

ASD is translating aeronautical technology into combat capability.

Coming On and Coming Up

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YOU'RE an F-16 pilot in Europe. You hear all the ballyhoo about the forthcoming wonders of the new avionics system called LANTIRN, meaning Low-Altitude Navigation and Targeting Infrared for Night.

With LANTIRN, you hear, you will be able to attack ground targets at night from altitudes as low as one hundred feet, under weather, hit them with great precision, and live to fly again.

You're a typical show-me fighter pilot, and you're skeptical. Then you hear from the States that, sure enough, LANTIRN is in deep trouble. It pushed too many tenuous technologies too far, too fast. Just another pipe dream of the R&D mavens.

Tactical Air Command seems to think differently, however. TAC is placing its bets on LANTIRN, pushing hard for it, and giving it top priority. There must be something to it.

The next time you take notice, in late 1984, LANTIRN is coming right along. Its navigation element is being tested on an F-16, at night and under combat conditions, with outstanding results. Its targeting element isn't yet ready for testing because its development has been much rockier. But it is a lot better and more amenable to fixing than its critics—many of whom are misinformed about what it's supposed to do—have made it out to be. Confi-

dence in its eventual success is, in fact, building.

The story is the same across a broad spectrum of programs that Air Force Systems Command's Aeronautical Systems Division (ASD) has brought along, sometimes bumpily, for several years. Concepts once considered in some circles to be too ambitious or not worth the candle, or both, are now being transformed into more capable airframes, avionics, and engines. Hardware contracts are being awarded all over the place.

These days, aeronautical systems newly in production, in flight testing, or well along in engineering development characterize the work of ASD at least as much as do those still in design or early in development.

Harvest of High Technology

The serendipity of all ASD programs firmly in hand or farther out is becoming more and more obvious. Each takes advantage of such advanced technologies as microelectronics, nonmetallic materials, and aerodynamic shapes that are fundamental, in varying degrees, to all.

For example, ASD's blue-chip Advanced Tactical Fighter (ATF) program is assimilating what is being learned about those technologies and others in their application to such current production aircraft

as the upgraded F-16C and F-16D, such technology demonstration aircraft as the forward-swept-wing X-29 (see "Forward Sweep," p. 60), and the Advanced Fighter Technology Integration (AFTI) F-16 and F-111 aircraft. ASD manages all these programs, and all benefit, in one way or another, from work done by ASD's Air Force Wright Aeronautical Laboratories (AFWAL) in flight dynamics, avionics, propulsion, and materials.

ATF program officials and contractors will also keep close watch on the maneuverability characteristics of the F-15 short takeoff and landing (STOL) demonstrator aircraft that ASD contracted to build late last year. The modified F-15 will incorporate engine nozzles for in-flight reversing and vectoring of thrust, a feature the ATF is likely to adopt. It could well provide the key to operating from bomb-damaged runways and thus staying in the fight.

Taken together as an increasingly logical whole, ASD's programs promise unprecedented combat capability for the Air Force. It is happening right now.

The B-1B bomber is in production. The highly upgraded single-seat F-16C and two-seat F-16D fighters, both wired for LANTIRN as well as for the Advanced Medium-Range Air-to-Air Missile (AM-RAAM), began entering the Air



Force's operational inventory in December.

A top-of-the-line Combat Talon C-130, with highly advanced avionics, is now being introduced to the Military Airlift Command's special operations fleet. The two-seater F-15E, having gained acceptance (if not full funding) in the Department of Defense and in Congress, needs only a final decision on the disposition of its cockpit technologies and on the division of duties between its frontseater and backseater in order to begin moving swiftly through final development.

The ATF, too, is coming on fast. DoD approval was imminent at press time. Design contracts are scheduled to be awarded to three airframe contractors, or three teams of such contractors, late next summer. One will be selected in late 1988 to start building the ATF, and it should be flying by 1991—only six years from now.

The ripening of so many interrelated ASD R&D programs at the halfway point of the 1980s is not the result of any all-embracing aeronautical master plan conceived years ago. Rather, it represents a fortuitous confluence of programs—many of them driven by advances in the microelectronics of sensors, signal processors, and data processors—that were instituted individually over the years to stay ahead of the growing, many-sided Soviet threat in the air.

"Our business is to manage projects that keep adding up to a running total of increased capability for the Air Force," declares Lt. Gen. Thomas H. McMullen, ASD's Commander. "We try to solve problems as they come—as we see them coming—in the aeronautical world."

