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SUBMERSIBLE AIRCRAFT: POTENTIAL MISSIONS, SELECTED SYSTEM OPERATIONS, AND COSTS

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PREFACE

The need for high-survivability basing modes for aircraft has led to the consideration of submersible aircraft--that is, aircraft that could be based, dispersed, or moored while submerged.

The feasibility of submersible aircraft was first indicated in RM-3683-PR, The Submersible Aircraft--Design Feasibility and Performance Calculations, for a class which utilized ballast-compensated JP-4 fuel as well as ballast for the basic portion of the aircraft. It was indicated that much of the performance loss attributable to the ballast could be recovered through the use of a hypothetical water-density fuel.

Broadened analyses of design parameters and technical innovations were subsequently reported in RM-4180-PR, Submersibly Moored and Submersible Aircraft: Comparative Design and Parametric Performance Analysis. By replacing both fuel and aircraft ballast weight with additional low-density fuel, combat-radius results comparable to those of contemporary aircraft were shown for these positively buoyant aircraft. Such aircraft could be submerged with an external force applied by an imbedment anchor or by attachment to a shiplike basing platform.

A recent request from AFRDC of Headquarters USAF for a broad presentation of submersible-aircraft flight characteristics, system capabilities, basing possibilities, and system costs resulted in the investigation reported here.

SUMMARY

This investigation extends earlier work on the technical feasibility of submersible aircraft to considerations of the operational employment of such aircraft in a variety of potentially interesting missions.

The performance of submersible aircraft in these missions is compared with that of relevant alternative systems in terms of 22 characteristics, such as initial survivability and multiple-recycle potential. From these qualitative assessments, two of the missions that appeared to be more attractive for the submersible aircraft were selected for operational analysis and system costing. Typical designs based on recent technical work were incorporated in the two operational systems--a submersible penetrator aircraft and a submersible tanker aircraft. Three deployment modes were considered for each of the submersible systems.

Submersible shiplike basing platforms have been investigated as a means of submerged transporting, deploying, and basing of submersible aircraft. To assist in the current assessment of the potential operational utility of submersible aircraft, system costs are developed for various levels of dispersal of submersible aircraft, and, for several degrees of mobility of the basing platforms, are compared with the system costs of alternative strategic aircraft systems in both the strategic-penetrator and tanker-support roles.

In the strategic-penetrator role, the five-year total-system costs of the submersible aircraft systems are generally comparable with those of an advanced, land-based, tanker-supported penetrator, and with those of a long-endurance aircraft which launches a small parasite (a manned penetrator). For advanced land-based penetrator systems, the submersible aircraft costs much more in the tanker-support role than either a modified KC-135 tanker or a tanker version of the advanced penetrator aircraft.

Qualitative considerations concerning system effectiveness and operational characteristics--especially survivability during initial attack, shortened response time, and increased force-recovery and reconstitution potential--are generally favorable to submersibly

based penetrator systems. This, coupled with the comparability of costs, suggests an advantage in cost effectiveness for submersible strategic penetrator aircraft and warrants more detailed design and operational studies than those which are briefly delineated. Also suggested are the subsequent design of a small developmental prototype aircraft and, if successful, its possible use for covert operations.

ACKNOWLEDGMENTS

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I. INTRODUCTION

Submersible aircraft are intended to take off from and land on water surfaces and to be able to submerge. Certain versions would also be able to propel themselves under water to a limited extent. These aircraft are designed to a density approaching that of water, since they must become neutrally buoyant to submerge and may, by discharging water ballast, emerge above the surface sufficiently to take off. In Fig. 1, a plan view of a relatively large submersible aircraft designed for low-altitude, subsonic flight is superimposed on the plan view of the B-52 which has approximately the same takeoff gross weight. The greatly reduced size of the submersible is due principally to a 2.5:1 ratio in average density relative to the B-52; furthermore, the submersible aircraft is designed for low-altitude flight and has a wing loading twice that of the B-52.

Submersible aircraft differ, of course, from conventional aircraft in design philosophy, operational usage, and basing mode. A first consideration for possible future aircraft systems is increased survivability in the basing mode during an initial enemy strike and follow-on attacks. An additional important consideration for manned aircraft is a recycling potential that would permit multiple-sortie operations.

To achieve these characteristics, the concept of submersibly based aircraft was evolved by combining aircraft and submarine technologies and operational considerations. Covert submerged deployment by one of several means inhibits various means of potential attack by the enemy. Ancillary logistic systems can be devised to provide survivable bases which permit recovery and recycling of such aircraft. Forward-area deployment tends to be desirable because of reduced aircraft response time and the removal from the ZI of targets attractive to the enemy.

To extend the time (to months, possibly) that an aircraft can remain on station submerged, large mobile shiplike submersible platforms capable of transporting and servicing a number of submersible aircraft and housing their crews could be stationed in suitable areas overseas.

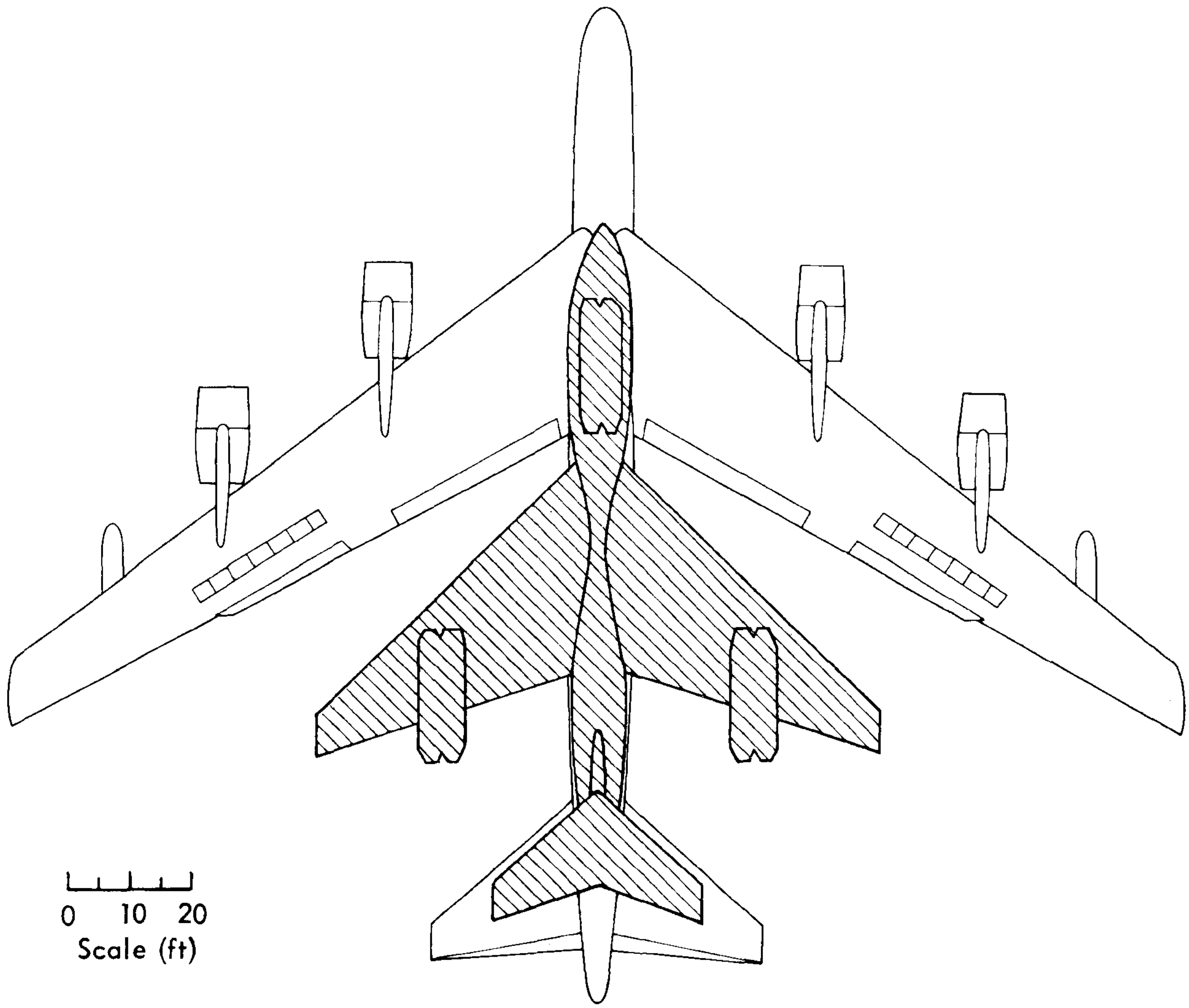

Fig. 1—Size comparison of high-density, highly loaded submersible aircraft with B-52 (equal gross weights)

The initial RAND work on submersible aircraft was reported in Ref. 1. This dealt primarily with the technical feasibility of truly submersible (JP-fueled) aircraft--those employing fixed ballast to achieve neutral buoyancy. The flight-performance characteristics of these aircraft were degraded considerably below those of comparable land-based aircraft.

In subsequent design studies aimed at increasing the flight performance of submersible aircraft, changes in the geometry of the aircraft were considered, as well as alternative structural materials, reduced ultimate design flight load factors, higher-density fuels, and schemes for submersibly mooring a positively buoyant submersible aircraft.

Since the use of the inherently positively buoyant aircraft, fueled with JP-4, indicates a potential improvement in combat radius by about 40 per cent, this operational class of submersible aircraft will be considered here. The water-ballast volume of the original class of submersible aircraft would be filled with additional jet fuel whose weight would be equal to that of the lead which had been previously allocated to ballast the truly submersible aircraft. This work is reported in Ref. 2 and is summarized briefly in Appendix A; the latter also includes recent considerations of high-density hydrocarbon fuels. If these new fuels are demonstrated to be operationally satisfactory and can be synthesized in the large quantities needed, a truly submersible aircraft without fuel ballast, and having an underwater, self-propulsion capability, could replace the submersibly moored, positively buoyant aircraft.

This Memorandum reviews a wide range of possible applications of submersible aircraft* and from an internally consistent qualitative evaluation selects several example applications which rank relatively high. Analyses are prepared for the selected systems, and relevant cost studies are presented.

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*Unless otherwise qualified, in this Memorandum the term "submersible aircraft" includes all aircraft that can submerge, irrespective of their buoyancy. When it is important to distinguish between the major classes of submersible aircraft, those designed for neutral buoyancy and capable of underwater locomotion are called "truly submersible aircraft"; positively buoyant aircraft that must be tethered to submerge are called "submersibly moored aircraft."

II. POTENTIAL OPERATIONAL CONCEPTS

GENERAL DISCUSSION

A number of operational modes in which submersible aircraft could be applied have been considered for the strategic, tactical, and other missions. For convenience these have been grouped under several of the DOD program-package categories, as shown in Table 1. For these operational modes, a qualitative comparison of appropriate submersible aircraft systems with likely alternative systems is made for the purpose of selecting for further analysis several which appear particularly attractive for submersible aircraft.

It should be noted that although such qualitative ratings tend to be subjective, there will be uniformity of treatment of the various missions for the several program packages. These limitations are not serious for the purpose of this Memorandum, which was to select potentially promising applications for more detailed quantitative analysis.

For these operational modes listed in Table 1 under Strategic Offense, the submersible aircraft can reasonably be compared to the B-52G or H, and for later time periods, to advanced manned strategic aircraft (AMSA)* and long-endurance aircraft (LEA) with a parasite penetrator.**

The assumed operational modes for submersible aircraft systems within the category of Strategic Offense are defined here and related to possible uses of alternative systems to facilitate comparisons.

1. Secure Retaliatory Force. Covert emplacement and submerged basing of alert strategic submersible aircraft in inland, coastal, or target-area peripheral waters provide security that is acquired in varying degrees by alternative systems with dispersal, ground alert, or airborne alert. The existence of such aircraft with assured continuing survivability in the basing mode suggests their use for first-response sortie, controlled both in extent and in time up to

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*A Mach 2.2/0.9 aircraft of about 345,000 lb, as described in Ref. 3.

**A Mach 0.3 aircraft of about 475,000 lb with a Mach 0.9 penetrator of about 55,000 lb, similar to those described in Ref. 4.

Table 1

POTENTIAL USES OF SUBMERSIBLE AIRCRAFT
BY PROGRAM PACKAGE

Strategic Offense	General Purpose	Continental Defense	General Support
(1) Secure retaliatory force (2) Withheld force (3) Dispersed & deployed strike force (4) Tanker force	(1) Overseas-based TAC (2) ZI-based crisis force	(1) Distant antibomber and anti-ASM defense (2) ASLBM system (3) Boost-phase ICBM intercept (4) Antisubmarine force	(1) Command and control (2) Reconnaissance (3) Special operations

weapon release, as a second-response sortie against inaccurately located or mobile targets and withheld missile forces.

2. Withheld Force. Submersible aircraft covertly emplaced and submersibly based, as described above, have an enduring security that permits them to be withheld without attrition for use, perhaps months later, in the late stages of a general war. This enduring strike and reconnaissance force could significantly increase negotiating power in general-war termination, because of its continuing ability to attack withheld enemy forces. Alternative systems might employ LEA or aircraft protected in hardened bases, as in the Cliff Dweller(5) concept once proposed for the B-70.

3. Dispersed and Deployed Strike Force. Submersible aircraft which are rear-area, airfield-based during peacetime conditions could be deployed and dispersed in forward areas with covert emplacement and submerged basing under high-alert conditions. Alternative systems could use airborne alert near the target system, forward-area bases, or widely dispersed ZI airfields under high-alert conditions to achieve reduced time to target and, in part, reduced vulnerability by dispersal.

4. Tanker Force. Submersible tanker aircraft covertly deployed and submersibly based along the planned flight paths of strategic aircraft either under high-alert conditions or under long-term cold-war conditions could support strategic penetrator aircraft without need of foreign bases in forward areas, or an increase in size or number of ZI based tankers needed to transfer a given amount of fuel. Subsequent reuse of submersible tankers would be possible by refueling them in their basing areas from submerged fuel caches.

For limited-war operational modes shown in Table 1 under the heading General Purpose, it is appropriate to compare submersible aircraft with F-105 or F-4C, F-111A, and F-4B carrier aircraft in the roles of an overseas tactical force and ZI-based tactical forces.

Consider next several operational modes under the Continental Defense mission. Here, appropriate submersible aircraft can be rated relative to shore-based patrol aircraft and to carrier-based aircraft for an anti-submarine-launched ballistic missile (ASLBM) system; and for the distant antibomber and anti-air-to-surface missile (AASM) system. For the boost-phase ICBM intercept mode, appropriate submersible aircraft can be compared to conventional aircraft employed in combat air patrol and to satellite-based intercept systems. As an antisubmarine force, submersible aircraft can be compared to hydrofoil craft, to ASW aircraft, to surface ships equipped with drone antisubmarine helicopters, and to attack submarines.

For the operational modes grouped under the General Support mission, submersible aircraft could be compared to present and future conventional aircraft for command and control, reconnaissance, and special operations. The use of submersible aircraft for special (covert) operations appears to be potentially interesting. Although the development of a possible operational plan for such aircraft is beyond the scope of this Memorandum, some aircraft design information for small submersible aircraft* is given in Appendix B.

In order to establish qualitative comparisons between submersible aircraft and relevant alternative systems, individual judgments have been exercised on a large number of specific system characteristics. As shown in the first column of Table 2, some 22 characteristics have been grouped in five somewhat arbitrary major categories; these are termed Effectiveness, Political Factors, Operations, Performance, and Support. The first two categories are regarded as the more important ones for gross evaluation of alternative weapon systems in terms of cost-effectiveness studies.

As a representative illustration of the manner of assessing the advantages and disadvantages of the submersible aircraft system relative to appropriate alternative systems, a discussion of the judgments made for the first strategic operational mode, Secure Retaliatory Force, is set forth below. (A similar assessment of other strategic, tactical, defense, and support missions is summarized in Appendix C.)

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*A 40,000-lb, one-man aircraft has Mach 0.92 combat radii of about 1800 and 900 n mi at optimum and low altitude, respectively.

Table 2

MAJOR CHARACTERISTICS AND RANKING OF SUBMERSIBLE AIRCRAFT RELATIVE TO ALTERNATIVE AIRCRAFT SYSTEMS--SECURE RETALIATORY FORCE

System Characteristics	Comparative Rating of Submersible Aircraft		
	B-52G	AMSA	LEA
Effectiveness			
Initial survivability	B	MB[a]	B
Recovery and reconstitution	B	B	B
Precision second strike	B	B	B
Multiple-recycle potential	B	B	B
Force durability	B	MB	MB
War termination and negotiation	B	B	B
Political factors			
Collateral damage	B	B	B
Show of force	S	S	S
OCLUS base rights	B	B	B
Operations			
Response under attack	B	B	B
Time to target	B	B	S
Command control	S	S	S
Cocked alert	B	B	B
Alert reaction time	P	P	MP
Climatological constraints	P	P	P
Performance			
Range	P	P	P
Flight endurance	P	P	MP
Speed at low altitude	B	S	B
Payload	S	S	S
Support			
Maintenance access	P	P	P
Maintenance cycle	S	S	S
Logistic support required	P	P	P

[a]This entry denotes that the submersible aircraft is rated much better than AMSA with respect to initial aircraft survivability against enemy attack on the normal operational base.

MB = much better
B = better
S = same
P = poorer
MP = much poorer

SAMPLE EVALUATION

Effectiveness

Under the heading of Effectiveness are shown the important characteristics of initial aircraft survivability on the base during a surprise attack, recovery and reconstitution of the force after the first strike, precision second strike, multiple-recycle potential, overall force durability for continued fighting, and availability of a significant remaining portion of the force for war-termination and negotiation activities.

Under the first characteristic, initial survivability, the dispersed and hidden submersible aircraft is rated better (B) than the B-52G and LEA as alternative systems principally because the nonairborne part of these systems will be more vulnerable to surprise attack. The much-better (MB) rating relative to AMSA stems from the assumption that an airborne-alert capability will not be built into the AMSA system. The uncertainty of location due to covert deployment and basing mobility reduces the prospect of effective attack by the enemy on the submersible system. The potential for submerged refueling and rearming in forward areas facilitates recovery and reconstitution of the reusable aircraft of the submersible systems.

Force recovery and reconstitution of the submersible is rated better than that of the alternative aircraft because the refueling and rearming of the operable aircraft surviving the first target penetration would be effected only a few hours after the strike and under the protective conditions of a submerged base. Reserve crews, necessitated by the prestrike alert function, would be available at that base also.

The precision second strike of the submersible systems would be enhanced by proximity to the target system and the assured availability of fuel and weapons needed for the second strike.

The multiple-recycle potential for the submersible system is rated better than the alternative systems because of the continuing survivability of the submerged base, which can be resupplied if desired for continued operations.

The entity of the submerged base and its aircraft provides better assurance of continuing force durability as a function of the self-contained, essential operational and maintenance elements surviving. In addition, rear-area stored or nonalert aircraft could be ferried to surviving submerged bases to replace aircraft lost in combat. The B-52G, AMSA, and LEA systems will probably be more vulnerable during the recovery to poststrike bases and return to reconstitution (forward ZI) bases. Additionally, the dependence of the AMSA on tankers and the low flight speeds of LEA subject these systems to more exposure and potentially greater attrition.

The submersible system is rated better than the three alternatives for the characteristics identified as war termination and negotiation potential because a significant portion of the initial force could be expected to be refurbished and used as a continuing threat during such phases of the war.

Political Factors

The characteristics shown under the heading of Political Factors concern the ability to minimize collateral or bonus damage to friendly territory or personnel in connection with enemy attacks on military targets, to mount a show of force at the critical time and place in order to exert the proper amount of politico-military pressure in a crisis situation, and to surmount the problem of aircraft base rights outside the continental limits of the United States (OCLUS).

Collateral damage to the ZI and the areas of friendly nations would inherently be less if forward-area submersible bases were attacked than if the attack were against ZI or overseas land bases for the three alternative systems. The lessened fallout problems associated with underwater bursts also contribute to this judgment.

The effectiveness of the submersible system and the three alternative systems in a show of force is rated the same because a positive-control launch, with subsequent recovery and redeployment of the submersible aircraft and base, has the equivalent effect of an airborne alert for the B-52G and LEA systems or the high-alert dispersal of AMSA.

The submersible system is rated better than the alternative systems in terms of OCLUS base rights because forward harbor facilities would not be as essential in supporting the submersible system as forward-area airfields would be in supporting the B-52 and AMSA systems and in maximizing the on-station alert ability of the LEA system.

Operations

Under the heading of Operations, the characteristics considered are the ability of the system to respond while it is subject to attack, the overall time from takeoff to target, communicating command control, the ability to remain in a state of cocked alert for long periods, the reaction time needed for takeoff after the go-signal is received in an alert condition, and the climatological constraints due to wind, low temperature, and major storms.

Response under attack is rated better for the submersible system relative to the alternative systems because the submersible aircraft dispersed under high-alert conditions would be distributed over a huge area of which only a small part would be affected by enemy action at any particular time. The airfields required for the launch of the B-52, AMSA, and nonairborne LEA systems are individually targetable, and the aircraft are even more vulnerable than the base.

For a given flight speed, time to target is directly proportional to distance between target and base, so that the forward-based submersible systems are rated better.

