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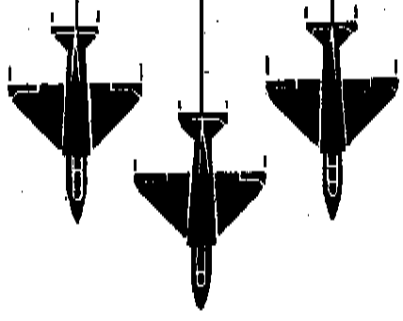
FIGHTER AIRCRAFT

Report of the
Defense Science Board Task Force



Volume I

EXECUTIVE SUMMARY

8 May 1968

Office of the Director of Defense Research and Engineering
Washington, D.C.

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Office of the Director of Defense Research and Engineering
Washington, D. C.

MEMBERSHIP

of

DEFENSE SCIENCE BOARD TASK FORCE

on

FIGHTER AIRCRAFT

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SUMMARY OF RECOMMENDATIONS

Major recommendations of the Defense Science Board Task Force on Tactical Aircraft are as follows:

General

. Programs should be started to provide new fighter aircraft for the Navy and the Air Force.

. The aircraft for both Services should be high-performance air-superiority fighters for close-in visual and all-weather combat, with the maximum ground-attack capability obtainable without compromise to their air-to-air effectiveness.

Development Strategy

. Separate aircraft development programs are recommended for the Navy and the Air Force rather than the development of a common airplane, but commonality of many items of installed equipment is recommended.

. The development approach should be one of separate competitive prototype-development programs in each major category, namely, airframes, engines, and avionics, with fly-before-buy competitions in each case.

Engines

. Two competitive engine-development programs should be funded immediately.

. Engines produced by the two developers must be interchangeable among the several prototype aircraft and between the final versions of the Navy and Air Force aircraft.

Airframes

. The aircraft should be highly agile, with a high thrust-to-weight ratio and low wing loading, outstanding cockpit visibility, excellent handling characteristics, and low vulnerability.

The decision between one or two crew members should be based on the degree of autonomous operating capability required with radar missiles, in conjunction with the adequacy of the avionics resulting from the development competition. A second crew member should not be added for the night all-weather ground-attack role, since this is not a design mission for the proposed aircraft.

. The competitive prototype airframe development should emphasize aerodynamic advances to increase maneuverability while minimizing drag penalties.

. The possibility of flight testing with substitute engines available earlier than the final engine should be studied carefully during the prototype airframe development lead time.

Avionics

. Radar capabilities should include look-down air-to-air detection and tracking and ground-mapping, but not necessarily terrain-clearance modes. A metal dish or a gimbaled phased-array antenna should be used, but not an electronically scanned beam.

. A LORAN-inertial (without doppler) navigation system is recommended.

. Provisions for penetration aids and a tail warning radar should be included, along with the normal functions of communication and other operational avionics.

. Head-coupled sights and displays should be tested. Results of these tests should be a major factor in the decision on the number of crew members needed.

. Design and location of switches and displays, both panel-mounted and head-coupled, should be an important feature of the avionics development competition.

Air-to-Air Armament

. The aircraft should carry internal guns, midrange missiles, and short-range missiles.

. An immediate test program for a guided gun is recommended, using primarily off-the-shelf hardware.

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. Development and test programs for short-range agile missiles and rearward-firing ordnance are also recommended.

The Ground-Attack Role

. The proposed aircraft should have an excellent capability for visual day ground attack without compromise to the air-to-air capability of the aircraft when configured for the air-to-air mission. Any added night or all-weather attack capability required should be pod mounted.

. Bombing accuracy with free-fall weapons should be improved via the use of new systems under development, if tests indicate their utility.

. The aircraft must be capable of delivering such standoff weapons as Walleye, Condor and laser-guided bombs. Capability to deliver other types of standoff weapons now under study whould be included if tests demonstrate their value.