ABOVE: An F-16 tests the high-priority LANTIRN avionics system. Navigation pod is mounted on the left of the aircraft; targeting pod, on the right. **RIGHT:** Artist's sketch shows how the Short Takeoff and Landing (STOL) and Maneuver Technology Demonstrator aircraft, a modified F-15, will take off from damaged runways.



LANTIRN Lights the Way

High on the list of such problems is how to attack ground targets at very low altitude, at night and under the weather, with precision. This is why the LANTIRN system, made up of a navigation pod, a targeting pod, and a head-up display (HUD) for the cockpit, is so important. It answers the "how."

"I think LANTIRN is doing real well, particularly in the navpod," General McMullen declares. "The targeting pod is a challenge, but I don't think there's any insurmountable problem with its technology. We're taking a little more time with it to make it well."

The navigation pod is the less intricate of the two. It embodies a wide-field-of-view, forward-looking infrared (FLIR) sensor, a terrain-following radar (TFR), supporting electronics, and an environmental control system. It has posed some problems of power sufficiency and of cooling, but these are relatively straightforward and are being rectified.

A widely overlooked attribute of the LANTIRN system is that its navigation pod, acting independently of its targeting pod, should enable single-seat aircraft to overfly and bomb targets in the dark, down low, more safely and effectively than any tactical aircraft anywhere (including the dual-seat F-111 with its terrain-following radar and its Pave Tack pod) have been able to manage in the past.

The targeting pod is a prerequisite for precision strikes at night. But even without it, the navigation pod would make USAF's ground-attack aircraft threats to be reckoned with around the clock.

As explained by Col. James A. Fain, Jr., ASD's LANTIRN program director, "If the target is big enough that I could see it in the daytime, then I could hit it at night with a navpod, because whatever I can do in the daytime—within certain limits—I can also do at night with the navpod. But the targets have got to be large, and I'd generally be using area-type weapons against them. We're not talking about surgical removal of high-value targets."

The bottom line, says Colonel Fain, is that with LANTIRN's navigational pod alone "we can take a

As depicted here, the LANTIRN system's "night window" cockpit HUD should enable ground-attack aircraft crews to fly and fight confidently at high speeds and low altitudes at night and under the weather.



big portion of the night away from the enemy . . . but if we want to be able to rule the battlefield at night the way we do in the daytime, then we need the targeting pod."

That pod is a technological humdinger. It contains a FLIR sensor system with both wide and narrow fields of view, a laser designator and laser ranger, automatic target trackers, a missile boresight correlator, all manner of supporting electronics, and an environmental control system.

Like the navpod, it must be fully integrated with the avionics of the aircraft carrying it. Those aircraft will be the F-16C, the F-16D, the F-15E, and the A-10. The targeting pod will enable them to deliver laser-guided glide bombs and imaging infrared (IIR) Maverick missiles.

Targeting Pod in Sight

The targeting pod was designed by Martin Marietta, builder of the LANTIRN system, to be effective at night against targets as small as tanks. The idea was that if the system could pick out a tank, it would have no trouble picking out larger high-priority targets like SAM sites, bridges, command centers, and dams.

"Hitting tanks has been oversold in a lot of cases," declared Colonel Fain. "People ask why we want to go hit an individual tank with a very expensive airplane. But that's not

the issue. We designed the targeting pod to be able to hit a tank because if it can do that, it can hit all the other targets it's assigned to hit."

The LANTIRN targeting pod is very densely packaged. At first, its innards sprang leaks, and wires and connectors broke. It was taken out of testing and repackaged. But then it proved to be incapable of attacking small tactical targets at required ranges. The Air Force considered giving up on this capability.

But the Air Force didn't. Instead, it took two new tacks on the targeting pod. One was the incorporation of a number of tracking improvements to allow the pod to acquire smaller targets farther away. This did not turn out to be satisfactory, however.

The other, more laborious approach was to improve the pod's optical chain by "cleaning it up from end to end, redoing it as much as we can to improve its transmissivity," says Colonel Fain.

This is being done. Some improved targeting pods were scheduled for delivery to USAF in December 1984. Others, even better, will be delivered in March of this year.

Colonel Fain expressed confidence that, by then, "the pods should have the capabilities we think are necessary to attack small tactical targets at the ranges we think are adequate for a single-seat [aircraft] work load."

