset “flying” attitude is sensed by gyroscopes and accelerometers which send corrective signals to the control surfaces on the foils. Thus, the hull can be maintained at a required height above the water and controlled for roll as well as pitch and yaw. In spite of the sophisticated machinery necessary to operate the stabilization systems, the fully submerged foils offer considerable savings in weight and drag. Therefore, higher speed with less horsepower is possible, as compared to the surface-piercing systems. The fully submerged system is obviously better for larger ships and for military purposes where a highly stable weapons platform is needed.

For both types of foil, the hull must be tailored carefully for its intended function. Structurally, it must be able to withstand repeated wave-impact loads which occur when the hull contacts the crest of the highest waves. Yet, the design must be light in weight and low in cost. Experience has shown that for most applications an aluminum structure constructed with a blend of aircraft and shipbuilding techniques is the best way to satisfy all requirements.

Most commercial hydrofoil ships in operation today utilize diesel engines. Diesels have the important virtues of proven reliability and low fuel consumption. But lighter and smaller en-

gines with higher power output would be much more efficient even under penalty of higher fuel consumption. Newer high-performance hydrofoil ships are therefore utilizing gas turbines, which have recently become available for marine use (see "Aircraft Jet Engines for High-Speed Sea Operations," p. 30, AF/SD INTERNATIONAL, January 1966). Presently, lightweight diesels are available only up to 3,000 horsepower. Gas turbines of relatively small size, on the other hand, are available up to 25,000 horsepower in continuous output. The Bristol Siddeley Marine Olympus, for instance, has a continuous rating of 22,000 horsepower. The availability of such high-power gas turbines is an important factor in designing larger hydrofoils where greater energy is needed.

As mentioned above, the hydrofoil ship operates in two modes—"flying" at cruising speeds and as a conventional displacement ship for low-speed operations and docking. In the displacement or hull-borne mode, a different power unit, independent from the main propulsion unit, is used. Here, too, the choice lies between a diesel or a gas turbine. Both have their merits, and the specific task for which the ship is designed will dictate which engines will be used. It is believed, however, that for both modes of operation the gas turbine will eventually become the standard power unit. The turbine engine has a marked advantage in specific weight and specific volume over the diesel engine. It gives the hydrofoil designer much more flexibility in locating the engine room to maximize space for cargo and passengers.

The relatively high-fuel consumption of the gas turbine is cited by diesel proponents as a major drawback. This drawback, however, is only superficial. The turbine consumes on the average only 1.7 times more fuel than the diesel. As an example, the difference in weight between a pair of 3,000-horsepower diesels and a gas turbine delivering their combined power output amounts to approximately 10,000 pounds (4,536 kg) in favor of the turbine and 10,000 pounds (4,536 kg) of fuel is equal to 5 hours of continuous power operation of the turbine. The turbine could therefore operate for 5 hours before its weight plus the fuel it used equaled the weight of the diesel.

A major problem is providing an efficient transmission system between the engine and whatever thrust device the boat uses. Almost all present boats use water propellers, driven by either a straight shaft or an angled zee-drive. Such systems attain propulsive



This is Boeing Company's hydrofoil vessel HIGH POINT, built for U.S. Navy to explore military potential in antisubmarine warfare. Powerplant consists of 2 Bristol Siddeley Proteus marine gas-turbine engines which can deliver "flying" speeds of 60 knots.

efficiencies up to 75 percent for speeds between 20 and 40 knots. But major hydrodynamic difficulties posed by propeller erosion at high speeds and by the difficulties of designing a transmission which can transmit loads up to 20,000 horsepower, has led to study of other schemes of thrust. Air propellers, straight jet engines mounted on the hull, and water jets are the major contenders.

Of these, the water jet shows substantial promise. In this system, water enters through an inlet at the bottom of the hull or through the hollow core of the front strut into a water pump. The pump is driven by the ship's main propulsion unit, preferably a gas turbine. The water is expelled rearward through appropriately shaped nozzles. Water pump technology is well proven in a multitude of industrial applications, and the construction of pumps for hydrofoil use should pose no problems. At lower speeds, the efficiency of the water jet is less than that of a propeller system. For cruising speed above 45 knots, however, water-jet efficiency improves rapidly. Further, the water jet generates a lower noise level than do propellers, an attractive characteristic for antisubmarine warfare operations. Air propellers and straight jets appear best suited for speeds above 100 knots. Tests have been conducted, but no conclusive results have been made public.

The straightforward commercial types of hydrofoil boats that are operational already have been technologically surpassed by the experimental or prototype boats built for military use. Although no operational military or com-

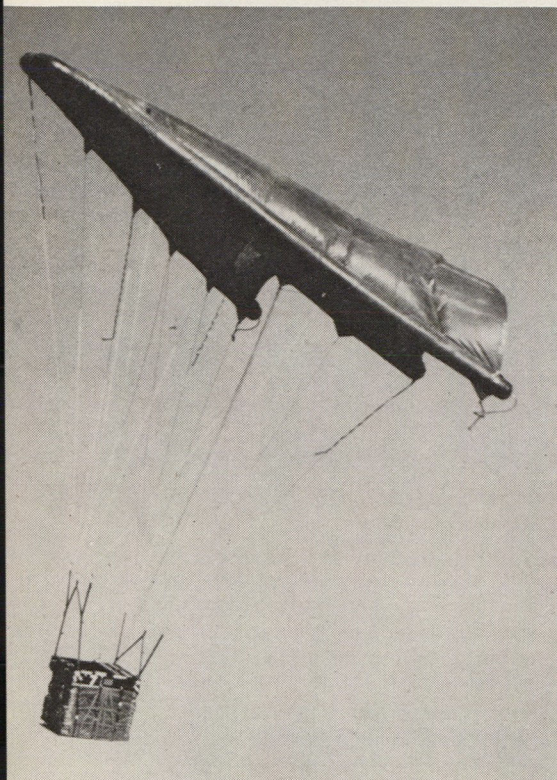
mercial hydrofoil boats are now in use in the U.S. or Canada, the state of the art for this type of vehicle is considerably more advanced in these countries than anywhere else. This is due to the early research programs sponsored by the U.S. Navy, the Royal Canadian Navy, and the U.S. Maritime Administration. The highly advanced aerospace industries in the U.S. and Canada have played a big role in hydrofoil progress since they were able to draw on high-quality materials and construction methods originally developed for aircraft technology.

The U.S. Navy first showed interest in hydrofoils during 1947 when the Office of Naval Research formulated a development program to assess their military potential. During the following years, feasibility and design studies explored the problems of control, drag, stability, weight, and powerplant design. In 1959 the U.S. Navy received Congressional approval to include in its 1960 Shipbuilding Program a hydrofoil craft suitable for carrying out antisubmarine patrols. A contract was awarded to the Boeing Company in June 1960 for construction of this vessel, designated the PCH-1. It was subsequently named HIGH POINT and was built to Boeing's specifications by the J. M. Martinac Shipbuilding Corporation at Tacoma, Washington. It was launched on August 17, 1962.

The HIGH POINT is 115 feet long (35 m) has a beam of 31 feet (9.4 m) and displaces 110 tons (99.7 mt). The hull is constructed of aluminum. Its bow and bottom are reinforced to withstand the shock-loading experi-

(Continued on page 36)

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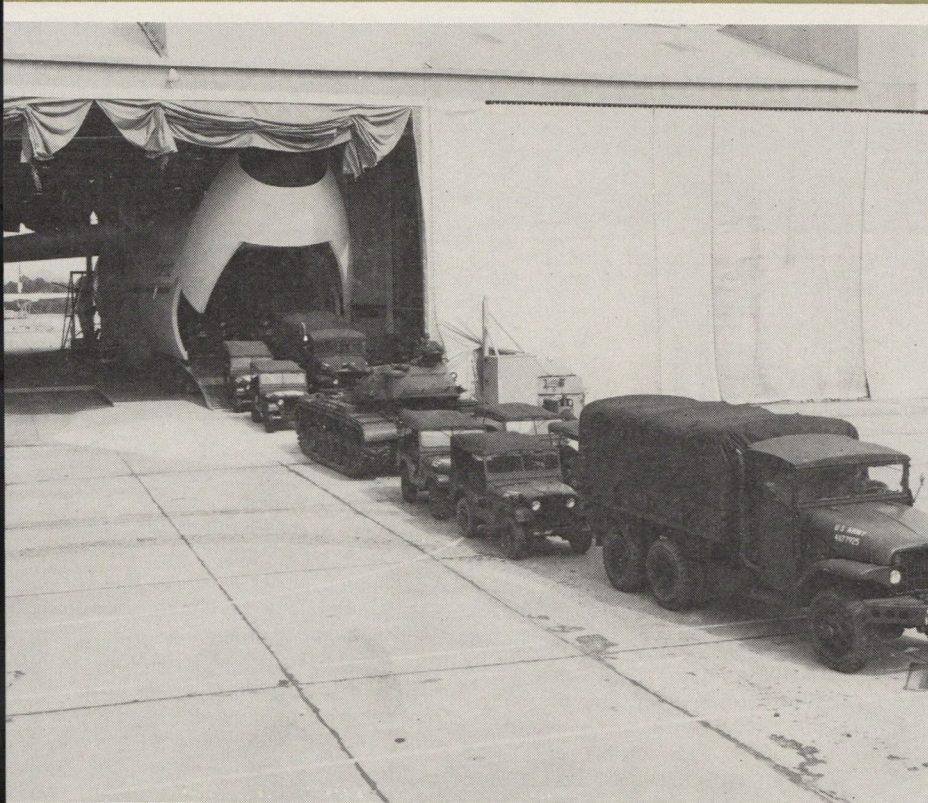
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Grumman's hydrofoil ship DENISON, built for U.S. Maritime Administration, uses 2 surface-piercing foils and 1 submerged foil. The primary powerplant is GE LM 1500 marine gas turbine. In hull-borne mode, it is powered by 2 GE T58 gas-turbine engines.

enced during the landing phase, when the hull settles on the water as the vessel decelerates from a high-speed run. The ship has 2 fully submerged steel foils located on retractable struts below the hull. The forward foil is mounted on a single strut, the rear foil is supported by 2 struts near the aft end of the hull. The powerplant consists of 2 Bristol Siddeley Proteus marine gas turbines, each delivering 3,100 shp with which, in the "flying" mode, speeds up to 60 knots have been achieved. Each engine drives through a right-angled transmission located at the top of each rear strut and connected to a drive shaft within the strut. At the base of each strut is a set of right-angled drives housed in a nacelle carrying 2 contrarotating propellers, 1 forward and 1 aft of each nacelle. The vessel has accommodations for 13 officers and men and carries sonar and radar equipment.

