"WE'RE on the threshold of something marvelous in aviation. The era of the starfighter is upon us. I'm not talking about technologies of the year 2100. I'm talking about technologies that are with us right now."

Lt. Gen. William E. Thurman, Commander of Air Force Systems Command's Aeronautical Systems Division at Wright-Patterson AFB, Ohio, made that statement not long ago in reference to AFSC's role in developing the hypersonic National Aerospace Plane (NASP), a joint undertaking of the Defense Department and the National Aeronautics and Space Administration in which ASD has much of the action.

General Thurman's context was much broader, though, in the sense that the work on the aerospace plane does not stand in splendid isolation from all else that ASD is doing or has ever done in developing modern, high-performance combat aircraft for the Air Force.

The NASP promises to be a breathtakingly unprecedented flying machine, at home in air or space, streaking through the upper atmosphere at twenty-five times the speed of sound or thereabouts, its airframe, engines, and avionics integrated into a coherent system of thoroughly interdependent elements.

For all its potentially peerless attributes, the NASP will not emerge as a technological creature wholly alien to the aeronautical world as we know it today. Its technologies will have filial connections to those of the fighters of this generation and the next.

The F-15, more than a decade in service and still the best air-superiority fighter in the world, heads the family. Its latest variant, the F-15E dual-role fighter newly in production, will do both the air-to-ground and air-to-air missions behind enemy lines better than any US fighter ever.

The F-16, singularly adept at ground attack and no slouch in the air-to-air regime, either, has demon-

This generation of fighters and the next lead naturally into development of the true aerospace plane.

Era of the Starfighter

"The era of the starfighter" has been inaugurated by the program to develop the National Aerospace Plane (NASP), a hypersonic flying machine for air and space. (© Keith Ferris 1986)

BY JAMES W. CANAN, SENIOR EDITOR

strated that "smaller" is no longer synonymous with "lesser" in terms of fighters' combat ranges.

Late last October, USAF decided to modernize its air defense fighter force with modified F-16As already in service in tactical squadrons. Their combat-range capability was an important consideration in their selection over the competing F-20, Air Force officials said.

The F-16As destined for conversion to the air defense mission will be replaced in ground-attack squadrons by the newer, more capable, and more versatile F-16Cs. They and the F-15Es will eventually be equipped with the Low-Altitude Navigation and Targeting Infrared for Night (LANTIRN) system that ASD has escorted through some technological thickets to the point of full-scale production. *(See also "Fighting Around the Clock" on p. 52 of this issue.)*

Next comes the Advanced Tactical Fighter (ATF), the apple of ASD's eye and legatee of just about everything ASD and its contractors have learned in creating and improving the F-15 and the F-16.

Northrop (teamed with McDonnell Douglas) and Lockheed (teamed with General Dynamics and Boeing) were chosen last October by USAF to build two ATF prototype aircraft each. Prototypes will be flying two years from now.

All these fighters are the NASP's progenitors. The NASP's technologies of fuels, engines, structural materials, aerodynamic shapes, avionics, and—perhaps most importantly—systems integration will have had their origins, however brightly or dimly, in ASD's work on the technologies of the F-15, the F-16, and the ATF.

Among innumerable examples of this are the research programs of ASD and its contractors on high-strength, heat-resistant alloys and cooling techniques for advanced fighter engines, on nonmetallic materials for engines and airframes, on the integration of aircraft avionics, on the use and integration of experimental aerodynamics and avionics as in the Advanced Fighter Technology Integration (AFTI)/F-16 and X-29 forward-swept-wing aircraft programs, and on variable-camber wings as in the AFTI/F-111 program.

AFTI/F-111 officials at ASD claim that the F-111s on the Libya raid of last April could have been back home an hour earlier, or could have forgone two of their aerial refuelings, had they been equipped with the mission-adaptive wings (MAWs) now being successfully tested in the ASD program.

Among other ASD projects germane to the development of the ATF and probably to the NASP as well are those on very-high-speed integrated circuits (VHSIC) as part of the rapid advances in microchip technology, on software that is so important to the automation of aircraft, on cockpit technologies that enable pilots to take full advantage of such automation, and on artificial intelligence (AI)—a technology that General Thurman says "is becoming synonymous with advanced aeronautics" and that ASD is just now beginning to get in hand.