The communication of increased defense readiness condition (DEFCON), surfacing, and preparation for positive-control launch instructions are considered to be more difficult than communications with SAC bases or aircraft in flight, but no more difficult than for the Polaris system. A number of different means of effective communication, for missile systems submerged at various depths, are reported in Ref. 6. Adaption of these results should meet the communication requirements of submersible aircraft systems. Subsequent to takeoff, these instructions are the same as for the alternative systems.

Total time in cocked-alert condition for the submersible system is considered better than for the alternative systems because of the favorable characteristics designed into the aircraft, necessitated by long alert periods without rotation of alert aircraft.

The alert reaction time for the submersible system would be poorer than for the B-52 and AMSA because of the time required to surface and prepare for takeoff, and it would be much poorer (MP) than for the LEA, which is assumed to be airborne and on alert station.

Climatological constraints are more severe for the submersible system because of the special features and operations required in ice-covered or very-low-temperature areas, and due to the fact that high-sea-state conditions (greater than sea state 4) would preclude takeoff and landing.

Performance

The four performance characteristics range, flight endurance, speed, and payload do not require definition.

The range and combat radius of the submersible aircraft have been described in Ref. 2 and shown to be moderately less than those of contemporary aircraft (having the same gross weight and payload) because the weight of ballast and the special submersible equipment reduce the net fuel weight allowable.

For the same reason, its flight endurance would tend to be less than that of the B-52 and AMSA, and markedly less than that of the LEA.

The low-altitude design Mach number is greater than that available to the B-52 and is similar to that of the AMSA. The speed of the submersible aircraft is greater than that of the LEA and is equal to that of the parasite aircraft.

Payload is an independent design variable and for purposes of comparison will be assumed to be equal to that of the alternatives.

Support

The support characteristics include external and internal access to the aircraft subsystems, the length of the periodic maintenance cycle, and the extent of special and unusual logistic support required.

Access for maintenance of submersible aircraft would be more difficult than for the alternatives because of the watertightening features and the high-density packaging of equipment components necessitated by the self-submerging capability.

The maintenance cycle (time between periodic overhauls) for the submersible aircraft is likely to be the same, since the annual flying hours per aircraft would be the same and the airborne systems would be generally comparable. The marine features (e.g., water ballast and underwater propulsion systems) that are unique to the submersible aircraft tend to require less frequent maintenance.

The forward-area basing that exploits the attributes of submersible aircraft inherently requires substantially greater logistic support than do ZI-based B-52 and AMSA aircraft. The surface and subsurface support of submersible aircraft is greater than the possible forward-base support required for the LEA.

SELECTION OF SYSTEMS FOR QUANTITATIVE STUDY

The above assessment procedure has been carried out for the other strategic operational modes defined in the first part of this section, and the results are given by Table 5 in Appendix C. Tables 6 and 7 in Appendix C show similar qualitative evaluations for General Purpose Forces and for Continental Defense Forces. The dissimilarity of the relevant characteristics for the antisubmarine-warfare mission resulted in its separate treatment in Table 8.

Basically, all the judgments which show the submersible aircraft systems to be better than alternative systems stem from the advantages of increased basing survivability during initial attack, reduced strike time due to forward-area basing, and increased force-recovery and reconstitution potential. These tend to establish a credible recycle potential. The judgments adverse to the submersible aircraft systems are associated with the inherent disadvantages of submersible aircraft; namely, some moderate performance penalties, a mechanically more complicated aircraft, an additional difficult operating environment, and greater logistic-support problems.

Two submersible-aircraft operational modes of the strategic type were selected on the basis of the preceding remarks for more detailed analysis: (1) a secure retaliatory force, since the intrinsic advantages of submersible aircraft--increased basing survivability and increased capability for force recovery and reconstitution--have the greatest advantage for systems designed to deter or fight general wars; (2) a fleet of submersibly based tanker aircraft in support of AMSA, in view of the current interest in AMSA and its possible limitations due to tanker-base locations and vulnerability. The analysis of the submersible, secure retaliatory force is given in Section III. However, since the five-year system costs for strategic aircraft systems using submersible-tanker support were found to be substantially greater than for similar systems using possible alternative tanker support, description of that system was relegated to Appendix D.

The operational modes listed under General Purpose in Table 1 also appear to be worthy of operational and cost analyses in subsequent investigations.

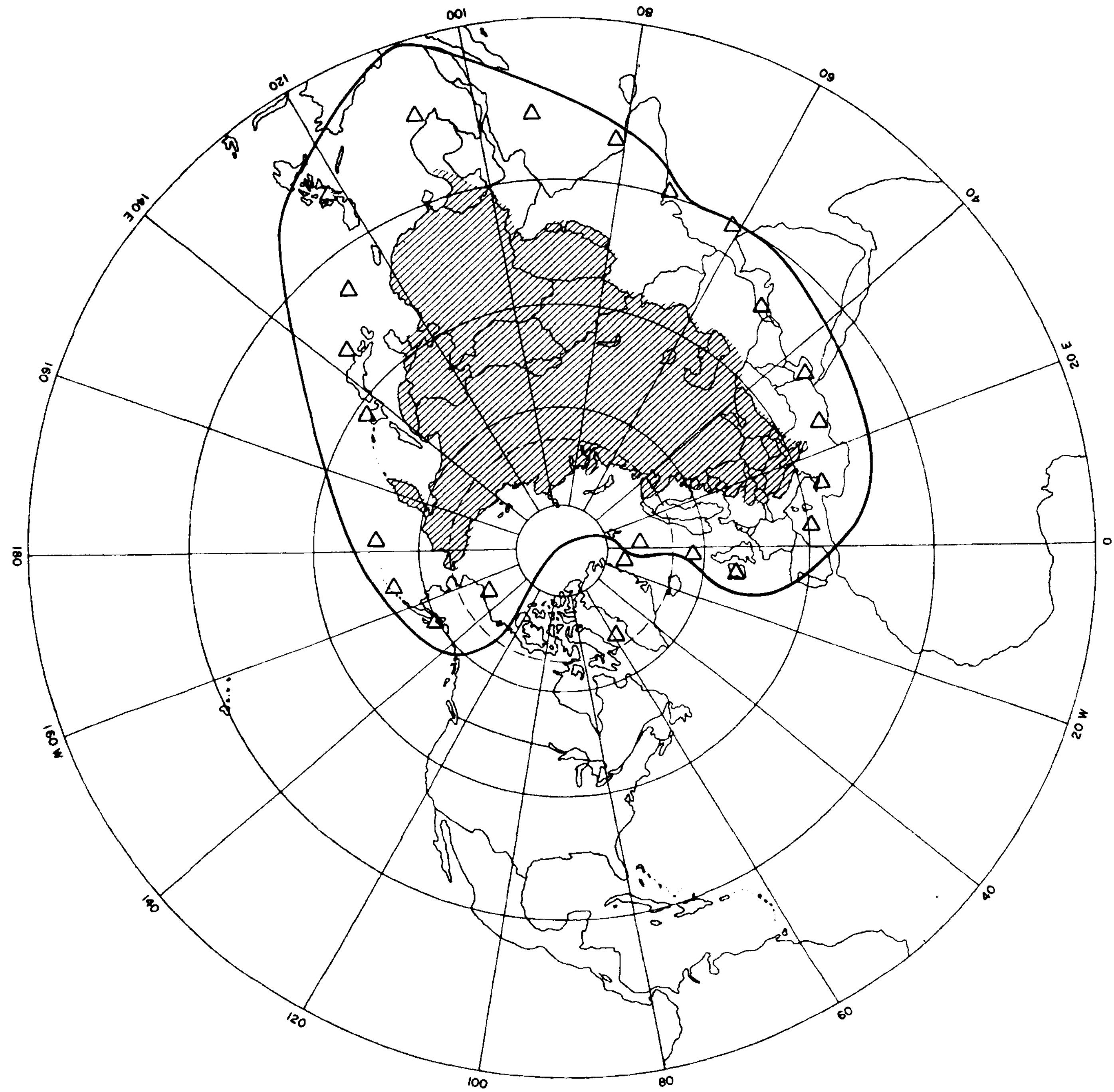
III. ANALYSIS OF STRATEGIC SUBMERSIBLE PENETRATOR AIRCRAFT SYSTEMS

The operational concept to be described in some detail here utilizes a forward-based submersible aircraft to penetrate to and attack the target system contained within the Sino-Soviet-bloc land mass. This target system is also utilized in consideration of alternative land-based systems discussed later. The submersible and alternative aircraft have a crew of four and an 8000-lb expendable military load of bombs or air-to-surface missiles. All aircraft are assumed to have the same penetration capability over enemy territory.

Submersible penetrator aircraft could be deployed to and submerged at locations indicated by the triangular symbols in Fig. 2. Three alternative degrees of mobility for the assumed force size of 100 alert aircraft are considered in basing the aircraft to determine the effect of mobility on vulnerability and system cost. The "low-mobility" and the continuously propelled "high-mobility" cases would utilize large shiplike submersible basing platforms which are covertly emplaced and recovered by detachable nuclear pusher-tug submarines. The third case is a "land-based-flyout" system which is deployed adjacent to prepositioned fuel caches in forward areas only under high-alert conditions.

To determine the basing system, the target system was assumed to be the entire Sino-Soviet bloc. Indicated in Fig. 2 are 23 potential submerged-basing locations selected for the smaller penetrator aircraft. These locations range from the northern coast of Alaska and the Aleutian Islands to the areas off Japan, the Philippines, and Vietnam, and some are in the Indian Ocean. Others are in the Mediterranean Sea, off the British Isles, and off Greenland. Climatological constraints, and possible means of compensating for them, such as zero-length aircraft launchings from surfaced platforms, are important considerations in the selection of specific basing locations.

The combat-radius requirements for the penetrator aircraft stem from the geography of the problem, including the closest allowed basing-locations contour, which is drawn about 1000 n mi out from the perimeter of the target system. A high-altitude flight of 1000 n mi



Δ Submerged-basing locations

Fig. 2—Sino-Soviet-bloc target system with contour ~ 1000 n mi from target perimeter

each way between the basing contour and the target-system perimeter and a minimum penetration and withdrawal capability at low altitude of 1000 n mi over the general target system were assumed. This is a 2000-n mi total combat-radius capability, with 1000 n mi each way available at low altitudes. For the present state of the art in submersible-aircraft technology, this corresponds to a 100,000-lb aircraft as shown by the circle in Fig. 3, which presents Mach 0.92, low-altitude penetration radius versus total combat radius for a series of submersible aircraft at different values of gross weight.

The submersible penetrator aircraft is assumed to have a wing aspect ratio of 4 and high-tensile-steel construction. The submersibly moored type is inherently positively buoyant by approximately 1/3 of takeoff gross weight. This mooring force is significant relative to the aircraft, but it would not pose a major problem to the basing unit even for the low-density-fuel cases described here because the total of the aircraft buoyant forces is less than 2 per cent of the displacement of the aircraft basing platform. This amount of change could be compensated by ballast tanks. Submersible penetrators using high-density, high-carbon fuels could be neutrally buoyant and capable of self-propulsion under water. This would facilitate engagement with the platform for penetrator refueling. There would be a possible time constraint on availability if the high-carbon synthesized fuel were selected for early use. This problem would be obviated by using JP-4, which introduces operational disadvantages mentioned above. Combat radii for aircraft using high-carbon fuels would be about 7 per cent less than those shown in Fig. 3. A more complete description of these penetrator aircraft, which provide for a four-man crew and an 8000-lb expendable military load consisting of air-to-surface missiles, is given in Appendix B.

AIRCRAFT DEPLOYED ON SUBMERGED PLATFORMS (LOW MOBILITY)

These small 100,000-lb penetrator aircraft would be deployed on submersible, shiplike platforms. One might choose, for example, to deploy eight alert aircraft on each of twelve platforms. The arrangement shown in Fig. 4 provides a 25 per cent increment (two additional

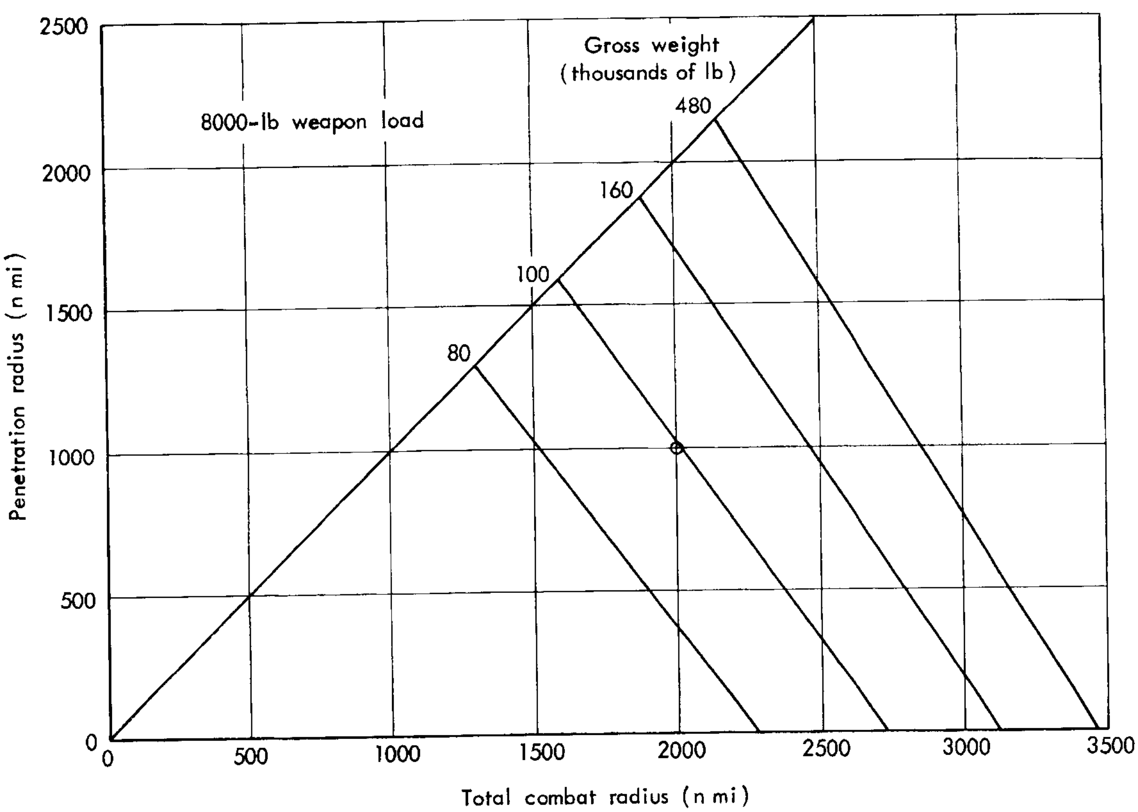


Fig. 3—Combat-radius capabilities of a class of subsonic, submersible penetrator aircraft (submersibly moored, high-tensile-steel construction, aspect ratio 4, JP-4 fuel)

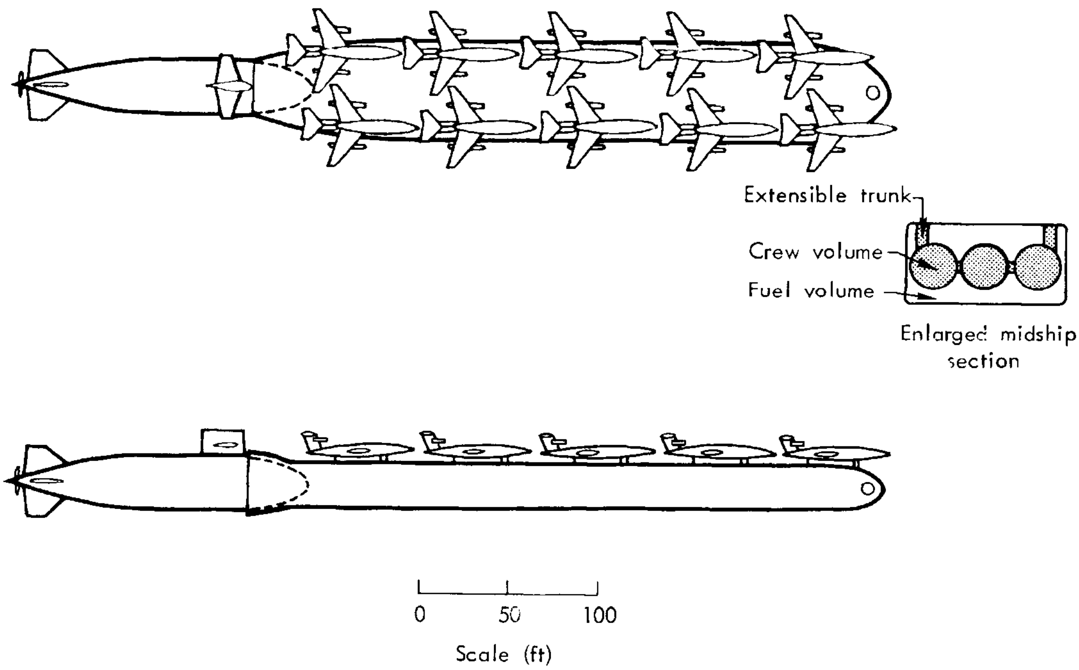


Fig. 4—Submersible penetrator aircraft platform with nuclear pusher tug and complement of ten aircraft

aircraft) to help insure high reliability of the overall system, on station, for an extended period of time. The midship cross section of the penetrator basing platform shown in Fig. 4 indicates a relatively high total volumetric allowance for crew members. The flight-crew ratio on board the platform for the aircraft is 2 to 1 because a relatively high degree of alert would be needed for an effective short-time response, which is important to strategic penetrator systems.

The communication capabilities included in the submersible-platform design are essentially those used in the Polaris missile system. This relatively sophisticated communication system,[(7)] with its several degrees of redundancy, permits the transmission of substantial quantities of information under certain operating conditions. The nominal 150-ft submergence depth suggested for these basing platforms permits the use of a high-data-rate communication system which may permit reception of retargeting information by the platform.

The alert function could be performed within the relatively commodious volume available in these hardened, ring-stiffened cylinders within the lightly constructed pressure-compensated platform. The flight crew would have access into the cockpit of the aircraft through extensible trunks directly above the accommodation space. This alert mode can be permitted, since its function is only to shorten the response time, not to decrease the vulnerability as in the case of runway-based aircraft before takeoff. The alert is not a necessary condition to survival of the aircraft under first-strike ICBM attack. There are personnel accommodations in the number of 50 for flight, 50 for support of the aircraft, and an additional 100 to support the former groups and to perform the operating functions of the submersible platform itself. Flight crews could be rotated more frequently than support personnel or the equipment. These personnel allowances are used principally to help determine volume requirements in the platform design. Fuel and additional weapon packages for ten sorties for each of the aircraft are provided in the platform, which has a submerged displacement of about 10,000 tons. A fuel allowance was made to be able to support for ten sorties each all the aircraft of an additional platform if necessary. This 10,000-ton displacement is about 25 per cent larger than that of a fleet ballistic-missile submarine. A 2500-ton submarine pusher tug would be adequate to propel the platform at a speed of 20 kn without aircraft or 16 kn with the aircraft on board. Some design information for the submersible platform and the nuclear pusher tug is given in Appendix E.

With the dispersion of penetrator aircraft bases around the entire periphery of the target system, perhaps six submarine pusher tugs would be required, in the low-mobility case, to deploy this system, to recover it, and to bring it to rear areas for training and general maintenance operations. The use of moored platforms results in very quiet operations (no propulsion or hydrodynamic noise) and corresponds to a minimum of nuclear pusher tugs. Provision is made in the platform design for sonar systems and torpedo defensive armament. Passive sonar that can be effectively used by a quiet system has about twice the range of the active sonar a potential attacker would need for search purposes. Discrimination techniques of sonar signatures would preclude firing against friendly forces.

Deployment in a moored fashion at a nominal depth of 100 to 200 ft beneath the surface was assumed. The rather small (16-ft diameter) crew-volume cylinders are the only structural elements that are substantially influenced by the submergence depth. This depth could be increased considerably at a small increase in cost if such were desirable. Refueling operations could be conducted by single-point refueling in a submerged condition, if the operational conditions required this. Previously prepared weapon packages could be attached as external stores by remote control from within the hull. The submerged reattachment of the maneuvering aircraft to the platform might utilize a cable-and-hook system similar to that used by in-flight cargo pickup systems.

The aircraft themselves constitute only a few per cent of the displacement of the platform. The total gross weight of the ten aircraft corresponds to about 5 per cent of the displacement of the platform; for JP-4 fueled aircraft the total buoyant force involved to be resisted by the platform amounts to about 1/3 of that or only 1-1/2 per cent of the platform displacement. For high-density jet fuel this would not be a consideration.

Aircraft deployed in a forward area, submerged and inoperative without engine runup or even surfacing for extended periods of time, raise a serious question about systems reliability. Reliability would have to be a key point in the design, construction, and operation of the aircraft. Because of this uncertainty, the fraction of aircraft which can be kept on alert while submerged has been parameterized. If the aircraft could be maintained on station in a reliable condition for two months and if one month were allowed for operational training and another month were allowed for maintenance purposes, the alert fraction would be 1/2. If the system could be maintained reliable for only one month for the same allowances for operational training and maintenance, the alert fraction would be 1/3. If it would go for four months on alert with the one month for training and one month for maintenance, the alert fraction would be 2/3.