. Adequate target-marking systems such as lasers and artillery-emplaced microwave beacons should be developed in order to increase effectiveness and reduce the aircraft attrition and peripheral damage in the air delivery of ordnance.

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1. TASK DEFEINTION AND PROCEDURES

The Defense Science Board (DSB) was requested by the Director of Defense Research and Engineering to examine the air-to-air and air-to-ground mission areas in relation to needs expressed by the Navy and the Air Force for new tactical aircraft. The request stated that the air-to-air problem should receive priority. The Board was asked to consider (among other problems) whether it is preferable to place emphasis on aircraft performance or armament performance for air-to-air combat, and what should be the balance between sophisticated systems in the aircraft for delivering free-fall ordnance and the use of terminally guided air-to-ground weapons.

The Task Force established to meet this request met for the first time on June 13 and 14, 1967. Subsequent 2-day meetings were held monthly through February 1968, except that no meeting was scheduled in December 1967. Briefings and discussions on topics relevant to the choice of design features for air-to-air and air-to-ground missions were presented to the Task Force by the Office of the Director of Defense Research and Engineering; the Office of the Assistant Secretary of Defense (Systems Analysis); the Departments of the Navy, the Air Force and the Army; the National Aeronautics and Space Administration; the RAND Corporation; and industrial contractors and other organizations. The agenda of the meetings and a supplementary description of proposed systems are presented in Appendix B and C of Volume II.

A draft report dealing with the air-to-air mission was issued by the Task Force on 26 September 1967. A revision to this draft was issued on 26 October 1967, and a further revision (including a section on the air-to-ground mission) was issued on 3 February 1968.

The present report supersedes the previous drafts and is the final report of the Task Force. It is presented in two separately bound parts—the basic report and the present volume, which constitutes an executive summary of the basic report. These reports reflect the comments and criticism from DSB members, expressed in letters or at the 10 April 1968 meeting of the full Task Force with designated members of the DSB. The present report was accepted by the DSB on 8 May 1968.

2. CONCLUSIONS AND RECOMMENDATIONS

The Task Force is unanimous in the findings reported here except in the few instances which are indicated to the contrary.

2.1 General Findings

2.1.1 The Need for New Aircraft: Chief among the conclusions of the Task Force is that the Navy and Air Force need new fighter aircraft now. The need is expected to be much stronger by the earliest time period when the new aircraft could become operational. The Task Force recommends timely action in beginning such aircraft.

2.1.2 The Basic Design Mission: The Task Force recommmends that the proposed aircraft be high-performance air-superiority fighters. The aircraft should also be capable of ground-attack missions. The Task Force recommends the maximum ground-attack capability that can be obtained without compromise to air-to-air effectiveness per aircraft.

2.1.3 Commonality: Even though the Task Force feels that both Services now need new fighters with the basic design mission stated above, and will need them much more by the early 1970s, we do not recommend a common aircraft. The weight penalty and other design restrictions incurred in making a fighter carrier-suitable should not be imposed on an Air Force fighter. The demonstrated difficulties of a joint project among the Services are too burdensome on a complex development program to be worth the apparent administrative simplicity of a single procurement. The Task Force does strongly recommend, however, commonality of many of the components and subsystems, such as engines, instruments, communications equipment controls, seats, actuators, ammunition, missiles, and other items of installed equipment.

2.2 Development Strategy

2.2.1 Competitive Prototype Development: The Task Force recommends prototype programs with a competitive "fly-before-buy" feature for airframe, engines and avionics. We feel that several advantages will accrue from this procedure as compared with the regular contract-definition approach:

. The Services will get a better product, because the contractors will be in a true competition where performance, not promises, determines the successful vendor. The contractors will tend

to keep their best people on the project through the entire competitive development.

. The government can encourage more innovation and bolder design approaches by individual participants in a competitive prototype program than would be wise in a single hardware-development program; and, at the same time, the overall program risk can be lower than in the single-source program. The probability that all contractors would fail is low.

