# flying

SAFETY

JANUARY 1990

System Safety - What Is It?

F-15 STOL/MTD - On The Leading Edge

A Lifesaver Called GCAS

Engine Plumbing - How Can You Safeguard It?

# The Age of Plastic Airplanes

# Greetings from the AFISC Commander

■ Happy New Year! With the end of the 80s, each of you can take great pride in your contributions to flying safety and enhancing our combat capability. Your accomplishments have been many. You are flying and maintaining the most sophisticated weapon systems in the world and training under very demanding scenarios. Last year was the seventh consecutive year the Class A flight mishap rate was below 1.8. Congratulations!

This issue of *Flying Safety* magazine focuses on safety and our future weapon systems and programs—**Safety Programs in Advanced Technology**. In FY90, the Air Force plans to spend nearly $50 billion on advanced weapons systems. This issue illustrates some of the system safety and engineering programs that are an integral part of the development and modification process. Your innovations and dedication to safe operations assure these advanced systems will be key elements of our national security as we approach the 21st century.

You can be proud of your past accomplishments in helping to secure the peace so many enjoy today. The challenges of the 90s are great, and I know you will successfully meet them head-on as you have done before.

Betty and I wish each of you a happy, prosperous, and safe 1990. ■

*Alexander K. Davidson*
Major General, USAF
Commander, Air Force Inspection and Safety Center

UNITED STATES AIR FORCE **flying** SAFETY MAGAZINE

AIR FORCE SPECIAL PUBLICATION 127-2 | JANUARY 1990 | Volume 46, Number 1



**CONTRIBUTIONS**

Contributions are welcome as are comments and criticism. No payments can be made for manuscripts submitted for publication. Address all correspondence to Editor, *Flying Safety* magazine, Air Force Inspection and Safety Center, Norton Air Force Base, California 92409-7001. The Editor reserves the right to make any editorial changes in manuscripts which he believes will improve the material without altering the intended meaning.

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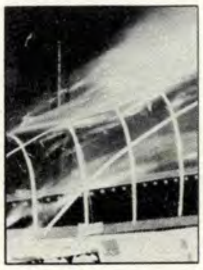

# SPECIAL FEATURES

This is a special issue devoted to Safety Programs in **Advanced Technology**.



# REGULAR FEATURES



DEPARTMENT OF THE AIR FORCE • THE INSPECTOR GENERAL, OSAF

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# SYSTEM SAFETY
## What is it?

LT COLONEL JOHN W. KOCH
Directorate of Aerospace Safety

■ How can system safety engineers help you keep from running your aircraft into the ground? Will they be able to prevent a fire should you have an unexpected collision with the ground or another aircraft? Can your handling of an engine tube cause that engine to fail? How do composites affect your safety? Should you be concerned about the software in that black box on your aircraft? What is system safety?

To begin with, system safety can, and has, made many significant contributions to the safety of the equipment and aircraft you work with and fly every day. Other articles in this issue describe some of the advances, and in the the following paragraphs, I'll give a brief history of the development of the system safety process, describe just what it is that system safety engineers do, and close with a suggestion on how you can help us do our job better.

### Historical Perspective

System safety has been an evolutionary process. Beginning with the Wright brothers and lasting well into the 1960's, the primary design philosophy prevalent in the aircraft industry can best be described as one of "fly-fix-fly." In other words, an airplane, or other system, was designed, built, and then flown. As parts or systems broke, failed to work properly, or caused mishaps, they were redesigned. The airplane was then flown again to see what else would happen, redesigned, and flown again until a relatively safe and reliable design was agreed upon.

The beginnings of system safety in the Air Force are difficult to pinpoint, but sometime in the late 1950's, designers began to realize there must be a safer and better way of doing business. It is generally accepted the space and missile community took the first steps toward initiating formal system safety programs in the development of aerospace systems in the late 50's and early 60's. From these tentative beginnings then has evolved the modern-day system safety discipline.

# And how you can contribute...

**Modern System Safety**

All major aerospace systems now have active, effective, and visible system safety programs. They are governed by MIL-STD-882B, System Safety Program Requirements, and AFR 800-16, USAF System Safety Programs.