An extensive test program with this experimental vessel furnished the first experience with a submerged foil system in all speed regimes. As expected, many technical difficulties, especially in the hydrodynamic field, were encountered. The so-called cavitation problem was encountered for the first time in hydrofoils. Cavitation can occur in any object moving at high speed through the water. In the case of hydrofoil ships it applies to the foils as well as to the nacelles or propellers. As water flows over a foil, the pressure on the upper side is decreased as the angle of attack increases. When this pressure falls below the vapor pressure of water, contact with the water is lost and a vapor

cavity formed. These cavities are not stable but oscillate rapidly in such a manner that water particles impinge with considerable force on the foil surface, quickly eroding the toughest metal. The seriousness of the cavitation problem may be judged by the fact that the propellers of the HIGH POINT have a life expectancy of only 2 hours at 45 knots.

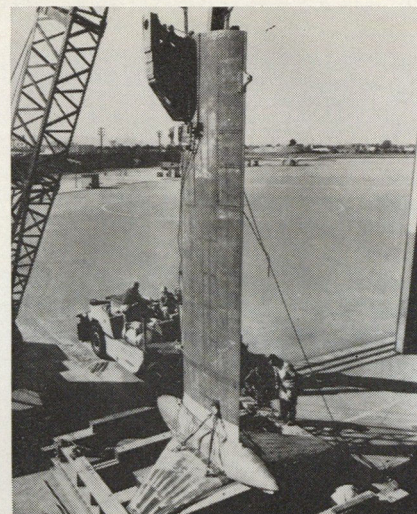
Cavitation alone would drop the military value of hydrofoil ships to an absolute zero if no remedies were in sight. The HIGH POINT, however, was built to study just such phenomena and a variety of newly designed propellers and erosion-resistant materials to cover the foils and struts were tried. It was found that both the foil and the propeller could be designed to be supercavitating; that is, that the whole upper foil surface becomes "unwetted." A vapor cavity stretching from leading to trailing edge is formed and then collapses behind the trailing edge, thus preventing any water droplets from collecting on the foil itself. Although supercavitating foils have lower lift coefficients at low speeds, they can operate at high speeds without cavitation damage. Since propellers are particularly sensitive to cavitation, a great deal of work has gone into the designing of new shapes and searching for new superhard materials. Although careful design can avoid many harmful cavitation-forming conditions, they are difficult to eliminate completely.

The propeller-driven hydrofoil boat, therefore, will probably be replaced eventually by the water-jet-driven ship, a design which circumvents the propeller-cavitation problem entirely. The

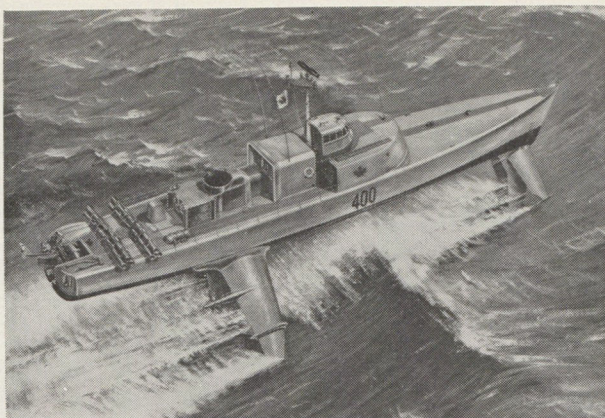
construction, however, involves completely new technology which has not yet been fully explored.

Whereas the Boeing HIGH POINT used a fully submerged foil system, the Grumman hydrofoil 80-ton (72.5 mt) boat DENISON, built for the U.S. Maritime Administration, uses 2 surface-piercing foils as well as 1 submerged foil. The DENISON features an inherently stable foil configuration in which the 2 surface-piercing foils are placed forward on either side of the hull and carry a major portion of the boat's weight, while a fully submerged tail foil under the stern carries the balance. This hybrid design can negotiate 5-foot (1.5 m) waves, but has the drawback of all surface-piercing foil systems in that it tends to ride up and down with the waves. The hull is constructed of corrosion-resistant aluminum alloys, with welded steel employed for the hydrofoils and struts. An unusual feature of the DENISON is that the 3 struts are attached to the hull by hinged joints and can be hydraulically rotated out of the water for hull-borne operation and berthing. The cleaning of the foils and simpler repair jobs on propeller and foils can thus be accomplished while the ship is afloat.

The DENISON'S primary powerplant is a General Electric LM 1500 marine gas turbine, a derivative of the J79 jet engine. It has a continuous rating of 14,000 shp. It transmits its power through gearing and drive shafts to the stern strut which bears a supercavitating propeller. In the hull-borne mode, power is provided by 2 General Electric T58 gas turbines of 1,000 shaft horsepower each, driving 2 water-jet pumps which give the ship a speed of



A giant hydrofoil assembly is checked out at Lockheed-California Company's Burbank, California, plant prior to shipment to Seattle, Washington, for PLAINVIEW.



De Havilland of Canada has developed surface-piercing hydrofoil designed for the high seas, using a supercavitating and delayed-cavitating strut and foil structure. Main unit is Pratt & Whitney FT4A-2 gas turbine. Built for Canadian Navy, ship is R.C.N. FHE-400.

11 knots. The DENISON was launched on June 5, 1962. During the guarantee trials, it performed at an average speed of 62 knots over a 5-mile (8 km) run. The ship was operated in wave heights up to 6 feet (1.8 m) at 55 knots in the foil-borne mode. Over more than 3 years, the DENISON has demonstrated its capabilities in coastal waters, including an 11,000-mile (17,700 km) cruise that touched all the major U.S. Atlantic coast ports.

Whereas the HIGH POINT and the DENISON were developed for operations in coastal waters, a third U.S. military hydrofoil ship, the Lockheed GEH-1 PLAINVIEW, is designed to operate on the high seas. The PLAINVIEW was launched in June 1965. It is fitted with engine foils and a stabilization system. It has a displacement of 310 tons (281 mt), a length of 212 feet (65 m), and a beam of 40 feet (12 m), making it the biggest hydrofoil ship afloat today. The GEH-1 has a fully submerged foil system consisting of 2 forward foils which are attached to 2 hydraulically retractable struts and can be lifted clear of the water into a nearly upright position for hull-borne

operation. Nacelles at the end of the struts carry the gearing, which drives supercavitating propellers. This arrangement of forward strut, foil, and propeller represents a major engineering feat, since the structure has to carry the full dynamic load of the power output of the 2 General Electric LM 1500 gas turbines which, with a rating of 14,000 shaft horsepower each, are the main powerplants. One fully submerged foil, likewise retractable, is located at the stern of the ship. For hull-borne operation, 2,600-horsepower diesels are installed. The ship is constructed of special extruded aluminum plating. Struts and foils are built of high-strength steel covered with an erosion-retardant surfacing to counteract cavitation damage. With a complement of 4 officers and 16 men, the ship will be used to test novel methods of antisubmarine warfare. If successful, it may become the forerunner of a sizable hydrofoil escort fleet.

A completely different approach was taken by de Havilland of Canada in designing its 200-ton (181 mt) FHE 400 ASW hydrofoil vessel. Though studies in other countries had concluded that

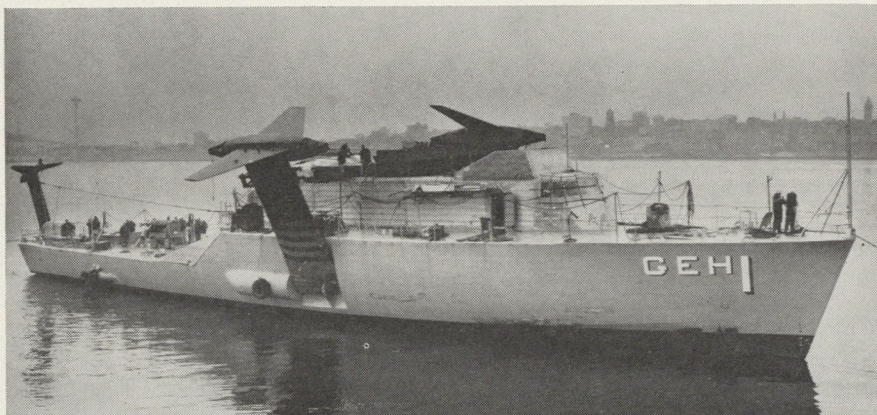
surface-piercing foils are not suitable for operation on the high seas, the Royal Navy and de Havilland decided otherwise. The result is a novel design using a supercavitating and delayed cavitating strut and foil structure.

The over-all length of the ship is 151 feet (46 m), the beam is 21 feet (6.4 m), and the top design speed is about 60 knots. The main propulsion unit is a Pratt & Whitney FT4A-2 marine gas turbine of 22,000 shaft horsepower. In the hull-borne mode the ship is driven by a Davey Paxman diesel of 2,000 horsepower. A United Aircraft of Canada ST-6 auxiliary gas turbine used for extra power-generation and boost purposes is included. Two supercavitating propellers drive the ship in the "flying" mode, whereas 2 controllable-pitch propellers are used while the ship is hull borne. The transmissions were designed and manufactured by General Electric under contract to de Havilland. The ship will carry a crew of 16 men and 4 officers and its stores will allow it to stay at sea for 2 weeks. After the first sea trials, which will take place early this summer, the ship will be fitted with ASW gear consisting of a variable-depth sonar probe and 6 launch tubes for homing torpedoes. The military evaluation is slated for the end of the year, extending into the early months of 1967.

The GEH-1 PLAINVIEW and the FHE 400 represent the most highly developed designs in the hydrofoil field. Both will start their sea trials this summer and it will be very interesting to observe which foil system, fully submerged or surface piercing, will receive the blessings of the naval staffs. Both have their advantages and disadvantages and a definite choice will be difficult. In the meantime, other nations have begun to design and construct hydrofoil boats. The German Navy has under construction 2 boats of apparently different designs about which no particulars could be obtained. Italy is strongly interested in hydrofoil gunboats, and the Soviets have, for many years, successfully built hydrofoil vessels for use on their inland seas and rivers. The British naval industry is collaborating closely with the Canadians on the FHE 400.