The NASP's developers will borrow from ASD's books on all these projects. Moreover, it is likely that the NASP program itself will contribute technological insights to other ASD programs, most notably to the ATF program somewhere along its way into the twenty-first century.

There are those who say that the advent of the presumably world-beating NASP will mean the end of fighters as we know them today and that the ATF will be the last of their long, evolutionary line.

Rearranging the Molecules

ASD is taking nothing for granted in this regard. Its laboratories are nurturing technologies applicable to both the NASP and the ATF programs, but they are also continuing to pursue technologies that may someday apply to flying machines not yet envisioned.

For example, ASD's Aero Propulsion Laboratory and Materials Laboratory are looking beyond the ATF in their research on highly advanced turbine engines and on exotic materials, respectively, for superswift jet aircraft that would not necessarily transcend the atmosphere in the manner—or with the hybrid rocket/scramjet air-breathing engines—now planned for the NASP.

Both laboratories are in the business of rearranging the molecules of Mother Nature's chemical elements. Their goals are endothermic "designer" fuels that will absorb heat rather than give it off and materials of enormous strength, of malleable ductility, and of mighty resistance to heat.

Such materials and fuels would be an unbeatable combination in the powerplants of high-performance aircraft, and the materials could be made into aircraft skins virtually impervious to heat and stress.

In one portentous project, the two laboratories are working together, as an Aero Propulsion Lab paper puts it, "to demonstrate a revolutionary advancement in turbine engine technology through the 1990s."

Their goal is to devise fighter engines capable of doubling the thrust-to-weight ratios of the engines now being developed by General Electric and Pratt & Whitney, also in prototype-construction competition, for the ATF.

Those ATF engines will greatly surpass the engines of the F-15 and the F-16 in terms of their thrust-to-weight ratios measured at supersonic speed and high altitude. They will enable the ATF to cruise supersonically over long distances without using fuel-gulping afterburners, an impossibility with existing fighter engines.

All such advances in the propulsion world will lead to dramatic improvements of USAF's warfighting prowess.

"We're not going to be range-limited any more," General Thurman asserts. "We'll be able to pack much more energy into fuels. This has tremendous implications for aircraft designs."

Among other things, it means that "our younger officers, in their career lifetimes, will probably see airplanes the size of F-15s going in and out of space," the ASD Commander asserts.

ASD itself is on afterburners in preparing for this and for more in the aeronautical arena.

"We've never had a better research program in our labs, and we're focusing our lab efforts on applied research," General Thurman explains. "There's a new excitement, a vibrancy, at Wright Field, because our people are working directly on the technologies that we'll need in the airplanes we're going to field in the coming decade and in the early years of the 2000s."

The principal draws upon those

Lt. Gen. William E. Thurman, Commander of Aeronautical Systems Division, reflects the upbeat spirit at ASD, now in its "glory days." Here, he checks out a cockpit-design engineering device configured for LANTIRN system technology.

technologies are the NASP program, the ATF program, and the Strategic Defense Initiative (SDI) program, in which USAF is a featured player.

General Thurman calls these programs "huge technological kickers" and includes among them, as well, the VHSIC program and the Air Defense Initiative (ADI) program that USAF sees as a necessary complement to SDI.

Serving as clearly delineated aimpoints for ASD's scientists and engineers, all such programs "give us focus for what in the past we always saw through a glass darkly," General Thurman declares.

ATF Avionics Integration

A prime example of how ASD's major systems development programs are now enfolding technologies once confined to its laboratories is that of avionics integration in the ATF.

ASD's Avionics Laboratory has worked for several years on the Pave Pillar program, in which its contractors defined a generic architecture for the automation and integration of aircraft avionics subsystems—combining, for example, fire controls and flight controls, along with navigation systems, electronic warfare systems, propulsion controls, radars, and cockpit controls and displays.

This program encompasses the Avionics Lab's development of the Integrated Communications, Navigation, and Identification Avionics (ICNIA) system, a project aimed at combining into a single, highly reliable radio all of the variegated communications that modern combat aircraft must rely on and manage.