The first production-line F-16C rolls out at General Dynamics Corp.'s Fort Worth, Tex., plant. USAF plans to order at least 1,800 F-16C and two-seater F-16Ds. Both are wired for LANTIRN and the Advanced Medium-Range Air-to-Air Missile (AMRAAM).



"We're talking about vast improvements in the optical chain through the pod," the Colonel added. "We're talking about almost a doubling of capability."

The software of the targeting pod's tracker, which works hand in hand with its FLIR system, is also being upgraded. This will allow the tracker to lock on to small targets at greater standoff ranges.

The control loop between the targeting pod and the Maverick is complicated. The FLIR system in the pod and the FLIR system in the missile continuously pass digital data to the pod's missile boresight correlator. It matches up such data. Then it signals the Maverick to lock on and the pilot to launch.

According to Colonel Fain, ASD anticipated that its improved targeting pods would be in shape to start handing off Mavericks in flight around the first of this year. These tests "will not include all the yanking and banking we're looking for, but we're expecting that capability in the March-April time frame," he said.

Initial go-arounds with the targeting pod's laser designator have been promising. Verification of the pod's boresighting accuracy for laser-guided munitions is well under way and looks good.

Night into Day

Final testing of the LANTIRN navigation pod on an F-16 over Can-

ada began last October 15 and was scheduled to end by mid-December. Under the terms of a joint agreement between the US and Canada, the testing took place in the vicinity of the Canadian Forces base at Gagetown, New Brunswick, where a European-type climate prevails. Test flights originated at Loring AFB, Me.

The navigation pod had already done very well in more than a year of testing at night, sometimes in highly humid conditions that threatened the workings of the pod's FLIR-protecting environmental control system.

The test flights were tough ones. Test pilots and TAC pilots logged about 480 flight hours over an estimated 15,000 miles, flying at an altitude of 500 feet or below. Above unfamiliar US terrain both flat and hilly, they dropped down to 200 feet at speeds ranging up to 615 miles per hour and down to 100 feet at up to 550 mph.

They reported that the navigational infrared display on their HUD, which brings into the cockpit what the system "sees," enabled them to fly with confidence, as if in daylight.

Reliant as it is on optics, the LANTIRN system will make aircraft capable of attacking at night *under* the weather but not *in* the weather. Existing FLIR systems do not see through clouds. It is tough enough to make the transition from

day to night attack, let alone to attacking in weather.

Even so, LANTIRN's TFR navigational capability will give pilots some in-weather leeway.

"Depending on their need, they should be able to top ridge lines, hit clouds, and punch over to clear air on the other side," says Colonel Fain. "They're not going to do that kind of thing in training, but in combat they could. They might have to do so."

In aeronautics, one advancement always leads to another. ASD's Avionics Laboratory is experimenting with highly advanced FLIR technology for the Advanced Target Acquisition Sensor (ATAS). This could give future combat aircraft, notably the Advanced Tactical Fighter, true weather-beating capability.

Right now, though, the issue is LANTIRN. An Air Force System Acquisition Review Council (AFSARC) decision on whether or not to finish developing and start producing LANTIRN navigation pods is expected early this year. The IOC date for the pod is classified, but it seems that USAF's ground-attack aircraft could be pretty well equipped with them by the turn of the decade.

And if ASD's optimism about the LANTIRN targeting pods is justified, production should be only a year or so behind.

The latest in the evolutionary line of F-16s will be on the ramps at op-

erational bases awaiting the arrival of LANTIRN pods. The F-16C and F-16D two-seat trainer variant have just begun entering USAF's inventory of combat aircraft. Both were rolled out at General Dynamics Corp.'s Fort Worth, Tex., production plant just six months ago. The Air Force plans to order at least 1,800 F-16Cs and F-16Ds.

Good Gets Better

The F-16C represents the fruits of the Multinational Staged Improvement Program (MSIP) undertaken four years ago by USAF and, to some extent, the four European governments participating in the F-16 program. It is a prime example of how to upgrade an existing aircraft—and to make it ready to accept such future systems as LANTIRN and AMRAAM—without rebuilding it from nose to tail.

The litany of improvements in the F-16C is a lengthy and impressive one. Its AN/APG-68 radar, featuring a software-programmable signal processor and a dual-mode transmitter, greatly extends its target detection and tracking ranges. Its fire-control computer has double the memory capacity and processing speed of that in the A and B models.