In letting contracts to Boeing and Grumman for the construction of 2 prototype hydrofoil gunboats in January 1966, the U.S. Navy demonstrated its growing need for fast ships. This general interest seems to show that hydrofoil ships utilizing modern technology will soon leave the realm of experimentation and appear in commercial use as an accepted method of transportation and, in the military field, as an effective weapon against the nuclear submarine.

☆☆☆



Builders of the Lockheed PLAINVIEW have borrowed freely from aerospace technology. The hull is made of extruded aluminum, and the 2 J79 hydrofoil engines are marine adaptations of the engines of Lockheed's F-104. Forty-knot speeds can be attained.

To carry out its varied missions, the U.S. Navy employs more than 8,000 fixed- and rotary-wing aircraft, together with missiles ranging from the Sidewinder to the Polaris. Here, in photos and words, are the . . .

Aircraft and Missiles of the U.S. Fleet

By Allan R. Scholin, Associate Editor



USS ENTERPRISE



Douglas A-3B Skywarrior refueling McDonnell F-4B Phantom II

In the United States Armed Forces, naval aviation performs a scope of missions almost as comprehensive as those in the U.S. Air Force. The current inventory of aircraft in the U.S. Navy and Marine Corps, which in the U.S. is a Navy component, totals more than 8,000—made up of fighter and attack planes, interceptors, reconnaissance and electronic-countermeasures aircraft, antisubmarine patrollers, carrier- and land-based transports, helicopters, and trainers.

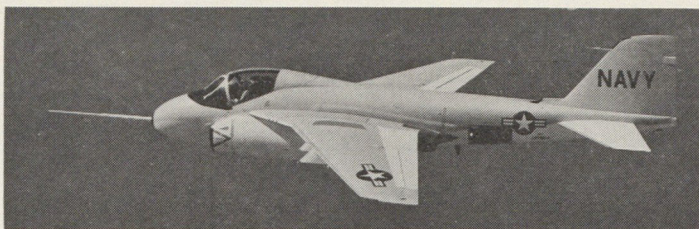
The force includes 28 carrier air wings—15 for duty aboard attack carriers (CVA) plus 2 shore-based training wings, and 9 operating from antisub carriers (CVS), also with 2

training wings ashore. There are 30 squadrons of antisubmarine patrol planes, of which 27 are land based and 3 are seaplanes. The Marine Corps operates 3 active air wings and 1 in the Marine Corps Reserve. One wing normally operates with each Marine division. A fifth division is now in process of being formed, but for the present it will not be matched with a new air wing.

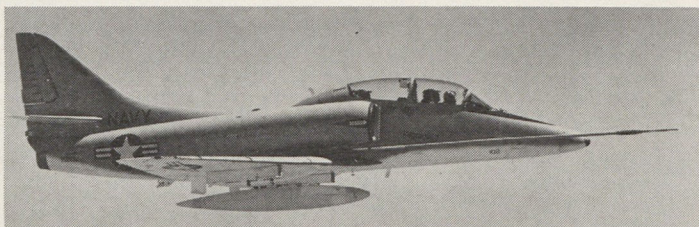
Missiles are a major element of the Navy's combat firepower, both airborne and ship-based. The Navy's fleet of nuclear-powered submarines—totaling 32 at present, 41 by October 1967—each carrying 16 Polaris long-range missiles, represents a significant

segment of U.S. strategic striking power. Naval aircraft employ air-to-air and air-to-surface missiles, while surface ships and other submarines are equipped with a variety of surface-to-air and surface-to-surface missiles.

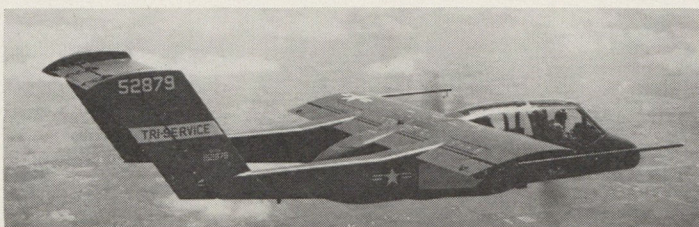
To maintain naval air striking power in Vietnam, 1 CVS antisub carrier has temporarily been assigned to the CVA attack carrier force, making 16 in all. These are made up of 1 nuclear-powered carrier—the USS ENTERPRISE, 7 FORRESTAL-class, 3 MIDWAY-class, and 5 ESSEX-class carriers. Construction of a second nuclear-powered carrier is scheduled to begin this fall, and 2 more will follow in succeeding years, looking toward an even-



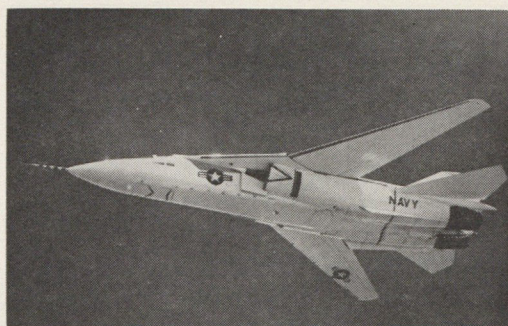
Grumman A-6A Intruder



Douglas TA-4F Skyhawk



North American OV-10A LARA



General Dynamics F-111B



LTV A-7A Corsair II

tual lineup of 4 ENTERPRISE-class nuclear carriers, 8 FORRESTAL-class, and 3 MIDWAY-class by the early 1970s.

A total of 12 air wings operate from the 15 carriers. Each carrier normally deploys with less than its full complement of aircraft, but additional planes can be flown to them as needed. In effect, each carrier becomes a forward floating air base, deploying aircraft as the situation may require. Total number of planes in a carrier air wing ranges from 80 to 95, depending on the carrier's size.

The antisub carrier force is made up of 9 ESSEX-class CVS ships, all but 1 of which have "angled" decks. The straight-deck carrier is being retired this spring, leaving 4 each in the Atlantic and Pacific, plus 1 training carrier in the Atlantic. Four more CVS ships in the Reserve Fleet could be made available if needed. Each CVS carries a complement of 35 to 40 helicopter and fixed-wing aircraft, including a few Douglas A-4 Skyhawks to give each CVS a limited intercept and air-defense capability.

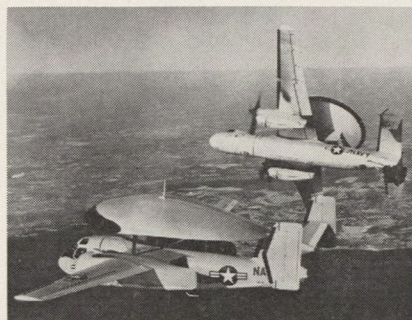
Tactical Aircraft

A number of Navy and Marine Corps planes were previously described in "A Gallery of U.S. Tactical Aircraft," in the December 1965 issue. They included the Douglas A-1 Skyraider, A-3 Skywarrior, and A-4 Skyhawk; North

American A-5A and RA-5C Vigilante; Grumman A-6A and EA-6A Intruder; Ling-Temco-Vought A-7A Corsair II; McDonnell F-4B and RF-4B Phantom II; LTV F-8 and RF-8 Crusader; General Dynamics F-111B; the Cessna O-1 Bird Dog; and such Navy and Marine Corps helicopters as the Bell UH-1E Iroquois; Kaman UH-2 Seasprite and UH-43 Huskie; Sikorsky HH-19 Chickasaw, UH-34 Seahorse, CH-34 Choctaw, and CH-37 Mojave; and Boeing-Vertol UH-46 Sea Knight.

Since the December issue appeared, U.S. Defense Secretary Robert S. McNamara has announced substantial increases in orders for the McDonnell F-4 Phantom II, Grumman A-6A Intruder, LTV A-7A Corsair II, and the Douglas A-4 Skyhawk. The latter is being produced in both single-seat fighter and 2-place trainer versions, designated A-4F and TA-4F respectively, and powered by a Pratt & Whitney J52-8 turbojet with thrust of 9,300 lb. (4,218 kg), 10 percent more power than the J52-6 in the A-4E.

Developed specifically for antiguerrilla warfare is the North American OV-10A LARA—light armed reconnaissance aircraft. Secretary McNamara has announced that contracts are being awarded for production of 100 OV-10As for the Marine Corps and 160 for the U.S. Air Force. With a wingspan of 30 ft. (9.14 m) and length of 39 ft. 3 in. (11.96 m), the OV-10A is adaptable to a variety of missions. It



Grumman's E-1B Tracer, foreground, E-2A Hawkeye, rear

can carry a payload of 3,000 pounds (1,360 kg) of cargo or up to 5 passengers, plus its 2-man crew. For combat operations, it can be fitted with up to 2,400 pounds (1,080 kg) of bombs, rockets, or incendiary on pylons under its wings and fuselage, plus a pair of Sidewinder missiles on its wingtips.

The OV-10A is powered by 2 AiResearch T76 turboprops of 660 hp each, giving it a maximum speed (without weapons) of 300 mph (480 km/hr). Its combat radius with maximum payload is about 60 miles (96 km) but ferry range can be extended to more than 1,400 miles (2,250 km).

(Continued on following page)



Douglas EA-1F Skyraider



Sikorsky SH-3A Sea King



Martin SP-5B Marlin



Lockheed P-3A Orion



Grumman C-2A Hawkeye

Special-Purpose Aircraft

For protection against enemy air attack, the aircraft complement aboard carriers includes all-weather airborne early-warning planes. The Grumman E-1B Tracer, developed from the C-1A Trader, and the EA-1E Skyraider are gradually being phased out in favor of the newer Grumman E-2A Hawkeye. Its purpose is to circle the carrier task force to detect approaching enemy aircraft and to control the interceptors. Its electronic gear, called the Airborne Tactical Data System (ATDS), is linked with the Naval TDS aboard the task force flagship, which also receives data from submarines, surface ships, and other aircraft to present an over-all evaluation of the combat situation. E-2A production is being terminated at the expiration of the present contract because some problems remain in development of its radar, but sufficient numbers are being procured to equip the 12 attack carrier wings. The Hawkeye is powered by 2 Allison T56 turboprops of 4,050 shp. It carries a crew of 5, and at its 200 mph (320 km/hr) cruise speed can remain airborne for 7 hours.