. The time spent during a-competitive prototype phase can be largely, if not entirely, recovered in the overall program time to an operational capability, because the contractors' work on design, fabrication and test is inherently more productive than the paper work of contract definition.

. Similarly, the costs of the competitive prototype phase can largely be recovered (or cost savings could even result). The contractors will be trying harder; and they will be able to use soft tooling, which costs less and allows for rectification of design errors without the penalties in capital investment (and time) of hard tooling.

2.2.2 Separate Competitive Programs for the Major Subsystems: The Task Force recommends that separate competitive development programs, rather than combined team efforts, should be conducted for airframes, engines and avionics. The avionics development should include the interface with the ordnance systems.

2.3 Engines

2.3.1 Immediate Funding of Competitive Engines Programs: The Task Force recommends that competitive prototype development programs for engines—engines being historically high-risk development items—be funded with the two major contractors as soon as possible. It may be necessary, for adequate prototype airframe tests, to use the final engines (see section 2.4 on airframes) rather than substitute engines that are now available; thus, the engines could become the pacing items in the program.

2.3.2 Interchangeability of Engines: The engines from the two development programs must be interchangeable among the prototype airframes and between Navy and Air Force aircraft. The argument that the attachment points, plumbing, controls, etc., of the two engines will be different because "that's the way the manufactureres do it" is untenable. If the government is to spend many millions of

dollars on these designs, it has a right to insist that the engines be interchangeable.

2.4 Airframes

2.4.1 Agility and Other Basic Design Features: The Task Force recommends that the aircraft be designed to have those features that will make for an extremely agile high-performance fighter that can fight and win in visual close-in combat. These features include high thrust-to-weight ratio, low wing loading, outstanding cockpit visibility, excellent handling characteristics for maneuvering, advanced fire-prevention provisions, armor for pilot protection, and other vulnerability-reducing measures. Any compromises that would reduce the close-in fighting performance should be considered carefully. For example, high top speed should not be designed in at the expense of fairing the canopy so that visibility is poor. The emphasis on close-in fighting capability does not at all imply that this is the only air-to-air task for the aircraft. The Task Force recommends that an excellent capability for medium-range and all-weather air combat be included in the design.

Although there may appear to be some attractive tradeoffs between airframe agility and ordnance agility, the Task Force is recommending a highly agile aircraft for two reasons: The agility advantages of new ordnance have yet to be demonstrated and fully evaluated, and aircraft agility is needed for defensive maneuvering.

2.4.2 Number of Crew Members: The Task Force has chosen not to take a position on the question of whether there should be one or two in the crew, but has the following observations:

- Provision for the second man costs weight—5000 pounds increase in gross weight being a number often quoted if range and maneuverability are held constant.

- The second man would be necessary in the night all-weather ground-attack role, even with the improved sensors that present technology will allow. However, the Task Force feels that night attack using all-weather sensors is not a proper design mission for this aircraft and that justifying the choice of a two-place aircraft on this basis is questionable.

- Given no improvement over present air-intercept radars and displays, a second man is necessary to operate the radar in a tactical combat situation. A suitable air-intercept radar for the new

aircraft will need a substantial look-down capability. This implies coherent processing, with synthetic display. It should thus be natural to include automatic detection of airborne targets. A head-coupled display would allow automatic "head-up" acquisition of targets designated by a head-coupled sight (see section 2.5 on avionics).

. The above arguments lead to the conclusion that, if full capability for autonomous operations (i.e., operations by single aircraft unaided by GCI) with radar missiles is required for the aircraft, the proposed aircraft could be single-place with automatic detection of airborne targets and proper man-machine interfaces, and two-place without such aids. The advocates of the single-place aircraft should not make large production contracts until suitable avionics are demonstrated, if such autonomous capability is required. On the other hand, if degraded autonomous radar-missile operation is acceptable, with adequate-to-excellent radar missile operations when GCI assistance is provided, a single-place aircraft should be satisfactory without the full spectrum of automatic detection and head-coupled avionics.