Lockheed and Northrop now head contractor teams competing in the development of the Advanced Tactical Fighter (ATF), as depicted by a Lockheed artist. The ATF program, a blue-ribbon ASD endeavor, is centered on construction of airframe, avionics, and engine prototypes and is scheduled to eventuate in an operational ATF around the mid-1990s.

The Avionics Laboratory completed the design specifications for the Pave Pillar system and has now handed it over to the ATF program office for development and incorporation into the fighter.

The eventual extent of such incorporation will be determined in the competition between the two ATF contractor teams. Each has been assigned by the Air Force to build and test ATF avionics-suite prototypes along with—and apart from—their aircraft prototypes.

"It may take longer to bring on the avionics prototypes than it will to bring on the airframe and engine prototypes," General Thurman says. "Avionics may turn out to be the long pole in the [ATF] tent."

ASD's experience with the B-1B bomber taught it not to take for granted that a new aircraft's avionics will need less time in development, solid advances in microchip technology notwithstanding, than will its airframe and engines.

In the B-1B, says General Thurman, "we packed all the offensive avionics in the front of the airplane and all the defensive avionics in the back and expected it all to work together when we turned on the switches."

Instead, it turned out, for example, that some of the bomber's transmissions were picked up by its receivers. This entailed rearrangements and better integration of its avionics systems.

Regarding the transition of technologies into systems, some Air Force officials are concerned that the major, blue-ribbon systems programs at ASD are preempting altogether too many of the laboratories' advanced development projects, perhaps prematurely. Some also fear that the Air Force, in its increasing emphasis on applied research amid a budget crunch, is drifting away from basic research.

Both trends threaten the labs and, in consequence, their development of the technologies that USAF will need for far-future systems distinct from those now soaking up technologies and resources, such critics claim.

General Thurman doesn't buy it. "We're spending more money on basic research at ASD than we ever have," he declares.

The General also notes that ASD is responsible for working up nearly three-fourths of the seventy advanced technologies and advanced systems concepts that AFSC's Project Forecast II study selected as having the potential to "revolutionize the way the Air Force carries out its mission in the twenty-first century, guaranteeing continued technological supremacy over any potential adversary."

Thanks to Forecast II

Keith Collier, ASD's deputy for development planning, tips his hat to the Forecast II study for having "provided us with a very rich set of identified technology potentials." His shop is mating Forecast II's technologies and systems concepts with what it perceives to be USAF's future requirements for them in terms of missions and is reshaping its studies accordingly.

Among the topics of such studies are cruise missile defense, nonnuclear strategic forces, unmanned systems, and "mission/flight systems integration, which anticipates that the next-generation avionics integration will be an order of complexity out beyond that of the ATF," Mr. Collier says.

Forecast II lends leverage to all this. AFSC's commitment to solid support and funding of the development of Forecast II technologies and systems bodes well for USAF's research community and should not be taken lightly, General Thurman claims.

"We're in the glory days of ASD right now," the General asserts. "On just the white [unclassified] side, we have more aircraft programs than we've ever had—the NASP, the ATF, the F-15E, the F-16C and D, the air defense fighter, the C-17, and the T-46 [trainer] or some variant of it, depending on how the Air Force decides to go."

The F-15E is now virtually a bird in hand. The first dual-role fighter, its engines and cockpit displays somewhat at variance with those of the production-line F-15Es that will follow, was scheduled to roll out last month at the McDonnell Douglas plant in St. Louis, Mo.

Production of the F-15Es will proceed at a measured pace, centering on five test-bed models, through most of 1987, and will start hitting its stride about a year from now.

The Air Force plans to buy 392 F-15Es for four operational wings and one training wing well into the 1990s. Destined for the demanding deep-interdiction mission, they are expected to be superior in many ways to the F-111s that they will replace over the next four to six years—most especially, perhaps, in their ability to fight their way out of trouble in air-to-air combat.

The F-15E's dual-role versatility has been put to the test in the fighter's simulator at McDonnell Douglas.

Col. Roy B. Marshall III, chief of the projects division of ASD's F-15 program office, recalled that it was "impressive how quickly we could go from air-to-air to air-to-ground" in that simulator.

"As we were going into the target, the simulator operators brought up a MiG-23," Colonel Marshall said. "We got radar contact, negated the MiG-23, went back down in the weeds, and continued our bombing attack. We were satisfied."