Several Navy aircraft have been adapted for electronic-countermeasures missions, to scout out enemy radar and to jam radar-directed anti-aircraft guns and missiles. Newest of

the ECM aircraft is the Grumman EA-6A Intruder, described briefly in the December issue. In addition to carrying more than 30 different antennas to sort out enemy radiation, it retains its weapon delivery capability.

The EA-6A is replacing the EA-1F Skyraider on ECM missions. The Marine Corps still employs the Douglas EF-10B Skyknight, particularly in Vietnam, but expects to acquire the EA-6A before long.

Antisubmarine Patrol

Martin's SP-5B Marlin flying boat is the ancient mariner of Navy aircraft. First ASW aircraft developed for the Navy after World War II, the Marlin is a big plane, 100 ft. 7 in. (30.7 m) long, with wingspan of 118 ft. (36 m), and maximum gross takeoff weight of 76,000 lbs. (34,475 kg). It is equipped with 2 Wright R3350 engines of 3,400 hp each, cruises at 250 mph (400 km/hr), and has an operational range of more than 2,000 miles (3,200 km). Three Navy patrol squadrons are equipped with the Marlin. Despite its advanced age, no flying boat replacement is in sight. One SP-5B was modified by installing a 3,000-lb. (1,360 kg) thrust Pratt & Whitney J60 jet engine in the tail to reduce takeoff run, but the modification has not been applied to others in the Fleet.

The Navy's major patrol plane since the mid-1950s has been the Lockheed SP-2H (P2V-7) Neptune, also well known in Europe, South America, Japan, Australia, and New Zealand. It is powered by 2 Wright R3350 engines of 3,500 hp, plus a pair of Westinghouse J34 jets, each with 3,400 lbs. (1,540 kg) of thrust.

SP-2Hs are now being replaced by the Lockheed P-3A Orion, military adaptation of the Electra commercial transport. The P-3A cruises at 400 mph (650 km/hr), about 100 mph (160 km/hr) faster than the Neptune, with a range of 3,500 miles (5,600 km). It employs 4 4,050-shp Allison turbo-prop engines. Secretary of Defense McNamara has announced that Orions to be purchased beginning in July 1968 will be equipped with a new avionics system, increasing their capability to utilize information from existing or new sensors and by automating more fully the analysis and correlation of acquired data.

New Zealand and Australia have announced they, too, will purchase the Orion to replace Neptunes.

Carrier-based antisubmarine warfare aircraft include the Sikorsky SH-3A/D Sea King helicopter and Grumman S-2E Tracker. The SH-3A, military counterpart of the Sikorsky S-61, is powered by 2 General Electric T58-8 turbine engines of 1,250 shp each. It



Lockheed C-130F Hercules



North American T-2B Buckeye



Boeing-Vertol UH-46A Sea Knight



Sikorsky CH-53A Sea Stallion

has replaced the older Sikorsky SH-34J Sea Bat aboard ASW carriers and will also be employed aboard attack carriers to improve their ASW capabilities. The S-2E, meanwhile, has replaced earlier versions of the S-2 Tracker, being equipped with more advanced electronic equipment. The Tracker employs a pair of 1,525-hp Wright R1820 engines, patrols at 150 mph (240 km/hr) over a range of 1,350 miles (2,170 km), and carries a crew of 4.

Cargo Aircraft

Newest Navy cargo plane is the Grumman C-2A, employed as a "carrier on board" delivery aircraft, ferrying personnel and cargo from shore stations to carriers at sea or from one carrier to another. As a counterpart of the E-2A Hawkeye, without the latter's huge supermounted radar dish and other early warning radar, it can be accommodated on a carrier elevator, parked on the hangar deck, and launched by catapult on departure. It carries a payload of about 15,000 lbs. (6,800 kg) or up to 39 passengers, plus its 2-man crew. Employing the same Allison 4,050-shp T56 turboprops as in the E-2A, it cruises at 300 mph (485 km/hr) over a range of 1,500 miles (2,400 km).

The Grumman C-1A Trader, similar-

ly derived from the S-2 Tracker, remains in carrier delivery service, but will be phased out as more C-2As are delivered.

Other transports operated by the Navy and Marine Corps are all widely known. They include the Lockheed C-130 Hercules; Douglas C-118 (R6D) Liftmaster, C-54 (R5D) Skymaster, and ubiquitous C-47 (R4D) Skytrain; the Lockheed C-121 Constellation, employed also in weather and electronic reconnaissance configurations; and the C-131F and G Convairliner, military version of the Convair 340 and 440 commercial transports.

Also employed in cargo airlift are the Boeing-Vertol UH-46 Sea Knight and the Sikorsky CH-53A Sea Stallion. The UH-46 is the key element in the Navy's Vertical Replenishment Program, which provides for fast continuous transfer of high-priority cargo from combat supply ships to combatant vessels throughout a task force under way at sea.

The CH-53A, just entering service with the Marine Corps, employs many components of Sikorsky's S-61 Sky-crane but with an integral fuselage and watertight hull. Primarily intended as an assault transport, it carries 38 combat-equipped troops or 13,500 lbs. (6,125 kg) of cargo. Normal takeoff weight is 33,500 lbs. (15,200 kg). It employs 2 2,850-shp General Electric

T64-6 turbine engines, giving it a maximum cruising speed of 172 mph (275 km/hr) and range of 280 miles (450 km).

Trainers

Two training aircraft are in quantity production today for the Navy and Marine Corps. They are the North American T-2B Buckeye, twin-engine advancement over the single-engine T-2A, and the Douglas TA-4F which, as noted above, is a 2-seat version of the A-4E Skyhawk.

The T-2B, which will enter pilot training units in May, is powered by a pair of Pratt & Whitney J60-6 turbojets of 3,000 lb. (1,360 kg) thrust, replacing the single 3,400-lb. (1,540 kg) thrust Westinghouse J34-36 in the T-2A. In addition to the improved safety factor of 2 engines over 1, the T-2B is capable of a top speed of 540 mph (870 km/hr) and its ceiling is upped to 44,000 feet (13,400 m).

Primary trainer is the Beech T-34 Mentor, an extensively modified version of the civilian Bonanza, also being flown in military forces of several nations in Latin America and Spain, Turkey, and the Philippines. Two other trainers nearing the end of their operational life are the T-33 Shooting Star or T-Bird and its modified version for

(Continued on following page)

carrier training, the T-1A Sea Star.

Enjoying a mild resurgence as a counterinsurgency fighter in several allied air forces is the North American T-28 Trojan, of which the T-28B is a basic trainer and the T-28C an adaptation for carrier operations. For training pilot and radar observer crews, the Navy employs the North American T-39 Sabreliner.

Two former fighter planes are also continuing in Navy service as training aircraft. They are the Grumman F-9 Cougar and F-11 Tiger, the latter flown also by the Navy's aerobatic demonstration team, the Blue Angels.

Utility

The amphibious Grumman HU-16 is the Navy's principal utility plane, employed primarily in search-and-rescue roles. The high-winged twin-engined Albatross is well known throughout the world, being represented in the naval air arms of several Free World countries.

The only other aircraft classified as utility are the de Havilland U-1B Otter, flown primarily in the Navy's Antarctic task forces, and the Piper U-11A Aztec, a light liaison and transport plane.

MISSILES

Surface (or Underwater) to Surface

The U.S. Navy's principal contribution to the Free World's deterrent strategy is the Polaris (UGM-27A) missile carried aboard nuclear-powered submarines capable of operating submerged for months at a time. By June 30, 1966, the Navy will have 32 Polaris submarines at sea, each with 16 Polaris missiles, and 9 more will become operational by October 1967. By that date the force will consist of 13 submarines with the Polaris A-2, 28 with the A-3.

A 2-stage solid-propellant rocket, the Polaris is 31 ft. (9.45 m) long and 4.5 ft. (1.37 m) in diameter. Launch weight is 30,000 lbs. (1,360 kg). Range of the A-2 missile is 1,725 mi. (2,775 km); A-3, 2,880 mi. (4,635 km).

The Polaris production team, under the prime contractor, Lockheed Aircraft Corporation, includes some 20,000 firms in the U.S. and overseas.

In advanced development as a successor to the Polaris is the Poseidon (UMG-27C), also under Lockheed direction. Its total development cost is estimated at \$1,300,000,000, with almost a quarter of that total to be spent in the year beginning July 1, 1966. The Poseidon is expected to have twice the accuracy and payload



North American T-28C Trojan



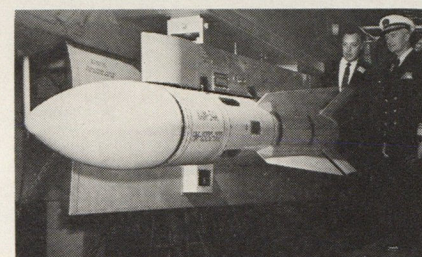
North American T-39D Sabreliner



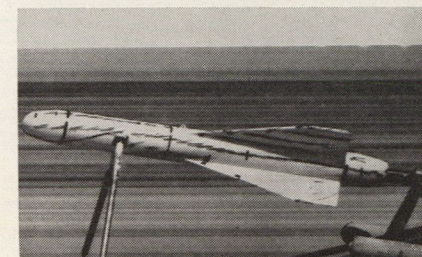
Grumman HU-16C Albatross



Piper U-11A Aztec



Phoenix (Hughes)



Walleye (NOTS)

of the Polaris A-3, permitting it to carry more and larger penetration aids. No decision has yet been made on the number of submarines to be refitted with the Poseidon.

To soften shore defenses in preparation for amphibious landings, the Navy employs the Talos (RIM-8F), also used as a long-range surface-to-air weapon. It is 31 ft. 3 in. (9.5 m) long, including an 11-ft. (3.35 m) booster; 2.5 ft. (76 cm) in diameter; and weighs 7,000 lbs. (3,175 kg). It flies at Mach 2.5 over a range of 75 mi. (120 km) or more, and its ceiling is 100,000 ft. (30,480 m). Bendix Aviation Corporation is prime contractor.

