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ABOUT THE COVER

A portion of the Fort Worth Division's mile-long assembly line is represented in this shot of F-16s in the final stages of production. Technology modernization efforts, coupled with improvements in F-16 production methods, have resulted in significant flyaway cost savings. The photo at left shows an F-111 undergoing a major rebuild as part of another money-saving program that restores service-damaged aircraft to flight status at a fraction of replacement cost.

*Code One is a trademark of General Dynamics Corporation.
Survival in today’s competitive environment requires a willingness to change

One of the most successful fighter aircraft production programs in aviation history is being carried out at a place ironically nick-named “the bomber plant.” Located on the rolling plains of North-central Texas, Air Force Plant No. 4 occupies the land immediately west of the main runway at Carswell Air Force Base. The plant was built in the early days of World War II to produce B-24 Liberator bombers, and a succession of other famous airplanes would follow, including the B-36 Peacemaker and the B-58 Hustler.

In the sixties, the bomber plant experienced a transition from pure bomber production when the swing-wing F/FB-111 was introduced. But a real break with tradition occurred with the F-16 Fighting Falcon—a small, single-engine, multirole, lightweight fighter. The F-16 contrasts sharply with the old B-36—an aircraft so massive that it was difficult to get the finished article out of the building.

But if you look carefully — down there beneath the roof and onto the mile-long assembly line — you may notice that a lot more is changing than just the shape, size, and type of airplanes being produced. The plant itself is in an unparalleled state of change as new technologies rapidly alter the way the industry does business. Survival in today’s competitive environment requires a willingness to change. And the Fort Worth Division has often been the catalyst of technological change. It was here that “variable-sweep wing”
entered the aerospace industry’s vocabulary. Terrain-following radar was born here, as was the world’s first fully fly-by-wire flight control system.

This willingness to pursue engineering and manufacturing innovations has paid off with the F-16 — outstanding in the visual ground attack role (as Gunsmoke ’85 made abundantly clear), without peer in aerial combat maneuvering capability (proven by its remarkable record in dissimilar air combat training exercises), and statistically the safest single-engine fighter in aviation history (see related article in this magazine).

Facts. All facts. But they don’t tell the whole story. Innovative efforts at the Fort Worth Division are hardly confined to aircraft design. For instance, production methods are constantly being investigated for better ways to “insert tab A into slot B.” (Robots are part of the answer here.) And the materials used in production are also changing. Would you believe a plastic airplane? It’s coming.

Long-term planning and dynamic programs are in place to ensure an ongoing effort to cut costs, automate production processes, and implement newer, more effective manufacturing technologies. It is conservatively estimated that by 1990 these efforts will have reduced production costs by over a half-billion dollars.

General Dynamics’ production improvement/technology modernization programs are guided by a strategic plan that includes every project either currently in work or planned; their start dates, major milestones, and the type of funding — be it IRAD, CRAD, technology modernization money, productivity funds, or straight capital investments.

By the early 1990s, the Fort Worth Division is planning to accomplish the following goals:

- Increase machine utilization by 15 percent
- Reduce touch labor by 20 percent
- Reduce inventory 45 percent
- Reduce nontouch labor by 50 percent
- Reduce the engineering change to stock time (the time from when a change is released for fabrication until the part is stocked) by 70 percent — with a quality improvement program to ensure that the materials used are of the best possible quality.
The following examples illustrate just a few of the many ways these goals are being achieved.

**ADVANCED MACHINING SYSTEM (AMS) PROGRAM**

This will include an integrated manufacturing system in which material will enter in block form and come out completely finished and inspected. All automatically. Untouched by human hands. Robotics will be used in conjunction with an automated material handling system. There will be six 5-axis machines—all tied together—with automatic tool changing systems, automated deburr, and an automated inspection system. Equipment purchases and software development for this unmanned production environment are already under way and, when finished, will improve machining productivity by 10 percent while reducing labor costs by 60 percent and paper requirements by 50 percent. It will also reduce scrap and rework requirements by a third and improve change response time by 70 percent.

**COMPOSITES**

Being used in airplanes in ever-increasing amounts, composites are stiffer, lighter, and stronger than metallic aircraft structures. Composites are more expensive than aluminum, but the number of parts per airframe is predicted to be only 50 percent of that of an aluminum aircraft. There are also savings in weight and in manhours per aircraft. Current composite manufacturing efforts involve a complex section of the aft fuselage skin and its inner structure.

**ROBOTICS**

For several years, robotic applications have been in development at the Fort Worth Division. Robots seldom make mistakes. They never get tired or sick, they don't require a paycheck, ... and they represent a substantial increase in production quality. The division currently uses 14 robots to work machined parts, canopy structures, aluminum panels, wing skins, and composite skins. There are robotic operations in tubing, and in the fabrication and subassembly areas. And the long-term prospects for robots in assembly operations are encouraging.

*A fuselage section awaits the next phase of the production process.*
The U.S. Air Force puts “seed money” into things like composites, automated machining systems, and robotics so that industry will have the incentive to take on these higher-risk programs. Additionally, however, Technology Modernization creates equipment incentives. Because savings are shared between industry and the USAF, industry is encouraged to invest in top-notch equipment. In the last decade, General Dynamics has invested a tremendous amount into the mile-long factory in Fort Worth. For example . . .

- Five-axis multi-spindle profilers have been jointly developed with Cincinnati Milacron.
- Old sheet metal presses were computerized. Years ago, a company had to have a highly trained operator who knew just exactly how to stretch and form material. Now, the process is all done by computer, and an untrained operator can run the system.
- Brand new one- and six-inch composite tape-laying machines have been developed and put into production. In fact, the Fort Worth Division holds the original patent for such a machine, built some 20 years ago.
- The composites center uses an automated guided vehicle that runs along an invisible track on the floor and carries material from one work cell to another. The multiple access and storage system (MASS) is changing all that. This corporate-funded project is aimed at eliminating paper waste. No longer will blueprints litter the floor. CRT’s will give a new look to the centralized engineering release system, often replacing blueprint copies with electronic images of schematics.

The very life blood of the aircraft industry is transition — to more advanced manufacturing methods, to new generations of aircraft, and to that elusive and ever-evolving concept of a Factory of the Future. In 1979, an F-16 required about 100,000 production manhours to produce. Today, the company is turning them out for about 30,000 production manhours per airplane. Our learning curve has never flattened out. As a result, our first “zero defect” airplane was delivered in 1982. The zero defect delivery rate since then has been about 39 percent of all aircraft produced — and projections indicate a 54 percent zero defect delivery rate for future F-16 production.

We’re introducing many new technologies here at the Fort Worth Division. Future issues of Code One will further detail the activities here, with articles that will hopefully make it clear that we’re doing all we can to expand our leadership in what may be the world’s most demanding industry.
Can you now understand why you keep hearing, "I never thought you'd be able to make that corner!"? Heard that in some of your debriefings? Ah haaa! Then maybe there is some method in their madness.

SEMPER VIPER!

by Joe Bill Dryden
Experimental Test Pilot

EDITOR'S NOTE: This is the second installment in a five-part series that seeks to describe—from a pilot's perspective—what's "different" about the F-16 Fighting Falcon. The first installment described the F-16's flight control system. This installment will begin with aerodynamics before proceeding to an in-depth discussion (to be concluded in the next issue) on departures. General Dynamics Test Pilot Joe Bill Dryden is an experienced fighter pilot whose insightful comments are aimed primarily at other fighter pilots ... yet his writing style is characterized by a descriptive ability that everyone will find enjoyable and informative.

When you start looking at the F-16 from the aerodynamic standpoint, one particular fact immediately stands out: This is the first operational aircraft intentionally designed to have a negative static margin. In subsonic flight, the F-16 is negatively stable (read "unstable") in pitch! I doubt if any of you have had the opportunity to fly an aircraft characterized by true negative stability; but if you did, you'd find that with a conventional displacement flight control system you'd spend at least 99 percent of your time just trying to keep the sharp end pointed into the wind. The closest any of you may have come is in the F-4—with three bags and two travel pods, just as you come off the tanker with a full load of gas. In that configuration, if you pull the F-4 to about 14 units, you'll find that it wants to keep right on going, and you have to maintain forward pressure to keep the AOA from increasing right through the departure boundary. Subsonic, the F-16 is constantly trying to do the same thing, but, because the flight control system is constantly monitoring g, AOA, and pitch rate (and comparing it to what you're asking for) you'll never see the same results.

Why design the aircraft in this manner? Because you get several performance benefits from doing so. One reason the F-16 turns as well as it does is because of this negative static margin. What you may recall from AERO 101 is that you must apply any time you try to evaluate the F-16. I've seen articles in Air Progress that show how the F-15 will turn so much better than the F-16 because the F-15's wing loading is lower. But this is where people get in trouble, because you can no longer apply wing loading to come up with a prediction as to how the airplane will turn. Let me explain this. Since the F-16 is negatively stable, the tail is lifting in order to control the AOA (while you're subsonic). And while the center of pressure shift is such that the F-16 is positively stable when you're supersonic, the amount of down force necessary to keep the aircraft trimmed to a given AOA is less than conventional fighters. As a result, the total lift acting on the airplane is more for a given angle of attack; therefore, the resultant induced and/or trim drag is reduced. Less drag of any kind means better sustained turn and cruise performance. Also, the F-16 has been designed to take advantage of the vortex lift generated by the strakes. This vortex is what you see trailing back on both sides of the F-16 when you turn it hard in moist conditions. They are not there just for more oooohs and aaahhs at airshows.

As a result of this vortex lift, there are areas in the flight envelope where as much as 30 percent of total lift is coming off the fuselage. So, if you fall into the same trap that Air Progress did and take the gross weight of the aircraft divided by the projected wing area, you'll come up with a wing loading of about 65 pounds per square foot. BUT (and this is a very BIG but), when you add in all the contributions of both tail and fuselage lift you'll come up with a wing loading of about 40 pounds per square foot. Now you're talking late World War II wing loadings. So can you now understand why you keep hearing, "I never would you'd be able to make that corner!"? Heard that in some of your debriefings? Ah haaa! Then maybe there is some method in their madness.

So it's really a combination of all these reasons that gives the F-16 the different characteristics we have to account for when beginning to fly this multirole fighter. The negatively stable aero and the rate command flight control system both go to make up a fighter that'll perform like no other!

CUES/AOA/DEPARTURES

I mentioned, in passing, some less than desirable features that resulted from new approaches to building a
fighter like the F-16. Forewarned is forearmed, so follow me through this discussion of how not to be surprised by the Fighting Falcon.

I've heard folks complaining about the lack of cues when flying the F-16. This is true and not true at the same time. The cues are there—it's just that they're so suppressed in magnitude (when compared to aircraft you've been flying) that they're often overlooked until you get some experience in the airplane. Without regard to any special order, let's look at some of the more common ones.

You will have noticed that there's a decided difference in the amount of time you spend trimming the F-16. This is primarily the result of the flight control system. Since we're using the flight control system to artificially create a neutrally stable aircraft, trim changes are taken care of automatically as we increase or decrease airspeed. Since the need to retrim the airplane is removed, we can no longer use this cue to tell ourselves on a subconscious level that we've changed airspeed.

The lack of a canopy bow frame increases visibility, but decreases a valuable airspeed cue—wind noise.