Optimally, each F-15E would carry four radar-guided, launch-and-leave AIM-120A Advanced Medium-Range Air-to-Air Missiles (AMRAAMs) and four infrared-homing AIM-9L Sidewinder missiles.

Colonel Marshall and Lt. Col. Edward J. Atkins, the F-15E program manager at ASD, acknowledge that some work needs yet to be done on making the fighter's avionics gear compatible and on integrating its software in a timely manner.

The F-15E will be "software-intensive," loaded with digital, programmable avionics, including the Joint Tactical Information Distribution System (JTIDS) and the Tactical Electronic Warfare System (TEWS).

The integration of all such systems is by no means easy, but "we don't see any real show-stoppers ahead," Colonel Marshall says.

Prospects for the F-15E

Powered either by P&W F100-220 engines or GE F110 engines, the F-15Es will be built for the carriage of conformal fuel tanks to give them the range they will need for their far-ranging interdiction forays beyond enemy lines.

The 81,000-pound (fully loaded) F-15E's range and advanced avionics will enable it to do something that the 68,000-pound F-15C was not built to do in the air-to-air regime, namely, to escort ground-attack fighters beyond the Forward Edge of the Battle Area (FEBA).

The ATF was designed from scratch—in its propulsion system, aerodynamics, and avionics—to do just that, without conformal fuel tanks, and to do it far better.

Cockpit technologies are at their contemporary zenith in the "missionized" forward and aft crew stations of the F-15E.

The front cockpit has two monochromatic displays, one color display, and one wide-field-of-view, holographic head-up display (HUD). The rear cockpit has two color displays and two monochromatic displays. All displays in both cockpits can show the fighter's attitude, altitude, and airspeed, plus information pertaining to its armament, forward-looking infrared (FLIR) navigation, radar altimeter, terrain-following radar, fire-control radar, and communications systems. A voice warning system will alert the crew to danger when the fighter dips down too low.

By mid-1988, the F-15E will be the only variant in production. Production of the F-15Cs and Ds, now entering its final phase, will have ended.

All USAF attack aircraft will benefit from ASD's AFTI/F-16 program. F-16Cs are being equipped with flight controls that the program has successfully tested, and the F-15Es will draw from its avionics innovations to some extent.

Such improvements, with more to come in the operational Air Force, will make it easier for F-16C pilots to handle LANTIRN, for example. Moreover, it is no stretch of the imagination to assume that AFTI/F-16-induced advances in digital, fly-by-wire flight controls, in aircraft maneuverability, and in a host of cockpit technologies, such as voice controls and voice warning systems, will find their way into the ATF and even—in forms much farther advanced—in the starfighters of General Thurman's foreseeable future.

Easing the Tough Tasks

In its current phase, the AFTI/F-16 program is concentrating on trying out the Automated Maneuvering and Attack System (AMAS) to ease the tough tasks of low-flying attack pilots.

Among the integrated technologies involved in AMAS are an IR sensor/tracker that provides precise target information with respect to the aircraft's position, a digital weapons interface called "standard avionics integrated fuzing" because it enables the fire-control system to fuze weapons automatically just prior to their release, and cockpit displays of terrain maps that are projected both on film and by means of digital electronics.

At this writing, AMAS features have been tested in nearly 200 flights of the AFTI/F-16. One of those features, a ground collision-avoidance system, has been validated while turning at five Gs at 200 feet, a bomb-run maneuver that the AFTI/F-16's qualities of aerodynamics and avionics can handle with hardly any sweat.

The AFTI/F-16's combination of terrain-avoidance and digital terrain-mapping systems may well turn out to be the biggest boon ever for such hill-hugging attack aircraft as the F-16Cs and the F-15Es.

The Marines and the Army—and the British, too—are interested in the AFTI/F-16 digital terrain management and display system's potential for improving their night-attack capability.

"The great thing about the system is that its data doesn't become obsolete," says Lt. Col. Donald H. Ross, ASD's AFTI/F-16 program manager. "They're not going to blow away the hills that we have on our digital maps."

Despite its successes, the AFTI/F-16 program, at this writing, is facing a severe drawdown and maybe even the termination of its funding at the hands of the Air Force.