Also under consideration as a ship-to-shore missile is the U.S. Army's Lance weapon, built by Ling-Temco-Vought's Michigan Division. The Navy is initiating a program to test the Lance in a shipboard environment. Employing storable liquid propellant, it has a range of 50 mi. (48 km) and launch weight of 3,200 lbs. (1,460 kg).

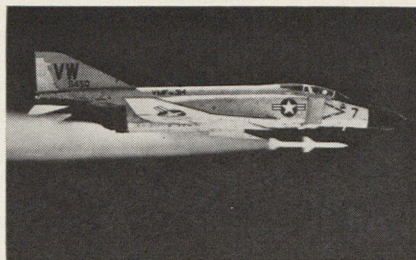
Surface to Air

The Talos, noted above, is 1 of 3 missiles for fleet air defense referred to as the 3 Ts, the others being the Terrier (RIM-2E) and Tartar (RIM-24B),

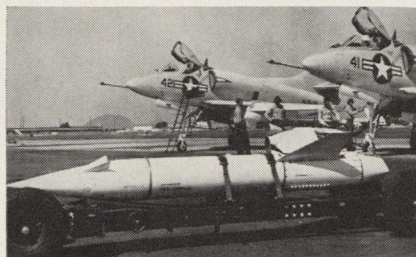
both produced under leadership of General Dynamics's Pomona Division. The Terrier is a 2-stage solid-propellant rocket, while Tartar employs a single solid-propellant engine which lowers its thrust for sustained flight after a short high-acceleration boost to cruise speed. The range of both is given as beyond 12 mi. (19 km) and ceiling above 50,000 ft. (15,240 m). They measure 15 ft. (4.6 m) in length and about 13 in. (33 cm) in diameter. Launch weight is 3,000 lbs. (1,360 kg).

A "standardized" Terrier/Tartar missile, now in production, offers improved reliability and performance at reduced cost. It employs the Terrier/Tartar shipboard control and launching systems, with only minor modifications. The missile is powered by a dual-thrust engine like that in the Tartar, but a booster can be added to extend its range to 35 mi. (56 km) or more.

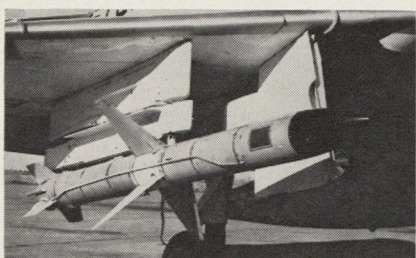
The Sea Sparrow is now being developed for use as a point defense surface-to-air missile for ships now equipped with only antiaircraft gun defenses. The missile is basically the same as that in the Sparrow air-to-air version (see page 43), while the launch equipment employs some components of the Army's Mauler surface-to-air system.



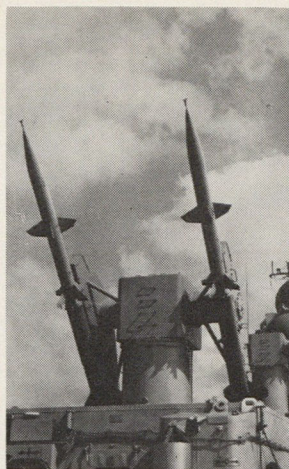
Sparrow III (Raytheon) and F-4B



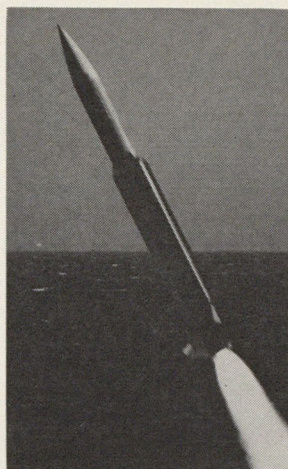
Bullpup (Maxson)



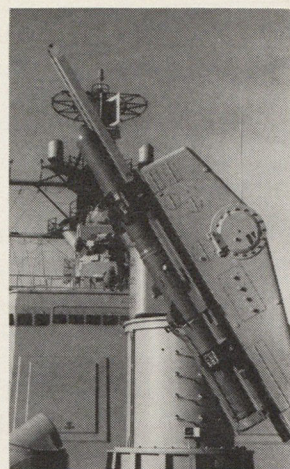
Shrike (NOTS, Texas Instruments)



Terriers (GD/Pomona)



Tartar (GD/Pomona)



ASROC (Honeywell)



F-9 Cougar
with Sidewinders
(NOTS, Philco)

An Advanced Surface-to-Air Missile System (ASMS), now under development, is intended to replace the 3-T missiles in the 1970s. It will share some components with a new Army anti-aircraft missile, the SAM-D. The latter, however, is assigned a higher priority, leaving ASMS in the early development stage for another year.

Air to Air

The Navy's best-known air-to-air missile is undoubtedly the Sidewinder (AIM-9), developed by the Naval Ordnance Test Station at China Lake, California, and widely employed in Free World air forces. Manufactured by Philco Corporation, it is equipped with either heat-seeking or semiactive homing radar guidance. Measuring 9.3 ft. (2.84 m) long and only 5 in. (12.7 cm) in diameter, it has an effective range of 11,000 ft. (3,350 m). The U.S. Army has recently developed a surface-to-air modification, called Chaffaral.

Both the Navy and Air Force employ the Sparrow (AIM-7) on the McDonnell F-4 Phantom II. Its guidance system, developed by the Raytheon Company, which also is the prime contractor, gives it a 360° attack capa-

bility. Powered by a solid-propellant Rocketdyne motor, it travels at Mach 3 over a range of 8 mi. (12.8 km). It is 12 ft. (3.7 m) long and 8 in. (20.3 cm) in diameter.

The Phoenix (AIM-54) is intended for use on the Navy's F-111B fighter, but Hughes Aircraft Company, its prime contractor, has not yet solved all development problems. Partly as a result of these difficulties, the Navy has delayed committing the F-111B to production at least until December.

Air to Surface

The Navy's primary weapon in this category is the Bullpup, employed also by the U.S. Air Force and air arms of several NATO nations. Now built by the Maxson Company, it is equipped with either conventional or nuclear warhead. Later models, the Bullpup C and D, have a range of more than 3 mi. (4.8 km) and a speed of 1,400 mph (2,240 km/hr). The missile, 10.5 ft. (3.2 m) long, and 1 ft. (30.5 cm) in diameter, is guided by radio signals from the launch aircraft.

Successor to the Bullpup is Wall-eye (AGM-62), a television-guided gravity glide missile. The video system "locks" the missile onto a still or

moving target, giving the pilot a picture of the target and enabling him to steer the missile even after he has turned away from the target. Walleye weighs 1,000 lbs. (453.6 kg), almost twice as much as Bullpup. A more advanced television-guided missile, the Condor (AGM-53), is in development.

For use against electronic targets, the Naval Ordnance Test Station has developed the Shrike (AGM-45). Its guidance system, produced by Texas Instruments Inc., homes on electromagnetic signals from enemy radar installations, such as those employed in guiding anti-aircraft missiles and guns. The Shrike has been employed against Soviet-built SAM sites in North Vietnam, but early results have not measured up to expectations. An Advanced Shrike, designated ARM-1, is under development, with several components in flight-test stage.

Among other Navy weapon systems in the rocket and missile category are ASROC (RUR-5), a ship-launched anti-submarine rocket for which Honeywell is the prime contractor, and SUBROC (UUM-44), produced by Goodyear Aerospace Corporation, a submarine-launched ballistic missile directed at submarine or surface-vessel targets.



The U.S. aerospace month was marked by the death of 2 U.S. astronauts just after a successful test of the Apollo moon spacecraft, disagreement between the Secretary of Defense and USAF Chief of Staff over the need for a new manned bomber, a misinformed report by a Congressional subcommittee criticizing Air Force support of ground troops in Vietnam, and the start of a U.S.-Sudanese study which may produce a blueprint for aid to less-developed nations . . .

AMSA, Apollo, and A.I.D.

By Allan R. Scholin, Associate Editor

The tragic death of 2 U.S. astronauts who had been selected to fly the Gemini-9 spacecraft mission will not delay that mission, the National Aeronautics and Space Administration has announced. It will be performed instead by the previously designated backup crew.

The astronauts, Elliott M. See, Jr., a civilian, and USAF Major Charles A. Bassett, II, were on an instrument landing approach at Lambert Field in St. Louis, Missouri, when their T-38 Talon jet trainer crashed into a building of the McDonnell Aircraft Company on the field on February 28. They had taken off that morning from the NASA Spaceflight Center at Houston, Texas, to undergo rendezvous simulator training at the McDonnell plant, where the Gemini spacecraft is built.

Now scheduled to fly the Gemini-9 mission are Lieutenant Colonel Thomas P. Stafford, 35, of the Air Force and Navy Lieutenant Commander Eugene A. Cernan, 32. During that mission, Cernan is programmed to fly a complete orbit while outside the spacecraft.

The accident occurred only 2 days after NASA logged a successful first test of the Apollo moon capsule in an unmanned suborbital flight from Cape Kennedy, Florida. Launched by a Saturn 1B booster, also tested for the first time, the Apollo capsule reached a height of about 300 miles (480 km) before being driven back into the earth's atmosphere at a speed of more than 17,000 mph (27,370 km/hr), approaching the speed of reentry on a return flight from the moon. Examination of the capsule after it was recovered by helicopter from the South At-

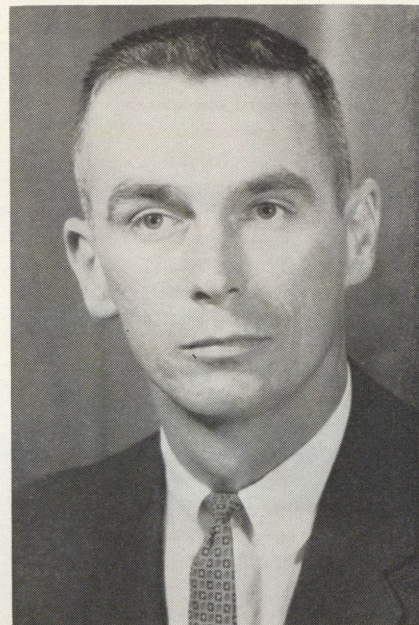
lantic near Ascension Island, 5,500 miles (8,850 km) from Cape Kennedy, showed no damage to the interior despite the temperatures of more than 5,000° F (2,760° C) it encountered on reentry.