It is a stronger, heavier aircraft, too, the better to bristle with weapons. Its gross takeoff weight is 37,500 pounds, or 2,100 pounds heavier than earlier F-16 variants.

To manage its weapons more smartly, the F-16C embodies the Advanced Central Interface Unit (ACIU). This feeds the airspeed and inertial and radar targeting data from the aircraft's computer to the missiles, such as the Maverick, and to other smart weapons. The ACIU also makes it possible for those weapons to keep that computer up to date on their status.

The pilot sees all this, and much more, on two new television screen cockpit displays that replace and do the work of many dials. He can call up on either screen, or both, any sensory or weapons data he needs at any time.

The F-16C also features a solid-state computer cartridge system for loading mission and navigational data. All innovations on the F-16C make it more quickly versatile in flight—for example, in switching from the air-to-ground mode with

USAF's F-15 has come a long way in evolution from this early model. Emphasis is now on fast development of the two-seater F-15E with great firepower and highly advanced avionics and cockpit technologies.



LANTIRN and Mavericks to the air-to-air mode with AMRAAMs.

F-16 pilots now have to enter weapons and navigation instructions into the aircraft's electronic memory while sitting in the cockpit prior to takeoff. This can take up to fifteen minutes. With the new system, the pilots can prerecord such data on a computer cartridge in the briefing room and load it into the computer system in less than a minute—almost like changing cassettes in a car radio.

The F-16C also has a wide-angle HUD for displaying more information over a larger area. This helps the pilot keep his head out of the cockpit, something he desperately needs to do while flying low-altitude ground-attack sorties.

The F-16C will have a better shot at surviving, too. Its rudder island assembly was reconfigured so that its tail can now accommodate two Airborne Self-Protection Jammer (ASPJ) electronic countermeasures black boxes. The sophisticated ASPJ system will be installed in production-line F-16Cs in about two years and retrofitted at that time in F-16Cs already in service.

Reworking the F-16 to make it more capable now—and amenable to even greater capability in the near future—is a prime example of ASD's latter-day emphasis on getting the most out of what USAF already has in the way of combat aircraft.

As General McMullen puts it: "History shows we'll be going to fewer systems. One of the shifts we're already in the midst of is keeping airplanes and engines longer, and improving their capability to do things that nobody even thought of when they were new—offensively and defensively, surviving in a high-threat environment. Electronics adds tremendously to our capabilities."

The late-model F-16s surely show this to be true. And so does the F-15E, no longer dubbed the dual-role fighter but designed to be one, nonetheless.

"One Damn Good Weapon System"

A demonstrably superb air-superiority fighter, the basic F-15 Eagle is also an inherently very capable air-to-ground machine as well—robust, big, with lots of room for ground-attack stores. The two-seater F-15E will incorporate avionics, such as LANTIRN, to carry out the long-range interdiction mission at night and under weather against high-priority targets.

The F-15E will also have almost all of the capabilities of the B-1B strategic bomber, such as terrain-following, navigation-update, and weapons-delivery avionics and internal electronic countermeasures. Like the bomber, the F-15E will be a software-intensive aircraft. Its offensive and defensive avionics can



be reprogrammed to keep it ahead of increasingly sophisticated and profuse threats from air and ground. It will contain a fully programmable set of armament controls for air-to-air and air-to-ground weapons.

In fact, the original F-15 was built for growth in air-to-ground capability. Its HUD technology and bombing modes made the original F-15 comparable, as a ground-attack aircraft, to the doughty A-7, which showed its mettle against ground targets in Vietnam.

"For the F-15E, we expanded all that and made it programmable," explains Col. John S. Smith III, ASD's F-15 deputy systems program director. "And we have a central computer to manage the requirements of the airplane that's a tenfold improvement over the computer in the basic F-15A."

Naturally, the LANTIRN system is coveted by F-15E program officials. They claim that even though LANTIRN's navigation pod would enable the F-15 to carry out many ground-attack missions at night and under the weather, the aircraft would also need LANTIRN's targeting pod to perform the full range of such missions envisioned for the aircraft.

Those missions would impose a very demanding work load on the F-15E's two crew members—one that, in many instances, would be comparable to the work load of the B-1B bomber's four crew members.