How does the modern system safety engineer reach his goal? By analyzing the design of a system to ensure risk is reduced to an acceptable level. The key is that at the same time, a system must meet its mission requirements. We in the system safety community realize you have an important mission to perform. So rather than totally eliminate all hazards (i.e., don't fly), our goal is to minimize your risk. We study past mistakes and redesign systems so similar problems are not repeated. We accomplish this by comparing parallel development efforts to prevent making the same mistake, at the same time, in two different systems and by learning about advances in technology to see where we can make improvements in both existing and future systems.

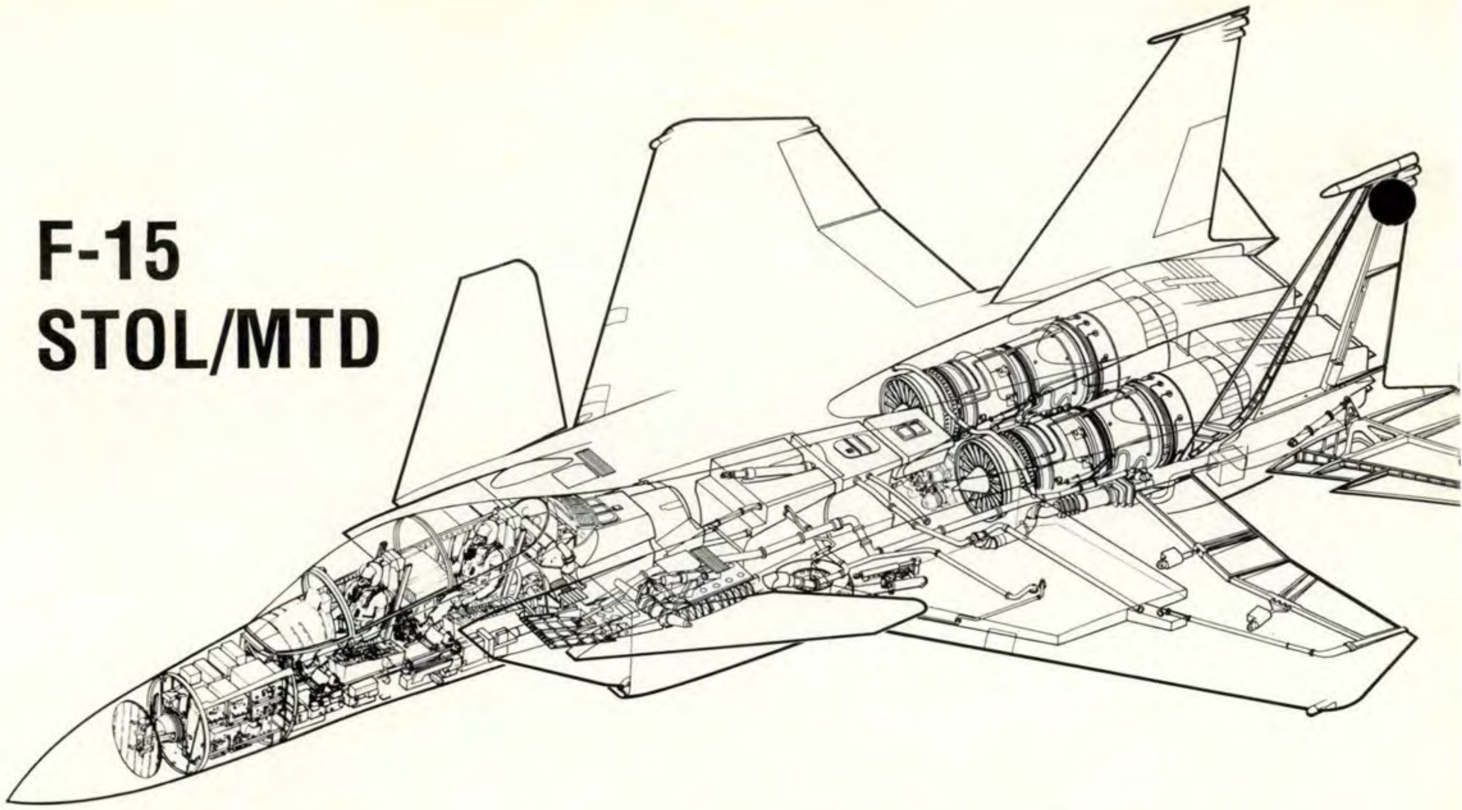
Our goal is to make inputs as early as possible in the life cycle of a system. Obviously, it is less expensive and easier to change a design that has not been put into production than to try to retrofit a fleet of operational aircraft. So although the bulk of our effort is with developing systems, the system safety process does not end until the last aircraft is in the boneyard.