Also, the lack of a canopy bow has removed one of the larger sources of wind noise in the cockpit, so we can no longer depend on louder background noise to tell us we're going faster. The increase in wind noise is really still there; it's just that the initial noise starts at such a low level (compared to aircraft such as the Rhino) that you really have to be paying attention in order to use this signal as a cue—which is hard to do until you get used to the new "feel" of the F-16. Both these characteristics are the reason that you find yourself going 450 KCAS when you wanted 250 KCAS, and vice versa. I regret that I have no real clue for you here other than to use the HUD and really listen to the airplane to show you just how fast you're really going. Rest assured that I don't want to go back to a positively stable airplane with a canopy bow to recover these cues.

I do, however, have some very important facts about what the angle of attack is, so pay attention. Most of you transitioning out of the F-4 are familiar with the fact that the F-4 would bludgeon you over the head with buffet levels to tell you, in no uncertain terms, that you were increasing the angle of attack. The buffet cues are still present in the F-16, but the magnitude is probably one-tenth that of the F-4. What happens is this: you're cruising along at about one or two degrees AOA and you start to turn the aircraft. The first thing you hear or feel is a small increase in the background aerodynamic noise (this usually begins at about six degrees AOA). What you're most likely hearing is the vortex that's beginning to be shed by the forebody strakes. This noise increases slowly until you reach 15 to 16 degrees AOA where you begin to get flow separation on the main wing. The result: turbulent airflow impinging on the rest of the F-16 gives you what has always been described as buffet.

This onset of airflow separation follows the rule we are already familiar with, in that it starts at about 15 degrees at sea level and decreases (as altitude increases) until we see the onset of buffet at about 9 to 10 degrees alpha at 40,000 feet. The reason for this decrease in AOA for the same airframe reaction has not changed since Icarus, and is unimportant here. The main thing to remember is this: IF THE F-16 IS BUFFETING (regardless of the power setting) YOU ARE SLOWING DOWN! If you don't get slow, the F-16 will NOT depart. If you have enough airspeed, the flight control system will not allow you to do anything that will progress to a departure. It is only when you begin to get below 200 to 250 knots (depending on the configuration) that the F-16 becomes "susceptible" to departure—but even then, you must still FORCE it to depart. So a very important lesson is to be learned here; i.e., pay attention to the buffet level. If you don't want the F-16 to get slow, don't fly into buffet. The F-16 will fly well beyond buffet very nicely (remember the unstable aero and fuselage lift) so, if necessary, don't be afraid to do so. Just remember to use the buffet as an important information cue, and you'll not become famous (or infamous) with your superiors!

As long as the g is low you can fly the F-16 well at 20 to 25 degrees AOA. Just don't ever forget that in order to fly at these angles of attack you're getting slow. What happens is the flight controls don't have enough authority at these airspeeds to overcome the bad parts of this unstable aero we've been using. So, if we make rapid pitch or roll inputs at low airspeed, the flight control system will try to honor your request. But then it quickly realizes that there's not enough energy in the air flowing around the control surfaces to stop the inertia it just started. So when the unstable aero gets the upper hand, and the F-16 keeps right on going. If you've been paying attention and KNOW you're slow, you're still not in any trouble. Simply put this knowledge to good use and smoothly approach the limits built into the flight control system. If you can do this in the heat of battle, the flight control system can handle the more benign rates that occur and will still keep you out of trouble. (Never fear. Even these "benign" rates are faster than the guy you're fighting will be able to generate.)

In addition to using the buffet level as an airspeed clue, there is another area that bears watching—flying the aircraft vertical, or even near vertical. Don't be led down the primrose path when you read stories about airplanes that supposedly have power-to-weight ratios greater than one-to-one. Writers often don't have a complete grasp of all the real-world physics involved. For example, despite the stories you may have heard or read, the F-16 will not accelerate straight up for very long... and neither will any OTHER aircraft, for that matter. Although the F100 engine is in the 25,000-pound thrust "class" it has never
seen 25,000 pounds of thrust in its life. When you (1) deduct installation losses, (2) realize the engine is probably not in perfect trim, and (3) account for the usual thrust-level deterioration from age, you'll see you don't have a great big area where the F-16 is really greater than one-to-one. Then, when you superimpose a nominal three percent per thousand feet lapse rate on the remaining thrust, you see that when you get to 10,000 feet you only have 70 percent left.

Now remember that in a vertical climb, thrust must overcome weight AND drag. You can see, can't you, that you need a lot more thrust than you have on hand? This is NOT an indictment of the F-16. What you've just read is true of ANY fighter aircraft flying in the world today. In a relative sense, the F-16 is still head and shoulders above anybody you're going to run across in the near future . . . A-N-Y-B-O-D-Y! Again, the real point is in not getting slow. While the F-16 will go straight up further than anybody you're going to run across in the near future, you're still going to be slowing down when the F-16 is pointed straight up. And whether you get slow through pulling a lot of g or through going vertical, you're now susceptible to a departure if you insist on forcing the issue. Pay attention and you'll know what energy state you're in at all times. If you're in a low energy state (low airspeed), then smoothly approach the limiter and you'll never get in trouble.

The minimum airspeed limits given in the handbook are a very good place to start for maximum maneuver limits. Below these we have to use a little skill and cunning. If you do inadvertently find yourself slower than the limits set forth in the Dash One, all is not lost. Simply keep your wits about you, be sm-o-o-o-o-o-th with your control inputs, and you're home free!

Now I know it has happened before (and it will happen again) that someone will not be as smooth as they should be in a low airspeed situation, and a departure is going to happen. Let's talk about what happens in a departure so you'll be able to (1) recognize one if it occurs, and (2) recover from a deep stall if the departure progresses to that point.

Just what is a departure? First of all it's quite different (Heard that before?) from the aircraft you've been flying. You're out of luck if you're looking for the cues you used in flying the F-4 or A-7. If you're looking for nose slice to tell you that you're about to depart, it's way too late. Why? Because the F-16 usually does not depart directionally (nose slice) but longitudinally (in pitch). So, by the time you see any left or right nose motion, you're already well into a departure. What has happened is that you've been turning the F-16 hard enough to slow it down, or going straight up in an effort to outzoom the other guy. For whatever reason, you're slow.

Now, suppose you insist on continuing to turn the F-16 hard by snatching on back stick, or couple it in pitch by pulling on the pole with a simultaneous rapid roll. What you've done is to play right into the hands of all the bad parts of the negatively stable aerodynamics I already pointed out. You've rated or coupled the F-16 into an angle of attack range where it wants to keep right on going. And, at the same time, the slow airspeed means the stabilator doesn't have sufficient authority to keep the angle of attack under control. So the F-16 departs. This is never a violent departure. Remember, I told you the F-16 will not depart unless you get slow. If you're going fast enough to give the airplane enough energy to provide a violent departure, then you're also going fast enough to give the control system enough authority to prevent that departure — the one you seem so determined to effect. (So perhaps there is a valid reason for the F-16's flight control system/aero combination.) As a result, departures are very benign. Sometimes you'll not even be aware that you've departed.

Now, about those previously mentioned exceptions. Most configurations will depart only if you let the F-16 get slow, and nose slices usually do not occur in the F-16. However, as happens in other parts of life, there are no absolutes. Nose slice may occur with a 300-gallon centerline tank, Cat I configuration, under certain circumstances above 35,000, or above about 25,000 feet with wing stores or suspension equipment. These nose slices occur only in the high subsonic speed range (i.e., above .88—.9 Mach with a moderate KCAS—something well below 300 KCAS) when making roll inputs on or near the AOA limiter. If you should ever experience one of these nose slices, your first reaction should be to release the stick and let the jet fly itself out. If the aggravating stick commands are maintained, the nose slice may transition into the more traditional upright pitch departure. This pitch departure will be more dynamic than the low speed case. The excess energy will quickly bleed off, however, and the two departures will then be very similar.

Now back to the discussion about pitch departures. What I've described is an AOA excursion to something beyond 25 degrees. The control system is trying to maintain a 25 degree AOA maximum at one g, and as low as 15 degrees at nine g. There is a definite reason for this difference, but it isn't important here. Even though the flight control system is trying all the time, you can force the F-16 beyond this design AOA limit — either through coupling beyond this in roll, by rating it through this limit with an abrupt pull at low airspeed, or by aggravating a nose slice. So what happens now? Usually nothing of which you're aware. Once the control system sees an AOA beyond 25 degrees, it tries to reduce it to below 25, regardless of what you do to the control stick. But if you somehow manage to get the AOA above 29 degrees, then the system, while trying to reduce the angle of attack to within limits, will also negate any yaw rate. So what usually happens is that you're out of the control loop for a few seconds while the "black box" lowers the angle of attack and then gives it back to you. You probably never even knew it.

So why get so excited? Because occasionally the F-16 can trim itself into what has been described as a "deep stall", . . . and if you get yourself into one of these you DO have some problems. Unfortunately, you'll have to wait until the next thrilling episode to find out just what a deep stall really is and how to get the airplane flying again if you manage to get yourself into one.
F-111 Restoration Program

The F-111 Restoration Program has successfully returned nine valuable but severely damaged combat aircraft to service in a timely and cost-effective manner.

by J.B. (Joe) Brown, Jr.
F-111 Restoration Program Office

On 2 August 1982, an F-111A piloted by Maj. William D. Patton departed Mountain Home AFB, Idaho, on a routine training flight. The mission included a low-level segment over southwestern Montana, and it was there that a large bird impacted the aircraft's right wing and engine intake area. A severe airframe vibration was felt as the right engine fire warning and bleed air duct failure lights illuminated. Maj. Patton and his Weapons Officer, 1st Lt. Christopher A. Singalewitch, quickly evaluated the situation and opted to try to save the aircraft. Despite a rapidly spreading fire, they maneuvered their crippled fighter to the Idaho Falls Municipal Airport. By this time, the fire had knocked out most of the aircraft's hydraulic systems, and the crew had to use emergency systems to extend the landing gear, lower the flaps, and stop the aircraft. They had to shut the aircraft down on the runway because it would not respond to nose wheel steering commands.

Post-flight investigations revealed that the bird strike had resulted in catastrophic engine fan blade failure—which caused significant engine and fuselage damage. Disintegrating fan blades had penetrated the fuel tanks, creating fuel-fed fires that burned large holes in the fuel tank structure around the engines. One large hole was burned through the wall of the right saddle tank and another through the aft fuselage above the right engine.

Although the damage seemed hopelessly extensive, the crew's heroic efforts to save their aircraft were not to be in vain. Three years later, this aircraft—F-111A No. 146 (Serial Number 67-1011)—was returned to active duty at Mountain Home. It was the ninth (and latest) F-111 to be given a new lease on life through a restoration program at General Dynamics Fort Worth Division.

The restoration program had its origins in February 1976, following a landing accident that caused severe structural and fire damage to FB-111A No. 8 (Serial Number 67-7194). While this accident did not destroy the aircraft, the damage was so extensive that no quick or standard repair would return it to service. The wreckage was placed in storage at the Sacramento Air Logistics Center while a USAF/General Dynamics team explored the feasibility of restoration. The Fort Worth Division contracted for the restoration effort on 1 September 1978.

A noteworthy feature of that first F-111 restoration was the approach used to overcome the massive burn damage sustained in the aft fuselage section. The fuselage was demated at the weapons bay aft bulkhead, and only the forward portion was retained. The fuselage of FB-111A No. 2 (an FB flight test program aircraft) was moved to Fort Worth from its storage location at Davis-Monthan AFB, Arizona. A major portion of No. 2's aft fuselage section and some newly manufactured components were used to restore the fuselage of FB-111A No. 8. This use of preexisting components greatly decreased both the cost and the time
required to complete the restoration task. The completion of the first F/RF-111 restoration effort was marked by a successful functional check flight on 18 September 1980.