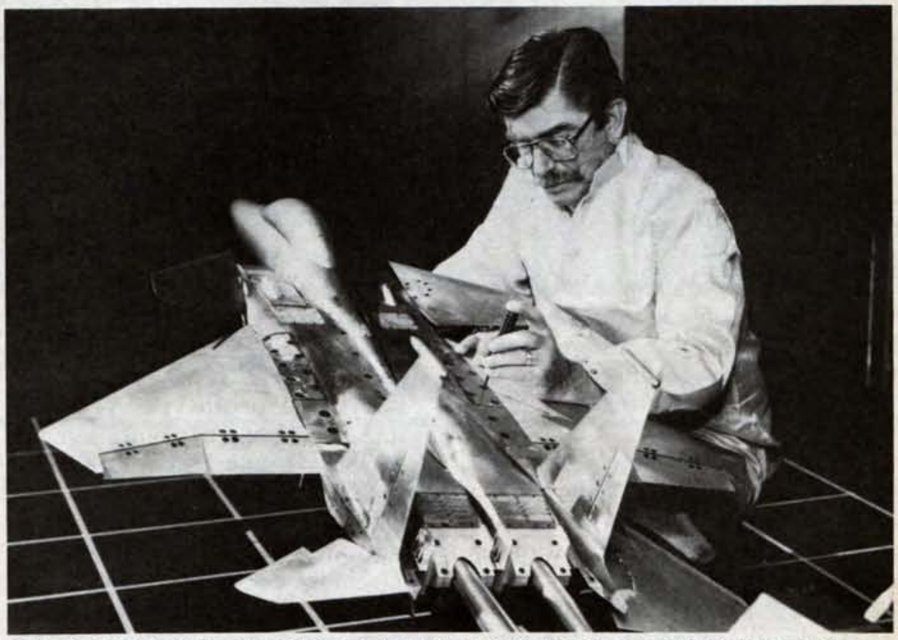
This is also true of the AFTI/F-111 program for testing the mission-adaptive wing.

That program has demonstrated that variable camber wings have the potential to make a major difference in flight efficiency and maneuverability and that such wings have a place in the Air Force's operational future. However, the program has not progressed to the point where the wings on the test-bed F-111 are controlled in the fully automatic mode.

Such testing is scheduled to begin in a few months. It may be curtailed for lack of funding, however, to the regret of program officials. "We're really just scratching the surface of what we can do with the MAW system," says Ron DeCamp, ASD's AFTI/F-111 program manager.

It is possible that both AFTI test programs have already contributed just about all that they need to contribute, for now, to USAF's understanding of the technologies they have explored. Now it may be time for USAF to concentrate on those technologies in a more pragmatic manner, namely, in the ATF program, some officials believe.

The AFTI/F-16's spin-off for the ATF seems clear and substantial. Less clear is the spin-off to be expected from the AFTI/F-111 program.



A McDonnell Douglas technician adjusts the wind-tunnel model of the F-15 short-takeoff-and-landing (STOL) and maneuvering demonstrator aircraft being developed by the company for ASD. It is scheduled to begin test flights in early 1988.

Applying the Lessons Learned

USAF wants the ATF to be capable of relatively short takeoffs and landings, given the wartime prospect of damaged runways in operational theaters. Consequently, the ATF designers will probably draw from lessons learned in yet another blue-ribbon ASD program, one that will demonstrate "STOL and maneuver technology" in a test-bed F-15 that is moving closer to production.

The ATF's engines are expected to be capable of reversing and vectoring their thrust in order to enhance the aircraft's maneuverability as well as to give it STOL capability. The key to this will be engine nozzles of the type to be tested on the F-15 STOL demonstrator aircraft.

Pratt & Whitney, one of the two competing ATF engine contractors, will supply two of its F100-220 engines for the modified F-15 and is now building the nozzles to go with those engines, with ground-testing of the whole system scheduled to begin later this year.

P&W expects that its nozzles will be capable of vectoring thrust as much as twenty degrees up or down.

GE, too, is involved in the STOL test-bed aircraft program. Its work has to do with coupling the controls of the thrust-vectoring nozzles and the canards with the conventional flight controls of the F-15, thereby making it possible for the pilot to handle the whole affair as a package of controls, not as controls in isolation from one another.