**How Can You Help?**

How does system safety relate to you, the operators and maintainers on the line? First, you are now flying and maintaining equipment that has been designed with a conscious effort to make it as safe as possible. Second, and most important, you can have an input into improving the safety of the equipment you work with because system safety is a never-ending process. We have designed the equipment for your use. If it can be improved through redesign, we need to know so we can evaluate the costs of fixing your equipment as well as changing future systems. When you find something we've missed, pass the information to your local safety office. They, in turn, can forward it to your command safety experts who will send it to the respective system safety group. You may also call us, AFISC System Safety and Engineering Division, AUTOVON 876-4104. By working together, we can all make our Air Force a safer place to work. ■


Shown here is the AMRAAM missile test over White Sands Missile Range, New Mexico. System safety analysis techniques were used to help ensure its safe launch and operation.

# F-15 STOL/MTD



# On The Leading Edge

MAJOR TONY D'ONOFRIO
Directorate of Aerospace Safety

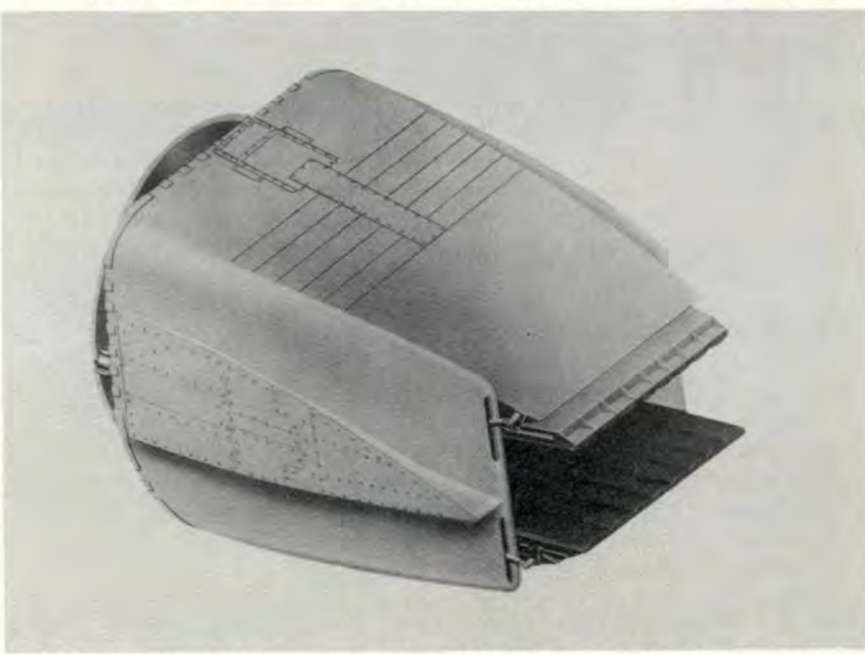
■ As you are reading this article, a most remarkable flight test program is winding down at Edwards AFB, California. The subject of this flight test program is a highly modified F-15 Eagle that was more than 4 years in the making.

From external appearances, it would seem the only differences between this flight test aircraft and other F-15s are those funny-looking canards forward of the wings and the square nozzles in back.

But looks can be deceiving. This aircraft was almost totally redesigned from the gear up. The canards and nozzles are part of four key technologies being evaluated that will hopefully greatly enhance both fighter takeoff and landing performance, as well as up-and-away maneuverability. This is one Eagle jet like none ever seen before!