The five-year total system costs have been estimated as described in Appendix F, and in more detail in Ref. 8. The results of the cost analysis are shown in Fig. 5 in terms of total system cost per alert aircraft for several assumed values of the alert fraction. Submersible penetrator systems are compared with AMSA ZI-based penetrators, and an LEA with parasite penetrator system. These costs include the RDT&E for the aircraft and submersible platforms, the initial investment, and the five-year operating costs relative to the number of alert aircraft. The force size was assumed to be 100 alert aircraft. The AMSA penetrator is supported by convertible AMSA tankers. The LEA releases and recovers a small parasite at the periphery of the target system.[(4)] The parasite aircraft, which would require only a 1000-n mi low-altitude penetration radius, is designed to the same high-density standards as the submersible aircraft but has a runway-type landing gear. The LEA system on air alert around the periphery of the target system has greater survivability under a first strike and shorter response time to the target than the ground-alert AMSA systems based in the ZI.

For the LEA system, the air-alert fraction is taken as 3/4, and for the AMSA system, the ground-alert fraction is 1/2. These alert fractions are comparable in that an allowance must be made in the

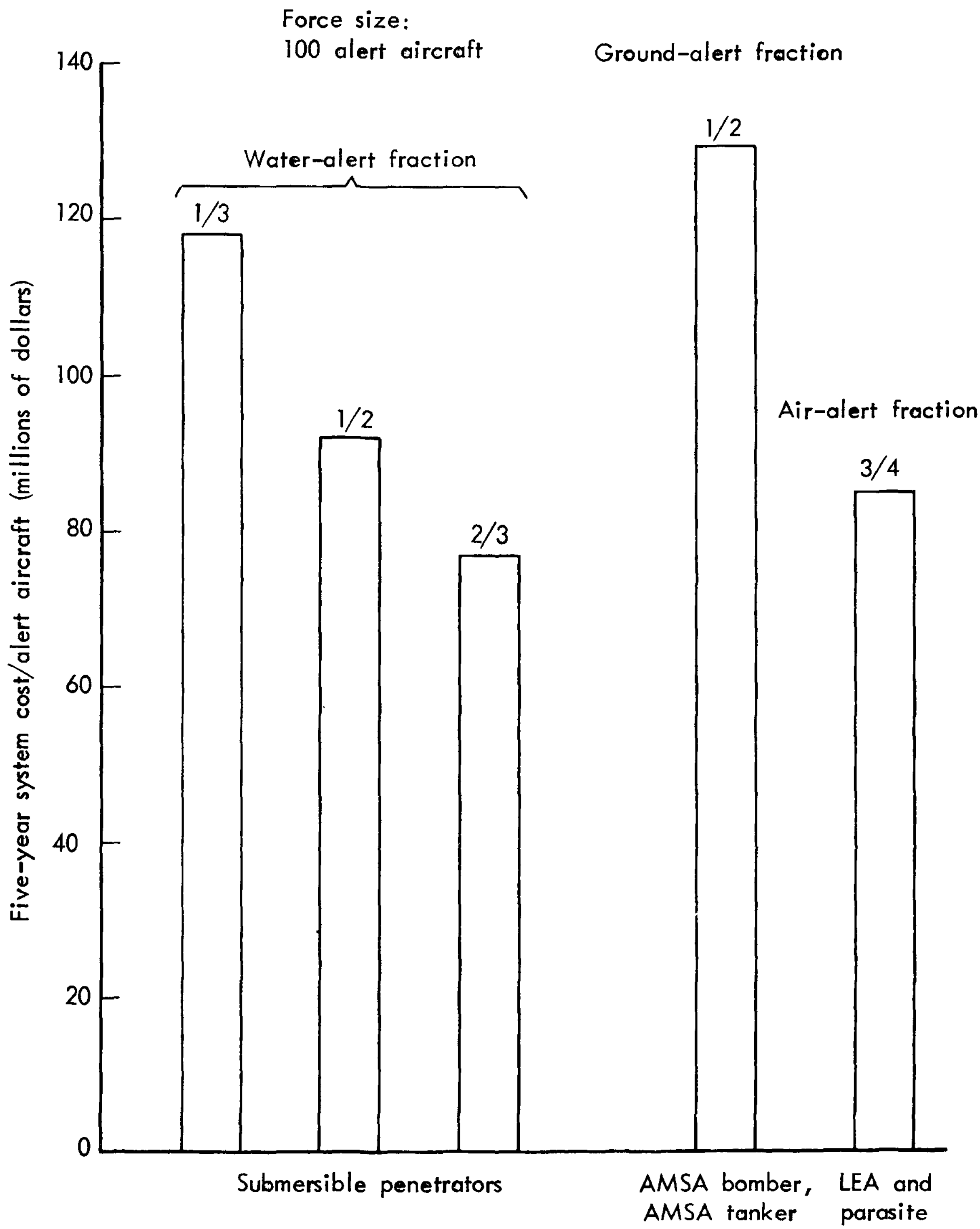


Fig. 5—System costs per alert penetrator aircraft with alternative supporting systems (submersible penetrators affixed for deployment and alert—low mobility)

ground-alert case for flight-training time, whereas in the air-alert case the crews get their operational training while airborne.

As stated in the introductory paragraph of this section, the penetration capabilities and the target system to be attacked are assumed to be common for the several aircraft systems compared here. The favorable effectiveness for the submersible penetrator derives principally from the previously discussed important characteristics under the heading of Effectiveness in Table 2. These attributes are survivability under initial attack, force recovery and reconstitution, multiple-recycle potential, force durability, and war-termination and negotiation potential. Over a wide range of assumed values of alert fraction, Fig. 5 shows the system costs of the submersible penetrator aircraft to be of the same general level as those of alternative future strategic systems discussed. Thus favorable effectiveness at equal cost to do the same job results in a better cost-effectiveness index for the submersible penetrator than for the alternative penetrators.

AIRCRAFT FERRIED AT ALERT TO INDIVIDUAL DISPERSAL (LAND-BASED FLYOUT)

Consider now a substantially different mode of peacetime basing, one substantially like current basing in that submersible penetrator aircraft would be airfield-based in the ZI or forward areas. Upon declaration of high alert these aircraft could be ferried to the basing areas along the target periphery shown in Fig. 2. The ferry range for the selected example aircraft would be of the order of 5000 n mi and even for extremes in redeployment would not require more than one aerial refueling during the ferrying operation. Upon alighting and submerging in the forward basing area, the penetrator aircraft would engage and refuel from a submerged automated fuel cache before assuming alert status in the prescribed basing area. A secure coded sonar beacon might be used to aid the aircraft in finding the fuel cache without compromising the cache's location to unfriendly forces.

The advantage of the high-density hydrocarbon jet fuel relative to JP-4 would be particularly significant for this case of individual dispersal, since self-propelled underwater operation would be possible for all fuel conditions, and an anchor-tether line would be used only to maintain station in underwater currents.

The command communication for such alert penetrator aircraft with previously assigned targets or missions could be a simple sonar signal delivered to the general area by an air-dropped sonobuoy or by the re-entry body of an ICBM booster, or relayed by submarine. The alert forces similarly could be recalled prior to the fatigue limit of the crew by that or other means of communication if the alert was cancelled.

The reliability and vulnerability of the submerged-fuel-cache system to various means of sabotage and attack would require realistic estimates. Various remedies and countermeasures would be needed.

The two principal advantages of this deployment mode are the elimination of the submerged platform and pusher-tug equipments as well as the lessened possible loss to the overall strategic system in the event a submerged platform with its aircraft were found and successfully attacked.

The apparent disadvantages of this basing mode are the potential vulnerability, to surprise attack when airfield-based, and the operational attrition resulting from fly-out deployment of the penetrators under emergency conditions. However, the important additional disadvantage peculiar to individually dispersed penetrator aircraft is the difficulty of replenishing the weapon load in the forward area for rapid recovery and reconstitution of the force. The ZI recovery and reconstitution of individually dispersed penetrator aircraft could be facilitated by submersible tanker aircraft which could perform the refueling operation from submerged automated fuel caches, but such tankers are not included in the system analyzed here.

For an alert force of 100 penetrator aircraft, the five-year system cost including RDT&E, initial investment, and operating expense is shown per alert aircraft for a 1/2 ground/water-alert fraction in Fig. 6. This overall system cost is relatively low because this system employs neither marine support craft nor tanker aircraft. Also shown is the system cost for an equal-size alert force of AMSA strategic aircraft supported by convertible AMSA tankers on 1/2 ground alert. The latter costs do not include specific allowances for the infrequent,

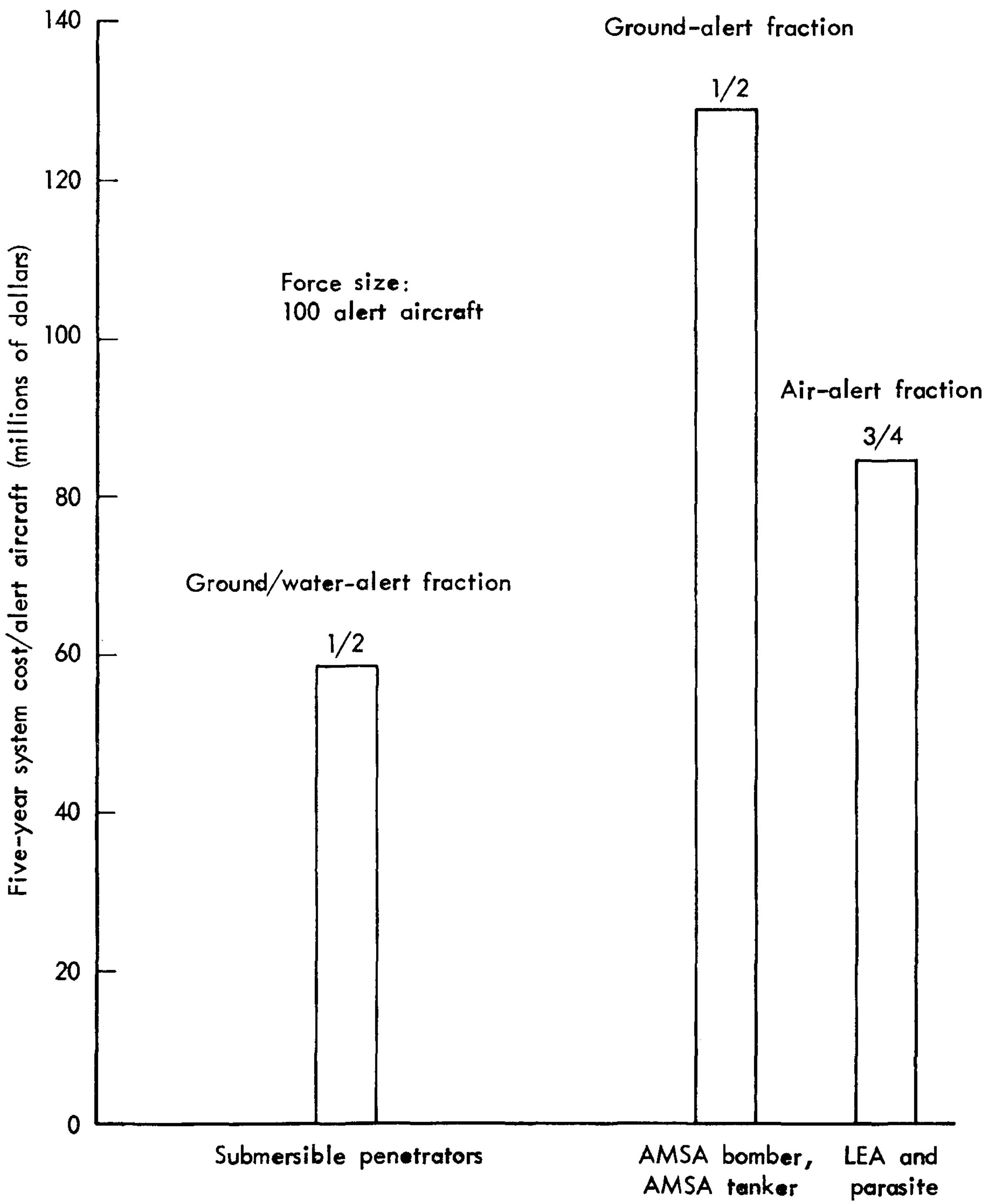


Fig. 6—System costs per alert penetrator aircraft with alternative supporting systems (submersible penetrators flown forward for individual alert—land-based flyout)

short, high-alert operations. The cost shown for the LEA system on 3/4 air alert is less than that of the AMSA system but still larger than that of the submersible system.

The possibility of combining the advantages inherent in these two extreme opposite cases of basing suggests a third basing mode for consideration, even though its system cost can be expected to be higher.

AIRCRAFT DEPLOYED BY SUBMERGED PLATFORM TO ALERT DISPERSAL (HIGH MOBILITY)

This third basing concept uses self-propelled basing platforms that have their complement of aircraft affixed for peacetime, forward-area, submerged deployment and have the capability of individually dispersing these aircraft in a tethered, submerged, alert condition within a radius of 25 to 50 n mi. This high-mobility system substantially reduces the apparent disadvantages of the two systems described above. The principal change from the low-mobility system is the additional number of submarines required to make each forward-area platform self-propelled at all times, which accounts for the higher system cost relative to the operation of the platform with the aircraft affixed. This permits powered, submerged operation of the platform for deployment and recovery of the aircraft, as well as continuous, low-speed, quiet, random movement within its general assigned basing area to reduce vulnerability to area bombardment with nuclear weapons. The platform's long-range passive sonar is effective even at low speed. This capability coupled with a defensive torpedo system reduces potential vulnerability to marine craft.

The survivability advantages relative to the low-mobility case differ for peacetime-alert conditions from those of high-alert conditions. For the former, area dispersion and continuous movement of the platforms with aircraft affixed reduce the likelihood of gradual attrition of the force, such as by attacks on individual platforms. However, for high-alert conditions, with the aircraft individually dispersed, the overall effect on the force due to the potential loss of one or more components of a system is greatly reduced. Command communications would be essentially as good as those of the submersible system with the aircraft affixed. Short-range underwater sound systems could be used to transmit retargeting information to the locally dispersed aircraft.

The five-year system total costs for the submersible penetrator aircraft (based in the high-mobility mode) for three levels of alert fraction are shown in Fig. 7. Again shown there for comparison purposes are the system costs of AMSA supported by convertible AMSA tankers and of an LEA and parasite system.

Relative to the AMSA and the air-alert LEA system, the overall merits of the submersible penetrator system are greater recycle potential, better recovery and reconstitution of the force, increased durability, and greater potential for war-termination and negotiation activities. Relative to AMSA, the survivability under initial attacks is substantially higher for the submersible penetrator.

The target system and the penetration problems are common to the several strategic systems compared here. The total system costs for submersible penetrators as shown on Fig. 7 are of the same general level as the costs of the alternative penetrator systems. Again as for the low-mobility and land-based-flyout submersible penetrator systems, increased system effectiveness in doing the same job at comparable overall system cost would lead to a favorable cost-effectiveness index.

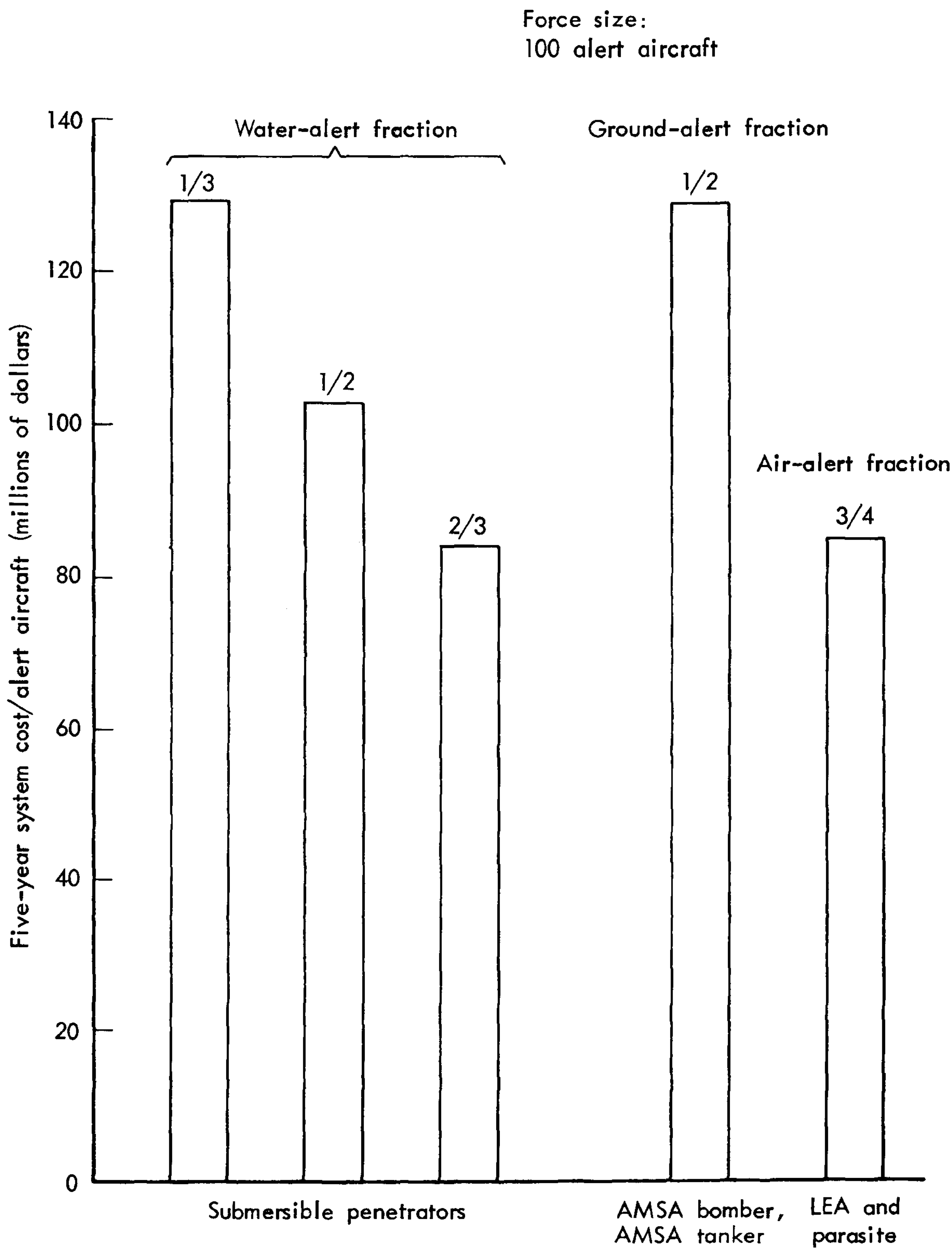


Fig. 7—System costs per alert penetrator aircraft with alternative supporting systems (submersible penetrators affixed for deployment but on individual alert—high mobility)

IV. CONCLUDING REMARKS

ATTRIBUTES

The submersible aircraft systems are conceived to achieve high survivability for submerged forward-area basing. This forward basing permits substantially reduced initial-strike times and appreciably shortens the time needed for force reconstitution for subsequent strikes, since the aircraft would not have to return to the ZI. The recovery, refueling, and rearming of submersible aircraft can be done while submerged in forward areas to enhance the multiple-recycle potential.

Whereas foreign basing rights are a continuing problem for forward-based strike aircraft and their supporting tanker aircraft, this problem does not exist for submersible aircraft systems. If necessary, the rear-area functions could be performed by logistic vessels and special tenders similar to landing ship docks (LSD's).

Aircraft submersibly based in rear areas could be used as replacement aircraft for those lost in combat which were forward-based on submersible platforms. In addition, it would be possible to base the entire strategic submersible penetrator aircraft system in rear areas and support that system with submersible tankers for the deployment to the forward area.

The combined effects of the higher recovery and restrike rate and multiple-recycle potential, as well as combat-loss replacement, indicate a high degree of force durability during a protracted period of general-war activity. This latter composite characteristic of force durability has not only an important bearing on the conduct of the war but perhaps an even more important bearing on the war-termination and negotiation activities.

Whatever is done in planning future strategic systems to minimize ZI basing will inherently reduce collateral damage to our civil populace.

COST COMPARISON

Solely for the purpose of exploring the potential military utility of submersible aircraft, several operational concepts have been compared with alternative, land-based strategic aircraft systems. The pertinent system-cost estimates are summarized in Fig. 8 which shows that submersible penetrator systems generally have about the same cost as the several AMSA systems and the LEA-parasite system. Even a conservatively assumed decrease in basing vulnerability and an increase in recycle potential, relative to these systems, would lead to a favorable cost-effectiveness index for the submersible penetrator system. The result for the submersible tanker in support of AMSA is taken from Appendix D.

POSSIBLE NEXT STEPS

A suggested next step to further the submersible-aircraft concept would be to perform preliminary design studies to quantify development problems and to assess the performance potential at various levels of the state of the art.

Concurrently, there should be continuous evaluation of the potential operational roles, of which a wide variety was displayed in Table 1. The roles of submersible penetrator and tanker aircraft have been considered in some detail in this investigation. Another role of considerable interest at the present time is that of a tactical aircraft for use in limited war. This application was considered only qualitatively in Appendix C, and has the interesting feature that in a time of increasing tensions, a submerged base could be covertly deployed to be available in case of escalation in the level of violence of the war.

Subsequent to this study work, the design and test of a small submersible aircraft may be appropriate. For example, initial operational tests could be conducted with the support of an obsolescent diesel-electric submarine of the type now being phased out of the fleet. The combination is depicted in Fig. 9, with the aircraft sized to 40,000-lb gross weight. If this test aircraft is successful, it could be used in covert applications. Such operations would, however, require very quiet submarines, such as the recent nuclear-attack class with sound-isolated machinery.