Among other technologies to be tested aboard the aircraft will be a STOL "mode guidance" system (featuring cockpit displays that will show the pilot the best pathway for landing on a bomb-damaged runway), a low-visibility, precision-touchdown system, and a landing gear system that couples nosewheel steering and braking controls with flight controls and thrust-reversing controls.

The demonstrator aircraft is expected to be capable of taking off from a 1,500-foot runway with full internal fuel and a 6,000-pound payload and of landing in that distance or less in the rain, under a 200-foot ceiling and crosswinds of up to thirty knots, with half-mile visibility and no landing aids.

Its radar and inertial navigation system will enable it to make such landings in daylight. For night landings, it will be equipped with a LANTIRN navigation pod and HUD.

"By the end of this year [1987], all flight units should have been delivered, and we will begin installing them in the airplane on our way to meeting our first flight date in April 1988," says David Selegan, who is ASD's deputy manager of the program.

"We are very fortunate," Mr. Selegan continues, "in that everyone involved in the program has put first-class people on it—first-class not only technically, but also socially. That's a big, big factor in this program because it's an integration program. We have broken ground in the relations between engine and airframe contractors and subcontractors that's never been broken before, because our integration of everything—such things as the landing gear with the flight-control system—has never been done before."

Hallmark of the ATF

Such integration will be the hallmark of the Advanced Tactical Fighter. The prototyping approach to its airframe, engines, and avionics as separate entities prior to final assembly of the competitive ATF flying machines should provide clear perspective, from the standpoint of actual hardware, on how to put them all together.

"The prototyping approach has changed the program in several ways," explains Col. Albert C. Piccirillo, the ATF program director. "We'll have prototype ATF airframes and engines flying almost two years earlier than originally planned."

The idea in the beginning, since abandoned, was to have several contractors compete on paper and with isolated hardware and then to choose one of them to build an ATF model for flight demonstration and testing.

As of now, ASD plans to have both the Lockheed-Boeing-General Dynamics YF-22A ATF prototype and the Northrop-McDonnell Douglas YF-23A ATF prototype flying by the end of 1989.

"The flight prototype will be a major part of the program," Colonel Piccirillo explains. "We need flight testing to demonstrate the proper balance among the critical ATF characteristics of supersonic cruise, high maneuverability, low [radar and IR] signatures, and excellent fighter handling qualities prior to pinning down the design for full-scale development and production."

ASD's Advanced Fighter Technology Integration (AFTI) F-16 heads out for yet another test of its highly sophisticated flight-control avionics and cockpit technologies. AFTI/F-16 innovations are being incorporated in current production fighters and will show up heavily in the avionics of the ATF.

All this will be mighty challenging. General Thurman's thoughts on it are as follows:

"In the past, the trade-offs were relatively simple. Questions of maneuverability, size, range, and speed could all be analyzed in the context of propulsion systems and aerodynamics.

"Now, we have to look at performance—maneuverability—against low observables. They aren't mutually supportive. The things you do to increase maneuverability may not be the things you do to lower your observables. The design team can't just say we're going to make the fighter highly maneuverable by putting a great big tail on it.

"So the problem of designing a fighter these days is tremendously complicated."

The saving grace in all this is the computer. "Computer power allows us to analyze those trade-offs and make them work," General Thurman says. "The exciting thing to me, as an old aerodynamicist, is to go out to an aircraft design shop and watch as they put their designs together on a big screen, with a computer.

"They lay down a design, and someone sitting there, maybe from the manufacturing side of the house or the maintenance side, says, 'Hey, you can't do that, because the airplane would be tough to build or to keep in shape.'

"Then they change it, move the lines around on the screen, and they say, 'There, how about that.' Someone says, 'Well, I want to make this little aerodynamic change right there,' and someone else says, 'Hold it, what are the implications of that change on the observability—the radar cross section or the IR cross section—of the aircraft?' "

This sort of computer-generated dialogue and teamwork, as it were, "now allows us to get an F-16C with superb performance and ninety-five percent availability," General Thurman adds.

Three Types of ATF Prototypes

The development of all three types of ATF prototypes—airframe, engines, and avionics—will tell the Air Force a great deal about how to make the trade-offs and still come up with a fighter of great speed, maneuverability, and range and of low radar and IR cross sections.