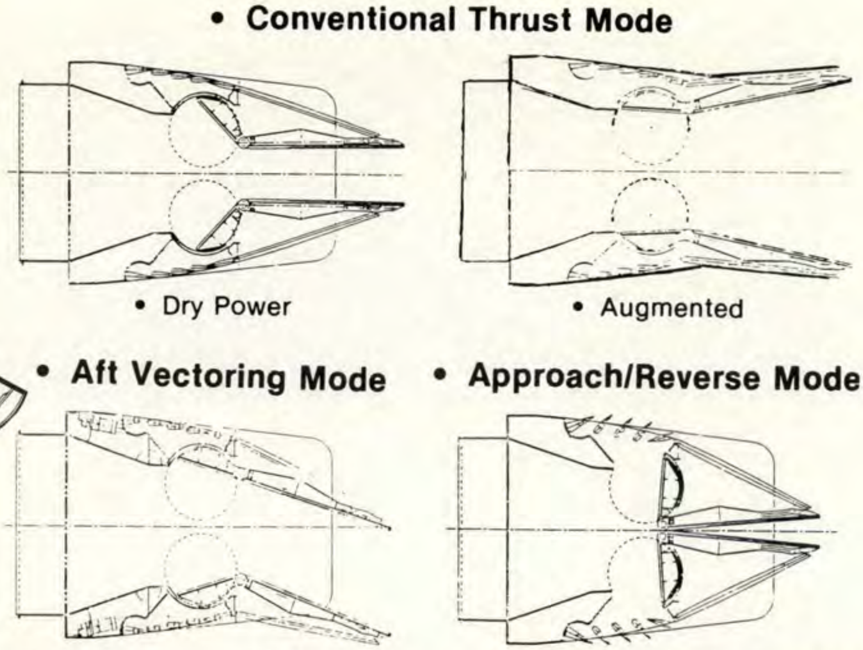
## STOL/MTD

The requirements for the Short Takeoff and Landing/Maneuver Technology Demonstrator (STOL/MTD) were generated by the threat facing our forward-deployed fighters, and called for a fighter which could operate from a runway 50 feet wide and 1,500 feet long with full internal fuel, 6,000 pounds of external stores, and in crosswinds up to 30 knots. It also had to operate on slippery runways and over re-



This 2D thrust vectoring/reversing nozzle is used on the F-15 Short Takeoff and Landing Maneuver Technology Demonstrater aircraft. It is held together by over a mile of welds.

Figure 1.




paired bomb craters. All this was to be attained with no penalty in the aircraft's baseline maneuverability and range.

Competition resulted in the F-15 being chosen to demonstrate the technologies required to meet the STOL/MTD requirements. These technologies included: (a) 2D vectoring/reversing nozzles, (b) rough/soft field STOL landing gear, (c) an integrated flight/propulsion control system, and (d) an advanced pilot-vehicle interface.

### New Nozzles

The development of the 2D vectoring/reversing nozzles is one area of the program that the author is greatly familiar with. I had the privilege of working within the program office at Wright-Patterson AFB, Ohio, during the time the nozzles were being constructed at Pratt & Whitney. Without a doubt, this nozzle is one fantastic and complicated piece of machinery. As you can see from figure 1, the nozzle can be used in a variety of modes to satisfy the STOL and maneuvering mission. The nozzle is capable of vectoring thrust within ± 20 degrees while the aircraft is in flight. The effects of vectoring are dramatic. For example, at mach 0.3, the F-15 STOL/MTD has a 33-percent improvement in pitch rate over the F-15B.

The effects on takeoff roll are just as spectacular. In-flight simulations, hopefully backed up by final flight test data, have shown takeoff roll under lightweight conditions to have been reduced to as little as 400 feet. Vanes mounted on the top and bottom of the nozzles can be scheduled from 45 degrees to 135 degrees, giving the pilot precise landing approach and reverse thrust capabilities. The reverse thrust capability not only allows shortfield landings, but also improves in-flight maneuverability. In combination with the additional lift and improved pitch, roll, and yaw characteristics provided by the canards, the 2D vectoring/reversing nozzles provide unmatched tracking and dogfighting capabilities.