While basically a one aircraft program, the restoration of FB-111A No. 8 provided the impetus for a program with broader scope. It verified the concept of returning severely damaged aircraft to "Code 1" status in an economical manner. In May of 1981 the USAF placed the Fort Worth Division under contract to restore three more damaged F-111s. General Dynamics then established an organization and facilities to perform the program on a continuing basis. Factory space was dedicated to the program. Mating fixtures, assembly fixtures, and tools were refurbished or fabricated. Office space was provided near the restoration area to accommodate personnel from engineering, planning, tooling, logistics, and material. Special procedures were implemented to guide a program that, to date, has returned nine F/RF-111s (and three F-111 wings) to service with the USAF—at an average restoration cost of $3.9 million and an average turnaround time of 19 months. These nine aircraft were returned to service in a "fully mission capable" condition. The significance of the challenges involved in the restoration effort can best be understood by first understanding the extent of damage:

- The inadvertent deployment of a practice bomb's parachute in the weapons bay of FB-111A No. 31 (Serial Number 68-259) caused major structural damage to the aft right portion of the weapons bay. The bomb's tail cone penetrated the weapons bay aft bulkhead, damaging the main landing gear wheel well forward bulkhead, ECS equipment, electrical harnesses, and the ECS water tank.
- Just after liftoff, a stall warning prompted the pilot of F-111E No. 92 (Serial Number 68-082) to abort the flight. A hard landing resulted, and even with maximum braking, the aircraft departed the end of the runway at approximately 90 knots. The nose landing gear collapsed, and the entire forward electronics bay was heavily damaged, as were the weapon bay doors, the forward fuel tank floor, the nose gear, and the nose gear doors.
- F-111E No. 4 (Serial Number 67-118) was parked on the ramp at Eglin AFB when a high-pressure bottle (used to inflate the impact attenuation bag) exploded, extensively damaging the crew module aft bulkhead and buckling the forward fuel tank bulkhead and the crew module floor.
- An inflight fire resulted from the failure of two second-stage fan blades on the left engine of F-111D No. 52 (Serial Number 68-136), extensively damaging the left-hand nacelle, engine bay, and speed bump. After landing, the spreading fire damaged the right empennage, flaps, wing seal, and engine bay doors.
- An engine fire on F-111D No. 64 (Serial Number 68-148) resulted from failure of a ninth-stage seal in the left engine. The fire caused serious damage to the left aft and center portions of the fuselage, including the left-hand nacelle, aft fuselage centerbody, left nacelle doors, lower nacelle frames, aft fuel tank bulkhead, and the left speed bump.
- Chafing between an electrical feeder line and a hydraulic line in F-111D No. 43's main wheel well (Serial Number 68-127) resulted in an inflight fire that damaged both inlets and the right wing. The fire continued after the aircraft was landed, and the main gear ultimately collapsed, causing major damage to the left inlet duct.
- An inflight fire in the right aft corner of the main wheel well prompted an emergency landing of F-111A No. 124 (Serial Number 67-079). The fire caused significant structural damage to aircraft systems in the right nacelle structure, and to the structure itself.

Because no two accidents are alike, each restoration effort is unique in its approach. Several restorations have been completed by reusing major components from production, preproduction, or test airframes, and others have benefitted from some unique engineering efforts. For instance, when the parachute deployed in the weapons bay of FB-111A No. 31, the replacement of the wheel well bulkhead could not be accomplished without major disassembly of the fuselage, so a new "two-piece" bulkhead was engineered, fabricated, and installed. In some cases, "healthy" bulkhead segments have been spliced into damaged areas for an effective—but inexpensive—repair solution. Sometimes the entire crew module must be removed before repairs can be effected.
To give you an idea of what is involved in a restoration, let's take a look at what happened to Maj. Patton's aircraft — F-111A No. 146 — following that successful recovery at the Idaho Falls Municipal Airport.

On 30 September 1982, less than two months after the incident, the Fort Worth Division was authorized to proceed with a receiving inspection and engineering evaluation, which entails a thorough inspection of the entire aircraft to determine damaged, missing, and otherwise unserviceable parts and components. The fuselage was placed in storage from mid-January 1983 until 29 August of that year when General Dynamics was contracted to make the necessary repairs, accomplish time compliance technical orders (TCTOs), perform programmed depot-level maintenance tasks, and prepare the aircraft for return to service.

The wings, which had been removed when the aircraft was trucked from Idaho Falls to Fort Worth, were sent to the Sacramento Air Logistics Center and used on other F-111A aircraft. The replacement wings ultimately mated to the fuselage of No. 146 were unique in that they also were products of the restoration program, both having been damaged in other, unrelated accidents. Both wings had lost approximately eight feet of their outboard tips. The repair in both cases would consist of splicing in new spars and skin sections.

Restoration of the aircraft's fuselage began by placing it in a holding fixture, removing the damaged structure and components, and removing adjacent items necessary for access. Nondestructive inspections were performed on heat-exposed structural components to determine serviceability. During the course of the restoration, over 4,200 different repair or replacement line items were used and 70 TCTOs were accomplished.

When basic structural repairs were completed, the fuselage was moved to a final assembly station where the wings, engines, landing gear, horizontal stabilizers, and aircraft systems were installed. All electrical, hydraulic, and mechanical systems were then checked out. After getting a new paint job and having the fuel system checked out, the aircraft was moved to the flight line, where the engines were run for the first time and all systems were given a final, thorough checkout. When the flight line technicians were satisfied, a functional check-flight crew was requested from SMALC. On 8 August 1985, following a successful functional check flight, F-111A No. 146 was back on duty at Mountain Home AFB, Idaho — three years and six days after the original incident.

The F-111 Restoration Program has now returned two FB-111As, two F-111As, three F-111Ds, and two F-111Es to the combat force and has three more F-111Ds in work. In addition, 26 wings from early test aircraft are being reworked (after having been in storage for many years) and brought up to current configuration to serve as spares for the F/FFB-111 fleet.

The F-111 Restoration Program has successfully returned valuable but severely damaged combat aircraft to service in a timely and cost-effective manner. The program was established at a relatively low investment cost and helps to keep the F-111 force level by overcoming attrition at a modest cost. The program provides an ongoing customer service by retaining some unique damage assessment, engineering design, and aircraft restoration capabilities that could be useful in future support efforts, such as expanded combat battle damage repair assessments or programs. Also, several F-111 TCTOs have been mocked-up and prototyped on restoration aircraft, thereby negating the need to set down a flying aircraft for such a purpose.

The future of the F-111 restoration program is not certain at this writing, but the feasibility of restoring some of the preproduction F-111A airframes into current F-111E configuration has been explored and looks very promising as a method of actually expanding the F-111 fleet — at a modest cost to the USAF — despite the fact that production was halted a decade ago. ■

... and are now back in the USAF inventory.
EDITOR'S NOTE: This article concludes a two-part series on engineering flight simulators and how they are used at General Dynamics Fort Worth Division.

In the last issue of Code One, we discussed how the Fort Worth Division's Flight Simulation Laboratory is used by the engineering department as a design tool to (1) develop new airplane designs and (2) incorporate new capabilities throughout the life of existing airplane programs. In this issue, we'll describe a typical engineering flight simulator, and we'll look at the simulation facility being developed at the Fort Worth Division.

The Technological "Edge" In Advanced Aircraft Design

by J.D. (Jack) Drewett
Manager, Flight Simulation Laboratory

A n engineering flight simulator can be best defined as "a device used in a laboratory environment to create the illusion of an aircraft in flight." To create this illusion, we must first create some form of motion — or the perception of motion.

Flight simulators come in two basic categories: motion- or fixed-base. Motion-base simulators are used extensively in the commercial aircraft industry, primarily for pilot training, and are seen frequently in magazine ads and TV commercials. They consist of a crew cab with TV-type displays where you'd normally expect to find windows. The cab is mounted on a platform supported by large, computer-controlled hydraulic rams. The rams provide motion, and the TV displays give the pilot a simulated visual scene of the outside world. When operating, a motion-base simulator resembles a giant spider that's been wandering around inside a wine barrel.

Fixed-base systems don't move. Instead, certain techniques create the illusion of motion. How is this done? Well, it's basically a high-tech mind trip. Normally, the inner ear senses motion. But the mind can sometimes be deceived by other body sensors, such as the eyes. For example, have you ever been stopped at a traffic light, looking at the car next to you, and suddenly realized your car was rolling backward? You jam on the brakes... only to find that you weren't moving at all — the car next to you was rolling forward. What you've just experienced is a visual illusion known as "relative motion." Or perhaps you've been in one those "omni" theaters (like the one at Disneyland) with a wrap-around projection system. Remember how the audience would lean over to one side, trying to compensate for "motion" in the scene being projected? An entire audience squirmed in response to a perceived (but nonexistent) motion. It was an illusion. A very effective one perhaps, but still just an illusion.

These same sensations can be created in a flight simulator by placing the pilot in a cockpit and providing him with a simulated, visual "world" that responds to his control inputs. The larger the scene, or the more "wrap-around," the easier it is to achieve the illusion of motion. The requirement for large wrap-around screens is particularly important when dealing with fighter airplanes such as the F-16 that feature a bubble canopy, and where air-to-air combat is involved in the simulation scenario.

Although motion-base systems find some application in the military aircraft industry (particularly where much of the development involves landing and takeoff performance), the fixed-base systems are becoming the norm for engineering development — mainly due to performance differences between commercial and military aircraft.

While commercial airplanes seldom experience g forces greater than 1.5, military airplanes are routinely sub-
jected to much greater stresses. The F-16, for example, is capable of sustaining 9 g, whereas the most advanced motion-base systems are incapable of producing forces much greater than 3 g. And even then, these forces can be achieved only for an instant — they cannot be sustained.

get. In a flight simulator, however, the computer-generated scene is connected to the cockpit through another, general purpose computer, and responds instantaneously to pilot commands. This real-time control is achieved through very high-speed digital processing and is an essential element in establishing to stimulate the senses of touch and hearing. The g suit is controlled by a general purpose computer. The suit inflates and squeezes the pilot just as it would during an actual flight maneuver (the tighter the turn, the harder the squeeze). The helmet earphones are driven by a special audio generator that replicates aircraft

A significant advancement in simulation technology has been the development of computer-generated imagery. Until recently, visual scenes were usually created by building terrain boards — large scale models of the desired geographical area. A television camera scanned the terrain board in response to the pilot's control inputs. But improvements in high-speed digital computer processing now allow the creation of visual scenes that replicate huge geographical areas of nearly anyplace in the world. The scenes are generated completely by digital processing, and each generation of these machines results in more and more realism.

To simulate flight, we project these visual scenes onto the inner surface of a dome. Besides being created by a computer, these scenes differ from those produced for movie theaters in that they are controllable. Hollywood movies have no provision for control; what you see is what you see. In years past, lack of fidelity has caused many experienced pilots to find flight simulators unacceptable — particularly in the case of high-performance aircraft. Simulators built in the last five years, however, have largely overcome this fidelity problem with the aid of high-speed digital processing. Even some of the most critical pilots have commented that "the simulator flies just like the airplane."