Propelled by 1,600,000-pound (726,670 kg) thrust generated by 8 North American Rocketdyne H-1 engines in the Chrysler-built Saturn 1B's first stage, the payload of 45,900 pounds

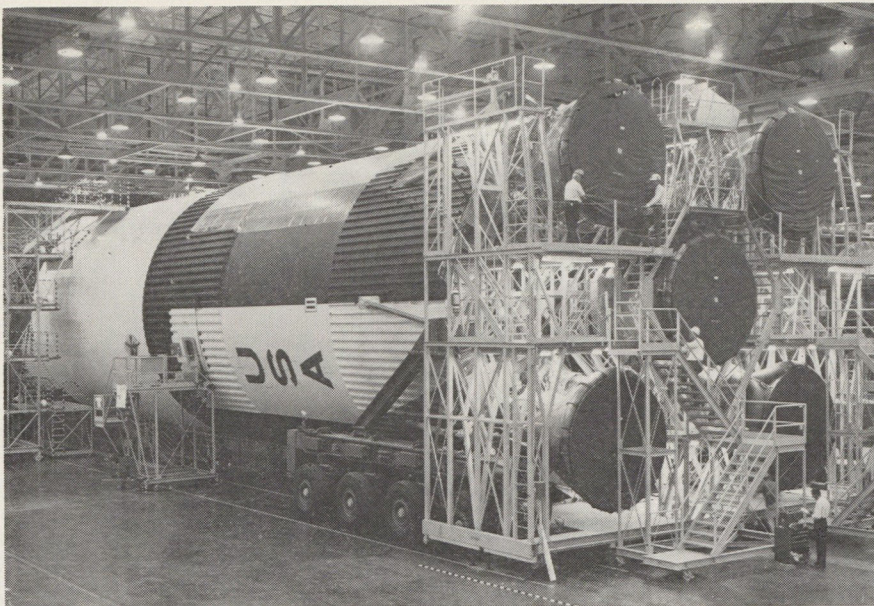
(20,820 kg) is apparently the heaviest ever boosted into space. The flight also marked the first successful test in space of the Douglas S-IVB stage, which serves as the second stage of the Saturn 1B and will become the third stage of the huge Saturn 5. The S-IVB produces a thrust of 200,000 pounds (90,700 kg), powered by a Rocketdyne J-2 engine burning high-energy liquid hydrogen and liquid oxygen.



As a result of accident which claimed the lives of 2 astronauts, USAF Lieutenant Colonel Thomas P. Stafford, second pilot in Gemini 6, has been moved up to command Gemini-9 spacecraft flight in May.



Navy Lieutenant Commander Eugene A. Cernan, 32, who will join Stafford in Gemini-9 mission, is scheduled to spend an entire 90-minute orbit "walking" outside spacecraft. This will be his first mission.



First stage of enormous Saturn-5 rocket is assembled at NASA's Michoud Plant near New Orleans, Louisiana. The 5 Rocketdyne engines produce a thrust totaling 7,500,000 pounds (3,402,000 kg).

Secretary of Defense Robert S. McNamara is still not convinced that the U.S. needs a long-range manned bomber to replace its Boeing B-52 Strato-fortress.

In testimony before a committee of the U.S. House of Representatives, he declared that "large expenditures on the development and production of a new advanced strategic aircraft do not appear to be warranted at this time."

But General J. P. McConnell, U.S. Air Force Chief of Staff, repeated his warning of last year that a decision to proceed with the Advanced Manned Strategic Aircraft (AMSA) to replace

B-52Gs and -Hs by the mid-1970s cannot safely be deferred beyond this Fiscal Year.

"In my judgment," General McConnell said, "it would take us from 8 to 10 years from the time of a decision to go ahead on a new bomber of the AMSA type to achieve a force of significant capability."

Secretary McNamara, Air Force Secretary Harold Brown, and General McConnell seemed to agree that the General Dynamics FB-111, which has already been approved for production, is not intended as a substitute for either the B-52G/H force or AMSA.

The FB-111, Secretary McNamara

explained, will be a "dual-purpose aircraft—strategic and tactical," to perform missions of the type now assigned to B-52s attacking Viet Cong targets in South Vietnam and to B-58 supersonic bombers marked for phaseout in 1971.

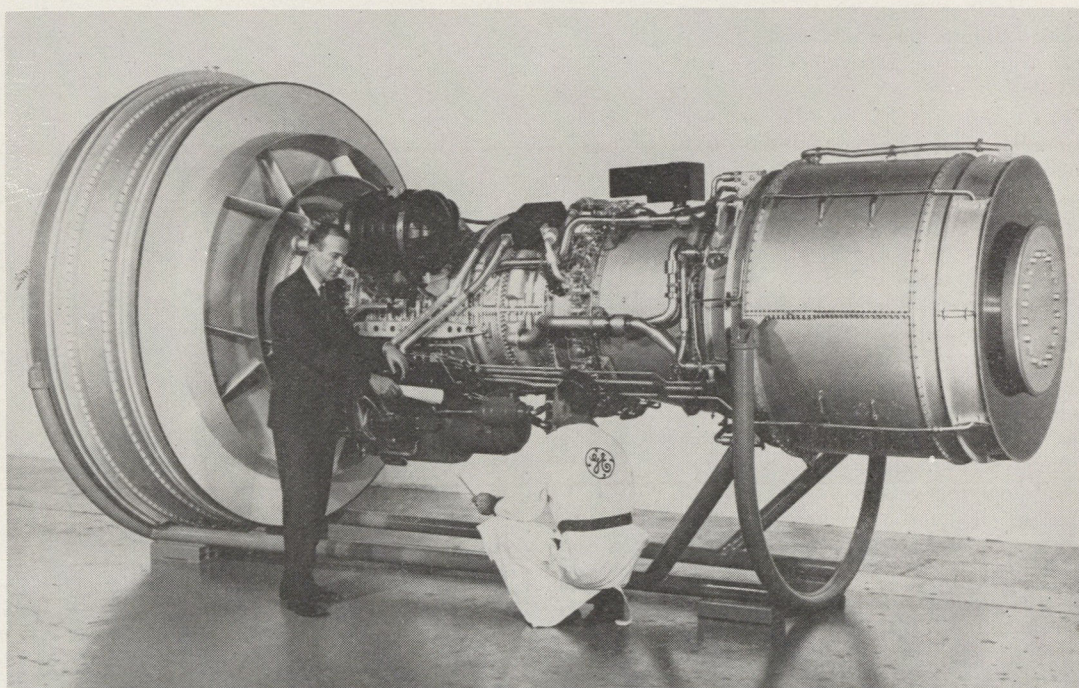
But, in a lengthy statement of his views on the relationship of missiles and bombers in strategic forces, Mr. McNamara indicated that the latter's principal function is to force the Soviet Union to allocate some of its resources to bomber defense and that, against Soviet defenses as they exist today, almost any bomber could serve that purpose.

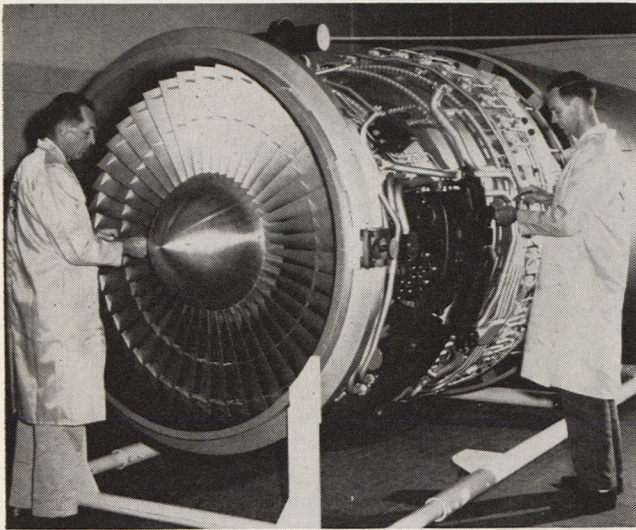
Even if the USSR were to direct its entire first-strike power at U.S. missile silos, he said, "a very large proportion of our alert forces would still survive. . . . The effective delivery of even one-fifth of the surviving weapons on Soviet cities would destroy about one-third of the total population and half of the industrial capacity of the Soviet Union. . . .

"A considerably smaller number of weapons detonated over 50 Chinese urban centers would destroy half of the urban population and destroy more than one-half of their industry. . . .

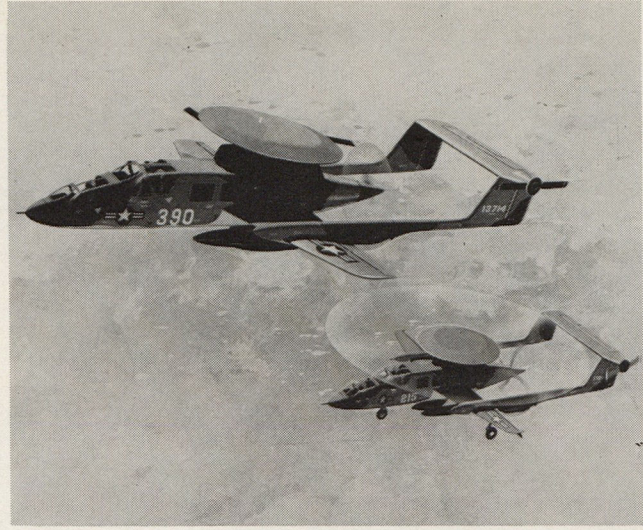
"Thus, without any use of the bomber forces, the strategic missile forces (Continued on following page)

Four of these General Electric TF39 engines will power Lockheed C-5A military transport at speeds of 500 mph (800 km/hr) with payloads up to 265,000 pounds (120,000 kg). More than 8 feet (2.4 m) in diameter, the high-bypass turbofan engine produces a thrust of 41,000 pounds (18,600 kg). Low fuel consumption will give C-5A an unrefueled range beyond 6,500 miles (10,460 km).





First indication of engine configuration designed for the U.S. supersonic transport is this photo of mockup of Pratt & Whitney JTF17A twin-spool turbofan, being developed at manufacturer's West Palm Beach, Florida, plant. First tests are expected in late spring, with 100 hours required by end of year.