This is why TAC and ASD are paying a great deal of attention to dividing the crew duties aboard the F-15E in the best possible manner and to determining the optimum configuration and placement of the aircraft's front-seat and back-seat technologies.

Initially, the idea was to give the frontseater control of air-to-air and air-to-ground weapons; the backseater, limited control of air-to-ground weapons and full control of radar navigation. But this was changed to give the backseater some air-to-air control as well. Defensive avionics were originally destined for the front cockpit. Now they will probably be put in the rear cockpit for management by the WSO.

Putting potential F-15E pilots and WSOs through their paces in cockpit simulators has been a big help in making decisions about such things. "We match them up in different scenarios, and they make their own assessments and tell us what symbology they want in there and let us know about extremes of work loads," says Colonel Smith.

The simulator was built by McDonnell Aircraft Co., which is working with a steering group, representing ASD, TAC, USAF, and PACAF, in making decisions on F-15E cockpit configuration and symbology.

However it comes out, F-15E cockpit technology is certain to represent "a real jump" over any such technology in existing fighter aircraft, says Lt. Col. Robert E. Lupini, ASD's F-15E program manager. Air Force officials acknowledge that the cockpit technology and layout of the F/A-18, produced by MacAir for the Navy, is—as one such official described it—"the very best now flying."

But the F-15E's cockpit will surpass it, they claim, with the best and latest in digital displays. "It will be a whole generation beyond," Colonel Smith asserts, "with a lot bigger HUD, symbols a lot sharper and brighter, and in colors instead of all green."

Even though the cockpit is the major technological challenge on the F-15E, a very big and related one, too, is the integration of all the aircraft's systems.

"We're not making any major

steps in technologies," says Colonel Lupini. "We are integrating proven technologies into one system, onto the airplane. Redoing the basic F-15A to accomplish this would have been a monstrous task."

"The F-15E," declares Colonel Smith, "is going to be one damn good weapon system."

Birth of a Great Baby

At some point in the future, if this indeed turns out to be true, and if the new and maybe even future variants of the F-16—almost certainly the F-16F—also live up to their billing, critics of USAF's mosaic of fighter programs are almost certain to start questioning why USAF needs the Advanced Tactical Fighter in view of the highly versatile, highly capable fighters it already has. Such questioning will be especially severe if defense budgets grow more slowly.

USAF's answer will be—and already is—that the ATF, being designed to incorporate and integrate engine, avionics, and other technologies that are maturing fast but are not quite ready, is sure to be the finest combat aircraft ever, far outstripping even the best, most versatile F-16s and F-15s imaginable—moreover, that USAF is not planning to build the ATF just for the hell of it, but to keep the fast-improving Soviet air and air defense arms from wiping the skies clean of US aircraft if war should come.

"The ATF will be in the same ball park as the F-15 in terms of size and gross weight, but it will have far, far better capabilities because it will have to deal with some very advanced threats," predicts Col. Albert C. Piccirillo, director of the ATF System Program Office under ASD's Deputy for Tactical Systems.

Picking up steam, the ATF program moved into ASD's tactical arena and out of its development planning arena last July.

At the time, Brig. Gen. Gerald C. Schwankl, ASD's Tactical Systems director, declared that "development planning gave birth to a great baby, and now everyone is eager to help with its growing up."

He was not exaggerating. The ATF program involves a host of ASD shops, such as those for propulsion, avionics, electronic coun-



Aeronautical Systems Division (ASD) will choose three contractors, or three contractor teams, late next summer to compete for full-scale development of the Advanced Tactical Fighter (ATF), shown here in generic design.

termeasures, aerodynamics, and materials. It is also being supported by AFSC's Armaments Division at Eglin AFB, Fla., by Electronic Systems Division at Hanscom AFB, Mass., and by Aerospace Medical Division at Brooks AFB, Tex.

TAC and Air Force Logistics Command officers have moved into the ATF office on a full-time basis. This is because the ATF program has entered the real-world, critical phase of getting down to cases in defining its operational requirements.

Taking the users' approach to the ATF, the TAC people are proxies for USAF and PACAF, too. The logisticians are making sure that the fighter's reliability and maintainability are not slighted in designing it to do what the pilots need it to do or what the technologists would like to see it try to do.

Excitement about the ATF program is palpable at ASD. "We're not dreaming; it's happening," Colonel Piccirillo declares, "and this next year should be extremely interesting."