The avionics prototypes "will be just as important as the flying prototypes," Colonel Piccirillo declares, adding that they "will be ground-based at first, and they'll take into consideration the insertion of new technologies, such as VHSIC, using a common-core architecture and distributed processing. Later in the program, both contractor teams will be flying their avionics prototypes in large, airliner-type test-beds."

Centered on all its prototypes, the ATF program's design demonstration/validation phase should take about four more years, and then the fighter will proceed—with the winning contractor team having been selected—into full-scale development on the way to production and operational service around the mid-1990s.

The initial, demonstration phase of the program will require an Air Force expenditure of about $2.5 billion; the full-scale development phase, about $7 billion; and the production phase, about $35 billion for 750 of the fighters, according to Thomas E. Cooper, Assistant Secretary of the Air Force for Research, Development, and Logistics. All prospective expenditures are quantified in terms of the buying power of the dollar in Fiscal Year 1985.

Dr. Cooper sees the integration of the ATF's avionics as the program's biggest challenge, but also regards it as holding the promise of "tremendous payoff."

The engines being developed for the ATF are already well along and are "the pacing items in the prototyping program," Colonel Piccirillo says.

ASD anticipated that the ground-demonstration version of the GE YF120 engine for the ATF would be up and running by the first of this year. The Pratt & Whitney YF119 engine ran for the first time last October.

Both powerplants are in large measure the products of technologies developed in the ASD Aero Propulsion Laboratory's Joint Advanced Fighter Engine (JAFE) program over the past few years.

That program has been folded into the engine portion of the ATF program itself. But this does not mean that the Aero Propulsion Lab has gone out of the business of developing advanced fighter engine technologies, not by a long shot.

"We're out to double the thrust-to-weight [ratio] of the ATF-generation engines—and to maintain the same level of reliability—by the year 2000," asserts Walker Mitchell, deputy director of the Aero Propulsion Lab. "Our technology program is embedded in Project Forecast II—we're a big player in that—and it is much broader than just looking forward to the next ATF. We're looking at hypersonic airplanes and missiles, among other things."

Endothermic fuels are a major consideration in all this. They are being researched in the lab's aviation fuel technology program, and they have enormous implications for air-breathing engines of the future.

"We call them designer fuels," Mr. Mitchell explains, "because we're rearranging molecules to get the characteristics that we want out of them. They absorb heat instead of giving it off."

In connection with this, high-performance aircraft and missiles may one day burn gaseous hydrogen compounds instead of liquid fuel, Mr. Mitchell says.

This is feasible in turbine engines, he says, "because they don't care what they're burning."

The laboratory is involved in a number of technology programs under the heading of "high-speed propulsion." They are aimed at "rapidly developing an Air Force capability for high-speed flight, including turboramjet engines for Mach 5 interceptors, hydrogen-fueled engines for hypersonic cruise vehicles or space boosters, and new engine options for high-speed missiles."

One of the lab's aspirations is a supersonic combustion ramjet (scramjet) engine of the sort slated for the National Aerospace Plane.

Hand in hand with the Aero Propulsion Lab's endeavors are those of ASD's Materials Laboratory. The lab is in pursuit of "intermetals," such as titanium aluminide, and, farther out, of carbon/carbon materials and ceramic composites that would far surpass today's composites and superalloys in strength and resistance to heat.

"Nickel-based superalloys are the backbone of turbine engine technologies," explains Larry Hjelm, assistant chief of the Materials Laboratory's metals and ceramics division. "They date back to the early 1950s. Incremental improvements in them have allowed us to double the thrust-to-weight ratio of fighter engines, but we can't take them any further, so we're looking for alternatives."

Titanium is one such alternative, but it is much too costly. Fused with aluminum in titanium aluminide intermetals, it becomes inexpensive enough to buy, in relatively small quantities, for engine components and for airframes.

The intermetals can stand temperatures that far exceed the melting points of titanium itself, let alone the melting points of nickel-based alloys.

The Materials Lab is also exploring the rapid solidification of aluminum and of other metals to make their molecules reform in unnatural, stronger patterns.

All such work is being driven by ASD's "activity in hypersonics," Mr. Hjelm says. Such activity "will carry our work along well past the aerospace plane," he adds, "and we expect to get some benefit from the NASP program." ■