2.4.3 Objectives of Competitive Prototype Airframe Programs: The Task Force feels that a prototype program with flying competition before source selection is needed for the airframes in order to:

. permit bolder design approaches to aerodynamic problems;

. provide increased certainty in deciding on design tradeoffs for the production versions chosen;

. provide demonstration of the relative success of the various contractor design groups in producing aircraft with good handling characteristics—a quality that is extremely important for an air-superiority fighter but difficult to specify or to evaluate in advance of flight testing.

With regard to the first of these objectives, it is the opinion of the Task Force that intensive effort should be given to high-lift devices, such as maneuvering flaps, to permit the aircraft to benefit from high agility during combat without suffering to the normal extent from the range and/or maximum speed penalties induced by a low-wing-loading configuration. Advanced canard configurations, as used on the Swedish Viggen, should also be investigated.

2.4.4 Flight Testing with Substitute Engines: The Task Force was informed by several witnesses that the procedure of flying prototype aircraft with other than the final engines could be wasteful because

it may not be possible to extrapolate from the data obtained and that it may be essential to conduct at least part of the flight tests using the final engines. We also note that there is a body of opinion to the effect that very useful testing can be done with substitute engines.

We recommend, therefore, that the competitive prototype-airframes development program be initiated immediately and pushed vigorously, and that the potentialities of flight-testing aircraft designed for the final engines but using substitute engines available earlier (e.g., J-79 or TF-30) be studied carefully during the prototype-airframe lead time.

2.5 Avionics

2.5.1 Airborne-Intercept Radar: This radar should have a substantial look-down capability. The present state of the art implies a high-PRF pulse-doppler radar, although the Services should be encouraged to explore the various large time-bandwidth-product schemes. It should also have a ground-mapping mode. This implies a low-PRF mode. The present state of microwave tubes is such that it might be preferable to put in both a magnetron for the low PRF and a traveling-wave tube or crossed-field amplifier for the high-PRF mode. A high-powered X-band magnetron and modulator package can be had these days for modest dollar cost and 35 to 40 pounds weight. The dual transmitter would have several advantages: The radar would be more difficult to countermeasure; if one tube failed, the radar would still have an operating mode; for tail-on attack, the high-power, low-PRF mode would probably give better detection and tracking. The radar should be a 4-lobe monopulse horn-fed metal parabola or possibly a gimbaled phased array, but not an electronically scanned beam. If the radar is to be used in a single-place aircraft, it should be capable of being pointed with some system such as the head-coupled avionics system (to be discussed in section 2.5.6) and should be capable of acquiring automatically.

2.5.2 Tail Warning Radar: A good case can be made for the usefulness of a tail warning radar if the weight penalty is not too great. The major part of the weight in such a radar is in the transmitter section. The need for the warning radar is the greatest when these aircraft are flying slowly, escorting a group of strike aircraft, or are themselves on a strike mission. It seems reasonable to the Task Force that one or two of these aircraft could use the transmitter power and the doppler processing circuitry of the forward-looking radar in conjunction with a rearward-looking scanning antenna. This would require only the addition of a waveguide switch and a run of waveguide

to the aft antenna. It should be noted that tail warning radar may not provide coverage at ranges greater than the distance to the nearest terrain.

2.5.3 Penetration Aids: Provisions should be made for penetration aids. The rapidly changing technology of surface-to-air missile guidance and ECM in general argues against calling out specific equipment, but it does indicate that weight and volume provisions should be made for such equipment.

2.5.4 Navigation Equipment: A reliable, accurate, and flexible navigation system is essential to reduce pilot work load and to allow high confidence target acquisition in the attack role. A LORAN-inertial system employing part of a redundant digital computer complex is a desirable approach, and a satellite radio-navigation system could replace the LORAN if it becomes available. A competitive program should result in LORAN-inertial systems of acceptable cost. Doppler navigation should not be incorporated. Proper presentation of navigation data (not numerical readings) is essential if the best use is to be made of the investment.