To understand how the flight simulator induces the pilot into perceiving motion, let's consider a climbing left turn. To execute this maneuver, the pilot advances the throttle and moves the control stick back and to the left. Instantaneously, the computer-generated scene moves downward and rolls right, creating the illusion of a climbing left turn.

To enhance the illusion still further, other body sensors are stimulated: the pilot wears a g suit and a helmet sounds. When the pilot advances the throttle, he hears an increase in engine pitch. If he squeezes the trigger, he hears the guns fire. Or he may hear tones warning of an enemy threat. All these sounds are reproduced with exacting realism.

So, when you consider that the pilot sees the visual cues, feels the g cues, and hears the audio cues — all occurring precisely in response to the stick and throttle movements that he has initiated — it's not difficult to understand how he can experience a very realistic illusion of flight. In fact, experiments conducted by the Human Resources Laboratory at Williams AFB revealed that, with the aid of a high-quality visual scene, the motion in a motion-base simulator could be alternately turned on and off without ever being noticed by the pilot.

Creating the illusion of motion, however, is only one element of an engineering simulator. To evaluate the
total weapon system, we must simulate all aircraft elements, including avionic systems, flight control systems, airframe control laws, aerodynamics, sensors, weapons, cockpit controls and displays, cockpit instruments, airborne threats, ground threats, targets, and atmospheric effects. In addition, a variety of special visual effects must be simulated —weapon impact, collision detection, clouds, and weather, to name just a few.

Finally, in order to conduct a realistic scenario, the computer-image generator must be able to replicate extremely large geographical regions of the world. This is done with the aid of large software programs called data base models. The Fort Worth Division currently has several large data base models, including the areas surrounding Edwards, Nellis, and Seymour-Johnson AFBs, and Central Europe’s Fulda Gap region.

Most of the elements described above are software-modeled through a number of general purpose computers and array processors, collectively referred to as the “host computer complex.” Some elements require special equipment to translate computer commands into proper cockpit displays (such as the radar, head-up, and multifunction displays). Obtaining ground map imagery on the radar display requires another very special digital processor called a radar landmass simulator. The graphics used by the multifunction and head-up displays are obtained from other digital processors called graphic generators. Sensor elements, like the infrared (IR) sensor and TV weapon sensors, require additional channels on the computer-image generator. To complicate the situation further, the radar, IR and TV sensor displays must be precisely correlated to the “outside world” scene projected on the dome.

Some of the simulator’s major elements, such as the computer-image generator and the digital radar landmass simulator, cost many millions of dollars and are usually time shared between two or more simulation stations.

THE FLIGHT SIMULATION LABORATORY

In 1981, General Dynamics initiated a program to expand and enhance our existing simulation capability. When completed in 1987, the Flight Simulation Laboratory at the Fort Worth Division will be one of the finest engineering flight simulation facilities in the world, and will feature ten individual simulator stations —four 24-foot diameter domes, two 40-foot diameter domes, and four high-resolution stations. A high-resolution station differs from the dome simulator mentioned above in that it uses a projection system similar to those found on commercial airline simulators.

The two 40-foot domes, known collectively as the dual-dome air combat simulator, are currently under construction. The first dome is...
scheduled for completion about the time this article is published, and the second will be completed nine months later. Each 40-foot dome will feature a full 360-degree field of view and, with additional projectors mounted below the pilot’s line of sight, will be able to project multiple high-resolution targets anywhere in the dome. The pilot will thus have the same visibility in the dome as he enjoys in the real world. This remarkable visibility is accomplished by mounting the projectors outside the dome and projecting the scene through a hole that is not discernible to the pilot. Initially, this simulator will be used almost exclusively in the air-to-air mode. Within the next year, however, a new and greatly improved computer-image generator — called the CT-6 — will be delivered to the Fort Worth simulation facility. It will improve the air-to-air capability while providing an air-to-ground capability never before attainable in an air combat simulator.

Each 24-foot dome is equipped with three large-screen projectors (GE Light Valves) mounted above and behind the pilot. The projectors are currently driven by a five-channel, Evans and Sutherland computer-image generator known as the CT-5 (scheduled for upgrade to eight-channel CT-6 capability within the next year). Three of the five channels drive the projectors; the other two generate IR and TV images on the cockpit displays. The CT-5 can replicate scenes from any part of the world for which terrain elevation data is available. In addition, multiple moving targets (such as other aircraft) can be included in the scene.

Although frequently used for air-to-ground simulations, the 24-foot domes are primarily designed for air-to-air simulations where a very large field of view is absolutely necessary.

Even so, the field of view in the 24-foot domes is effectively limited to the forward hemisphere due to the location of the projectors. Future enhancements will relocate the projectors and expand the field of view to achieve the same visibility as the 40-foot domes.

Unlike the domes, the high-resolution stations are used almost exclusively for air-to-ground simulations due to the greatly enhanced image quality available. These stations can also use the CT-5, but more frequently use the less expensive SP-3T. Although somewhat less capable than the CT-5, the SP-3T is used extensively in the simulation business.

Each simulation station is equipped with its own cockpit, display generators, host computer complex, and projection system. But, as mentioned earlier, the image generation equipment must be time shared between the various stations. Currently we have a five-channel CT-5, a three-channel SP-3T, and a single-channel SP-2. Within the next twelve months, the CT-5 will be expanded and enhanced to an eight-channel system, the SP-2 will be upgraded to a three-channel SP-3T, and a new eight-channel CT-6 will be delivered. Each eight-channel system can provide visual scenes for two stations flying in the same data base (or geographic area) simultaneously.

The first digital radar landmass simulator will be delivered in the summer of 1987, and three more systems are planned for the following year.

Other features of Fort Worth’s simulation facility include TEMPEST-qualified computer rooms (for classified programs), simulation control and display rooms, briefing and debriefing rooms, pilot locker and shower rooms, a mission planning area, a data base development area, fabrication and maintenance areas, and office space for the engineering staff. The total facility occupies an area in excess of 55,000 square feet.

The Flight Simulation Laboratory is currently being used to support some of the most exciting projects in the industry. The Advanced Fighter Technology Integration (AFTI) program, for example, used simulator technology to develop a digital flight control system that permits the pilot of a modified F-16 to change elevation without changing pitch, or to change heading without commanding a roll attitude. The AFTI simulator is also being used to link the fire control computer with the flight control computer so the airplane can be automatically steered to the optimum weapon release point, and to develop new features for incorporation in future production airplanes, such as voice control, digital moving maps, etc.

In addition to the AFTI program, there are a number of other programs currently being supported in the Flight Simulation Laboratory, including a reconnaissance version of the F-16, production digital flight control systems for the F-16 and F-111, a number of advanced capabilities for the F-16, and certain classified programs. Finally, a considerable effort is being expended to conceptualize and simulate the next generation fighter . . . the Advanced Tactical Fighter.

Fighter aircraft have clearly become more sophisticated since the P-47, for instance, was first introduced in World War II. But so have the tools used in their design, and the Flight Simulation Laboratory at Fort Worth gives General Dynamics the technological edge in advanced aircraft design. ■
NOTE: “Farewell 1084” begins a new series in Code One magazine. The interview segments contained in this and future issues were originally compiled for Out of the Sun, an F-16 promotional movie produced by the Marketing and Multimedia departments at General Dynamics/Fort Worth Division. Segments used in the movie dealt mainly with fighter design philosophy, leaving unseen and unheard much that was interesting in the way of action and historical color. Interviewed were actual “aces” of aerial combat, from World War I through Vietnam. Here then, for the first time in print, are these personal accounts of war in the air.

The first air warriors were the pilots of World War I. Prominent among these was William C. “Bill” Lambert, America’s second-ranking ace of that conflict. Born at Ironton, Ohio in 1894, Lambert was 85 years old when interviewed by Mr. Robert J. Smith, then Chief of the Office of History, U.S. Air Force Museum, Wright-Patterson AFB, Ohio. The intervening years had not dimmed Lambert’s vivid memories of combat, nor his love of aviation. Although all his WWI combat was with the Royal Flying Corps, Lambert served in the U.S. Army Air Corps during WWII, achieving the rank of Lieutenant Colonel. Following WWII, he remained in the inactive reserve until 1954. Col. Lambert died in 1983.

—Bob Cunningham
in October of that year. He trained at Chattis Hill near Stockbridge, England. Following this, he shipped to
France. He arrived at the front in March of 1918, went
on his first offensive patrol on 1 April, and by the time
he had completed his tour of duty, he had destroyed 22
enemy aircraft.

Col. Lambert, let’s talk about your World War I
experiences.

LAMBERT: OK. Which one do you want to talk about?

SMITH: When you arrived in England and began flying
at Stockbridge, what aircraft were you being trained to
fly?

LAMBERT: Well, the function of those training fields is
for the pilots who had been through preliminary schools
to learn to fly combat aircraft: SPADs, Camels (that’s Sop-
with Camels), Sopwith Pups, S.E.-5s, Nieuports, Bristol
Fighters, and DH fighters. We had to learn to fly any
combat airplane that they wished, wherever they wanted
to put us, and that was it.

SMITH: Did you immediately like the S.E.-5?

LAMBERT: I liked the general appearance of it, the
length of the engine out in front of it, far enough away
that there were two firewalls. Gasoline tank was right in
front of you, but everything was perfect. Suited me to a
“T.” Period.

SMITH: What about the flight characteristics of that
airplane?

LAMBERT: Excellent, excellent.

SMITH: Col. Lambert, how did the S.E.-5 compare with
the SPAD or the Camel?

LAMBERT: Well, as I’ve told you, I worked with my air-
craft to try to get them superior in maneuverability and
service, like I told you, and I succeeded to doing it
to suit myself and it was, I’d say, as near
perfect as you can make ‘em. I could have it trimmed
and I could fly “hands off” for, I’d say, maybe two minutes without touching
anything and she’d still be in a safe condition.
I had ten hours in the Camel. Ten hours, and
that was ten hours too much. To me, that was
a dangerous airplane, but you’d find
some of these Camel fliers that would
say it was the best thing that
was ever made. But you had to
give it your personal attention with
your eyes and your hands all the time. You
had to fly it all the time due to the torque of those rotary
engines . . . slap you over in the opposite direction into a
spin. Some of the boys got them out, some didn’t. And
the rumor around France at the time was that the Camel
killed more of its own pilots than the Germans killed.
That wasn’t so good, was it?
The SPAD was an awful nice airplane to fly, and if I'd had one, I'd have worked on it just the same as I did on my S.E.-5 to help improve it. But when they dived, they went down like a ton of bricks. Boy, they really... it was a heavy airplane. And it really dived. There was no dihedral on it, so there's no resistance in that dive, and that's the only thing about it that I didn't like. But I'd say this, if we hadn't had the S.E.-5, I'd of had that SPAD because it was good. But on two-seaters, like the Bristol Fighter... I never wanted to be responsible for another man's life... or death.

SMITH: You've mentioned before to me, Col. Lambert, that the S.E.-5 would fly itself. What did you mean by that?

LAMBERT: We worked... I worked personally with my mechanics at the end of each and every patrol. We rerigged if we had to. We tightened up some turnbuckles; we loosened turnbuckles. We adjusted everything until we got that airplane where, after I tested it, and if it didn't suit me, we worked it over again. But I wanted it to do just what I wanted it to do, and that was it. A lot of pilots, they didn't. They just climbed out of their airplane, and that was it. But I worked right along with my mechanics, pretty near all the time, to get it trimmed and everything to suit me.