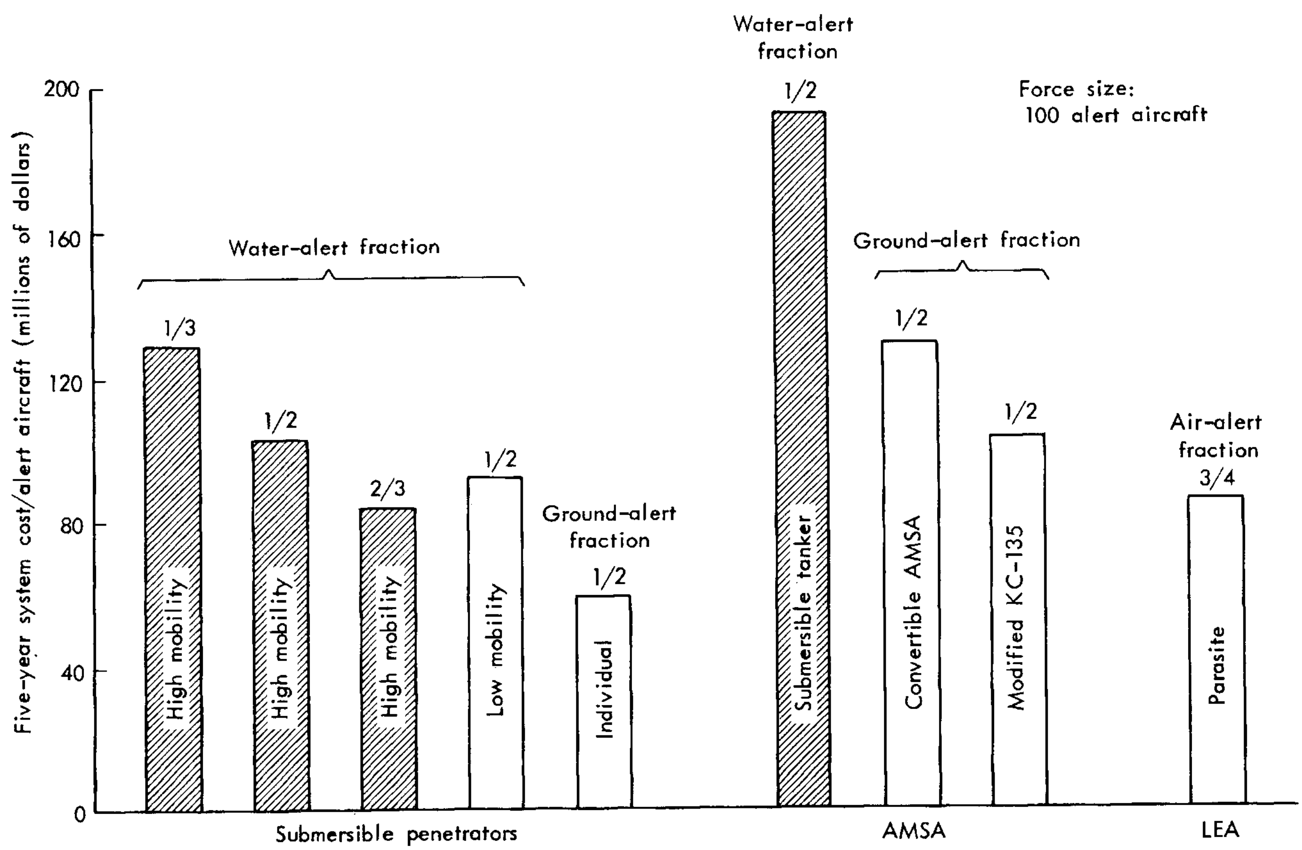


Fig. 8— Summary of system costs for alternative systems

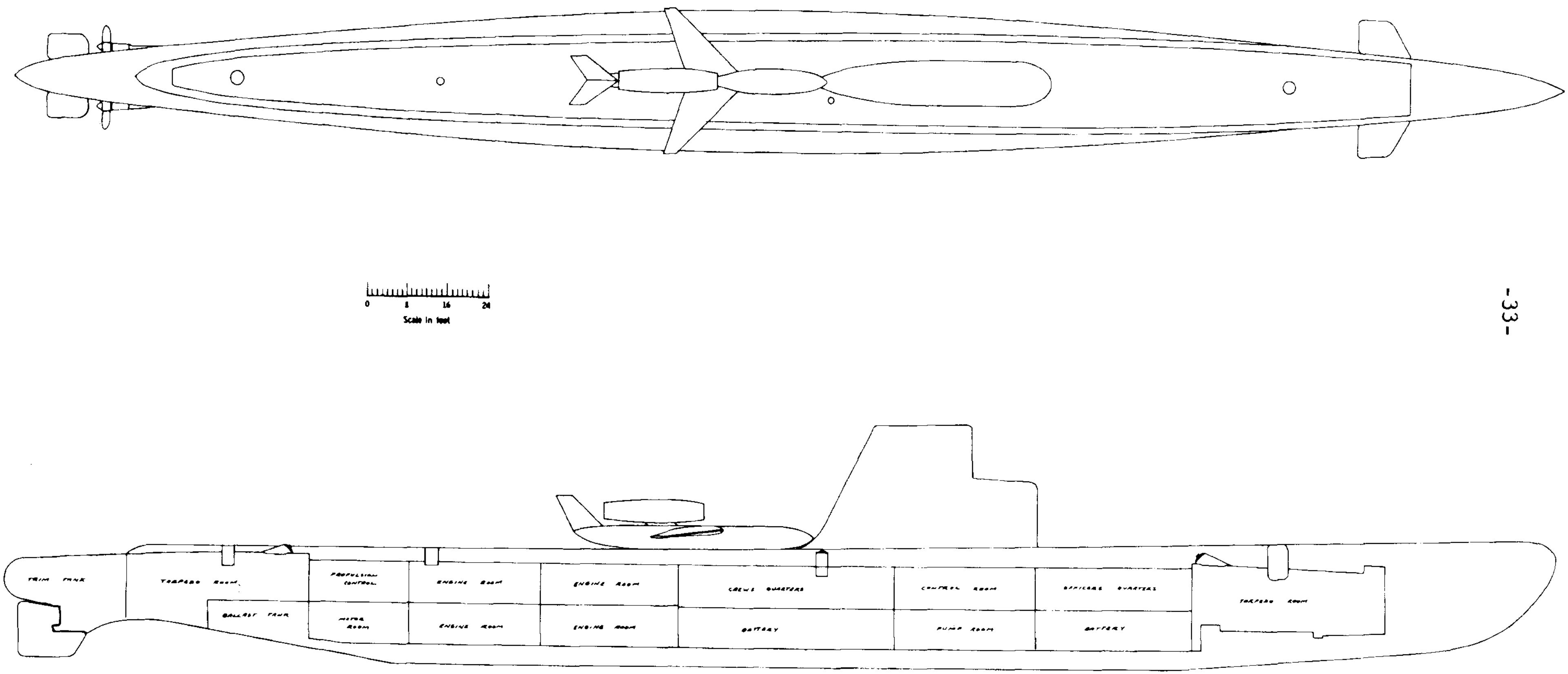


Fig. 9—A 40,000-lb submersible aircraft affixed to WW II diesel-electric submarine

Appendix A

RECENT TECHNICAL EXTENSIONS

Various technical areas have been considered on a broader basis since the publication of earlier RAND work,[1] which indicated the technical feasibility of submersible aircraft. Certain component characteristics considered only briefly in Ref. 1 have now been considered more fully.[2] Such items include the state of the art of the hydroski alighting gear and watertightness of the engine portion of the nacelle package. Alternative design philosophies and variations in the structural design load factor and various structural materials have also been investigated.

Submersible aircraft as a general class tend to require a limited amount of fixed ballast to bring the basic aircraft weight and volume to a condition of neutral buoyancy when submerged. If a jet-fueled submersible aircraft is to achieve neutral buoyancy when fully fueled with conventional jet fuels, nearly one-fourth of the weight otherwise available for fuel must be allocated to fuel ballast.

The submersibly moored aircraft concept which requires an external force to hold the aircraft beneath the surface also has been analyzed recently.[2] Such an aircraft requires neither fixed nor fuel ballast and can therefore carry a substantially greater weight of fuel than the truly submersible aircraft. This results in an approximate 40 per cent improvement in combat radius over the ballasted, submersible aircraft. However, the inherent positive buoyancy substantially eliminates the possibility of self-propelled navigation beneath the water surface.

The external force to overcome the positive buoyancy of conventional jet fuels could be provided by attaching the fueled aircraft to a large submersible shiplike platform. The platform with a complement of externally affixed aircraft can navigate or be propelled beneath the surface of the water. Alternatively the external force (about one-third of the aircraft takeoff weight) can be provided by one of several very-lightweight imbedment anchors of high holding power, which could be carried aboard the aircraft. Imbedment anchors with holding power up to 50,000 lb (400 lb anchor weight) are available, and much larger ones are under development. The anchor is a finned, missilelike object which is lowered on a nylon tether from a floating aircraft and then imbedded in the bottom by a solid-propellant charge.

The high-density-fueled submersible aircraft could combine the operational advantages of the fuel-ballasted submersible aircraft and the combat-radius advantage of the buoyant submersibly moored aircraft. The most important operational advantage of aircraft which can self-submerge under any fuel condition is that it can propel itself under water by means of small, lightweight, bipropellant, auxiliary propulsion machinery. Speeds to 5 kn for a total of 8 to 10 hr of operation can be realized for a very moderate penalty to the flight performance. The importance of higher-density fuels was indicated in Ref. 1 for these aircraft, but the feasibility of the hypothesized 30 per cent amorphous boron slurry in turbomachinery was not assured.

However, it has been recognized that hydrocarbon fuels of appropriate density have been chemically synthesized and appear to possess the necessary characteristics. Thus the operational and much of the combat-radius advantages of the hypothesized slurry fuels may be attainable without the substantial developmental problems associated with the compatability of boron slurry fuels (of water density) with turbomachinery.[1]

The high-carbon hydrocarbon fuels investigated[9] to reduce high-temperature (supersonic-flight) stability problems suggest a variety of possible applications. These fuels indicate the potential for synthesizing a specific hydrocarbon fuel that has satisfactorily compromised characteristics for submersible-aircraft application. Table 3 shows the characterisitics of five such fuels whose density approximates that of water. (The corresponding characteristics of JP-4 fuel are also shown for comparison.) The significant point of this selection of high-carbon fuels is the wide range in the variation of some of their physical properties. Also shown in Table 3, under the name of Shelldyne, are the properties of a more dense fuel produced in England in pilot-plant batches up to 8000 lb. This mixture of three isomers can be blended with JP-4 fuel to reduce the average density

Table 3

HIGH-DENSITY HYDROCARBON FUELS

Fuel	Density at 68°F (lb/gal)	Molecular Weight	H/C Ratio	Freezing Point (°F)	Boiling Point (°F)	Decomp. Temp. (°F)	Luminometer Number	Formula	Btu/lb	Btu/gal	Viscosity at 100°F (c.s.)
JP-4	6.5	...	0.162	-76	319	...	...	$C_nH_{2.2n}$	18,680	121,300	1.9
Fluoranthene, perhydro	8.195	218.4	0.136	-38	594	740	24	$C_{16}H_{26}$	18,150	148,760	9.7
Pyrene, 1-ethyl-perhydro	8.203	246.4	0.140	25	...	744	35	$C_{18}H_{30}$	18,060	148,190	17.23
Tetracyclo [3.3.1.$0^{2,4}$ $0^{6,8}$]nonane	8.269	130.2	0.112	-59	353	705	...	C_9H_{12}	18,300	151,330	11.0
Pentacyclo [6.5.1.$1^{3,6}$$0^{2,2}$ $0^{9,13}$]-pentadecane, trimethyl	8.332	244.4	0.131	-10	586	675	43	$C_{18}H_{28}$	18,130	151,020	24.4
Tetracyclo [4.4.0.$1^{2,5}$ $1^{7,10}$]-dodecane	8.387	162.3	0.126	62	458	740	18	$C_{12}H_{13}$	18,120	152,130	8.12
Shelldyne	9.1	...	0.096	-13 to -150	482	..	0	...	17,886	163,000	11.5
HTF 59-24	7.2	...	0.125	-98	452	710	42	...	18,460	132,900	2.55

to the desired 8.5 lb/gal for neutral buoyancy in sea water. High-temperature fuel, HTF 59-24, described in Table 3, although not up to the density desired, has been used in a 26-flying-hr flight-test program[10] involving an unmodified J-79 engine in an F-104D aircraft, with no adverse effects.

The example aircraft examined recently are high-density aircraft, as before, and the assumed wing loading is 200 lb/ft^2. Figure 1 shows that for the same gross weight, the wing area of the overlaid submersible aircraft is approximately half that of the B-52. The geometry of the wing is of lower aspect ratio, which is more suitable for a low-altitude penetrator of very high wing loading.

In addition, the overall envelope volume for this example machine is substantially smaller because of the high average density. The B-52 at maximum gross weight is about 18 lb/ft^3, whereas the submersible aircraft, allowing for the ballast volume--or in the submersibly moored case, the additional fuel volume, which is about an equal amount--has an average density of about 45 lb/ft^3. When the aircraft is submerged, the tank volumes are flooded, and the density increases to 64 lb/ft^3 for neutral buoyancy. For the submersibly moored aircraft, the density remains at 45 lb/ft^3, and the mooring force overcomes the positive buoyancy.

As shown in Fig. 10, the extended investigation of technical considerations considered alternative wing geometries with aspect ratios higher than the original value of 2.[1] The initial assumption on ultimate design load factor has been varied from 10 to 7 and to 3. The structural material originally specified was a minimum thickness of 1/4-in. high-tensile steel* (equivalent thickness), since saving of weight was not essential in the structure of an aircraft with a requirement for fixed lead ballast. Other cases considered in the recent work had strength-determined high-tensile-steel structure, titanium structure, and--for a few cases, particularly to help compare the high-aspect-ratio, low-load-factor designs with contemporary designs--aluminum structure with conventional runway-type landing gear.

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*Steel with a yield strength of 50,000 psi; used in submarine construction circa 1942 - 1958.

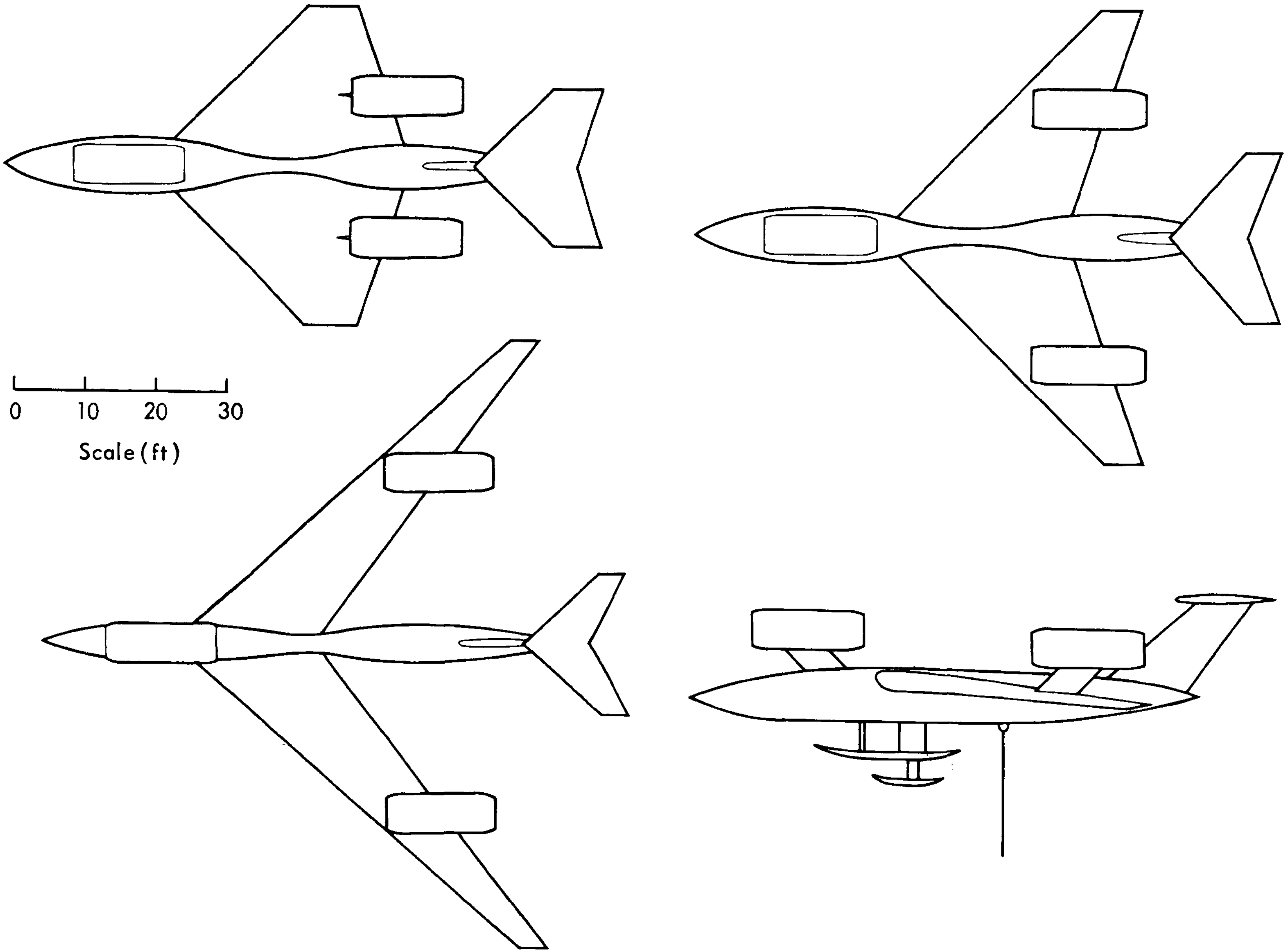

Fig. 10—Alternative wing geometries for submersible aircraft

The utilization of a single hydroski alighting gear that will retract into the lower surface of the fuselage in lieu of the normal flying-boat hull reduces the normal accelerations on impact by nearly an order of magnitude. There is a small secondary ski, which can be extended downward by means of a hollow strut on the large ski. The small ski, normally retracted flush into the bottom of the major ski, is a further development of quite recent date.(11) Flight tests have shown that by having this smaller ski for the very-high-speed planing conditions or the initial impact with the waves, the normal accelerations have been reduced further, by nearly another order of magnitude. This is very significant because of the inherently high landing speeds for aircraft with a 200-lb/ft^2 wing loading.

The engines are carried well above the airframe to minimize the water-ingestion problems at takeoff. When the aircraft is submerged, the engine could be protected from corrosion effects by one of several means. The first of two suggested here would be to make the engine portion of the nacelle package watertight by using iris-type closures at the face of the compressor and aft of the final stage of the turbine. With the proper choice of materials, the inlet and afterburner volumes could be flooded with water to minimize the positive buoyancy of the nacelle package. Alternatively, the entire nacelle package including the engine portion could be flooded with fuel pumped from the tanks after end closures were closed. This would avoid the problem of engine corrosion and would reduce the possibility of water damage to the bearings, as well as further reduce the buoyancy of the nacelle package.

Preliminary discussions of possible retractable end closures have been held with a designer and manufacturer of folding, petal-type, paraboloid solar reflectors.(12) This has reinforced the earlier judgment(1) that it is technically feasible to make the engine or the entire nacelle volume watertight.

Making the crew volume and the engine watertight are important problems that are under consideration in a study by General Dynamics, San Diego, funded by the Bureau of Naval Weapons in July 1964.

Appendix B

SELECTED SUBMERSIBLE AIRCRAFT

Several types and sizes of submersible aircraft have been studied[1,2] in sufficient detail to identify their important characteristics. Table 4 presents pertinent data for four examples which are referred to in this Memorandum. The design data were determined by the methods set forth in Refs. 1 and 2.

The relatively high subsonic cruise Mach number of 0.92 for both high- and low-altitude flights of the example aircraft having an aspect ratio of 4 results from major emphasis on the transonic area rule in the configuration design. This emphasis on transonic design and the use of tapered-thickness-ratio wings and wing-shock bodies permits relatively high wing-root-thickness ratios. This results in relatively lightweight wings and high volume utilization therein. The choice of aspect ratio 4 for the wing planform is the result of combat-radius optimization for both high- and low-altitude flights.

The concern for low-altitude ride characteristics for penetrator aircraft tends to result in wings of very low aspect ratio or variable-sweep configurations. Because of the aerodynamic and structural disadvantage related to these possible solutions, the example configurations used here have fixed wings of aspect ratio 4. To improve their ride characteristics it is suggested that adjustable-height aerodynamic spoilers could be used to reduce the effective lift-curve slope for low-altitude flight and to directly reduce such gust-load accelerations at the cost of slightly reduced low-altitude lift-drag ratio.

The configuration illustrated for the example aircraft reflects simultaneous concern for hydrostatic, hydrodynamic, and aerodynamic problems. At such a preliminary stage, determination of number and location of engines is only tentative. Although each design team to consider such an aircraft configuration would generate a somewhat different design, the weight and performance estimates should not be materially affected.