2.5.5 Other Avionics: The aircraft must have the normal functions of UHF radios, TACAN, ILS and other gear required for normal operational use. A provision should be made to allow spread-spectrum coded voice communications to minimize jamming. The development of an integrated communications, navigation and identification system (ICNI) should be seriously considered for these aircraft.

2.5.6 Head-Coupled Avionics: The Task Force was very favorably impressed by the progress reported by the Army and others in developing head-coupled sights and displays. It seems clear that, with head-coupled avionics, many fleeting opportunities to acquire targets that would be lost if conventional acquisition techniques were used could become effective opportunities for weapon launch. It also seems clear that head-coupled avionics would greatly reduce the pilot's work load. Among the possible uses in air-to-air and air-to-ground operations would be the following, all in a head-up manner:

. directing video contrast (electro-optical) trackers so that they can lock automatically on the target for such functions as aiming a guided gun, and then monitoring the performance of the trackers;

. pointing the radar antenna for automatic lock onto an aircraft seen visually by the pilot but not yet "seen" by the radar;

. viewing air-intercept radar video and designating targets;

. viewing through high magnification forward-looking (and perhaps rearward-looking) TV units to identify targets visually;

. viewing video ground-map presentation;

. viewing Walleye or other missile video presentations and directing the tracking gate;

. viewing gyro-horizon and other flight-control data.

The members of the Task Force are enthusiastic about the potential tactical advantages of the head-coupled avionics; and we strongly recommend that each of the Services devote sufficient resources to investigating and testing this concept so that, barring unforeseen difficulties, head-coupled avionics may be incorporated as the primary display system.

2.5.7 Man-Machine Interface: Design and location of switches and displays, both panel-mounted and head-coupled, should be a key part of the avionics development competition. It is recommended that the results of the extensive Navy study for the A6 aircraft be examined carefully. Particularly worthy of study are the contract-analog situation display and the gauge design wherein the needles all line up when the situation is normal. By contrast, the A6 study showed that digital readouts require the eye to recognize the number and the brain to compare that number to the normal or recommended number. The analog system, wherein the needles all line up merely requires one scan of the pilot's eye and recognition of a simple geometrical pattern.

2.5.8 IFF: The Task Force did not consider the design of IFF equipment but does note that the long-range air-intercept radar and missiles to match will be distinctly limited in utility unless a usable and trustworthy IFF system is evolved. We do recommend incorporation of a stabilized and tracking electro-optical TV recognition system. Consideration should not be limited to individual IFF, since theater air-traffic control and communications have much to contribute to solution of this problem. In particular, if AWACS is a serious development program, then secure communications, data link and display must be included in the new fighters in order to work with AWACS.

2.6 Air-to-Air Armament

2.6.1 Types of Ordnance: The Task Force recommends that the aircraft be equipped with three types of air-to-air ordnance.

- internal gun(s)
- medium-range (≳ 20 nautical miles) missile
- short-range missile

Prior to design freezing, the latest available test and design data should be used in deciding the specifications for the specific items of ordnance.

2.6.2 Gun(s): An internal, forward-firing gun is needed for close-in air combat and for strafing. The Task Force feels that a major improvement in air-to-air gunnery can be achieved via an automatically directed gun, trainable through about 20 degrees in elevation (say, -2 degrees to +18 degrees) and a few degrees (say, ±2 degrees) in yaw—a "guided gun" of the type now under consideration for an Air Force test program. The Task Force recommends that a forward-firing guided gun be tested during this Calendar Year, using primarily off-the-shelf components, including an electro-optical tracker for guidance. A decision as to whether the guided gun is applicable and desirable for the next fighter aircraft should be made as soon as the results of such tests are available. A conventional fixed gun should be installed if the guided gun is not chosen.