You bet. It is getting on toward crunch time for the seven companies—Boeing, General Dynamics, Grumman, Lockheed, McDonnell Douglas, Northrop, and Rockwell International—now in competition to design the ATF. Three of them, or three teams of them, will be chosen, probably in August, to get down to the nitty-gritty of ATF

design and plans for its early development. Three years from then, one will be chosen, and full-scale development will begin posthaste. First flight is scheduled for 1991.

This is a high-stakes program for the aerospace industry. Give or take, the seven companies have spent an estimated \$10 million to \$20 million apiece on it so far. The winner, or winners as a team, will almost certainly dominate USAF fighter production, and possibly fighter avionics integration, in the 1990s.

Losers will risk being in tough shape in those years unless they move into different kinds of combat flying machines, such as the Transatmospheric Vehicle (TAV) now being conceived by several of them in concert with ASD.

What ATF Will Do

At this juncture, no one knows what the ATF will look like, but there is no mystery about what it is expected to embody and to do.

Its ultrasophisticated avionics for fire controls, flight controls, weapons delivery, and whatnot will be totally integrated from scratch. It just might have movable canards. Much of its airframe will be built of tough, lightweight advanced composites.

It will be capable of cruising at supersonic speeds and yet be very efficient with its fuel. It will be supple, agile, and proficient at attacking

ground targets in a secondary role. It will be hard to spot by radar and by infrared and optical seekers. The ATF will be able to cruise supersonically without afterburners because each of its two engines is expected to provide more than twice the thrust, in relation to its weight, of any current, state-of-the-art fighter engine. Advanced composites should make it possible to build an ATF airframe that is fifteen to twenty percent lighter than it would be were it totally metallic in structure.

Its avionics, characterized fully by light, compact circuit boards with very-high-speed integrated circuitry (VHSIC) in the form of tiny, reliable semiconductor chips, should allow for additional, enormous savings in weight.

Given that the ATF is expected to weigh about as much as an F-15, such savings presumably mean that it will be able to carry vastly more fuel and weaponry and will feature more fight per pound.

The ATF may well be the first fighter to cost less, rather than more, as a result of its incorporation of highly advanced engine, structural, and avionics technologies. The reason is that fighters—indeed, all aircraft—are always priced pretty much by their poundage. And in order to build it to do what it will need to do, an ATF without those weight-saving high technologies might cost as much as \$60 million, knowledgeable officials estimate.

But the ATF will very likely come in at one-third less than that, and its life-cycle costs, given the reliability that can be predicted for its engines and avionics, will be way down as well.

The possibility that the ATF will have movable canards and a variable-camber wing is why its designers show great interest in the X-29 and AFTI/F-111 technology demonstration aircraft. The AFTI/F-111 is the test-bed for the Mission Adaptive Wing (MAW) developed by ASD's Flight Dynamics Laboratory and Boeing Airplane Co.

Wings that change shape, and other surfaces that also move—all managed by superfast flight controls reacting automatically to conditions of flight and demands of maneuverability—should team up with thrust-reversing and thrust-vector-

ing engine nozzles to give the ATF wasp-like agility and elusiveness.

It really won't need those vectoring nozzles for short takeoffs, according to Robert J. May, manager of ASD's Joint Advanced Fighter Engine program. Mr. May claims that the ATF's engines will be powerful enough to get it airborne "in fairly short distances," nozzles or no nozzles.

The nozzles will be a big help in landing, however, "especially on a wet or an icy runway," says Mr. May, because they will make slow approach speeds possible and will rapidly provide high levels of reverse thrust on touchdown.

An Engine for ATF

Details of the advanced fighter engine being developed for the ATF by Pratt & Whitney and General Electric are highly classified. However, Mr. May provides a general description of it as follows:

"We are seeing a lot of advanced materials incorporated in the design and tremendous improvements in the form of advanced aerodynamics—so we're going to see a great reduction in the number of stages in the engine and about fifty percent reduction in parts.

"That means reliability, right there. Also, we're seeing improvements in cooling effectiveness so that we can run high turbine temperatures and get the performance, and yet still get the durability, we want.

"Some really advanced structural concepts will help us save weight. And we're going to the full-authority digital electronic control. This, too, will improve the reliability of the engine. Control is one of the more unreliable elements in current engines."

The current P&W F100 fighter engine has thirteen compressor stages and four turbine stages. The GE F110 has twelve compressor stages and three turbine stages. The ATF engine will likely reduce the number of such stages "on the order of fifty percent," Mr. May predicts.