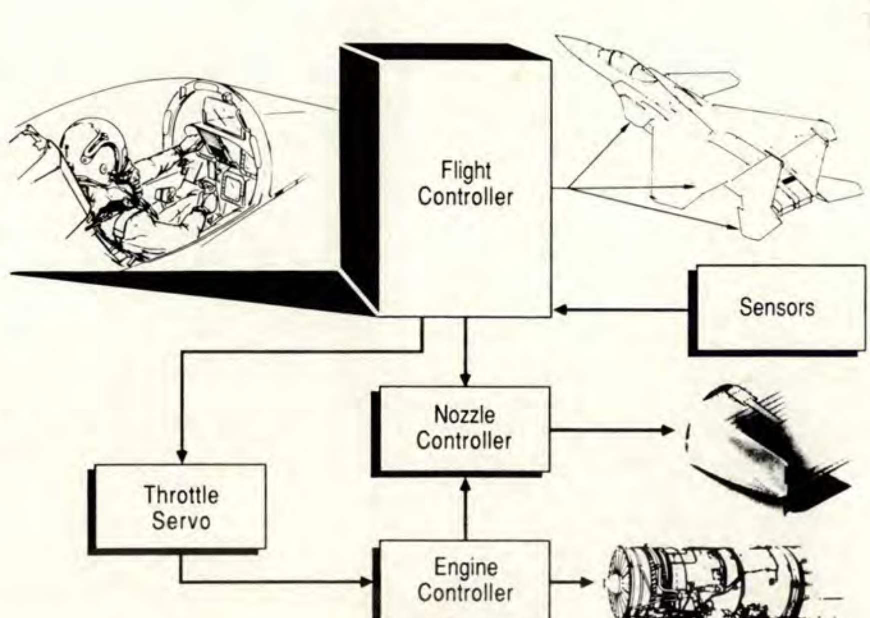
### Landing Gear

The landing gear on the F-15 STOL/MTD aircraft is based on the F-15C/D aircraft with modifications to improve durability. The increased sink rate and the requirement to operate over bomb-cratered runways resulted in changes to orifice areas, bearings, and pressures within the strut high and low pressure chambers.

The addition of canards and vectoring nozzles provides the F-15 STOL/MTD pilot with the equivalent of four additional independent flight control surfaces. As you can imagine, a system was required to integrate these surfaces into the rest of the F-15 flight control system. The Integrated Flight Propulsion Control System (IFPC, see figure 2) was designed to make the additional control surfaces transparent to the pilot. The system is fly-by-

continued

Figure 2.



# F-15 STOL/MTD

# On the Leading Edge

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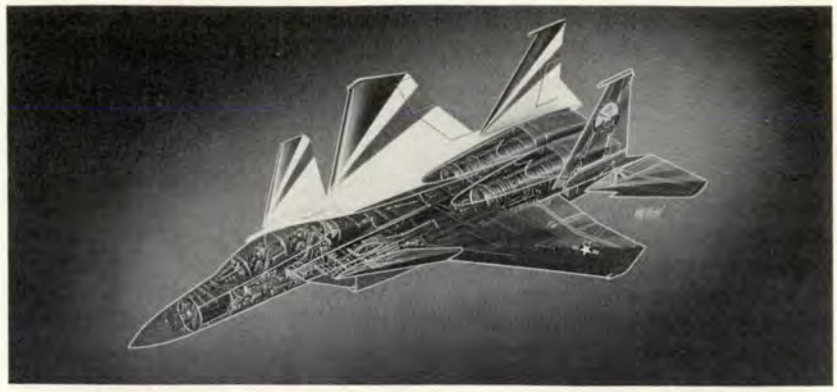


wire and is centered around a master flight control computer linked to sensors providing flight data, as well as servos providing pilot-requested flight control and engine thrust inputs. The flight controller combines the pilot-requested inputs with available flight data and decides which control surfaces have to be moved and how much to move them. The flight control computer commands nozzle positions and modes through the nozzle controller. The bottom line is the IFPC allows any pilot to fly this aircraft with very little special training.

If the F-15 STOL/MTD was to meet its requirement of precise landings on bomb-damaged runways in poor visibility without the use of outside landing aids, a system was needed to locate and direct the pilot to a usable portion of the runway. The system that was developed is referred to as the pilot-vehicle interface (PVI, see figure 3). The PVI is based on F-15E technology and makes use of a forward looking infrared radar (FLIR) with a high-resolution mapping radar to designate a runway touchdown point on the HUD. An E-shaped bracket on the HUD will inform the pilot if his approach is correct. Flightpath corrections in the STOL landing mode are made by adjustments to airspeed using throttle controls. The pilot basically just points the aircraft to where he wants to land.