Case 1 is a submersible aircraft of 40,000 lb gross weight with a crew of one, such as might be considered as an initial developmental

Table 4

DESIGN DATA FOR EXAMPLE AIRCRAFT

Item	Case 1	Case 2	Case 3	Case 4
Basing capability	Submersible	Runway	Sub. moored	Sub. moored
Description	Prototype	Parasite	Penetrator	Tanker
Payload delivery capability				
Payload, lb	...	8,000	8,000	155,000
Range, n mi	...	1,000	2,000	500
Structural material	HTS	Al	HTS	HTS
Ultimate load factor	7	7	7	7
Wing loading, lb/ft^2	200	200	200	200
Crew size	1	4	4	4
Fuel	(a)	JP-4[b]	JP-4[b]	JP-4[b]
Combat radius, n mi				
Sea level	950	1,000	1,600	...
Altitude	1,780	...	2,700	500
Mach number	0.92	0.92	0.92	0.92
Aspect ratio	4	4	4	4
Sweep (¼ chord), deg	39.5	39.5	39.5	39.5
Taper ratio	0.2	0.2	0.2	0.2
Thickness ratio, wing root	0.180	0.174	0.157	0.128
Span, ft	28.28	33.2	44.7	77.4
Length, ft	45.6	50.7	62.0	89.4
Fuselage diameter, ft	5.70	5.54	7.09	11.18
Weight, lb				
Fixed military load	2,900	8,000	8,000	8,000
Structure	4,720	4,800	11,596	50,280
Alighting gear	2,400	1,650	6,000	18,000
Propulsion	3,990	5,090	9,980	29,940
Fuel, hyd., elec. systems	2,620	3,115	4,600	11,200
Fixed ballast	3,820	...	...	...
Fuel	19,550	24,345	51,820	182,580
Payload	...	8,000	8,000	...
Aircraft gross	40,000	55,000	100,000	300,000

[a]High-density hydrocarbon, specific gravity = 1.025.

[b]Specific gravity = 0.78.

prototype or for possible covert operation. Since the fuel is assumed to be a chemically synthesized high-carbon hydrocarbon of sea-water density, no fuel ballast is required in a true submersible aircraft. Even for the relatively heavy structural material (HTS), a moderate amount of fixed ballast is required to bring the basic components of the aircraft to neutral buoyancy. There is an allowance of 1000 lb for electronic equipment as a part of the fixed military load of 2900 lb. A single-engine version without external store is illustrated in Fig. 9.

Case 2, the small aluminum parasite penetrator used as a comparison case with the submersible penetrator, is not a submersible aircraft, but its geometry, wing loading, and general appearance were made similar to those of the submersible aircraft in order to simplify the cost comparison with the submersible penetrator. This parasite aircraft, which would be air-launched from an LEA, is illustrated in Fig. 11. The crew size is four, and the expendable military load is 8000 lb.

Case 3 is the submersible penetrator aircraft of 100,000 lb gross weight. The sizing of this aircraft was discussed earlier in the Memorandum. A schematic drawing is shown in Fig. 12. The structural material would be high-tensile steel, and the ultimate design load factor would be 7. When submerged, it would be positively buoyant if it used JP-4 fuel and neutrally buoyant if it used the high-density hydrocarbon fuel. The aircraft would have a crew of four and carry a payload or expendable military load of 8000 lb. It would have a total combat radius of 2000 n mi, 1000 n mi of it at low altitude.

Case 4 is the submersible tanker which is illustrated in Fig. 13. The structural material would be high-tensile steel, and the ultimate design load factor would be 7 because of the water loads incurred in high-sea-state operations. For a gross weight of 300,000 lb, it would be capable of transferring 155,000 lb of fuel at a radius of 500 n mi from its submerged base. The crew was assumed to be four men.

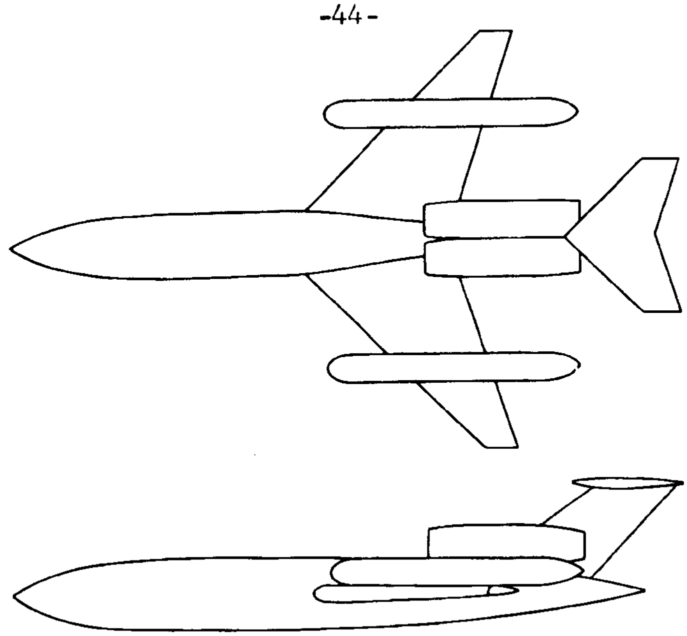

Fig. 11—Air-launched, aluminum parasite penetrator
(55, 000-lb gross weight)

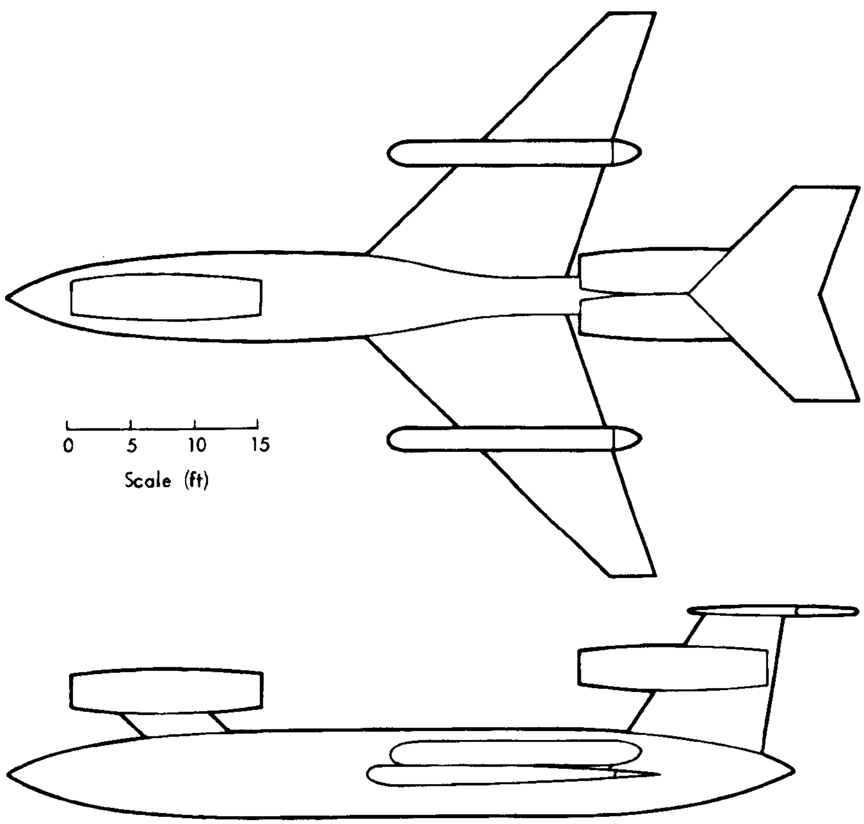

Fig. 12—Submersibly moored penetrator of high-tensile steel
(100, 000-lb gross weight)

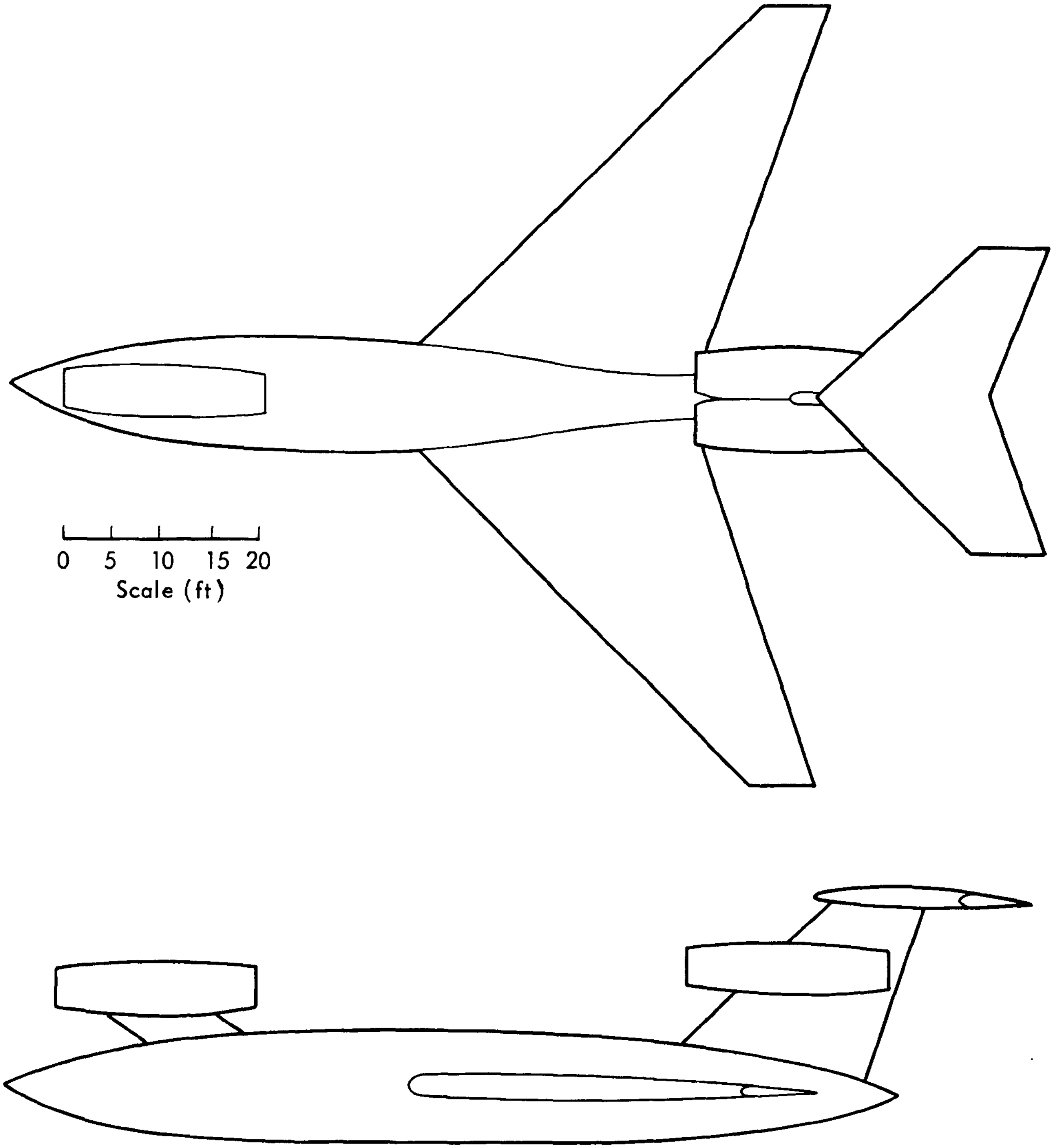

Fig. 13—Submersibly moored shuttle tanker of high-tensile steel (300,000-lb gross weight)

Appendix C

EXTENDED EVALUATION OF SUBMERSIBLE AIRCRAFT RELATIVE TO SEVERAL ALTERNATIVE SYSTEMS

GENERAL DISCUSSION

A number of possible missions for submersible aircraft were presented in Table 1 in Section II under four headings corresponding to DOD program packages. A list of characteristics to be used as the basis for qualitative comparisons of submersible aircraft relative to a number of alternative systems was also given in Section II. This appendix extends the comparisons for strategic operational modes and also presents the qualitative comparisons of submersible aircraft in appropriate basing systems for General Purpose Forces and Continental Defense Forces. Supporting arguments for the qualitative judgments made in carrying out the above-mentioned comparisons were given in Section II.

STRATEGIC OFFENSE FORCES

For the strategic-offense operational modes listed in Table 1, the submersible aircraft can reasonably be compared to the B-52G or B-52H, and for later time periods to AMSA and LEA with parasite penetrators. Such comparisons would apply to (1) a ZI-based, minimum-reaction-time (secure) retaliatory force operated similarly to the current B-52 force; (2) an initially withheld force, which could survive by being placed possibly in local endurance flight or in a hardened basing mode as in the Cliff Dweller concept once proposed for basing of the B-70; (3) a strike-aircraft force dispersed and deployed under conditions of high alert perhaps to forward crisis areas; and (4) a tanker force supporting strategic aircraft.

Table 5 summarizes the results of the qualitative comparisons of appropriate submersible aircraft with alternative possible aircraft when used as Strategic Offense Forces.

Table 5

COMPARISON OF SUBMERSIBLE AIRCRAFT WITH ALTERNATIVE AIRCRAFT WHEN USED AS STRATEGIC OFFENSE FORCES

	Secure Retaliatory Force			Withheld Force			Dispersed & Deployed Strike Force			Tanker Force	
Characteristic	B-52G	AMSA	LEA	B-52G	AMSA	LEA	B-52G	AMSA	LEA	AMSA	LEA
Effectiveness											
Initial survivability	B	MB	B	MB	MB	B	B	MB	B	MB	B
Recovery and reconstitution	B	B	B	B	B	B	B	B	B	B	B
Precision second strike	B	B	B	MB	B	B	MB	B	B	B	B
Multiple-recycle potential	B	B	B	B	B	B	B	B	B	B	B
Force durability	B	MB	MB	B	MB	MB	B	MB	MB	MB	MB
War termination and negotiation	B	B	B	MB	B	B	MB	B	B	B	B
Political factors											
Collateral damage	B	B	B	B	B	B	B	B	B	B	B
Show of force	S	S	S	..	..	..	B	S	S	S	S
OCLUS base rights	B	B	B	B	B	B	B	B	B	B	B
Operations											
Response under attack	B	B	B	B	B	B	B	B	B	B	B
Time to target	B	B	S	B	B	S	B	B	S	B	S
Command control	S	S	S	S	S	S	S	S	S	S	S
Cocked alert	B	B	B	MB	B	B	B	B	B	B	B
Alert reaction time	P	P	MP	P	P	MP	P	P	MP	P	MP
Climatological constraints	P	P	P	P	P	P	P	P	P	P	P
Performance											
Range	P	P	P	P	P	P	P	P	P	P	P
Flight endurance	P	P	MP	P	P	MP	P	P	MP	P	MP
Speed at low altitude	B	S	B	B	B	B	B	S	B	S	B
Payload	S	S	S	S	S	S	S	S	S	S	S
Support											
Maintenance access	P	P	P	P	P	P	P	P	P	P	P
Maintenance cycle	S	S	S	S	S	S	S	S	S	S	S
Logistic support required	P	P	P	P	P	P	P	P	P	P	P

MB = much better
B = better
S = same
P = poorer
MP = much poorer

Basically, all the judgments which show the submersible aircraft systems to be better than alternative systems stem from the advantages of increased basing survivability during initial attack, reduced strike time due to forward-area basing, and increased potential of force recovery and reconstitution. These tend to establish a credible recycle potential. The judgments adverse to the submersible aircraft systems are associated with the inherent disadvantages of submersible aircraft: namely, some moderate performance penalties, a mechanically more complicated aircraft, an additional difficult operating environment, and greater logistic-support problems. These advantages and disadvantages were discussed in more detail for the sample-evaluation case in Section II.

The relative rankings of submersible aircraft are generally favorable in Table 5 for the important categories Effectiveness and Political Factors. For the categories Operations and Performance, the rankings show no special advantages, whereas they show disadvantages for Support.

GENERAL PURPOSE FORCES

For general-purpose operational modes identified in Table 1, comparisons of submersible aircraft with F-105 or F-4C, F-111A, and F-4B carrier-based aircraft in the roles of a survivable overseas tactical force and ZI-based tactical forces for limited war are appropriate. The results of qualitative evaluations of appropriate submersible aircraft with alternative aircraft are given in Table 6. The arguments for the judgments exercised here are essentially the same as those presented in Section II.

The relative rankings of submersible aircraft are generally quite favorable, as shown in Table 6, but their overall advantage appears to be smaller for General Purpose Forces than for Strategic Offense Forces.

CONTINENTAL DEFENSE FORCES

For the continental-defense operational modes, appropriate submersible aircraft can be rated relative to shore-based patrol aircraft

Table 6

COMPARISON OF SUBMERSIBLE AIRCRAFT WITH ALTERNATIVE AIRCRAFT WHEN USED AS GENERAL PURPOSE FORCES

Characteristic	Overseas-Based TAC			ZI-Based Crisis Force		
	F-105, F-4C	F-111A	Carrier-Based Aircraft	F-105, F-4C	F-111A	Carrier-Based Aircraft
Effectiveness						
Initial survivability	MB	MB	B	MB	MB	B
Recovery and reconstitution	MB	MB	B	MB	MB	B
Recycle potential	MB	MB	B	MB	MB	B
Force durability	MB	MB	B	MB	MB	B
War termination and negotiation	MB	MB	B	MB	MB	B
Political factors						
Show of force	S	S	S	S	S	S
OCLUS base rights	B	B	S	B	B	S
Operations						
Response under attack	B	B	B	B	B	B
Time to target	S	S	S	S	S	S
Command and control	P	P	P	P	P	P
Cocked alert	S	S	S	S	S	S
Alert reaction time	P	P	P	P	P	P
Climatological constraints	P	P	P	P	P	P
Performance						
Range	P	P	S	P	P	S
Flight endurance	S	S	S	S	S	S
Speed at low altitude	S	S	S	S	S	S
Payload	S	S	S	S	S	S
Support						
Maintenance access	P	P	P	P	P	P
Maintenance cycle	S	S	S	S	S	S
Logistic support required	P	P	S	P	P	S

MB = much better
B = better
S = same
P = poorer

and to carrier-based aircraft for an ASLBM system, for the distant anti-bomber, and for the AASM system.* For the boost-phase ICBM-intercept mission, appropriate submersible aircraft can be compared to conventional aircraft employed in combat air patrol and to satellite-based intercept systems. The qualitative judgments for the ranking of submersible aircraft relative to these alternatives are given in Table 7.

As Continental Defense Forces, the advantages of submersible aircraft are restricted largely to the category Effectiveness.

As an antisubmarine force, submersible aircraft can be compared to hydrofoil craft, to ASW aircraft, to surface ships equipped with drone antisubmarine helicopters (DASH) and to attack submarines. In this operational mode, the alternative systems are so dissimilar that a different list of characteristics upon which to make the comparison judgments is presented in Table 8.

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*A comparison with the improved manned interceptor (IMI) is not included because this would require design data for supersonic submersible aircraft which are beyond the scope of the analyses performed to date.

Table 7

COMPARISON OF SUBMERSIBLE AIRCRAFT WITH ALTERNATIVE AIRCRAFT WHEN USED AS CONTINENTAL DEFENSE FORCES

Characteristic	Distant Anti-bomber and Anti-ASM Defense: Shore-Based Patrol Aircraft	Distant Anti-bomber and Anti-ASM Defense: Carrier-Based Aircraft	ASLBM System: Shore-Based Patrol Aircraft	ASLBM System: Carrier-Based Aircraft	Boost-Phase ICBM Intercept: Combat Air Patrol	Boost-Phase ICBM Intercept: Satellite
Effectiveness						
Initial survivability	MB	B	MB	B	B	P
Recovery and re-constitution	MB	B	MB	B	B	P
Recycle potential	MB	B	MB	B	B	P
Force durability	MB	B	MB	B	B	P
War termination and negotiation	MB	B	MB	B	B	P
Political factors						
Show of force	S	S	B	S	B	B
Operations						
Response under attack	MB	B	MB	B	B	P
Time to target	B	S	B	S	B	P
Command and control	P	P	P	P	P	S
Cocked alert	B	S	B	S	B	P
Alert reaction time	P	P	P	P	P	P
Climatological con-straints	P	P	P	P	P	P
Performance						
Range	P	P	P	P	P	P
Flight endurance	P	P	P	P	P	P
Speed at low altitude	S	S	S	S	S	P
Payload	S	S	S	S	S	S
Support						
Maintenance access	P	P	P	P	P	B
Maintenance cycle	B	B	B	B	B	P
Logistic support required	P	P	P	P	P	P

MB = much better
B = better
S = same
P = poorer

Table 8

COMPARISON OF SUBMERSIBLE AIRCRAFT WITH ALTERNATIVE CRAFT WHEN USED AS ANTISUBMARINE FORCES

Characteristic	Hydrofoil Craft	Carrier-Based Aircraft	Surface Ship With DASH	Attack Submarine
Endurance	B	S	P	MP
Climatological constraints	B	P	P	MP
Maintenance access	S	P	P	P
Logistic support required	S	S	S	S
Sonar capability	B	B	P	P
Payload	B	S	P	P
Speed	B	S	B	B
Range	B	S	P	P
Time to shift from run to listen or vice versa	P	B	P	P

B = better
S = same
P = poorer
MP = much poorer

Appendix D

SUBMERSIBLE TANKER AIRCRAFT AND AMSA

The generally favorable rating of strategic tanker aircraft under the program package identified as Strategic Offense in Appendix C leads to its consideration here as a possible support system for AMSA. As a possible tanker aircraft, a submersible aircraft would have fewer subsystem complications during development than the penetrator aircraft. described in Section III.