P&W and GE have learned a great deal about how to design an engine for the ATF as a result of their work on upgrading the F100 engine and on developing its latter-day competitor, the F110 engine, respectively.



Artist's rendering shows how fighter aircraft may someday take off from air-cushioned platforms that propel them to rotation speed over bomb-damaged runways.

Air Cushions and Fast-Acting Sensors

Imagine a fighter aircraft taking off from a bomb-damaged runway by sliding over the craters and gaining airspeed atop an air-cushion platform that the fighter itself propels along the ground.

Imagine that same fighter, or any other, losing a vital chunk of its wing or tail to enemy fire—and continuing not only to fly but to fight.

Air Force Systems Command's Aeronautical Systems Division (ASD) has passed beyond the point of merely imagining such prospects. It is well along with research and development programs aimed at turning them into reality.

Much of ASD's work is concentrated on "sortie generation," one of its Flight Dynamics Laboratory's four "major thrusts" of research and development. The "pivotal program" in that regard, says FDL Deputy Director James J. Mattice, is the Short Takeoff and Landing (STOL) and Maneuver Technology Demonstrator aircraft, an F-15 now being modified to embody movable canards and thrust-reversing and thrust-vectoring nozzles.

But FDL is also developing the Air-Cushion Equipment Transportation System (ACETS) and the Self-Repairing Flight Control System, both of which could someday make Air Force aircraft much more capable of joining and sustaining combat.

FDL has tested an air-cushion equipment transporter in a joint program with, and in, Canada. The test-bed platform successfully carried aircraft and other heavy equipment over rough terrain and over craters thirty feet in diameter.

That platform has its own engines. They push air into rubber cushions, or skirts, beneath the platform, enabling it to float on air over rough terrain, much as a hovercraft floats on air over water.

Among other things, it has great potential for transporting combat equipment to and from intratheater airlifters over rough or scarred countryside in combat zones.

With data in hand from the tests in Canada, FDL is now looking at the possibility of an air-cushion transporter that would get its thrust from the aircraft mounted on it. When the platform reaches the aircraft's rotation speed, the aircraft would disengage and take off.

FDL is also exploring the feasibility of using an air-cushion transporter as a carrier of the Transatmospheric Vehicle (TAV), now being conceived under ASD's direction for takeoff and direct ascent through and above the atmosphere.

Fast-acting sensors and computers have given rise to FDL's high hopes for aircraft that can take heavy damage to control surfaces and then compensate—instantaneously and automatically—for such damage in order to stay airworthy.

For example, the aircraft's flight control computer would reconfigure other control surfaces—such as rudders, flaperons, ailerons, and stabilators—to take up the slack induced by the loss of part of a wing.

For another, the loss of one side of a stabilator on the tail of an F-16 would cause a control problem requiring instant rectification. The pilot probably could not provide it. He likely would not be aware of exactly what was wrong, and even if he were, he likely could not react fast enough.

But the combination of sensors and flight control computer that FDL has in mind, and is preparing to develop and test, could presumably reconfigure the F-16 in a flash by substituting a combination of, say, flaperons and speed brakes to permit the pilot to keep control.

The computer and its associated sensors would have two main tasks: diagnosing the problem and doing something about it immediately. It would then tell the pilot what the aircraft is still capable of doing—whether he can continue the mission or should head for a friendly airfield.

"Telling him what the failure is doesn't tell him what he needs to know," says Boris J. Tirpak, FDL's program manager. "He needs to know what capability he has remaining, such as his maximum Gs are four, his altitude is limited to 30,000 feet, and so forth. He needs to know if he still has control of the airplane, and how much."

—J.W.C.

Col. Howard E. Bethel, ASD's Deputy for Propulsion, describes both the new F100-PW-220 engine and the GE F110 as "super" in durability and reliability, compared to their predecessors now on USAF fighters.

Both of these engines incorporate advanced materials, cooling techniques, and electronic controls that are precursors of such innovations, to be even more advanced, in the engines of the ATF.

The technologies of those engines are "converging very nicely," says Colonel Piccirillo, and "the engine program is on a good schedule. It will be ready in plenty of time, and we'll be able to upscale it easily if necessary."

Accelerated mission testing of the ATF engine is expected to begin in just a little more than two years from now.