Disc rotor system, developed by Ryan Aeronautical Company, combines helicopter and fixed-wing aircraft capabilities. The conventional 3-blade rotor arrangement is retracted into the thin discus-shaped center body during high-speed flight. Pivotal motion minimizes force of airstream, increases control accuracy.

recommended for the Fiscal Year 1967-71 period would provide substantially more force than is required for an assured destruction capability against both the Soviet Union and Communist China simultaneously."

Only if missile effectiveness were to drop to less than half of U.S. expectations would bombers enter into the equation, according to Mr. McNamara.

"Against current Soviet defenses," he declared, "the presently available B-52G/H force (255 aircraft) is adequate to hedge against complete failure of the missile force. . . . Against possible improved Soviet defenses, we must be willing to believe that our missile effectiveness could turn out to be lower than 30 percent of what we expect before we would wish to ensure with . . . aircraft rather than with missiles."

For these reasons, he said, manned bombers "must be considered in a supplementary role. In that role they can force the enemy to provide defense against aircraft in addition to defense against missiles."

For example, he explained, bombers can be a useful adjunct to missiles in a battle strategy in which the U.S. might choose to attack some targets with missiles alone and others with bombers alone, "thereby forcing the defender to 'waste' a large part of his defensive resources."

For this reason, he said, "we propose to maintain indefinitely an effective bomber capability," but "considering the role of the manned bomber in the strategic offensive mission, as we see the threat today and over the next 5 years, large expenditures on the development and production of a new

advanced strategic aircraft do not appear to be warranted at this time."

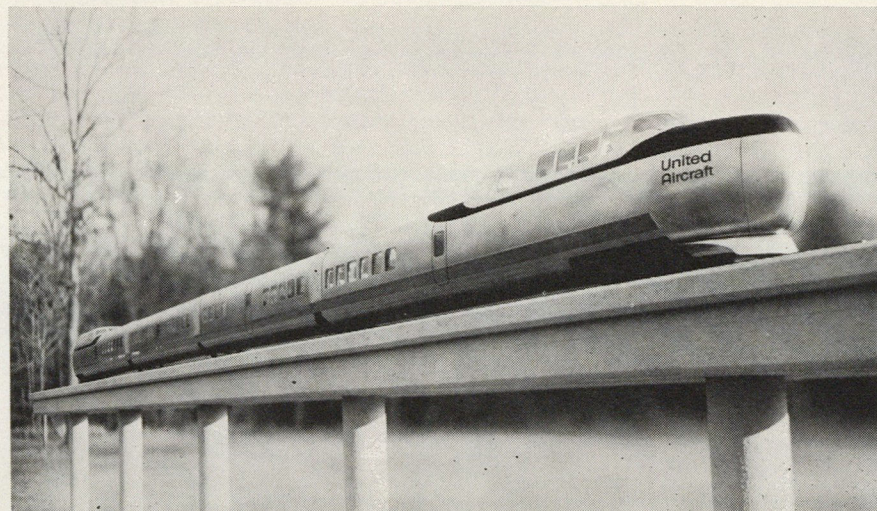
He did add, however, that "we plan, as a hedge against unforeseen improvement in Soviet antibomber defenses, to continue development work on the components and subsystems which would be required (for the AMSA) if it should ultimately become desirable to deploy such an aircraft."

* * *

A report highly critical of U.S. Air Force close-support operations in South Vietnam was issued recently by a subcommittee of the House Armed Services Committee. The subcommit-

tee was headed by Representative Otis G. Pike, a New York Democrat and World War II Marine Corps fighter pilot.

The Pike report declared that "the record is replete with admissions that since World War II the Air Force has not designed any aircraft for the primary mission of close support for ground troops." It noted that the Air Force borrowed the A-1 Skyraider from the Navy, the O-1 Bird Dog spotter plane from the Army, is ordering a quantity of Navy-developed OV-10A light armed reconnaissance aircraft, and lacks an all-weather, close-support



A solution to commuter problems in the northeastern U.S. has been offered by United Aircraft of Canada, Ltd. This high-speed train, encased in smooth aluminum "skin" and powered by 7 ST6 gas-turbine engines, applies aeronautical technology to surface travel. The train will travel at 160 mph (257 km/hr) on existing tracks. Two are scheduled to operate next year between Boston, Massachusetts, and Providence, Rhode Island.

fighter like the Navy's A-6A Intruder.

Particularly appalling, the subcommittee said, was the fact that despite years of tactical missions with the Army, Air Force planes could not communicate with Army units on the battlefield until recently, because their radios were not on the same frequency.

In gathering material for its report, the Pike subcommittee remained in Washington, interviewing personnel recently returned from Vietnam combat, and senior officers of the Air Force and Army aviation corps. When Mr. Pike later visited Vietnam, he refused to include statements by Army leaders commending USAF close-support missions because theirs was not "sworn testimony."

In a memorandum to the subcommittee, the Air Force explained that under joint Army-Air Force doctrine in effect from 1957 to 1965, the Army was responsible for furnishing communications equipment and vehicles and operating the air request net. After joint exercises under the U.S. Strike Command, this doctrine was revised, transferring these responsibilities to the Air Force. Besides acting quickly to correct the communications discrepancy, the Air Force pointed out, it has set up a system of positive response procedure, which requires that "upon request by a ground commander, an air strike is launched unless an intervening ground echelon vetoes the request."

The Tactical Air Control System (TACS) and first-line aircraft now operating in South Vietnam, the Air Force said, "have significantly increased our capability to provide responsive and accurate close air support. Recent reports from COMUSMACV (Commander, U.S. Military Assistance Command,

Vietnam) and U.S. Army officers in the field attest to the effectiveness of this increased capability."

To avoid embarrassing Mr. Pike, the Air Force did not mention in its report that the House Armed Services Committee, of which Mr. Pike is a member, 2 years ago turned down a Defense Department request for authorization to develop a triservice light tactical aircraft. When it was subsequently approved, the Defense Department assigned interservice development responsibility to the Navy, which led to the OV-10A.

It is also a matter of record that the Cessna O-1 Bird Dog was operated by the Air Force in the Korean War, and later turned over to the Army.

The Air Force did point out that most of its fighter aircraft are capable of point bombing in any weather, day or night, but support missions in South Vietnam often require attacking enemy elements as close as 10 meters from friendly units, a degree of accuracy that requires visual sighting. The Navy's A-6A Intruder, which not so incidentally is manufactured in Mr. Pike's home district, has flown its bad-weather missions against fixed targets in North Vietnam.

* * *

The U.S. Federal Aviation Agency and the Agency for International Development (A.I.D.) have signed a new agreement under which the FAA will continue to provide aviation assistance to foreign countries through A.I.D. It supersedes an older agreement in effect since 1954.

Civil Aviation Assistance Groups (CAAGs), manned by 84 FAA aviation specialists, work in 17 countries under A.I.D. sponsorship. They advise and assist those countries in planning and

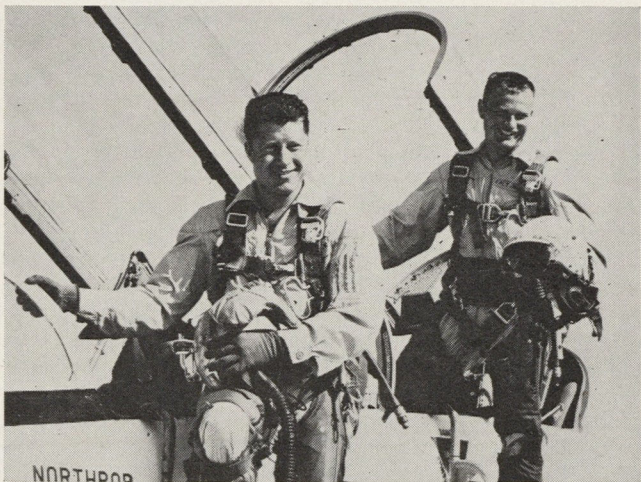


Winston Churchill, II, as war correspondent in Vietnam for the London Sunday Express, finds his job involves more than standing around with a pad and pencil. The grandson of the late British Prime Minister is briefed by USAF Major John Sercel before flying a strike mission.

organizing the management and development of all phases of their national aviation.

The Groups help develop aviation statutes and regulations, establish airways and airports, organize aircraft operation and inspection procedures, and improve air traffic control methods. They also assist in planning, procuring, and installing communications equipment and air navigation aids, as well as selecting suitable sites for their location.

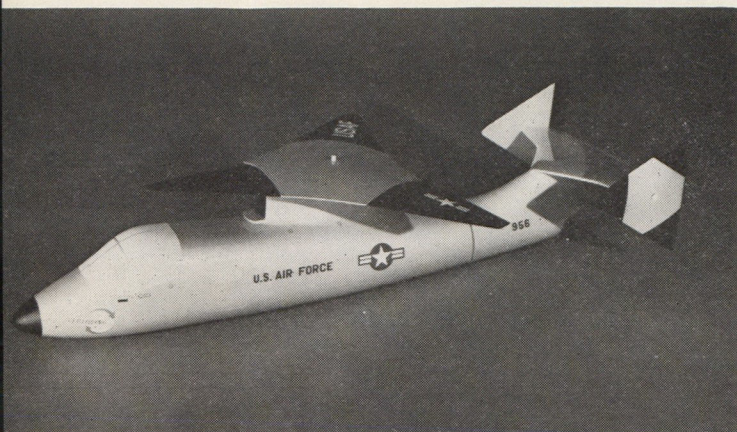
Another 27 FAA personnel work at FAA's Washington, D. C., headquarters. (Continued on following page)



Two of the pilots who delivered first 11 Northrop F-5 jet fighters from U. S. to Norway were Captain Per Ekholdt, left, and Captain Arne Madsen of Royal Norwegian Air Force. F-5s are the first of 64 being built for Norway by Northrop's Norair Division. Captain Ekholdt was Norway's chief F-5 test pilot.