The limited combat-radius capability of AMSA places a high premium on forward-based tanker aircraft to refuel it. The potential vulnerability of forward-based tanker aircraft awaiting the target-bound bomber stream for a period of hours is great because of a variety of possible means of attack. The ability of such tanker aircraft to rendezvous with and to refuel the poststrike AMSA aircraft is questionable. Conversely, the incremental value to the strategic force of a highly survivable tanker system would be substantial.

Three degrees of mobility are assumed in the basing of submersible aircraft to determine its effect on the vulnerability and system cost of submersible-aircraft strategic systems, as in Section III which treated submersible penetrator aircraft.

The assumed target region for developing the operational concept of this strategic system is that of the entire Sino-Soviet bloc. The bomber-base locations, which are generally in the eastern, central, and western portions of the ZI, are not specifically tailored for AMSA basing. Symmetrical round-trip, minimum-penetration bomber missions from these base locations are assumed using approach and withdrawal paths as shown in Fig. 14. The square symbols indicate a number of desirable base locations for submerged platforms with their tanker aircraft at approximately 2500, 4000, and 5000 n mi from the ZI. They are adjacent to bombing tracks where refueling would be done. In general, the principal example relates to an alert AMSA force. This deployment provides for minimum penetration distance to the target for the strike aircraft.

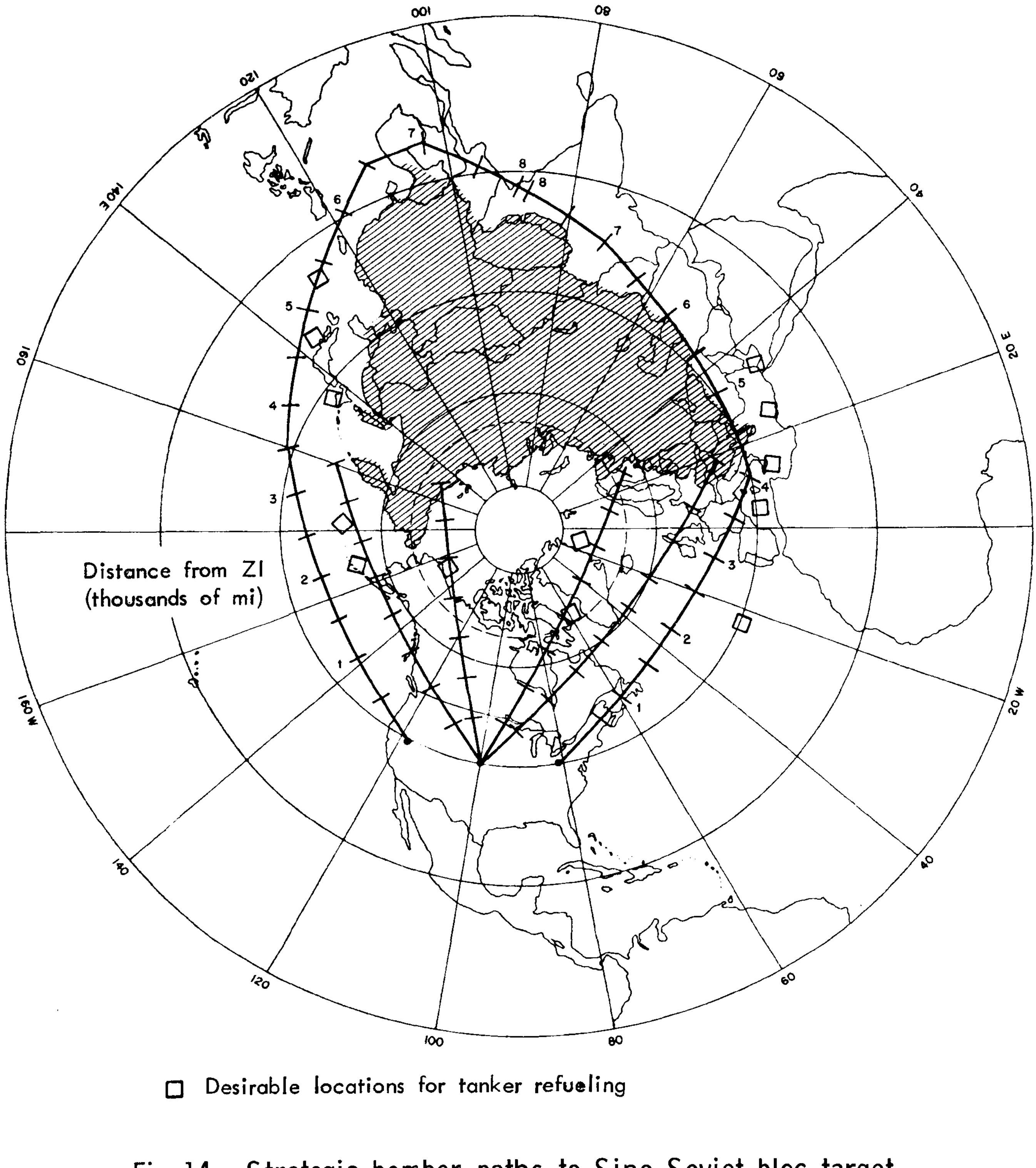

Fig. 14—Strategic-bomber paths to Sino-Soviet-bloc target system for minimum target-penetration distances

The size of the submersible tanker required for this function is determined from considerations of the appropriate transfer locations and fuel weights relevant to AMSA refueling operations. Accordingly, an aircraft that would be capable of transferring approximately 155,000 lb of fuel at a distance of 500 n mi from a submerged base was selected from Fig. 15. The specified combat radius would permit reasonable flexibility in selecting protected areas for basing of a submerged platform and operation of aircraft from the water surface. As shown in Fig. 15, this corresponds to a 300,000-lb tanker aircraft, which is described in Appendix B.

The submersible tanker aircraft is assumed to have an aspect ratio of 4 and high-tensile-steel construction. A flight crew of four is assumed. The submersibly moored type as used in this example case is inherently positively buoyant by approximately one-third of the takeoff gross weight.

TANKER AIRCRAFT DEPLOYED ON SUBMERGED PLATFORMS (LOW MOBILITY)

An alert AMSA force of 100 would require approximately 90 of the submersible tanker aircraft of 300,000 lb gross weight which could be deployed as five alert tankers attached per submersible platform. An additional aircraft (20 per cent allowance) is assumed for each platform to help insure a high reliability. The combination would be covertly deployed, submerged in a forward area for a finite period of time. Thus, six tanker aircraft are shown on the platform in Fig. 16. The ratio of flight crew to alert aircraft, on board the platform, was taken at 1¼, since it appears that the tanker alert function would be less demanding than for the penetrator aircraft described earlier. The alert would be performed within the hardened cylindrical volumes internal to the hull of the submerged platform, and access to the aircraft would be provided by extensible trunks attaching to the cockpit space. Flight crews could be rotated from the platform more frequently than other personnel or the equipment. Appendix E describes the platform design.

Basically, the platform is a large fuel cache. Of the total submerged displacement of 16,000 tons, 8000 tons is in jet fuel. This

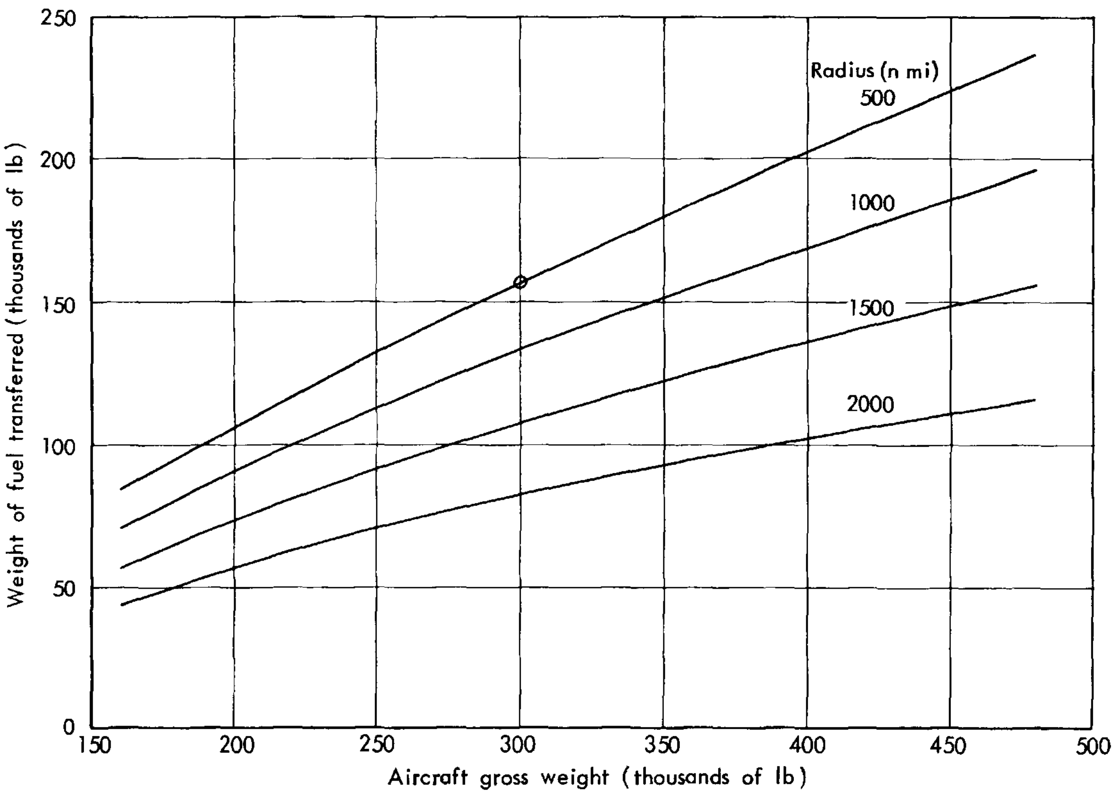

Fig. 15—Fuel-transfer capability of submersible tanker aircraft (submersibly moored, high-tensile-steel construction, aspect ratio 4, JP-4 fuel)

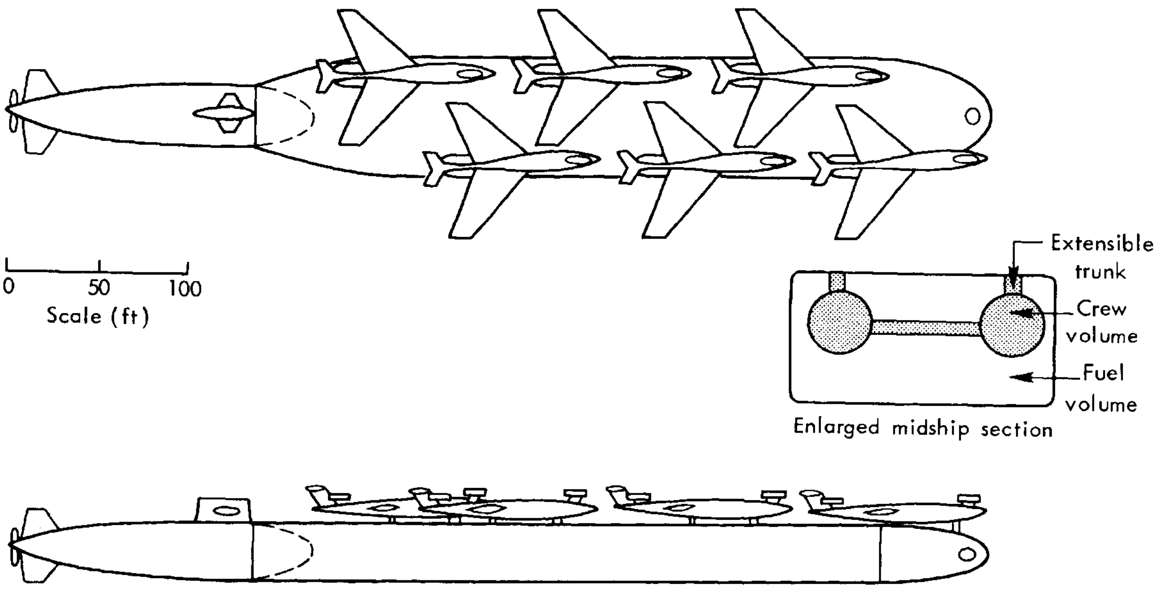

Fig. 16—Submersible tanker-aircraft platform with nuclear pusher tug and complement of six aircraft

would provide adequate fuel for each operational tanker aircraft to deliver 155,000 lb of fuel 10 times. In addition, an equal amount of fuel is carried on the platform so that it could service, for 10 sorties each, all the operational aircraft from an adjacent platform if the latter should be operationally unavailable. Provision is made in the platform design for sonar systems and torpedo defensive armament. Volume allowances within the ring-stiffened cylinders would provide for 25 flight-crew members, 25 support personnel for the aircraft, and an additional 50 for the operation and maintenance of the submerged, moored platform. Refueling operations while the aircraft are affixed to the platform in a submerged condition would be conducted by single-point refueling.

The submersible base with aircraft affixed would be deployed by a nuclear pusher submarine. The 3000-ton submarine shown in Fig. 16 is about 25 per cent smaller than current attack-class submarines. It would be adequate to propel with the 16,000-ton platform without aircraft at 20 kn and with aircraft affixed at 16 kn submerged speed. This would reduce potential vulnerability to enemy submarine action. The vertical and lateral bow-thruster units indicated at the bow of the platform would be used for pitch and yaw control of the platform. The platform would be moored some 100 to 200 ft beneath the surface in the forward areas indicated previously, and the tug would be withdrawn to perform other services.

For 12 platforms, approximately four tugs would be required to deploy these in the areas indicated, and a 50 per cent allowance for contingency and reserves in the nuclear tug system is assumed. Additional platforms are provided for rear-area operational training and maintenance purposes. The use of moored platforms results in very quiet operations and corresponds to a minimum of nuclear pusher tugs.

Aircraft deployed in a forward area, submerged and inoperative without engine runup or even surfacing for extended periods of time, raise a serious question about systems reliability. Accordingly, the three values of the alert fraction parameter have been considered.

The system costs, which include RDT&E, initial investment, and five years of operation, have been prepared on the basis of three assumed values of alert fraction. The five-year system cost per alert AMSA aircraft, based on a force of 100 alert AMSA aircraft, is shown in Fig. 17. This compares the overall AMSA strategic system costs when supported by submersible tanker systems to those when supported by two other tanker systems. The alternative tanker systems are the convertible AMSA and the KC-135, modified for short takeoff, as the tanker aircraft. For the force of 100 alert aircraft discussed in this operation, the related cost data for the major functional components of the system can be obtained from Appendix F.

Figure 17 shows that for the same alert fraction, the case involving the convertible AMSA as a tanker involves a substantially lower system cost than does the submersible tanker case. This results from the fact that only one aircraft need be developed rather than two as in the submersible tanker cases.

In evaluating the desirability of such alternative systems, more than the system cost is involved. There are a number of important but less tangible factors: The vulnerability of the tanker aircraft themselves is one important consideration; in the case of runway-based tanker operations, the tankers would be vulnerable on the ground for some number of hours before scrambling to rendezvous with the bomber aircraft. Furthermore, the potential ability of submersible systems to recycle the tankers to aid the recovery and reconstitution of bombers is extremely important if multistrike bomber operations are anticipated. This may be regarded as an incremental improvement in the war-fighting endurance of the AMSA system itself. The amount of fuel available at the forward area may be greatly increased for submersible basing systems at a modest increase in system cost.

TANKER AIRCRAFT FERRIED AT ALERT TO INDIVIDUAL DISPERSAL (LAND-BASED FLYOUT)

The opposite basing mode to that of the tanker aircraft continuously attached to the submersible platform with crew alert performed inside the platform at all times is the individually dispersed tanker which is flown into the indicated basing areas from ZI or advance-area airfields upon declaration of a high-alert condition. For a maximum

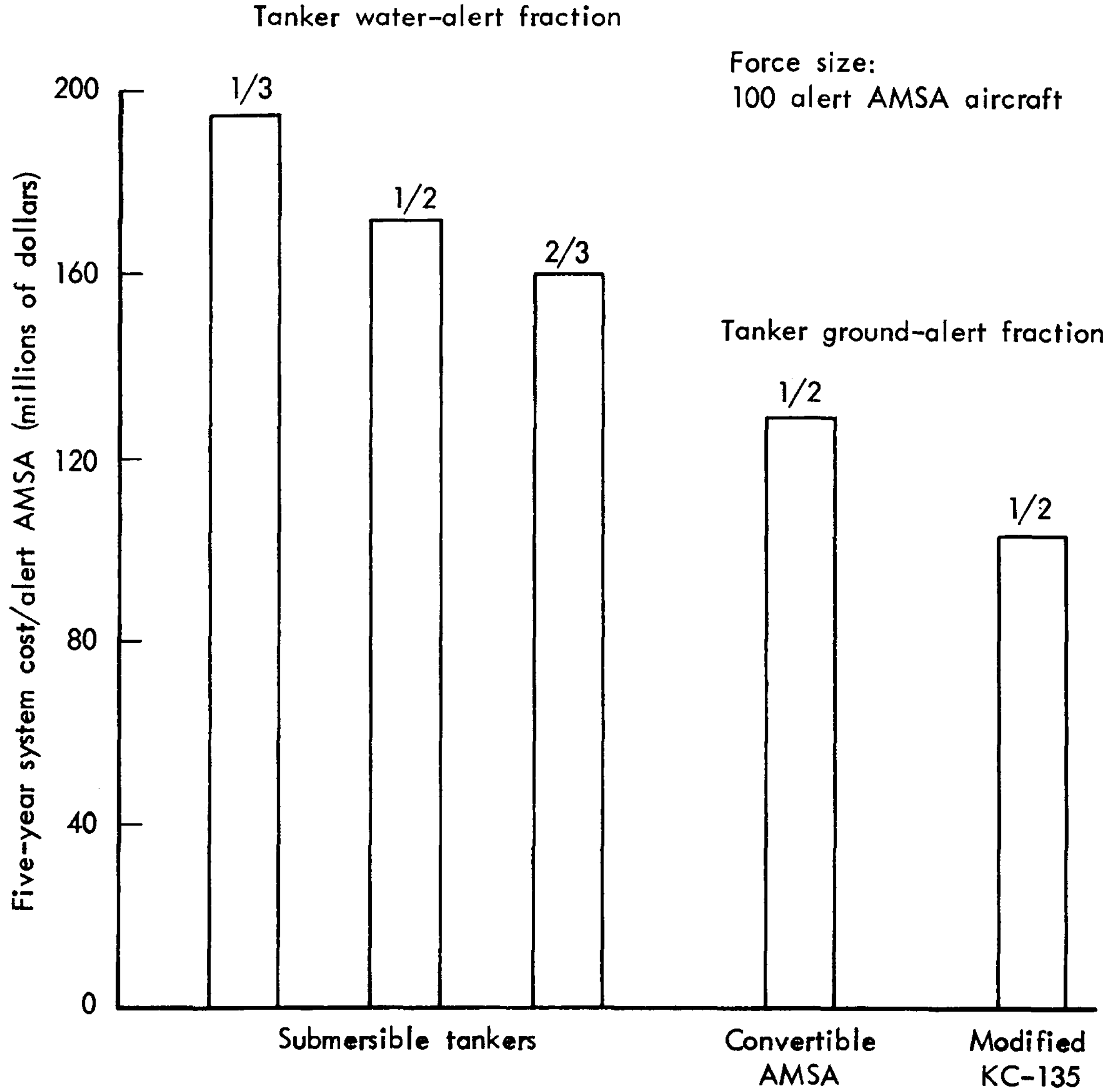

Fig. 17—System costs per alert AMSA with alternative supporting tankers (submersible tankers affixed for deployment and alert—low mobility)

period of 4 to 5 days, the alert function would be performed by the flight crew within the submerged tanker. Additional fuel would be obtained from unmanned, automated fuel caches which were prepositioned during a cold-war period. These caches could be fitted with provisions for aircraft engagement and for single-point refueling devices that could be activated by coded sonar signals.

However, this submersible-tanker support system would incur many of the disadvantages generally ascribed to contemporary tanker aircraft. For example, (1) they would be vulnerable to surprise attack if based in the ZI or at advance airfields; (2) the aircraft and flight crews would have to be maintained on some alert fraction at such installations; and (3) the ferrying operations out to the alert stations would be performed just prior to anticipated use. For the latter item the attrition of such hurried deployment would have to be anticipated in establishing support-system sizes.

The reliability and vulnerability of the submerged-fuel-cache system to various means of sabotage and attack would require realistic estimates. Various remedies and countermeasures would be needed.

The two principal advantages of this deployment mode are the elimination of the submerged-platform and pusher-tug equipments, as well as the lessened possible loss to the overall strategic system in the event a submerged platform with its aircraft were found and successfully attacked.

The five-year system costs for overall strategic systems utilizing AMSA bombers and submersible tankers at an assumed ground/water alert fraction of ½ are compared in Fig. 18 with the previously illustrated strategic systems involving convertible AMSA tankers and modified KC-135 tankers. The extra costs for the submersible-tanker-supported systems are less than those shown in Fig. 17, but they are significant amounts which must be evaluated relative to increased survivability, flexibility, and endurance.