The expected F-15 STOL/MTD performance improvements (see figure 4) alone would, no doubt, make any pilot drool at the thought of flying this aircraft. However, lest we forget this is a safety magazine, I should mention the ability to land on runways 1,500 feet long by 50 feet wide dramatically increases the chances for safely returning from a mission. Even if runways are wiped out, taxiways, even roads, become suitable substitutes because of STOL/MTD technologies. ■

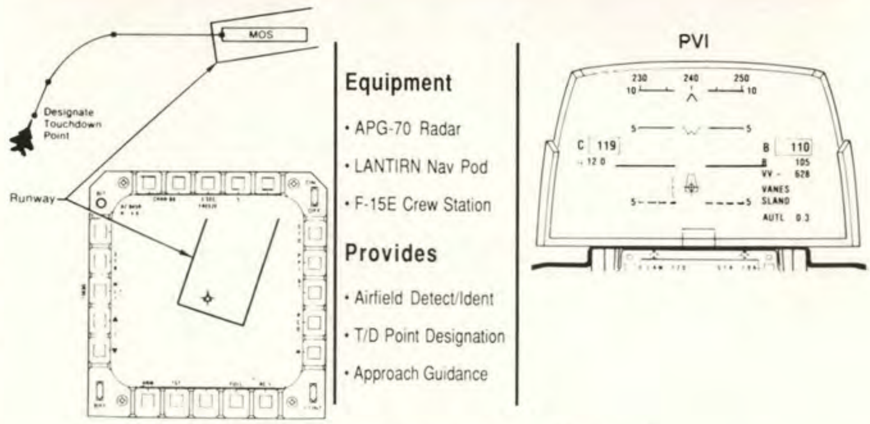
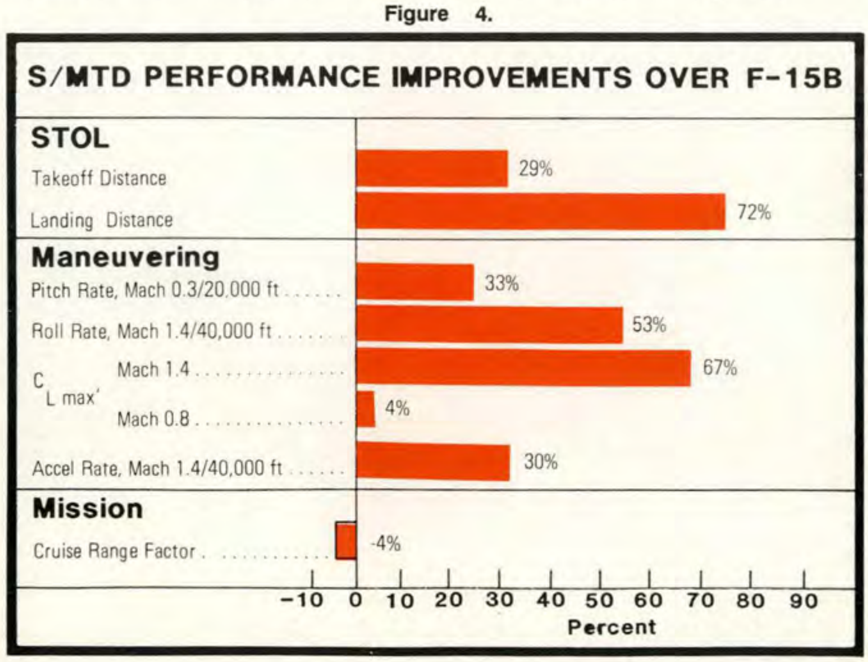
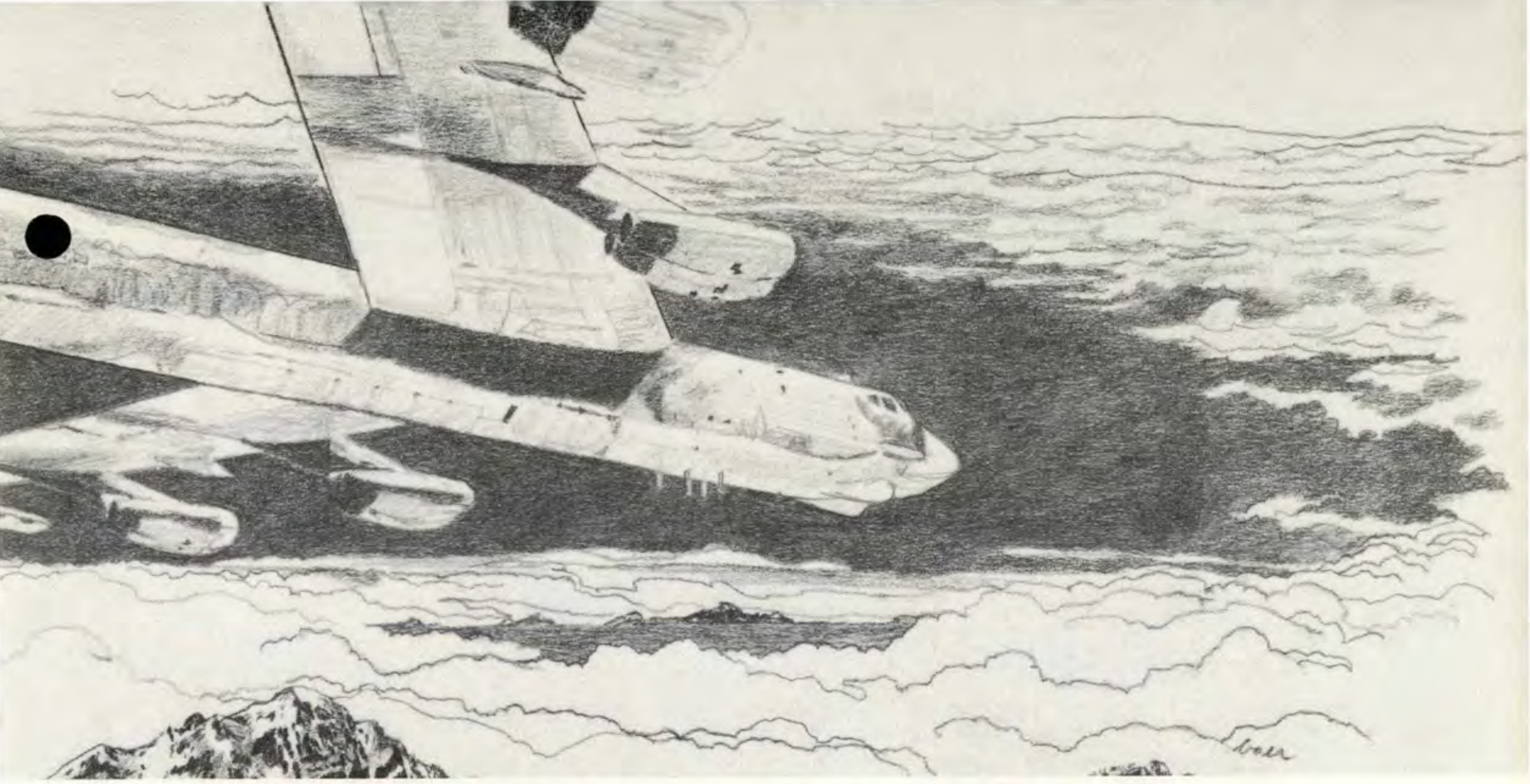