2.6.3 Medium-Range Missile: A medium-range missile is required for the fleet defense role and for Air Force missions where a GCI environment (or AWACS) is available or where there is no doubt that the target is hostile. The present Sparrow III (AIM-7F) or a growth version would be suitable for this task.[1]

2.6.4 Short-Range Missiles: A new highly maneuverable missile to cope with the close-in combat situation is highly desirable. The Task Force recommends that two types of short-range missiles be developed and tested: one with semiactive radar guidance and one with infrared or electro-optical (TV) guidance. Seeker gimbal and fire-control flexibility should permit pre-launch lock-on to targets up to 40 or 50 degrees off the nose of the launching aircraft. As new missiles

[1] It is not clear to the Task Force why a separate illuminator for the Sparrow missile must be provided when the central spectral line of the high-PRF pulse-doppler transmitter would be suitable and has adequate power.

with demonstrated capability become available, they should be incorporated or retrofitted into the design.

2.6.5 Rearward-Fired Ordnance: The Task Force is not unanimous on the utility of rearward-fired ordnance, either guns or missiles. This ordnance might have great utility but will certainly add weight and complexity. Its development will require the solution of some significant problems in sensors, fire control, airframe design, and system integration. The problems involved are not altogether different in kind from those associated with developing new forward-firing guided guns or missiles, but appear to the Task Force to be more difficult of solution. A careful and unbiased analysis should be made, based on experiments.

2.6.6 Flechettes: The Task Force recommends that the work being funded by the Air Force at Eglin on flechettes be studied carefully by both Services. The Task Force feels that this high average velocity and long range could be vital in making guns more useful air-to-air weapons. The Task Force recommends continued support of this effort.

2.7 The Ground-Attack Role

2.7.1 Design Requirements for Ground Attack in Relation to the Overall Design: The primary mission of these aircraft is that of air superiority. It is clear, however, that they should be useful in a ground-attack role. This is particularly true in the case of a Navy fighter because of the limited deck space on an aircraft carrier. Aircraft with the power and wing loading required for successful close-in air combat should be able to carry a very useful air-to-ground ordnance load. The survivability provisions recommended should make it better than any of the present aircraft in terms of getting home after suffering hits.

If enemy defenses are as effective at night as in daylight then attacked on fixed targets should be performed during the day. However, if enemy fighters continue to lack a look-down capability and much of the enemy's surfaced-based defenses continue to be visually aimed, our attack aircraft may survive much better at night. The new aircraft can be equipped with podded laser target designators and laser-homed bombs, or other effective night-attack equipment, when they are used in this role.

What the Task Force is recommending, then, is a fast, tough fighter that can carry a full load of bombs on a day attack mission and

fight its way out after delivery. It is likely that the new fighter can serve as the basis for a family of aircraft, derived by modification of the basic air-superiority machine.

2.7.2 Bombing Accuracy: It is mandatory that better bombing accuracy be obtained. Several schemes are being worked on, among them are the Angular-Rate Bombing System at China Lake and the laser rangefinder and bombing computer at Hughes. These systems hold great promise and should be watched with interest as candidates for incorporation in the new aircraft, if tests indicate their utility. They are, however, in competition with Walleye and with laser-homed bombs, which have demonstrated much better accuracy and which must also be included.

2.7.3 Standoff Weapons: It is clear that many targets are so heavily defended that they cannot be dive-bombed without unacceptably high attrition. It is here that the Walleye, Condor and similar standoff missiles will become extremely useful; thus, the aircraft should be capable of launching these weapons. Missiles such as semiactive laser homers and hyperbolic guidance schemes using loran principles are under study at several laboratories. As their capabilities are demonstrated in flight tests, they also should be considered for use on the new aircraft.

Adequate target-marking systems must be developed, including lasers and artillery-emplaced microwave beacons.