SMITH: Was there anything about the S.E.-5, Col. Lambert, that you didn't like? Were there any peculiarities about it that you had to watch?

LAMBERT: There wasn't anything on there that I didn't like, but there were a few things that I thought might could be corrected. For instance, we had a fairly steep dihedral. Five or eight degrees, somewhere like that. I don't know what. I got the idea to reduce that dihedral. They put the big dihedral in there for stability. I cut it down, or me and my mechanics cut it down just about one-half. (Reducing the dihedral angle reduces stability but increases maneuverability—a very important aspect in aerial combat. —Editor)

SMITH: Now, you shot your first enemy aircraft down on April 7, 1918. Tell us about it, if you will.

LAMBERT: I'm scared to death. "C" flight went out by ourselves to hunt some enemy, and we got mixed up. I got lost. I lost all the others. There were six of us. Six pilots, six machines to a flight. I lost them. There I was out by myself, nothing around me but the sky. I didn't know what to do. Suddenly, off in the distance, I saw five or six airplanes coming towards me. I figured, "Well, that's the rest of my flight," and I was still scared. What'd I do? I went towards them to meet them, got right in the middle of 'em for safety and what did I see? German crosses all around me. I was right in the middle of a flock of German airplanes. Boy! I figured, well, this must be it. So I shut my eyes, kicked the stick back and forth, kicked the rudder back and forth, pulled her up and down, anything. Didn't see what happened. When I got back home, back to the squadron, two or three of them had seen it, watched it, and they congratulated me. I said, "For what?" They said, "When you shot that Albatros down, you burnt him." I didn't even know it. I didn't know what I'd done. They said I'd made the damndest airplane maneuver that they'd ever... they were sitting up about a thousand feet above me. Then they came on down later; they said I created the damndest maneuver they ever saw any aircraft going through. What I did, I don't know. The stick this way, that way. The rudder. Everything. So that was it. Pressed the buttons for both guns. Luckily, I hit an Albatros and burnt him.

SMITH: Well, from that point on, your confidence built.

LAMBERT: The thinking was that if you can survive the first two weeks, you have a pretty fair chance of getting through, and that held true. We had one boy, poor devil, he was scared to death. And so was I. Sitting on the ground, I was scared to death. After you get in action, you don't have time to be afraid. You just forget it. But all he talked about was, "I'll never go home." And sure enough, at the end of about three weeks, they'd killed him. That's all that was in his mind.

SMITH: Tell me, Col. Lambert, did you ever run out of ammunition and pull out your pistol and shoot it at a pilot in the air?

LAMBERT: Yep. Yes, I have done that. And I've been out of ammunition and threw a fire extinguisher at one.

SMITH: You threw a WHAT at one?

LAMBERT: A fire extinguisher. And I damn near hit his prop. If I'd hit the prop, I'd have had a credit for another victory... with a fire extinguisher. I hit it and damaged the wing or something, but I didn't hit what I needed. That's all I had then. Another time I had an empty Vickers cartridge drum, almost empty up there, and I had an empty... we had an empty container down here, where we put the empty drums. I poured one of them out and threw that at one of them. And it went sailing off through the air, and I didn't even hit him. But my fire extinguisher did hit him.

SMITH: When your flight ran into enemy aircraft on an offensive patrol, what maneuvers did you try to make to get in an advantageous position?

LAMBERT: Get the sun behind us, Period. Sometimes they'd get the sun behind them. But we always tried to get the sun behind us so we could come in on 'em out of the sun.

SMITH: Was there a teamwork effort?

LAMBERT: On "C" flight, I had a British West Indian boy, a pilot, name of James Albert Edward Robinson Dacie. He and I took to each other right off the reel and we got to playing around together when we weren't flying and we eventually got to team up together, side-by-side, or behind; this, that, and the other... just the two of us. And finally, the other four boys, they did the same thing.
They saw what we were doing and they went out by twos. We didn’t leave the flight, but we worked two to a team. Sometimes Daley would pull somebody off my tail, sometimes I’d knock somebody off his tail. And it worked out a pretty nice scheme, because we always, some way, had protection behind us.

SMITH: Did you ever get together after an offensive patrol and discuss the mission?

LAMBERT: Very, very seldom. We didn’t talk about it when we got back. We forgot it. We flew, we had the combat, we had the mission. When we came home, some of them got drunk, some of them tore up furniture in the mess hall, and everything else. The mess hall was just a shack, a Nissen hut, but it was comfortable. We never talked about that stuff. Period.

SMITH: In your book, Combat Report, you give the impression that the 24th always took the war to the Germans.

LAMBERT: Ninety-nine percent of the time, we had to go to them. Rare occasion, we would find them on our side of the line. Richthofen (Manfred, Baron Von Richthofen—Germany’s top scoring ace of WWII) made his biggest mistake, He left his group to chase after a Camel. The rest of my flight was fighting the rest of his organization about ten miles farther east on their own side of the lines and that’s where the bulk of the fighting came. That’s the reason we lost a lot of pilots as prisoners of war. We'd come down, the man wouldn’t be hurt at all, but they were prisoners because they were in German-held territory. Richthofen was so sure he had cold turkey in that Camel out there in front of him, I don’t know what was the matter with him, cause I never saw him on our side of the lines before, never. But he chased that Camel. The result was he was out about ten miles back of our lines when he shot down. I met Richthofen possibly three or four times. See, he was killed on the 21st of April (1918) and I didn’t start until after the 9th. So we only had about three weeks out on the lines together and I did meet him and his outfit. He got on my tail once, and then I managed to get away from him. But the day he was killed he just evidently wasn’t thinking and that was it. (Richthofen was under fire both from the air and from ground antiaircraft batteries. He was killed by a single bullet through the heart. — Editor)

SMITH: Let’s talk about code of honor and chivalry. Did it exist in World War I?

LAMBERT: Didn’t around me. Didn’t in my time. They claim in the early days they’d wave at each other, but it wasn’t done in my time. There were only two things there — I killed him or he killed me. No chivalry. Hear a lot of it in the paper novels, but uh-uh — not true.

SMITH: Did you ever see any unusual weapons being used, such as grappling hooks to drag behind the aircraft?

LAMBERT: No, that was done in the early days. What good would they do? They’d both crash. If you’re flying with a grappling hook and you grab me, what’s going to happen? Both of us might go down, and you’d go down before I do ’cause it will jerk your airplane out of control. That... I think you read that in the paperback novels. I don’t think it was ever tried. One thing that was tried in the early days... you’ve been to the dart boards, haven’t you, and you know how the darts are. We made some steel ones (flechettes) about that long and a little tiny fin on the back to guide them, too, and we used to take two or three buckets full of them and drop them over the trenches and this, that, and the other. And they were pretty darned effective. One of them coming down and hitting you in the head is going through your skull, because they’re pointed and the actual instrument is about that long (six to seven inches). They had some weight by the time they’d fallen like that. It was effective.

SMITH: Did you ever get into trouble by letting your mind wander off what you were doing?

LAMBERT: Well, I was flying my favorite S.E.-5, No. 1084, and daydreaming one day (July 4, 1918)... nice, beautiful sky. Not a cloud in it. Nobody around to bother you. And I was daydreaming, and thinking back home on the river, the Ohio river, was what I was doing. Definitely unconscious of anything around me. Far as I knew, there was nothing. And all of a sudden, bullets started going through the wing, some through the fuselage, I looked back. Here were three... two D-7s, Fokker D-7s, and one little Pfalz D-3. All three of them coming right at me. Possibly five or six hundred feet above me. All three of them. Two guns each airplane, six hundred rounds a minute each gun. And they were shooting both guns. Thirty-six hundred rounds of ammunition coming down while I was daydreaming. So I was scared Hellbent for election by that! But there again, I think I dived so fast, I don’t know who took over the airplane, whether 1084 did it herself, or whether I... well, I must have blanked out. My speedometer had a needle on it and it had gone over so fast and so hard that it was bent that needle. And I think its redline was around 200. So the first thing I knew, I was on top of those two D-7s and the Pfalz was right down here below me. 1084 managed to burn each one of those D-7s and a friend of mine took the Pfalz D-3 and burnt him. All three of them hit the ground within two hundred yards. Both of mine were burning when they went down. The little Pfalz wasn’t, but I’d say there wasn’t more than two or three hundred yards diameter that all three of them were piled up in, period. Was I daydreaming? Yes, but I didn’t do it any more.

SMITH: You were very fond of your S.E.-5 1084, weren’t you?

LAMBERT: Yes.

SMITH: But lost her?

LAMBERT: Lost her to ground fire. Had to land her between the lines, and she rolled into a shell hole. And that was it. I got out and saw troops and horses off to my left, about 200 yards in some trees. They waved to me. It was a troop of our cavalry and I started toward them just as the Germans started shelling 1084. I heard that and I ran back to her and tore the clock from her dashboard, I still have it at home. Then I stood there a minute thinking, “Farewell 1084. You’ve pulled me out of many a tight, and never let me down. Now we have to part.” I took one last look at her and ran for the trees. I looked back later and she was gone.

NEXT: An interview with Sir Douglas Bader, the double amputee who later became an ace in the Battle of Britain.
Let's Get Physical

A “Conscious” effort can keep you alive!

by Joe Bill Dryden
Experimental Test Pilot

Those of you familiar with automobile racing will immediately recognize the names of Roger Penske and Mark Donohue, an owner/designer and engineer/driver team that dominated automobile racing for a long time. Each time they would enter some new class of racing they would immediately begin to be a threat to the “old heads,” and would soon be winning everything in sight. On one occasion, Mark was being questioned by reporters as to the secret of his success. He replied that he had an unfair advantage... and let the question drop. For weeks this answer drove the reporters nuts as they tried to figure out just what this “unfair advantage” really entailed. When finally pressed further, Mark said this unfair advantage was, simply, attention to detail. Please keep that remark in mind as you read the remainder of this article.

Several F-16 accidents give all the indications that the pilot hit the ground in a perfectly good airplane. One reason advanced for some of these accidents was that the pilot was unconscious at the time.

Why was he unconscious? (A rhetorical question.) It appears that he had pulled more g than his body was capable of withstanding. How could this happen? Are you not a dyed-in-the-wool fighter pilot, ever capable of sustaining at least 12 g?

Can you really? Any time you want? Let’s look a little deeper into the mechanics of functioning effectively (the operative words here) under the g loads the F-16 is capable of delivering.

How about your own pink body? What kind of physical condition are you in? Are you really? Do you take proper care of the carcass the genetic pool provided for you? Do you get the proper diet? Do you get the right amount of rest? Do you sometimes fly despite a partially debilitating illness? Worse yet, do you sometimes indulge in a little self medication for the aforementioned illness? Do you take good care of the equipment issued you? Do you use all the equipment that is available? Do you drink a little too much? Hummmmm?

If you’re serious about flying high-performance fighter aircraft, then you’d better get serious about just how you condition your own body. Consider the following:

- How much exercise do you get?

The idea here is not to become a marathon runner or a triathlon competitor. In order to be really in shape for these events your blood pressure would become too low to fly fighters effectively. But neither can you emulate a sloth, swilling beer in front of your TV set every
evening and weekend. It's up to you to establish a routine that will provide a lot of walking, a moderate amount of running (especially up stairs), a reasonable amount of sit-ups, and a general routine of weight work in order to be in the physical condition necessary to really use the airplane to its maximum.