TANKER AIRCRAFT DEPLOYED BY PLATFORM TO ALERT DISPERSAL (HIGH MOBILITY)

A third operational case, one that combines the better features of the two previously described cases, involves deployment of tanker

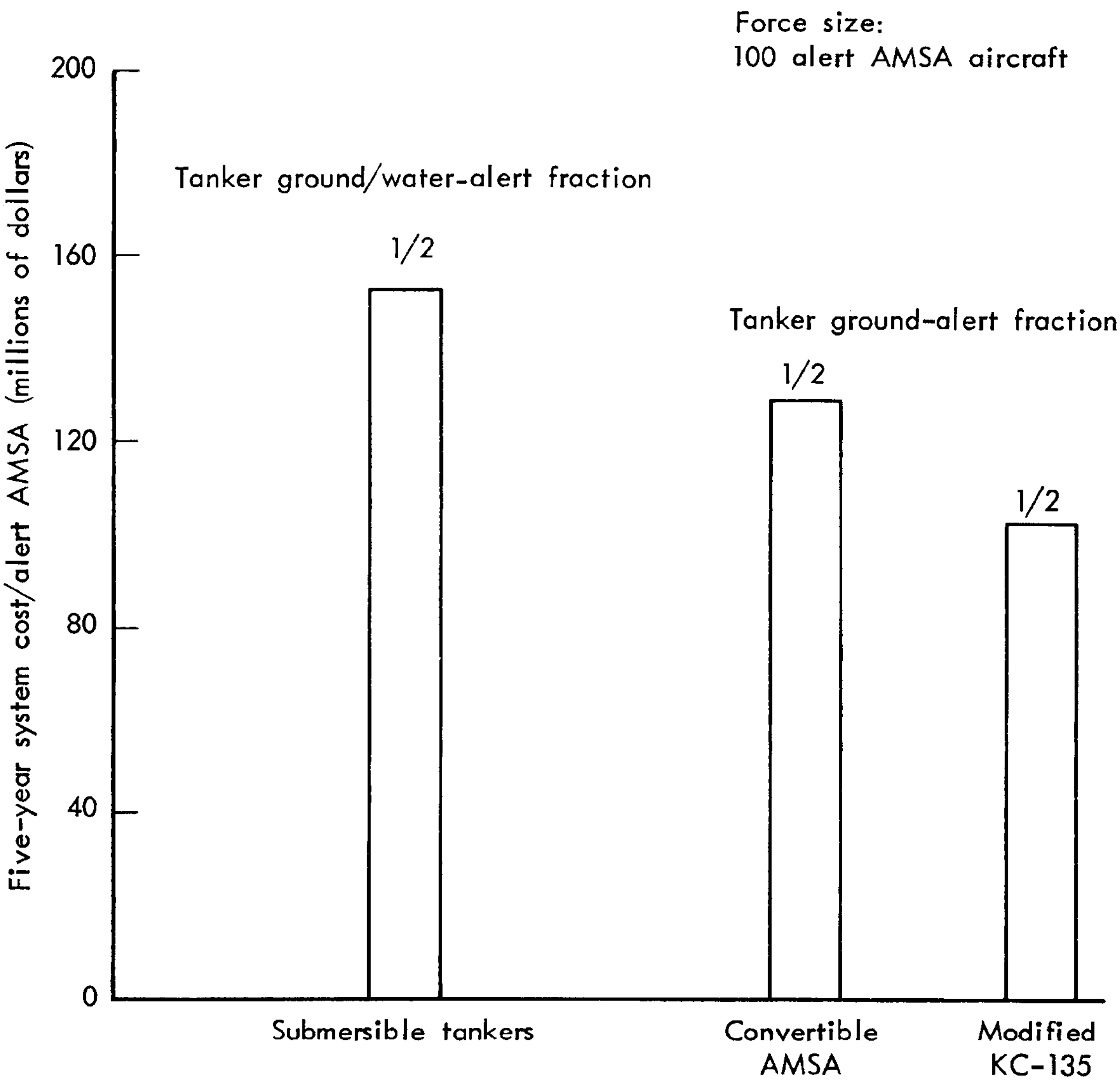

Fig. 18—System costs per alert AMSA with alternative supporting tankers (submersible tankers flown forward for individual alert—land-based flyout)

aircraft to forward areas by means of submersible platforms and then, at the time of high alert, utilizes area dispersal of the individual tankers to locations within a radius of the order of 25 to 50 n mi of the platform. From these dispersed basing sites the submersible tankers would surface and perform shuttle refueling operations in support of strategic aircraft by returning to the platform (fuel cache) for the several sorties flown by each tanker.

The physical components and the individual operations of this third case have all been introduced and discussed in the two previous cases. One of the important advantages of this combined case is the reduced potential of a major loss in the event of a successful attack on a platform with its complement of aircraft. Another important advantage is the elimination of the vulnerability problem of contemporary aircraft, which would arise if the submersible tankers were airfield-based until the alert was declared. Also, the operational attrition related to urgent deployment involving uncontrollable weather conditions and hurried refueling from a fuel cache would be avoided.

On the other hand, this third type of submersible-tanker operation can be expected rightly to be the most expensive of the three discussed here. This is indicated in Fig. 19, which again shows five-year system costs per alert AMSA bomber for the several strategic systems involving the submersible, convertible AMSA, and the modified KC-135 tanker support system.

For comparable alert fractions the submersible-tanker-supported AMSA system is approximately 50 per cent more expensive than the convertible-AMSA-supported overall system and 90 per cent greater than the modified KC-135 tanker-supported AMSA system for the small force size of 100 alert aircraft.

Vulnerability, flexibility, and an increased strategic-system endurance would be considered in evaluating objectively the greater cost of the submersible-tanker system relative to the suggested alternatives.

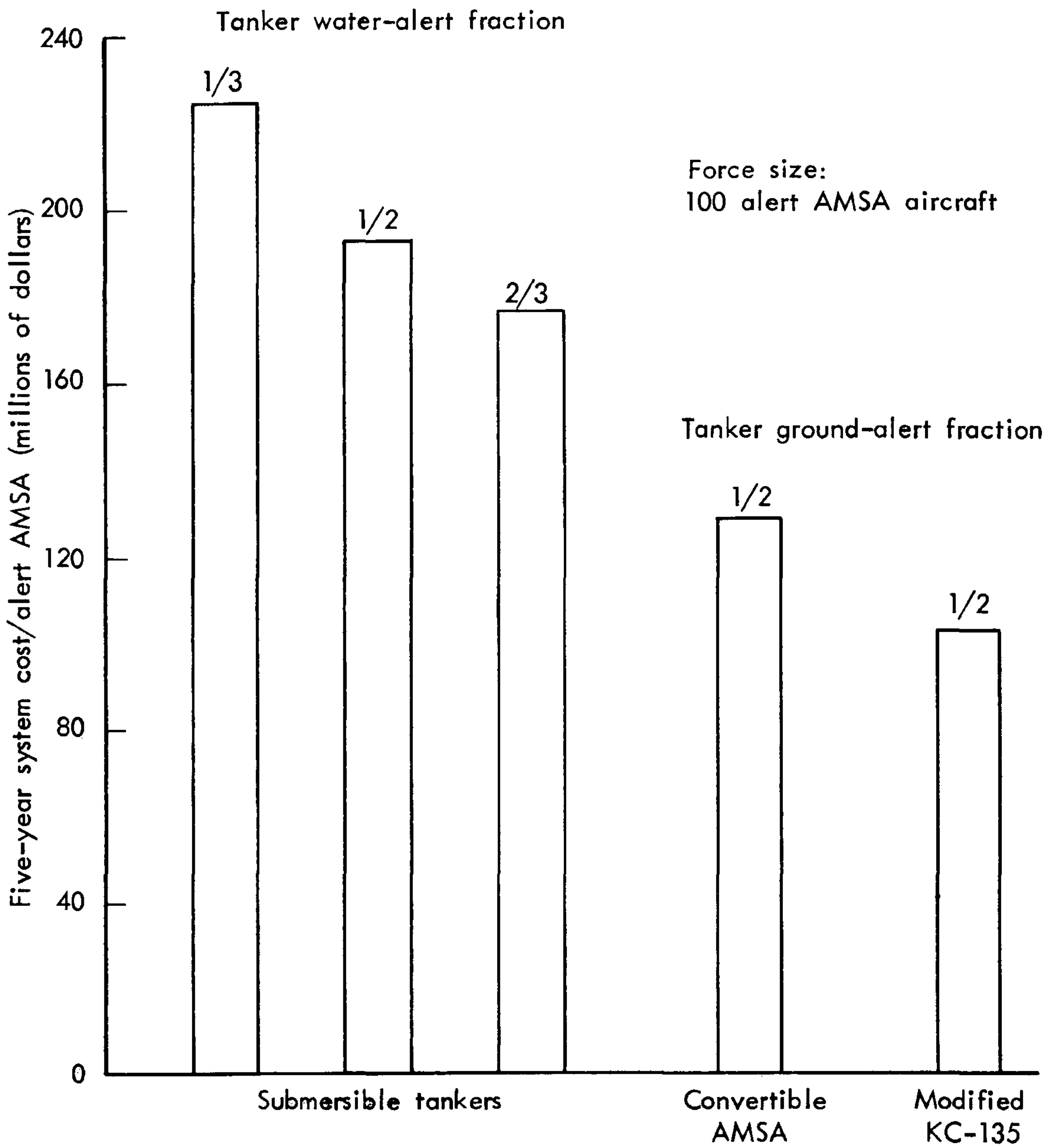

Fig. 19—System costs per alert AMSA with alternative supporting tankers (submersible tankers affixed for deployment but on individual alert—high mobility)

Appendix E

SUBMERSIBLE PLATFORMS AND NUCLEAR PUSHER-TUG SUBMARINES

The design and performance characteristics of the submersible platforms and nuclear pusher-tug submarines were determined by using design synthesis techniques previously developed for another investigation which has not yet been reported.*

The gross envelope volumes of the platforms, which are illustrated in Figs. 4 and 16, were determined by adding to the large fuel volumes appropriate allowances for crew and equipment volumes, which were approximately equal to the volume of a submarine of the Lafayette (SSB-(N)616) class. The weights of fuel load, structure, equipment, and crew were estimated by conventional procedures. The weight and volume summations as given in Table 9 were used to determine the amount of lead ballast required. The amount of water ballast was taken as approximately 15 per cent of the surface displacement of the platform in order to provide a reasonable draft and freeboard. Bow-thruster devices remotely operated from the pusher-tug submarine are included in the platform to provide yaw and pitch control when traveling as a combination vehicle at low speeds.

Using the platform displacement and dimensions, it is possible to calculate the horsepower required to propel the platform and the nuclear pusher-tug at 20 kn submerged. By use of weight and volume equations in an iteration process one can determine the dimensions and principal weight components of the two sizes of nuclear pusher-tug submarines required to propel the 10,000- and 16,000-ton submerged-displacement platforms for the penetrator and tanker aircraft, respectively. The component weights and volumes of these submarines, referred to as "small" and "large," are given in Table 10. The approximate configuration of the nuclear pusher-tug submarines is shown in Figs. 4 and 16.

The important physical characteristics of all four of these submersible craft are summarized in Table 11.

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*Supporting analyses and extensions of parametric analysis of submersible missile basing.[13]

Table 9

WEIGHTS AND VOLUMES FOR SUBMERSIBLE AIRCRAFT PLATFORMS

Item	Weight (long tons)		Volume (ft^3)	
	Penetrator	Tanker	Penetrator	Tanker
Outer shell and framing	1,815	2,850	8,350	13,000
Crew and equipment structures	1,770	1,180	8,150	5,400
Propulsion	...	...	....	....
Auxiliary power plant	160	80	....	....
Auxiliary systems	550	440	12,000	10,000
Communication and navigation	70	70	2,000	2,000
Outfit and furnishings	279	186	2,000	1,000
Armament	81	81	5,000	5,000
Light ship weight	4,725	4,887	.....	.....
Personnel and equipment	350	200	113,000	70,500
Aircraft spares and equipment	60	40	15,000	10,000
Fuel load	2,700	8,000	124,000	368,000
Lead ballast	470	800	1,500	2,500
Water ballast	1,260	1,920	44,100	67,200
Submerged displacement	9,565	15,847	335,100	554,600

Table 10

WEIGHTS AND VOLUMES OF NUCLEAR PUSHER-TUG SUBMARINES

Item	Weight (long tons)		Volume (ft^3)	
	Small	Large	Small	Large
Hull	1,065	1,245	4,900	5,720
Propulsion	895	1,045	59,300	72,600
Auxiliary systems	135	155	...	...
Independent and crew	80	80	16,800	16,450
Lead ballast	160	195	500	600
Salt-water ballast	330	390	11,700	13,630
Total	2,665	3,110	93,200	109,000

Table 11

SUBMERSIBLE AIRCRAFT BASING PLATFORMS AND PUSHER TUGS

Submersible Craft	Displacement (long tons)		Dimensions (ft)			SHP	Speed (kn)	
	Submerged	Light Ship	Length	Beam	Depth		W/O A/C	W A/C
Platform, 10 penetrator A/C	10,000	4,700	356	54	27	......	20	16
Nuclear pusher tug	2,655	2,125	167	30	30	14,900		
Platform, 6 tanker A/C	16,000	4,700	405	64	32	......	20	16
Nuclear pusher tug	3,060	2,450	176	32	32	18,900		

Appendix F

COSTS FOR STRATEGIC PENETRATOR AIRCRAFT SYSTEMS

GENERAL

This appendix presents cost estimates for the previously described weapon systems and the assumptions under which the estimates were prepared. These system costs are valid only in the comparative context of this Memorandum and the assumptions given herein. No attempt is made to measure the effectiveness of any of the systems as peacetime deterrents or in their wartime roles.

The system-cost estimates are presented for the RDT&E, the initial investment, and the five-year operating cost, as well as the total of these, for the total alert force of 100 penetrator aircraft. The five-year system-cost estimates are also presented in terms of the major types of equipment in the several systems as well as the total cost of equipment. A more detailed treatment of the development of these cost data is given by Ref. 8. The individual pieces of equipment are detailed there from a cost analysis standpoint. It also presents the RTD&E and production costs for each subsystem, the related cost-quantity curves, and the manning criteria.

The first group of estimates pertains to strategic-aircraft weapon systems utilizing submersible penetrator aircraft and to alternative strategic-aircraft weapon systems utilizing land-based penetrator aircraft. The second group of estimates pertains to strategic-aircraft weapon systems utilizing AMSA as penetrator aircraft supported by submersible tanker aircraft or by convertible AMSA aircraft as tankers or by modified KC-135A land-based tanker aircraft.

DEFINITIONS AND ASSUMPTIONS

A weapon system is defined here as an instrument of combat, consisting of primary mission equipment, support equipment, material and supplies, bases, trained personnel, and related support, which refers to support both on and off the tactical base; e.g., depot maintenance and advanced flight training. Estimated total system costs include those required to develop, introduce into the force, and operate for five years a given weapon-system unit or assumed force size. A detailed explanation of the major cost categories and representative charts of account may be found in Ref. 14.

Total-system cost estimates are sensitive to many factors which can best be handled by total-force cost analysis. In an individual weapon-system cost analysis these factors can be handled only by assumption regarding, for example, the availability or inventory level of adequate bases and trained personnel. The appropriateness of each assumption is less important than the fact that when an assumption changes, so must the estimate of costs.

It is assumed that the systems would become operational in the mid-1970's, replacing phased-out B-52/KC-135A squadrons. Like the B-52/KC-135A units, the weapon system under study would be located on bases in the continental United States. In the mid-1970's, manning criteria, dispersal mode, and maintenance policies are assumed to be reflective of the current SAC environment, except as noted for the submersible systems.

The training program is also assumed to be similar to current B-52 programs with additional training for submergence operations. Peacetime flying hours for the penetrator systems are assumed to be 650 hr per aircraft per year. Flying hours for the tanker aircraft are assumed to be 475 hr per aircraft per year. It is assumed that trained personnel will be available without costs, except for flight crews who would require transitional training. Each penetrator aircraft is assumed to have a flight crew of four, a fixed military load of 8000 lb, and an expendable military load of eight short-range attack missiles of 1000 lb each.

Neither past nor current Air Force programs could be used to postulate a credible peacetime operational environment for the submersible systems. It is yet to be determined how long an aircraft can remain submerged and still operate properly. The uncertainty in the design and utilization of this equipment is reflected in many of the system assumptions. In order to reflect this uncertainty, a range rather than a point estimate was made in those cases where the aircraft was to remain on water alert. The range of alert postures and their sensitivity to the resource requirements will be discussed as part of each case comparison.

SUBMERSIBLE AND ALTERNATIVE STRATEGIC PENETRATOR-AIRCRAFT SYSTEMS

Cost estimates were prepared for three mobility levels for the submersible penetrator systems: low mobility, land-based flyout, and high mobility, as discussed in Section III. In both the low- and high-mobility cases three different alert fractions, 1/3, 1/2, and 2/3, have been postulated. For the land-based flyout the single value of 1/2 was used. The alert fractions refer to the ratio of submersibly based aircraft to the total force. For example, a 1/3 alert fraction would imply a system in which a platform with its ten penetrator aircraft would remain submerged on station for one month at a time. Upon coming off alert it would be rotated back to a rear area for one month of training. One month would then be available for base- or depot-level maintenance. The 1/2-alert-fraction case assumed two months' continuous submerged alert duty and the 2/3-alert-fraction case four months' continuous alert duty, each having the same one-month allowance for training and maintenance.

Submersible Aircraft and Supporting Platforms and Pusher Tugs

The number of aircraft in the inventory to support a water-alert penetrator force of 100 is dependent upon the additional aircraft provided to help assure high reliability--those utilized in training activities in rear areas and those undergoing maintenance in the ZI--and upon the major effect of the assumed alert fraction (see Table 12). For the land-based-flyout case only one value of alert fraction is shown in this table. In this case no additional aircraft are needed to help assure high reliability.

In the computation of the number of basing platforms for submersible aircraft, platforms would be provided for the aircraft in the training mode as well as for those aircraft on water-alert duty. An

Table 12

WATER-ALERT PENETRATOR FORCE

Aircraft Force	Water-Alert Fraction: Low or High Mobility 1/3	1/2	2/3	Land-Based Flyout 1/2
Aircraft on alert	100	100	100	100
Submerged but not alert aircraft	25	25	25	..
Aircraft in rear-area training	125	62.5	31.25	50
Aircraft in maintenance in ZI	125	62.5	31.25	50
Total aircraft	375	250	188	200

additional ten per cent more platforms would be included to meet the assumed overhaul schedule rate estimated to be once every 30 months. Platforms are not needed for the aircraft undergoing maintenance. For each assumed alert fraction the submersible platforms needed are the same for both the low- and the high-mobility cases. The computations, given in Table 13, were for 100 alert penetrators.

Table 13

PLATFORM FORCE FOR WATER-ALERT PENETRATORS

Platform Force	Alert Fraction: Low or High Mobility 1/3	1/2	2/3	Land-Based Flyout 1/2
Platforms on alert	12.5	12.5	12.5	..
Platforms for rear-area training	12.5	6.3	3.2	..
Pipeline platforms (10 per cent)	2.5	1.9	1.6	..
Total platforms	28	21	17	..

In the low-mobility cases it was assumed that one nuclear-submarine pusher tug would be needed in each of six general geographic locations. Three additional tugs were added to this for backup purposes. For the high-mobility cases one pusher tug was assumed for each submersible platform on alert, plus one for each two platforms supporting rear-area training activities. To each of these totals a 10 per cent pipeline or overall backup allowance of tugs was added.

Alternative Strategic Penetrator-Aircraft Systems

Long-Endurance (LEA) and Parasite-Aircraft Systems. For the purpose of comparison with submersible penetrators, the LEA system was studied in two operational modes, 1/2 ground alert and 3/4 airborne alert. A penetrator with speed and payload comparable to the submersible penetrator is carried externally by a Mach 0.3 airborne platform.[4] The penetrator is released about 1000 mi from the target, and upon completion of its mission it is recovered and ferried back to the ZI. The system assumptions for the 1/2-ground-alert case are similar to the B-52 system in terms of deployment, peacetime operations, and flying-hour program. For the airborne-alert case the operational training time is included in the alert fraction of 3/4. This brief statement of system-cost derivation omits the detailed assumptions under which the estimate of costs for the airborne-alert case were derived. The methodology, however, is consistent with that used in estimating the submersible systems and the land-based, ground-alert systems.

AMSA Systems. The AMSA penetrator systems used as alternatives to the submersible penetrator systems in the comparisons made in Section III are supported by AMSA's converted to tanker aircraft (K-AMSA) or by KC-135A aircraft modified for short-field compatibility with AMSA. The K-AMSA tanker incurs a modest incremental RDT&E cost as well as procurement and operational costs, whereas the KC-135A modified tanker incurs only modification and operational costs. The AMSA RDT&E, procurement, and operational costs are common to the two systems.