Avionics—The Toughest Challenge

The ATF's avionics are the "toughest challenge," Colonel Piccirillo claims, "because there are so many things going on in avionics—a real explosion. We have so many technologies coming out of the labs that have to be integrated [in the ATF] that our problem is going to be in deciding where to cut it off in order to get an airplane on the ramp."

All avionics for the ATF are being integrated in an "architecture" being devised in the ASD Avionics Laboratory's Pave Pillar program. It is heavily dependent on the advent of the VHSIC chips and on their performance and reliability as advertised.

Those chips promise improvements of computational speed, of reliability, and of weight and space savings that "blow my mind," says Col. Frank Moore, director of the Avionics Laboratory.

For example: The existing F-15 radar signal processor weighs fifty pounds, contains 5,000 integrated circuits (chips), and needs 1,600 watts of power. Doing its job with VHSIC chips would require one thin circuit-board card containing only forty-five chips, weighing a total of only three pounds, and requiring only fifty watts, claims Colonel Moore.

Moreover, he says, the use of

such a card would reduce the number of connectors in the radar signal processor (connectors are responsible for a great many failures of avionics) "by a factor of one hundred to one." This could increase the reliability of the aircraft's avionics by a factor of ten and cut maintenance in half.

Each F-16 now contains fifty-eight avionics black boxes, each weighing about fifty pounds. Called Line Replaceable Units (LRUs), they are manufactured by several different contractors and are not standardized. Consequently, each F-16 also requires, at operational bases, 437 separate types of LRU replacement spares.

According to Colonel Moore, it would take only forty-three VHSIC Line Replaceable Modules (those three-pound cards) to do what that entire assortment of avionics black boxes does in the F-16.

Reduction of weight would be compounded throughout the aircraft. Given the rule of thumb that a saving of one pound in an aircraft's avionics translates into a saving of five pounds in its takeoff weight (in the form of structural racks, cables, fuel, and the like), an aircraft replete with VHSIC cassette-like circuit boards, such as the ATF is expected to be, would trade off tons of "dead" weight for "live" weight—as in weaponry and other features that embellish its performance.

This prospect gives the ATF designers tremendous leeway. It also makes the logisticians happy. They foresee the ATF's maintenance crews simply pulling defective avionics modules from the ATF, inserting new ones on the flight line (the module cards can be carried in one hand), and shipping the bad ones back to the States for repair after having collected a batch of them—no hurry.

The ATF will not be the only beneficiary of VHSIC technology. Plans are afoot to retrofit existing aircraft with the superchips whenever feasible over time.

All Aboard!

In anticipation of those chips, which are now being manufactured at very slow rates and upgraded by the six contractors in the VHSIC program, Pave Pillar officials are bent on integrating all signal pro-

cessors, data processors, and sensors destined for the ATF.

The final trick will be to provide the pilot with displays that make it easy for him to take notice of, and act on, the disparate information from the sensors that the computers show him in coherent fashion. Designers of such displays for the ATF have been given a big leg up by work on cockpit technologies in the AFTI/F-16 program and by such work for the latest variants of the F-16 and for the F-15E.

The AFTI/F-16 program, now entering its second phase; is also exploring technologies that may permit the ATF pilot to speak some of his commands to the aircraft. Given the urgency of the ATF program, however, it is unlikely that such voice-control technologies will be ready for employment in the fighter right off.

The ATF's technologies will be "frozen," says Colonel Piccirillo, in less than three years in order to get it built with technologies then available. But like all fighters, the ATF would undoubtedly be upgraded through several successive models, and the original ATF is being designed with an eye to technological growth into the twenty-first century.

Many programs subheaded under Pave Pillar should produce avionics systems ready for incorporation in the ATF.

The Ultra Reliable Radar (URR) is a big one. Another is the Integrated Inertial Reference Assembly (IIRA) system that pools information from all gyroscopes, accelerometers, and other positioning equipment on the aircraft (even gunsights have gyroscopes) to keep the pilot constantly posted on the state of the aircraft and its systems.

Yet another endeavor pegged to the ATF is the Integrated Communications, Navigation, and Identification Avionics (ICNIA) program, which will provide, in a few fault-tolerant units, all externally received radio, navigation, and Identification Friend or Foe (IFF) information, even from satellites, needed on tactical missions.

These and other programs supporting Pave Pillar are already under contract.

"This train," asserts Colonel Moore, "is running." ■