- How much rest do you get? Do you really get a good night's sleep before you go fly? If your body is not rested and ready, then neither are you. I think it was Casey Stengel who, when asked by a sports reporter about his rules concerning sex before the "big game," replied, "Hell, it's not the sex that gets you, it's the staying up all night looking for it!" The moral of the story is this: if you're accustomed to getting six, seven, or eight hours sleep a night, then don't stay up to one or two in the morning and expect to be a hundred percent four hours later when you strap yourself into your F-16.

- Do you eat right? Just like your jet, you need the right kind of fuel in order to fly. I'm not going to go into a nutrition course here. You all know what is contained in a "balanced diet." Make sure you eat the right kinds of food before thrusting yourself into the high-g environment.

- Do you smoke? There's been a controversy lately about "blood doping" by some of our Olympic athletes. What they've been doing is extracting and saving some quantity of their own blood. Then, just before the big event, they infuse the additional blood into their system. The idea is to "supercharge" their blood system with an additional amount of oxygen-carrying red blood cells. This is certainly nothing that we could or even should try to do ourselves, but why go to the opposite extreme and tie up a large proportion of what red blood cells you have with useless CO2? DON'T!

- Then there's the touchy subject of drinking. Fighter pilots are somewhat the victims of a macho, hard-living, hard-drinking image that has existed since WWI. I'm not a teetotaler. I drink something besides diet soft drinks. But I don't drink more than one beer if I'm going to be flying the next day (especially if I'm going to be flying EARLY the next day). We're nowhere near the limit of a human's ability to fly airplanes, but you're sure cutting into your margin if you insist on staying up late and trying to drink everybody under the table. You are NOT sober the next morning if you try to go fly. For that matter, you can sometimes find traces of alcohol in your system more than 48 hours later. A very insidious side effect is that alcohol in your system can infuse and partially replace the fluid normally contained in the inner ear, which can screw up your inner ear calibration and give you erroneous inputs under g just when you can ill afford them.

OK. Enough about your body. It's all yours, but it's up to you to take the proper care of it. Just don't forget that the high-g environment you're trying to exist in is more than the average citizen can tolerate. You must have the self discipline not to fall prey to the wrong fighter pilot image. That should have changed about the time we quit flying P-51s and P-47s.

Now let's talk about your equipment. In what kind of shape is your g suit? I know of two individuals who thought it wasn't macho to wear a g suit. (One of them is a mort. In an airplane. While pulling a lot of g.) Make sure your suit is in good condition and is properly fitted; i.e., snug if not downright tight. Do you always make sure you zip up the thigh zippers? I'll bet you sometimes forget. Do you always plug the sucker into the connection—properly or otherwise? (The new connectors will go a long way to insure that the connection stays put once you've pressed them firmly together.) Make sure you have the g suit refitted after it stretches (they all do). The new quick-fill valve now being installed in the airplane will help a lot.

I definitely get the impression that we're not all doing the right kind of M-1/L-1 (select one). Make SURE you know just what it is that you're trying to accomplish with the maneuver. In its simplest terms, you're trying to artificially raise your blood pressure while pulling g. Over any period of time, it's up to you to provide about 80 percent of your g tolerance by this straining maneuver. EVERY muscle in your body should be tense. You should feel like you're hyper-constipated. Your thighs and calves should be tensed. You should be trying to curl your toes out at the bottom of your boots. You should be straining with every muscle in your upper body. You should also be aware of your breathing. The worst thing you can do is hold your breath while pulling g. I've seen people who try to do exactly that (not recommended!). The medical community tells me you should be taking a breath about every three seconds. I'm not sure this is true for each and every one of us, but it seems fairly close. I breathe at about that rate. Check yourself. It's easy. Just go hot mike during your next engagement and then listen to the tape. What you should hear is a sharp (i.e., rapid) intake of breath, about three to five seconds of relative silence while you really bear down with the M-1/L-1, and then a sharp exhalation followed instantly by the next inhalation to start the next cycle.

Now here's a g-tolerance tip I'll bet you haven't heard about. I saw an article in the 2 June 1980 issue of Sports Illustrated that really started me thinking. The article was about our Olympic Luge team and how they had been helped by a dentist. It seems that he'd made them a mouthpiece to wear during their runs on the luge to improve their ability to pull g during the turns. I figured that if it could help these folks pull three to four g for less than ten seconds, then it should certainly be able to help us pull nine g for a longer period of time. I had the dentist at Edwards AFB make one for me and I'm convinced it improves my g tolerance by at least one g. This is just my subjective judgement, but I'm sure that the improvement is at least that much. The kind of mouthpiece I'm describing is a TMJ bite block. It is very important that you make this distinction. It is NOT the kind of mouthpiece you wear playing football or any other contact sport. It's not there to keep you from chipping your teeth. TMJ is short for temporomandibular joint ("jawbone" for you ag majors). The principle involved is
that all of us have some degree of misalignment as to how our teeth match up. We subconsciously hold our jaw in the proper position so our teeth mesh. This TMJ bite block helps align the jaw properly so we can now relax and not have to use unnecessary muscular strength. It also gives us something to bite on to help strain. The more muscles we can use effectively, the higher we can raise our blood pressure to combat g effects. I know some of you think this is a bunch of BS, but give it a try before you write it off. Go to your dentist on base and tell him you want to be fitted with a TMJ appliance. I'll be surprised if you don't think it makes an improvement in your ability to sustain g. It is not magic. (The bite block is just one more item to add to what you already should be doing.)

Before I end, I want to discuss one more aspect of pulling g. There’s some concern that the ability of newer airplanes to pull g in a hurry, or “onset rate” (specifically the F-16, but with its new g limiter the F-18 is probably as quick) decreases your ability to pull g. I don’t see where this is a player. If you’re flying the airplane, it should never be a surprise that there’s suddenly a rapid increase in g. If the message goes from your brain to your right hand (“Mongo, PULL now!”) it should also be able to send a message in parallel to the REST of Mongo—“Here comes a lot of g!” Although these new airplanes are capable of high onset rates, you’re the one controlling the onset of the onset. Understand? It should come as no surprise, then, that there’ll be a lot of g to contend with shortly after you yank on the stick.

You're the one in control. Get ready early! Just because you know that the g limiter will prevent you from an over-g on the airplane does not remove your obligation to prevent an over-g on YOU!

Attention to detail. You can make it work for you. I’m no superman, but I’ll be happy to demonstrate a constant nine g for more than 45 seconds. Any time you’d like. Because I’m looking for any detail that will help me win... I’m looking for that "unfair advantage."

Check six. ■

Probe Heater Circuit Breakers
Push'em in Before You Fly Again

by H.Z. (Scotty) Scott
Staff Specialist, Flight Controls

An F-16 pilot, while returning from a mission, was descending through 15,000 feet when the angle-of-attack (AOA) gauge went off and the avionics light illuminated. Less than a minute later, at about 10,000 feet and 300 knots, the aircraft pitched violently nose low (at least minus three g, it was later reported) and the pilot could get no initial stick response. Two seconds later (it probably seemed much longer to the unfortunate pilot) control response was restored and a recovery was effected. Following recovery, the ADC, FLT CONT SYS, LE FLAPS, and DUAL FC FAIL lights illuminated. All lights were successfully reset and the pilot noticed that the pitot heater switch was on.

During the brief loss of control and ensuing recovery, the aircraft lost about 1000 feet in altitude. Had this been in a low-level environment, a disaster could easily have resulted. As it was, the pilot declared an inflight emergency but landed without further incident.
So what happened? And what can be done to keep it from happening again? An analysis of the flight data recorder revealed that the aircraft had been flown at 30,000 feet for over an hour prior to the incident. Just before control was temporarily lost, the aircraft was in a 10 degree nose-low attitude, in clouds with light precipitation, 2,500 feet above the freezing level. The recorder revealed that the AOA gauge went off at 15,000 feet when the left conical AOA probe rotated to its maximum limit of 32.5 degrees. Fifty-five seconds later, at about 10,000 feet, the right conical probe also rotated to the 32.5-degree limit and the computerized flight control system temporarily took control from the pilot and pushed the aircraft abruptly nose low.

The culprit? A maintenance inspection revealed that five probe heater circuit breakers (located in a fuselage compartment separate from the cockpit) were out. After pushing these breakers back in, all aircraft systems checked good.

Before attempting to explain the chain of events that led to this incident, it's important to point out that the F-16's flight control system is characterized by some rather unique functions, including an AOA "limiter" which, along with the g limiter, allows the pilot to routinely fly his Fighting Falcon to the very edge of the envelope without fear of overstressing the airframe. Due to aerodynamic principles that we won't try to explain here, the pilot cannot maintain lateral control of his aircraft once it exceeds a certain AOA. This loss of control is called a "departure"—which the F-16's AOA limiter is designed to prevent. It does this by taking control away from the pilot if the AOA limit is exceeded. While the limiter is in control, it recovers the aircraft in the early stages of departure, before a spin or deep stall can develop, then returns control to the pilot.

Basically, the system operates from two external probes which determine AOA by measuring pressure changes. Each probe has two port openings. When AOA changes occur, air pressure at the two ports will become unequal and the probe will then rotate until the port pressures are again equalized. The angle of probe rotation is read in the cockpit as an AOA value. The ports can rotate 32.5 degrees, but above 15 degrees AOA the pilot's g capability is restricted, and above 29 degrees his roll control is overridden and the nose is forced down to prevent departure. If moisture gets in the probes and freezes (as happened during the incident described above) the system can erroneously "read" an excessively high AOA, take control away from the pilot, and push the nose low. Normally, this malfunction can't happen, because the probes are heated so that any moisture coming in contact with them does not freeze.

But the system can be defeated. In normal operation, the probe heaters are automatically activated whenever the weight on either main gear is less than 5,000 pounds, or when the weight-on-wheels circuit breaker is pulled. Removal of weight-on-wheels is required for certain maintenance actions (such as a simple tire change, or troubleshooting the environmental control system). To prevent serious burns from accidental contact with a probe, the crew pull the five probe heater circuit breakers (located in an external fuselage compartment) before performing any maintenance that requires weight off wheels. But if the circuit breakers are not reset following completion of the maintenance action...well, the result can be disastrous.

In this case, the breakers were left open and the aircraft was flown in the super-cold atmosphere at 30,000 feet. Although the air was dry, the aircraft was flown at that altitude for over an hour. Since the probe heater circuit breakers were off, the probes became very cold. Once the aircraft was flown through light precipitation which immediately froze upon contact with the cold probes. The probes then rotated to their limit and "instructed" the system to take command of the flight controls, pushing the nose violently low in a vain search for equalized pressure readings. Fortunately, the probes somehow cleared themselves after just a couple of seconds.

Flight control system redundancy and self test features are provided to preclude any single failure from causing a problem for the pilot in flight. Until recently, however, self testing would not detect an open probe heater circuit breaker and no indication of an open breaker was provided to the pilot in the cockpit. Failure to close all five probe heater circuit breakers after maintenance action will, under normal circumstances, present no problem to the pilot; but in adverse weather he could have a real challenge at a time when he needs all the help he can get.