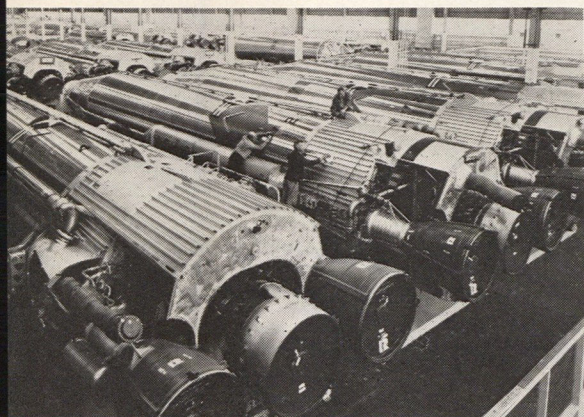


Norway-bound F-5 supersonic tactical fighters take off from Edwards Air Force Base, California, on 6,200-mile (9,980 km) delivery mission. Mass flight of 11 F-5s in late February was one of largest airborne deliveries of aircraft to an overseas ally since World War II. Speed of F-5 is 1,000 mph (1,610 km/hr).



Second of 2 stopped-rotor flight systems proposed by Ryan Aeronautical Company employs delta-shaped rotating "vertiwing," combining vertical lift with fixed-wing capabilities. Once airborne, delta-wing rotation is stopped for high-speed performance.

First European operator to use de Havilland DHC-6 Twin Otter on scheduled passenger service will be General Air of Hamburg, Germany, which expects to put it in service for vacationer flights by summer of 1967.



Atlas intercontinental ballistic missiles withdrawn from Strategic Air Command silos are being modified by Convair Division of General Dynamics for Air Force research-and-development flights. After refurbishing, vehicles will launch scientific satellites and upper-stage vehicles for Advanced Ballistic Reentry Systems (ABRES) program, and will serve as targets in Nike-X antiballistic-missile tests.

ters to support the field teams and conduct aviation training and orientation programs for nationals of other countries who come to study in the U.S. under AID sponsorship.

More than 2,000 AID-sponsored trainees from other lands have been trained in the U.S. under FAA direction in the past 15 years.

* * *

On a broader scope than the programs discussed above, AID and the Government of Sudan are pioneering a new technique to examine socioeconomic needs of less developed countries.

A country-wide survey just launched in the African nation by Lockheed Air-

craft International, Inc., of Los Angeles, California, under contract with AID and the Sudan's Under Secretary for Economic Planning of the Ministry of Finance and Economics, is expected to lead to development of a long-range transportation plan to support economic growth in the Sudan.

The systems analysis of Sudan transportation will provide a master plan for development of all forms of transportation from 1968 to 1980, listing essential projects and establishing priorities.

The survey will cover all modes of land transportation, including highway, railroad, and pipeline, as well as air and water transport.

The master plan and final survey report will consider such factors as capital requirements and foreign exchange needs, earning power, manpower, increased potential for foreign exchange income through exports, operating and maintenance requirements, and long-term goals.

Throughout the life of the study, Lockheed will help train selected Sudanese personnel working directly with them. Some will be brought to the Los Angeles area for specialized training.

* * *

The new Chief of U.S. Army Aviation is Brigadier General Robert R. Williams. He succeeded Brigadier General George P. Seneff, Jr., now in charge of all U.S. Army aviation in Vietnam on the staff of General William C. Westmoreland, over-all commander of U.S. forces in Vietnam.

General Williams is a former commander of the U.S. Army Aviation Center at Fort Rucker, Alabama. He is rated a Master Aviator, having logged more than 3,000 hours in fixed-wing and rotary aircraft over the past 15 years.

* * *

An American company will design and build the flight-test system for the Anglo-French supersonic airliner Concorde.

The United States firm, Radiation Incorporated of Melbourne, Florida, was selected by the United Kingdom to build a giant data acquisition system to fly aboard the sleek Mach 2.2 airliner throughout performance trials and certification tests. The equipment, largest capacity system of its kind ever built, will be developed in conjunction with the Guided Weapons Division of British Aircraft Corporation. The latter will manufacture test system components from pilot models provided by Radiation Incorporated.

The system will employ pulse code modulation (PCM) techniques pioneered by the Florida-based firm. Using PCM, an extremely accurate and efficient method of obtaining usable information from remote points, the test system will act as a large on-board information-gathering center. Data from sensors located throughout the plane will be channeled to the flight-test system where they will be clocked, converted to a digital format, and recorded on magnetic tape. Later, when the test flight is completed, the tapes will be processed and analyzed using high-speed digital computers. During early performance tests, the taped data will serve as design checks for the plane's builders. In later flights the test data will be employed in certification trials conducted by the governments of prospective buyers of the airliner.

☆☆☆



**CHINOOK FLEET HAS
OVER 50,000 FLIGHT HOURS...
12,000 HOURS OF
VIETNAM COMBAT FLIGHT**

Surprise, neutralize, destroy

Guerilla warfare. Shifting, difficult, bitter—full of traps. How do you cope with it? Against the surprise of guerilla tactics, the U.S. Army can deliver its own brand of surprise—right out of its CH-47A Chinook transport helicopters.

To pin down the enemy, the Chinook can carry—into areas inaccessible to surface transport—a complete artillery section, including two howitzers, ammunition and gun crews. All in one load.

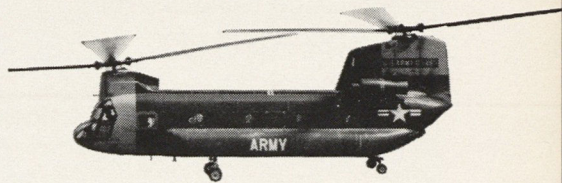
Hitting the enemy with troops where he least expects it, the Chinook can debark a fully-equipped combat platoon. And then lift away in seconds as the last man comes charging off the rear loading ramp.

Over 30 feet long and 7½ feet wide, the Chinook's cargo compartment can be loaded with Pershing Missile system components, or with infantry support weapons or the latest combat vehicles. Because of its large capacity, the Chinook reduces the number of helicopters needed for an air mobile mission, lessens traffic congestion and permits the use of smaller assault landing sites.

Now operating with the 1st Cavalry Division (Airmobile) in Viet Nam, the CH-47A Chinook has become the U.S. Army's standard medium transport helicopter.

The U.S. Army's foresight, guidance, and support, joined with the resources, man-

agement, and technical capabilities of the Boeing Company, have made the Chinook a performance-tested tactical transport.

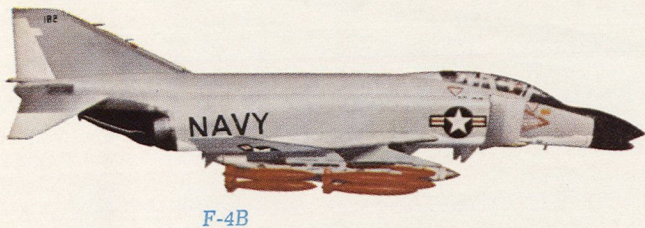


BOEING

VERTOL DIVISION

MORTON, PENNSYLVANIA

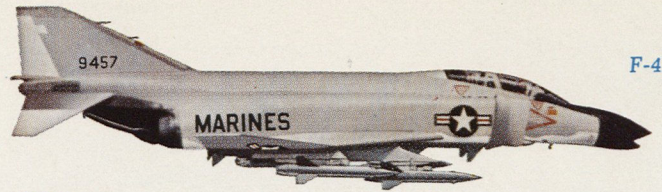
COMMONALITY



F-4B

Commonality is a product characteristic sought after by defense planners. Commonality permits planners to meet economically and effectively the multiple mission weapon requirements of multiple services. Commonality is a characteristic of the Phantom.

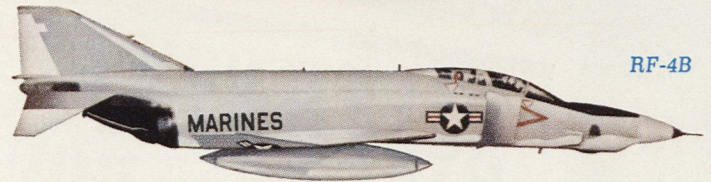
The McDonnell engineering team that designed commonality into the multiple-mission Phantom has proved that commonality can be achieved without performance compromises. This team is now designing even more advanced fighters in which commonality will be a fundamental characteristic.



F-4B



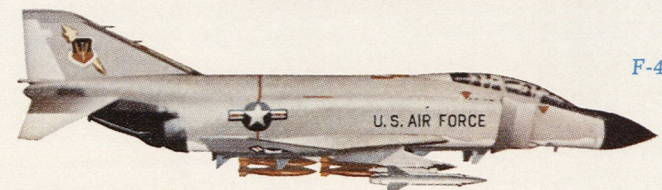
F-4C



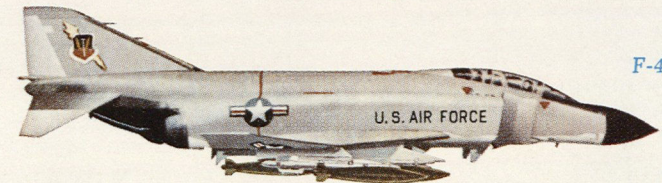
RF-4B



RF-4C



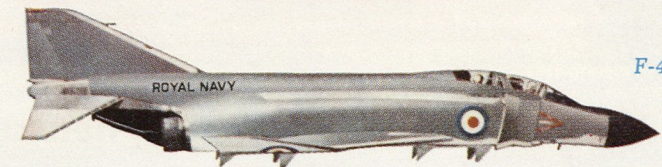
F-4D



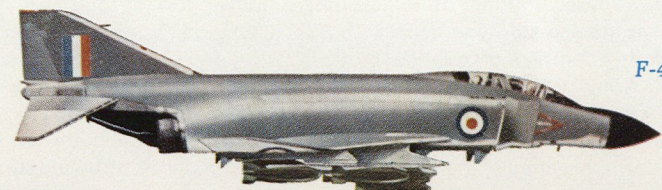
F-4E



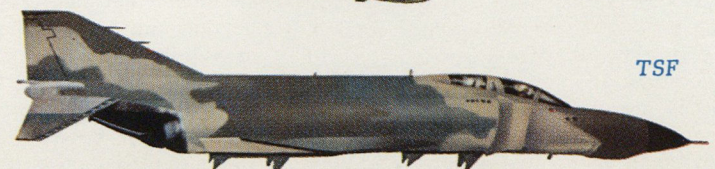
F-4J



F-4K



F-4M



TSF

MCDONNELL
ST. LOUIS