SYSTEMS-COSTS SUMMARY FOR PENETRATOR CASES

The cost estimates for each of the penetrator systems described above are summarized in Table 14. For the three levels of mobility of the submersible aircraft system, and for the alternative systems, the numbers of the several major equipments are given, and the five-

Table 14

COMPARISON OF EQUIPMENT AND COSTS FOR 100 SUBMERSIBLE PENETRATORS ON ALERT

Item	Alert Fraction										
	Low Mobility			Land-Based Flyout	High Mobility			AMSA		LEA Parasite	
								KC-135A	K-AMSA	Ground Alert	Airborne Alert
	1/3	1/2	2/3	1/2	1/3	1/2	2/3	1/2	1/2	1/2	3/4
Unit Equipment											
Penetrators	375	250	188	200	375	250	188	200	200	200	134
Airborne platforms (LEA)	..	..	..	..	..	..	..	..	..	200	134
Tankers	..	..	..	..	..	..	..	198	190	..	..
Submersible platforms	28	21	17	..	28	21	17	..	..	..	..
Nuclear pusher tugs	9	9	9	..	21	19	17	..	..	..	..
Five-Year System Cost Per Alert Penetrator (in millions of 1964 dollars)											
Penetrators	91	71	57	48	91	71	57	88	88	28	21
Missiles	12	8	6	5	12	8	6	5	5	6	4
Tankers	..	..	..	..	..	..	..	9	36	..	..
Airborne platforms (LEA)	..	..	..	..	..	..	..	..	..	38	60
Submersible platforms	6	5	4	6	6	5	4	..	..	..	..
Nuclear pusher tugs	12.7	9	17.1	..	15.5	20.1	25	..	...	..	..
Total	118	93	76	59	129	103	84	102	129	72	85
Five-Year System Cost for Total Force (in billions of 1964 dollars)											
RDT&E	1.6	1.6	1.6	1.5	1.6	1.6	1.6	2.0	2.1	1.2	1.2
Initial investment	5.2	3.9	3.2	2.9	5.8	4.5	3.6	4.8	7.0	4.0	4.6
5-year operating cost	5.0	3.7	2.9	1.5	5.5	4.2	3.2	3.5	3.8	2.0	2.7
Total	11.8	9.2	7.7	5.9	12.9	10.3	8.4	10.3	12.9	7.2	8.5

year system-cost data are presented in relation to those equipments as well as in the usual breakdown of RDT&E, initial investment, and annual operating cost. For the low-mobility case the submersible equipments are of the order of 15 per cent of the total cost, whereas they are of the order of 20 per cent for the high-mobility case. However, the dominant cost item in each case is that of the penetrator aircraft.

Higher mobility resulting from approximately doubling the number of nuclear pusher tugs, as discussed in Section III, results in an increase of about 10 per cent to the total system costs. Employing the land-based-flyout submersible penetrator system appears to be considerably less costly, since submersible equipments are not utilized. The peacetime costs for this system do not include additional costs relating to operating this system in a submerged posture for any length of time.

The cost data for the alternative strategic systems of AMSA on 1/2 ground alert supported by K-AMSA or by modified KC-135A and of LEA with parasite for 1/2 ground alert and 3/4 air alert are also presented in Table 14. Entries for tanker support or airborne platforms are the counterparts to the submersible equipments discussed above.

The total system costs which include RDT&E, initial investment, and five-year operating costs, normalized to the 100 alert penetrators, are presented in Fig. 20. In order of descending system cost, the strategic systems involving submersible penetrator aircraft for the three mobility conditions, each at several alert fractions, are compared with the AMSA and LEA-parasite strategic systems to demonstrate the overall comparability of costs.

SUBMERSIBLE AND ALTERNATIVE TANKER AIRCRAFT IN SUPPORT OF AMSA

Tanker-Support Requirements

The AMSA system was assumed to be base-operated and maintained in a peacetime manner similar to the current B-52 fleet--50 per cent ground alert, single squadron basing, and a flying-hour program of 650 hr per aircraft per year.

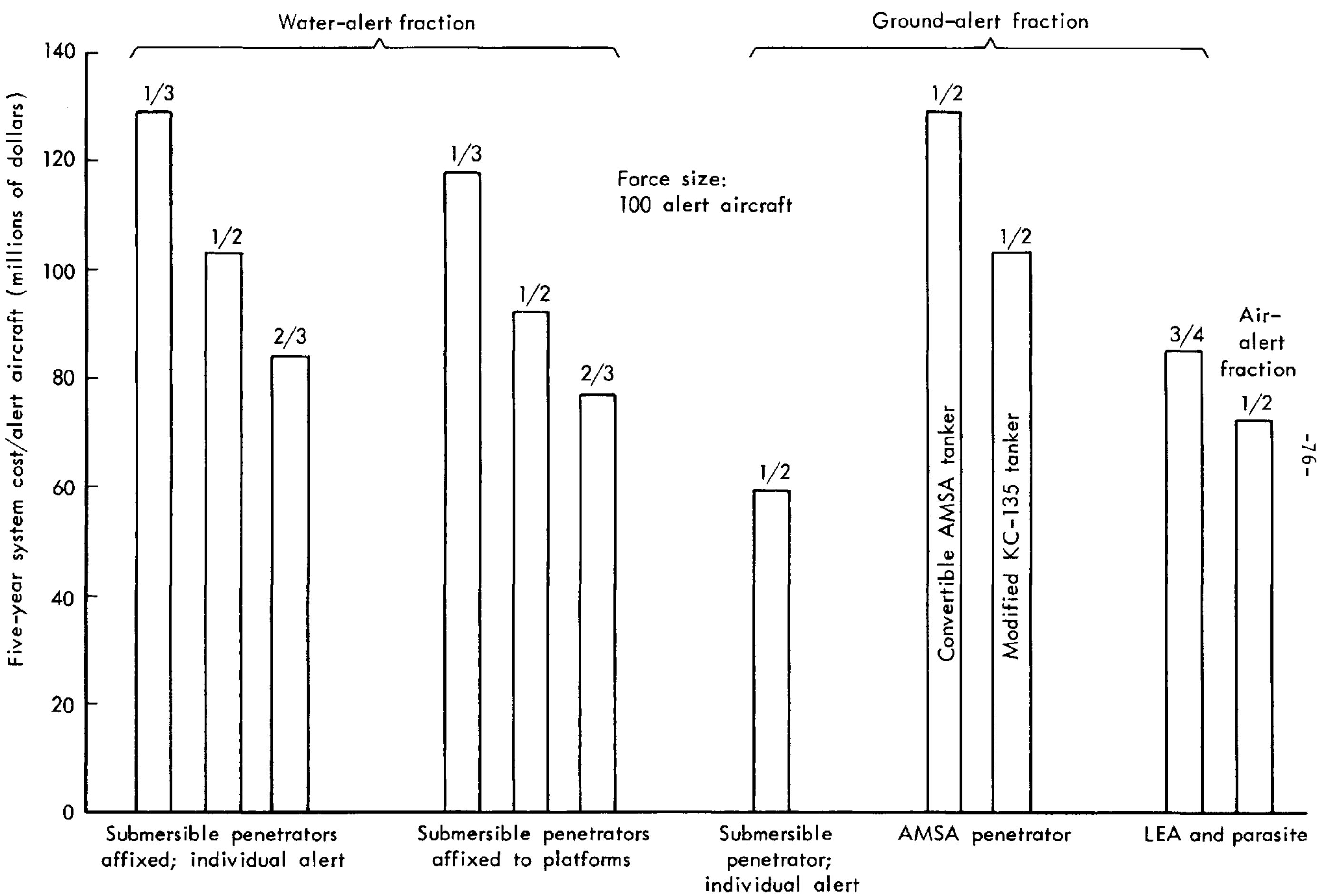

Fig. 20—System costs per alert penetrator aircraft with alternative supporting systems

The number of tankers required to support 100 alert AMSA penetrators was determined by close analogy to the study in Ref. 4, using data that appear in Table 15. The data presented in Table 15 are for the K-AMSA tanker, for the modified KC-135A tanker with assisted takeoff (ATO) units for short takeoff compatibility with AMSA, and for the submersible tanker. On the basis of ZI basing, bomber paths enroute to target, and minimum penetration of the target system shown in Fig. 14, the work of Ref. 4 was extended to include submersible tanker aircraft. Referring to the right-hand portion of Table 15 headed "300,000-lb Submersible Tanker," one may note that the several portions of the bomber force would be refueled at differing nominal distances from base. The tanker/bomber ratio (T/B) at the nominal distances varies from about 0.7 to 1.3. The suggested tanker-base locations, corresponding to these nominal distances from base, rim most of the periphery of the target system. The final column indicates the approximate breakdown between the several locations at the same nominal distance from base. At the bottom of the table the portion of the total target area covered (97 per cent) is noted for these refueling capabilities. The average tanker/bomber ratio of 0.91 is a weighted average (by bomber force fraction) of the tanker-bomber ratios shown in the upper part of the table.

Submersible Tankers and Supporting Platforms and Pusher Tugs

Cost estimates are developed here for three mobility levels for the submersible tanker aircraft supporting AMSA on 1/2 ground alert: low mobility, land-based flyout, and high mobility.

In both the low- and high-mobility cases we have again postulated the three alert fractions, 1/3, 1/2, and 2/3. This fraction has a major effect in determining the number of tanker aircraft and submersible platforms required to support a given number of penetrator aircraft.

Five of the six tankers on each platform are considered to be on alert duty, and the sixth tanker is included as backup in order to help maintain high system reliability. The tankers required to support 100 alert AMSA penetrators are presented in Table 16.

Table 15

TANKER OPERATIONS AND BASING FOR THREE TANKER-SUPPORTED AMSA SYSTEMS

	345,000-lb AMSA Tanker				297,000-lb KC-135A Tanker				300,000-lb Submersible Tanker			
Refueling Mode	% of Bomber Force	T/B	Tanker-Base Locations	Allocations (%)	% of Bomber Force	T/B	Tanker-Base Locations	Allocations (%)	% of Bomber Force	T/B	Tanker-Base Locations	Allocations (%)
Unrefueled	7	0	----	---	7	0	----	---	7	0	----	---
Prestrike buddy	35	1.000	U.S. ZI (refuel 2750 n mi)	100	31	1.000	U.S. ZI (refuel 2400 n mi)	100	28	1.000	U.S. ZI (refuel 2250 n mi)	100
Prestrike and poststrike at 2500 n mi	23	0.757	Alaska, Aleutians } West Canada, Greenland } Center England, Spain } East	49 28 23	27	0.812	Alaska, Aleutians } West Canada, Greenland } Center England, Spain } East	49 28 23	30	0.732	Aleutians, Alaska } West Canada, Greenland } Center Ireland, Azores } East	49 28 23
Prestrike and poststrike at 3750 n mi	19	1.087	Japan West England, Spain, Italy, Libya } East	45 55	19	1.162	Japan West England, Spain, Italy, Libya } East	45 55	19	1.052	Japan West W. Mediterranean East	45 55
Prestrike and poststrike at 5000 n mi	16	1.380	Okinawa, Philippines } West Greece, Turkey, Iraq } East	34 66	16	1.480	Okinawa, Philippines } West Greece, Turkey, Iraq } East	34 66	16	1.335	Okinawa, Japan } West E. Mediterranean East	34 66

Item	345,000-lb AMSA Tanker	297,000-lb KC-135A Tanker	300,000-lb Submersible Tanker
Target area covered, %	97	97	97
Average T/B	0.951	0.986	0.913
Bombers using fwd tankers, %	58	62	65

Table 16

TANKER FORCE FOR WATER-ALERT PENETRATORS

	Alert Fraction			
	Low or High Mobility			Land-Based Flyout
Tanker Force	1/3	1/2	2/3	1/2
Tanker-to-penetrator ratio	0.91	0.91	0.91	0.91
Alert tankers	91	91	91	91
Additional submerged tankers	18.2	18.2	18.2	..
Rear-area training tanker	109.2	54.6	27.3	45.5
Maintenance tankers	109.2	54.6	27.3	45.5
Total tanker requirements	328	218	164	182

As in the submersible-penetrator-aircraft case, platforms would be provided for tankers in the training mode as well as for those on water-alert duty (see Table 17). There is also a 10 per cent allowance for overhaul and transit.

Table 17

PLATFORM FORCE FOR SUBMERSIBLE PENETRATORS

	Alert Fraction			
	Low or High Mobility			Land-Based Flyout
Platform Force	1/3	1/2	2/3	1/2
Alert platforms	18.2	18.2	18.2	18.2[a]
Platforms for rear-area training	18.2	9.1	4.55	4.55[a]
Pipeline platforms (10 per cent)	3.6	2.7	2.2	2.2[a]
Total platforms	40	30	25	25

[a]In the land-based-flyout case, automated fuel caches of similar configuration would be used instead of manned submersible platforms.

In the low-mobility case one nuclear pusher tug is needed for platform emplacement in each of four general geographic locations for platform deployment, regardless of the assumed value of alert fraction. Two additional tugs are needed as backup to insure a high degree of system reliability. In the high-mobility case, one nuclear pusher tug is needed for each alert platform and one is needed for each two platforms in the training mode. An additional 10 per cent is added as an overhaul and transit allowance.

The submersible tanker in the land-based-flyout system would be land-based in peacetime rather than submersibly based. Its peacetime deployment, alert status (50 per cent ground alert), and operational environment would be similar to that of the current Strategic Air Command (SAC) tankers.

The land-based system requires no submersible pusher tugs and utilizes unmanned submerged fuel storage caches instead of submersible platforms.

Alternative Tanker Aircraft

The K-AMSA or KC-135A modified are included as the conventional alternatives to the submersible tankers.

The K-AMSA would have airframe and engine similar to the AMSA penetrator discussed earlier.

It is assumed that the KC-135A tankers would be available during this time period without initial investment cost. The available tankers would be unchanged except for the ATO modifications. The operating costs can be estimated in accordance with current operations.

Both the K-AMSA and KC-135A systems would be operated in a manner similar to that of the current SAC tanker systems, i.e., they would be based in the ZI. One-half of the aircraft would be on ground alert and each aircraft would fly 475 hr per year.

SYSTEMS-COSTS SUMMARY FOR TANKER CASES

The summary costs estimated for each AMSA penetrator/tanker system are shown in Table 18. The estimates are shown for only one force size, 100 alert penetrators. As can be seen, each alternative has a different number of tanker aircraft. This quantity is based upon the

Table 18

COMPARISON OF EQUIPMENT AND COST FOR SUBMERSIBLE-TANKER SUPPORT OF 100 ALERT PENETRATORS

Item	Low Mobility			Land-Based Flyout	High Mobility			K-AMSA	Modified KC-135A
Alert fraction (per cent)	33-1/3	50	66-2/3	50	33-1/3	50	66-2/3	50	50
Alert tankers (per cent)	33-1/3	50	66-2/3	50	33-1/3	50	66-2/3	50	50
Alert penetrators (per cent)	50	50	50	50	50	50	50	50	50
Tanker/penetrator ratio	91	91	91	.91	91	91	91	95	99
Unit Equipment									
AMSA penetrators	200	200	200	200	200	200	200	200	200
Tankers	328	218	164	182	328	218	164	190	198
Submersible platforms	40	31	25	25	40	31	25	..	..
Nuclear pusher tugs	6	6	6	6	30	26	22	..	..
Five-year System Cost per Alert Penetrator (in millions of 1964 dollars)									
Penetrators	88	88	88	88	88	88	88	88	88
Missiles	5	5	5	5	5	5	5	5	5
Tankers	85	65	54	54	85	65	54	36	10
Submersible platforms	10	7	6	6	10	7	6	..	..
Nuclear pusher tugs	7	7	7	7	37	28	24	..	..
Total	195	172	160	160	225	193	177	129	103
Five-year System Cost for Total Force (in billions of 1964 dollars)									
RDT&E	3.9	3.9	3.9	3.8	3.9	3.9	3.9	2.2	2.0
Initial investment	10.2	8.7	7.9	8.0	11.9	9.9	8.9	6.9	4.8
Five-year operation	5.4	4.6	4.2	4.2	6.7	5.5	4.9	3.8	3.5
Total	19.5	17.2	16.0	16.0	22.5	19.3	17.7	12.9	10.3

tanker/bomber ratio as shown in Table 15 and upon the tanker water-alert fraction. The number of submersible vehicles or equipments supporting each tanker system is in turn a function of the number of tankers and the operational scheme for each system, i.e., low mobility, land-based flyout, or high mobility.

The estimates of costs which reflect the resources required for each alternative are presented in two different ways. Five-year system costs (RDT&E, initial investment, plus five years of operation) are first shown, per alert penetrator, by the type of equipment. This presentation provides an index of the relative magnitude of the cost of each of the equipments included in the several alternative systems. For example, in both the low-mobility and high-mobility alternatives the five-year system cost of the submersible platforms is about 5 per cent of the total cost, and the percentage ascribable to missiles is even less. The ratio of the cost of the pusher tugs to the total varies from about 4 per cent to over 16 per cent, depending on the degree of mobility assumed. The tanker costs are at least 30 per cent of the total in each case except in the KC-135A alternative, which includes only modification and operating costs.

The second cost presentation is five-year system costs for the total force by major cost categories. It is useful in indicating the magnitude of each major cost category of the total system costs.

Total RDT&E costs are, of course, insensitive to force size and, as can be seen, are substantial (15 to 25 per cent of the total costs). This percentage would become larger if a smaller force size were contemplated, and conversely. Initial investment, or one-time system costs, accounts for about one-half of the total system costs. The ratios of annual operating, or recurring, costs to the total costs average about 5 per cent per year.

In analyzing the estimates of costs presented in Table 18 a number of observations can be made. The first is that the AMSA aircraft included in the several systems dominate the cost. In almost every alternative the penetrator-aircraft system accounts for over 50 per cent of the total costs. On the other hand, the submersible shiplike equipment is much less dominant. In the 1/2-alert-fraction cases a cost increase of 12 per cent provides high mobility with great benefit in survivability.

The total RDT&E, initial investment, and five-year operation costs are presented in Fig. 21 for the several strategic systems using AMSA bombers. Those systems using submersible tankers are shown for three mobility conditions at several alert fractions. Similarly shown are the system costs for AMSA strategic systems supported by convertible AMSA tankers and by KC-135 modified tankers.

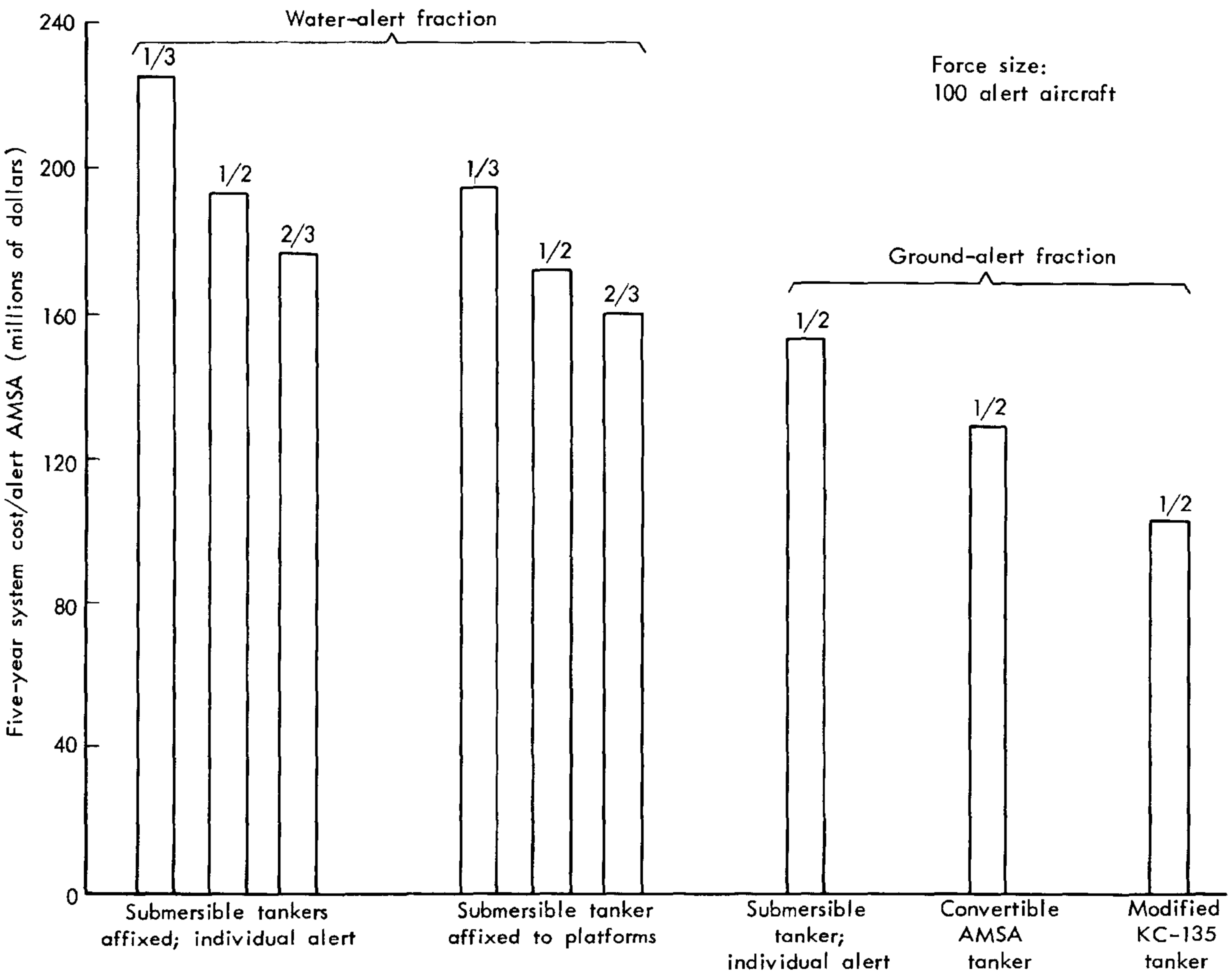

Fig. 21—System costs per alert AMSA with alternative supporting tankers

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