The problem won't occur if you (1) make the proper RED X entry in the AFTO 781A maintenance discrepancy and work document when the breakers are pulled, (2) always reset the probe heater breakers after the job is done and sign off the AFTO 781A, and (3) don't assume that self test or someone else will discover the mistake—before it's too late. ■
F-16
Sets the Safety Standard

by J.E. (Ed) Hartman
Safety Analysis

The F-16 is the United States Air Force’s primary multi-role fighter, responsible for air-to-ground missions as well as air defense and supremacy. Since delivery of the operational aircraft began in 1978, more than 1,500 F-16s have been delivered to the ten nations currently flying the aircraft. The F-16’s safety record, particularly in the last four years, has been effectively demonstrated through lower accident rates and increased mission responsibility. This record did not just happen. It is the product of efficient technology use, systems analysis, and resource management—particularly at the user level.

Activities during 1985 demonstrated the F-16’s ability to sustain prolonged operations, high-intensity/short-term surges, and international deployments—while maintaining “mission capable” rates previously thought unattainable. And these activities were accomplished without sacrificing the safety level demonstrated over the last three years. In 1985, USAF F-16s saw a ten percent increase in flight hours over the previous year (214,000 vs 196,000) while two more aircraft were lost than in 1984 (eleven vs nine). The USAF loss rate in 1985 was 5.1 aircraft per 100,000 flight hours (4.6 in 1984). The fleet at large flew 278,000 hours with fifteen losses for a loss rate of 6.0 per 100,000 hours. The USAF was the only using country to sustain an engine loss in 1985.

Design changes have significantly enhanced the aircraft’s maintainability, reliability, supportability, and thus its overall capability. These design changes have effectively reduced, and in some cases completely eliminated, the causes of previous accidents. Refinements to the engine, for example, include enhanced fuel pump inspection and overhaul procedures, and improved quality control procedures. These procedural changes, identified early in the program, have encouraged the incorporation of other corrections that have resulted in accident prevention. The annual fleet-wide loss rate

Single Engine Fighter/Attack Safety Comparison

Multirole Aircraft Safety Comparison
from engine-related problems declined from 3.7 per 100,000 flight hours in 1982 to 1.1 in 1985. USAF engine-related losses also decreased from 4.8 to 1.4 in the same period.

The F-16 fleet at large has flown over one million hours while conducting tactical operations in all weather conditions, and in the demanding, low-altitude flight regime. Cumulatively, USAF F-16s have flown 760,000 hours while sustaining 55 losses for a loss rate of 7.3 aircraft per 100,000 flight hours. When considering worldwide cumulative fleet statistics, the loss rate through December 1985 is 9.1 aircraft per 100,000 flight hours.

No F-16s were lost during initial development and testing (1975-78). The F-16 did, however, experience mishaps after introduction to tactical operations and realistic combat training—as has every other fighter. A review of F-16 history, especially since entering the mature phase of flight operations, reveals it to be the safest multirole fighter and the safest single-engine fighter in USAF history.

To date, casual fleet loss factors show operations (basically pilot error) as the major contributor (51 percent for the USAF, 62 percent for others). Engine-related problems account for 34 percent of USAF losses and 20 percent for other countries. Aircraft system-related problems have accounted for 11 percent of USAF accidents and only six percent for all other countries. Bird and lightning strikes and one USAF "undetermined" accident make up four percent of USAF losses and 12 percent for other users.

Almost every fighter has shown a tendency to encounter higher, statistically erratic attrition rates earlier in its service life than it displays after reaching maturity. The USAF F-16, however, began its operational service with a much lower rate than those experienced by most other USAF fighters. This was due to the high priority placed on systems and flight safety during the F-16 program's design phase.

The F-16's safety performance is a direct result of initial design integrity and subsequent improvements incorporated into the aircraft. These involve specific improvements to basic aircraft systems, to the cockpit, and to the Pratt & Whitney F100 engine. Of less importance, however, are the contributions made by the pilots flying the aircraft and by the ground crews maintaining it. The effectiveness of this combination of factors has borne fruit through more effective employment and safer aircraft utilization. It has also expressed itself through record-breaking readiness levels, greater unit proficiency, and higher mission performance rates.

Additional capabilities are being programmed for the F-16, such as LANTIRN, AMRAAM, GPS, and ASPI. Each new system brings new tactics, new delivery techniques . . . and new safety risks. Before any new system is introduced into the field, however, it is thoroughly "scrubbed" by test pilots and by engineers of all types; e.g., human factors, design, and system safety.

Some might think it strange to equate safety with a high-performance fighter such as the F-16. After all, we're not talking here about passenger planes or cargo haulers. We're talking about a combat machine capable of sustaining nine-g turns while operating at terrain-hugging altitudes, delivering a variety of weapons with pinpoint accuracy. We're talking about an airplane that is repeatedly pushed to limits that far exceed the abilities of almost any other airplane in the world. Yet the F-16 operates in this environment with comparative safety. Modern technology has provided today's fighter pilot with a single-engine machine that is inherently safer than any of its predecessors—not because of its mission, but in spite of it. And you can be assured that every effort is being made at General Dynamics Fort Worth Division to maintain—and even improve—this record.
General Yates' comment in July 1984 is still true today. The F-16 has the highest reliability of any operational fighter in the U.S. arsenal. To date, 400 "zero defect" F-16s have been delivered to the USAF, including four "perfect" F-16s. These four aircraft passed company acceptance flights, USAF acceptance flights, the ferry flight, and receiving inspections without a single discrepancy.

THE FACTS
The F-16's sortie effectiveness has been proven in both competition and combat. Combat sortie production rates from Mideast engagements are classified, but in October 1985, the USAFE surge record was broken by F-16s of the 496th Tactical Fighter Squadron, 50th Tactical Fighter Wing. (The previous record holder was also an F-16 unit.) They were able to produce a one-day, 8.0 sortie-per-aircraft surge in less than 12 hours. Fifteen aircraft flew eight or more sorties, and one aircraft actually flew 13. The unit's surge rate would have been higher had USAFE regulations allowed pilots to participate in more flights per day. Fifteen of the squadron's 18 aircraft were still Code 1 when all available pilots had reached their sortie limit.

The F-16's reliability has also been demonstrated through what may be a USAF fighter record for most consecutive sorties without an abort. Sgt. Douglas McWhorter, a crew chief with the 4th Aircraft Maintenance Unit, and...
his assistant crew chief, A1C Pete Smith, managed to keep their Fighting Falcon flying through 168 sorties and 230.7 flight hours.

And Thunderbird pilot Lt. Col. Hoss Jones reports flying more than 100 straight sorties without a writeup. Col. Jones also has more than 1000 hours in the same F-16.

R&M results like these are cause for pride for the entire F-16 team — General Dynamics, the F-16 SPO, and the operational units — but they must not be cause for complacency. At a ceremony to commemorate the delivery of the fourth “perfect” F-16, Fort Worth Division General Manager Herb Rogers said, “I can’t be more proud than I am today, because what I see today is what we can do in the future.”

THE FORESIGHT
The Fort Worth Division’s commitment to reliability/maintainability (R&M) began almost 20 years ago after jointly funded USAF/General Dynamics studies found that a small, low-cost fighter would be the most effective addition to the USAF inventory. The studies revealed that very complex and expensive fighters — while highly capable — posed a serious dilemma: failures resulting from increased complexity were dramatically escalating operations and support costs. Affordability, then, was threatening to adversely impact combat readiness.

The F-16 was the first aircraft to reverse this trend toward increased complexity. Its small, simple, single-engine design meant low acquisition cost. Additionally, operations and support costs were reduced by using a fuel-efficient engine with a fixed inlet, a single vertical tail, an 80 percent aluminum structure, and modular construction. USAF planners and General Dynamics designers realized that readiness rates would be improved, sortie surge capabilities would increase, and operating costs would be reduced if support features were incorporated into the F-16’s basic design.

The YF-16 prototypes built as a result of these design concepts reflected a balance between simplicity and technology. For example, simplicity was enhanced by a fuselage-mounted accessory drive gear box that allows engine changes without disturbing the hydraulic and electrical systems. On the other hand, technology produced the world’s first electronic fly-by-wire flight control system — an innovation that combines high performance and high reliability. Performance benefitted from a flight control computer, while reliability was improved by eliminating the problems associated with “normal” flight control systems — mechanical linkages, cables, and bellcranks. During the prototype flight test program (1972-1974) an additional 75 R&M improvements were identified.

To further optimize the F-16’s design, over 400 formal trade studies were conducted during full-scale development. These studies had wide ranging impacts — from AIS improvements to a decision to use carbon rather than steel brakes. Top management also supported the development of a standard parts program, extensive use of mockups, and rigorous subcontractor R&M test requirements. R&M development activity extended beyond contract requirements through additional testing, analysis, design improvements, and the Zero Defect program.

The success of the F-16’s full-scale development R&M program was demonstrated by an innovative approach to contractual incentives. The “target logistics support cost” program was established by the USAF and is based on life cycle cost projections. During a nine-month, 3500 flight-hour operational measurement period, logistics support costs were six percent below the targeted fig-
ure for the basic aircraft and 30 percent below target for
the avionics, allowing projected savings (or cost avoid-
ance) to the USAF of $170 million, based on 650 aircraft
operating over a 15-year period.

In pioneering many R&M features, General Dynamics' 
system designers applied three basic principles of reliabil-
ity:
• Simple systems, with fewer parts, fail less often than 
  complex systems.
• The use of mature, off-the-shelf components reduces 
  failure potential. (Over 65 percent of the F-16's com-
  ponents were selected from this category).
• It is less expensive to consider reliability in the original 
  design than to solve problems later.

Test programs assured that field reliability goals and 
requirements would be met, and included vibration tests 
for extended operating periods, and at severe operating 
temperatures — including rapid transitions from -65 to 
+160 degrees Fahrenheit.

The F-16's environmental control system was designed to
maintain uniform operating temperatures for the 
advanced avionics. The system's cooling air flow is bal-
ced to provide avionic systems with the correct tem-
peratures during ground operations and throughout the 
flight envelope. These uniform operating temperatures 
increase avionic reliability by reducing thermal stresses 
resulting from sudden temperature changes or from high 
temperature operation. The value of this type of tem-
perature integrity is reflected in the reliability performance 
of the F-16's radar.

Extensive self-test/built-in test capabilities (capable of 
identifying 95 percent of all avionic failures) were 
designed into the digital hardware, while various status 
indicators were designed into the mechanical hardware.
To facilitate repair, over 60 percent of the F-16's surface 
is removable, using over 250 access doors and covers.
Interchangeability of these doors and covers between 
aircraft was a major breakthrough in aircraft mainte-
nance. Once inside, ease of maintenance was assured 
by placing 90 percent of the components in a single-
Reliability considerations were designed into the F-16 from the very beginning.

tiered configuration (without other components behind them). Daily and phased inspection tasks were minimized by a thorough, reliability-centered maintenance analysis. These inspections were then simplified, and scheduled depot maintenance was eliminated.

Development and production break-in of F-16C/D upgrades was accomplished with the same rigorous R&M program requirements used successfully on the F-16A/B. The effectiveness of these efforts is now being demonstrated in the supportability performance incentive program for the advanced central interface unit, the enhanced fire control computer, the multifunction displays, and the programmable display generator. The mean time between demand (MTBD) for these avionic units is now being closely monitored — by both the USAF and the contractors — to evaluate their performance against target MTBDs. The potential incentive awards focused contractor attention on early R&M improvements to optimize the learning curve during the program’s early measurement period. In all cases, this equipment is exceeding target levels. A second mature measurement period (in two years) will maintain contractor emphasis on problem identification and correction.

THE FUTURE

As threat capabilities increase, so must the F-16’s capabilities. The challenge is not merely to maintain the F-16’s R&M achievements, but to go beyond them as additional capabilities are added to the aircraft. In that spirit, future supportability enhancements under consideration include:

- Seal bond fuel tanks
- Engine durability improvements
- Improved R&M testing
- Improved diagnostics
- Improved avionics cooling
- Further contractual incentives
- Computer aided R&M engineering
- Very High Speed Integrated Circuit (VHSIC) insertion

These and other improvements will be necessary to maintain the F-16’s preeminence among the world’s combat aircraft. It is anticipated that the F-16 will comprise one half of the Tactical Air Force inventory (including Guard and Reserves) in the year 2000. Continued technical excellence and R&M dedication will ensure that those F-16s will continue to represent an unsurpassed R&M success story — one that was planned from the beginning and has been accomplished throughout the program via (1) USAF and General Dynamics emphasis on supportability and life cycle cost, (2) an innovative and comprehensive R&M program to meet challenging USAF requirements, and (3) aggressive R&M design, testing, and correction of problems. ■
ROKAF receives first F-16

The Republic of Korea Air Force took delivery of its first F-16 multimission fighter in ceremonies at General Dynamics Fort Worth Division.

A two-place F-16D was accepted by Lt. Gen. Suh, Dong-Yull, Vice Chief of Staff, Republic of Korea Air Force, during ceremonies in early March at General Dynamics Fort Worth Division. Single-seat F-16C aircraft are to be delivered later.

With the delivery, the Republic of Korea became the first allied nation to receive the most advanced version of the Fighting Falcon.

"Today is a memorable day for all Koreans," Gen. Suh said during the ceremony. "At the outset of the Korean War back in 1950, we had only a few, primitive T-6 light trainer aircraft. Today we are here to receive the world's most prestigious tactical fighter, the F-16 Fighting Falcon . . . truly the most capable fighter of this generation.

"The combat capabilities of the F-16 will play an important role in deterring communist North Korea," Gen. Suh said. "The acquisition of F-16 fighters by the Republic of Korea Air Force will enable us to better contribute to the maintenance of peace and stability in the Far East, and especially on the Korean peninsula."

Maj. Gen. Michael Carns, Deputy Chief of Staff for Operations and Intelligence for the Pacific Air Forces, speaking on behalf of the USAF, noted that the Republic of Korea Air Force's acquisition of F-16C/D aircraft marks the introduction of advanced Fighting Falcons to the Pacific, preceding the scheduled basing of USAF F-16C/Ds at Kunsan Air Base, South Korea.

In other remarks, House Majority Leader Jim Wright, representing the U.S. Congress at the ceremony along with Rep. Richard K. Armey (R-Tex.), reaffirmed the United States' defensive partnership with the Republic of Korea by saying, "Let us with the ceremony here today give expression to our absolute determination that the flowers of freedom and political liberty and friendship between our countries . . . may continue to blossom and flourish forever in the fertile soil of the Korean peninsula.

"I have come today . . . to extend a salute to the men and women of General Dynamics for the magnificent manner in which, over the past seven-and-a-half years, you have produced such an outstanding aircraft as the F-16," Wright said.

Ambassador Kim, Kyung-Won, Ambassador of the Republic of Korea to the United States, said the F-16s being supplied to the country "will go a long way to enhance the security (of the Republic of Korea) and also help preserve the precarious peace that exists on the Korean peninsula.

"We (South Koreans) face a very serious military threat from the North Korean communists, and we do not see any prospect in the immediate, foreseeable future of the North Koreans changing their strategy," the ambassador said.

Stanley C. Pace, General Dynamics Chairman of the Board and Chief Executive Officer, called the F-16D delivery "an exciting and at the same time gratifying moment for the people of General Dynamics."

Working with the Republic of Korea on the F-16 program "has enabled our employees to become acquainted first-hand with the talented South Korean people and organizations which are building one of the strongest economies in the Far East," Pace said.

The Republic of Korea becomes the tenth nation to receive F-16s, joining the United States, Belgium, Denmark, The Netherlands, Norway, Israel, Egypt, Pakistan, and Venezuela. The aircraft has also been ordered by Turkey, Greece, Singapore, and Thailand.
F-16s Arrive at ... 

Tucson

The Arizona Air National Guard’s 162nd Tactical Fighter Group was officially activated in a recent ceremony at Tucson International Airport. With the activation, Tucson becomes the 29th F-16 site worldwide and the second Air National Guard unit to receive the Fighting Falcon.

The ceremony was punctuated with an old-and-new aircraft flyby as one F-16 made a pass of the airport, followed by four A-7s. The unit’s F-16 squadron, the 148th Tactical Fighter Training Squadron, joins two A-7 training squadrons in the 162nd TFG.

Col. Glen Dyeke, 162nd TFG Commander, was master of ceremonies. Dignitaries present included Maj. Gen. Donald L. Owens, Adjutant General of the Arizona Air National Guard, and Dr. Ted Webb, Vice President — F-16 Programs, General Dynamics Fort Worth Division.

The Arizona ANG F-16s are painted with a distinctive tail flash featuring a red and yellow sunrise pattern around an orange star, over a blue field. The tail also has “Arizona” painted on it in stylized, cursive lettering.

The 148th TFTS will train Air National Guard and Air Force Reserve pilots in air defense and tactical fighter roles. This training task is a large one, since the F-16 will constitute about half of the Air National Guard’s fighter forces by the early 1990s.

and Ramstein

The 512th Tactical Fighter Squadron at Ramstein Air Base, West Germany, officially became the first F-16C/D unit in the U.S. Air Forces in Europe in a ceremony held at the base on December 21, 1985. The event marked the beginning of the 86th Tactical Fighter Wing’s conversion from F-4 aircraft to F-16s, and the activation of the third F-16 site in USAFE. F-16A/B aircraft are already based at Hahn AB, Germany, and Torrejon AB, Spain. The 86th TFW is scheduled to complete its conversion to the Fighting Falcons late this year.

As principal speaker at the event, Brig. Gen. Cecil W. Powell, Commander of the USAF’s 316th Air Division, praised the operational record and capabilities of the F-16. The ceremony also marked the change of command of the 512th TFS from Lt. Col. Joseph H. Wehrle, Jr., to Lt. Col. Thomas O. Fleming, Jr.

A number of USAF dignitaries were present, and West German attendees included mayors and other leaders from communities in the Ramstein area. Lt. Col. Giselher F. Kroll and Lt. Col. Karl-Heinz Pietsch represented the West German Ministry of Defense.

In mid-1986, Ramstein will be the first USAF unit to receive the F-16 Block 30 version, which is powered by the new General Electric F110-GE100 engine.

DelHoyo, Stellmon are first to reach 2000 Hours

Lt. Col. Serje DelHoyo and Lt. Col. Larry Stellmon recently became the first two pilots in the world to exceed 2000 hours in the F-16. DelHoyo, operations officer for the 10th Tactical Fighter Squadron at Hahn AB, Germany, achieved the milestone in December 1985 — just three weeks before Stellmon surpassed 2,000 hours while flying as Thunderbird Commander/Leader.

DelHoyo began flying F-16s with the 388th TFW at Hill AFB, Utah, when the first F-16 squadron was activated there. He said that being an F-16 instructor pilot, plus his later participation in two Gunsmoke competitions, helped him accumulate so many hours so quickly. DelHoyo has now been flying the Fighting Falcon for more than six years.

Stellmon also got his start in F-16s with the 388th TFW. He joined the Thunderbirds in June 1982 as the Operations Officer, later became Slot Pilot, and was Commander/Leader for the 1984-85 show season. He was selected for promotion to Colonel upon completion of his Thunderbird tour in February of this year, and will attend the National War College in Washington, D.C. in July.
Have A Heart
On Valentine's Day, this F-111 crew helped save a life

A 46-year-old Pine Plains, N.Y., man received a most unusual Valentine's Day gift—a new heart—courtesy of the 509th Bombardment Wing, Pease AFB, N.H. The unique humanitarian mission took place Feb. 14 when an F-111A crew transported a donor heart from Oklahoma City, Okla., to Hartford, Conn.

Capt. David R. Lefforge, aircraft commander, and Capt. Steven J. Bruger, radar navigator, were scheduled for a regular training mission when they were redirected for a lifesaving, near-supersonic dash halfway across the United States. Richard Reinhardt, a patient in a Hartford, Conn., hospital, desperately needed a heart transplant to survive. A donor heart was available for him, but it was in Oklahoma City—some 1,415 miles to the west. To give the patient the optimum chance for success, the heart must be transplanted within four hours of being removed from the donor, according to a hospital official. Because there were no available commercial or medical aircraft capable of transporting the heart to Hartford in time, the USAF was called upon to assist.

The race was on.

One F-111 and a KC-135 took off from Pease and headed for Tinker AFB, Okla. At Tinker, the precious cargo was secured on Bruger's lap—because it was the only place in the cockpit where the container would fit, and because the cabin is the only pressurized area on the airplane. Captain Lefforge said that during the mission, he and Captain Bruger concentrated their attention on the details of their flight plan.

"It was Valentine's Day. We had this heart. We were going to save someone's life," Captain Lefforge said in a post-flight interview. "After we figured out what it all meant, it was pretty sobering."

"I was sitting there with it (the heart) in my lap," Captain Bruger added. "We just kind of looked at each other. I know I'll remember this for a long time."

After a 700-mile-per-hour flight (just under the speed of sound), the F-111 landed at Bradley Air National Guard Base, East Granby, Conn., at approximately 5 a.m., Feb. 14. A helicopter transported the heart to Hartford Hospital where it was successfully transplanted... three hours, 59 minutes after being removed from the donor.

—USAF News Release

FB-111A AMP Aircraft makes first flight

The first flight of the FB-111A Avionics Modernization Program (AMP) trial installation aircraft took place 13 January at Fort Worth, Texas, culminating a 23-month modification effort aimed at upgrading the aircraft’s mission capabilities.

The initial two-hour flight was described as an "outstanding success" by James I. Humphries, Manager of the F-111 AMP program. "The initial flight verified the integrity of the aircraft configuration and the new avionics. The extensive flight test program that is planned for the aircraft can now begin," Humphries said.

On 10 February 1986, following preliminary testing at Fort Worth, the aircraft was delivered to the U.S. Air Force's Sacramento Air Logistics Center at McClellan AFB, Calif., for a period of developmental and operational testing and evaluation.

The AMP avionics have already undergone several months of integration testing at Fort Worth.

The principal program upgrade, in which the entire USAF FB-111A fleet will be modified, is replacement of the first generation, 20-year-old bomb-navigation system with a modern digital system. This and other AMP modifications offer significant improvements in reliability and maintainability at reduced logistic support costs.
NOTE: Heat detecting infra-red (IR) "guns" are used to insure probe heater operation during run-up procedures. Without heat to the F-16's angle-of-attack probes, an in-flight loss of control could result.

THAT'S WHY I ALWAYS WEAR THE CORD AROUND MY NECK, ... NEVER POINT IT AT THE SUN, ...

... AN' KEEP IT IN THE BAG WHEN NOT IN USE.

THIS GUN COULD SAVE A LIFE!

O'COURSE IT ALSO HELPS TO REMOVE ALL THE PROBE COVERS FIRST!
ROKAF receives first F-16