**Figure 3. Advanced Pilot-Vehicle Interface**

**Figure 4.**





# THERE I WAS

■ A simple pattern mission can turn sour in a hurry, even for an old experienced wing safety officer and an assistant wing DO. Late one gray, chilly afternoon at a SAC base, we joined a crew aboard a mighty B-52 for a local instrument training mission. We had 3 hours of fuel on board, plenty for a few instrument approaches and some touch and go's. Shortly after takeoff, the field went below minimums, and as luck would have it, our heading system rolled over and died.

We checked with command post, and they directed us to a "suitable" alternate airfield. Unfortunately, as we discovered upon arrival, the weather there had dropped below minimums. A third base was then recommended, but it was unsuitable because it was also IFR with heavy thunderstorms between us and them. We were quickly running out of fuel, ideas, and locations.

We knew of a base some 500 miles to our west, well within range, where the weather was VFR. It was a good decision for an airframe with heading problems. We suggested it to our command post who responded they were "working our problem and would get back to us." As far as we were concerned, the problem was already worked, and we had decided where we would spend the night. As darkness fell on the snow fields below, we headed west.

A few minutes later, our command post advised us our new alternate was a base to the east where the weather was 2,000 feet overcast. That meant penetrating at night with an unreliable heading system. No thanks. We continued westward and asked our command post to advise their counterparts at our chosen destination that we were coming.

The controller was doing all he could to help, but he wasn't in command of the airplane. I was. He might not have understood the severity of our heading system problem. I did. He and those who helped him work my problem were not in the key position to decide on the best choice of divert base. I was. Picking the best alternate wasn't his responsibility. It was mine. Had I asserted that responsibility earlier, I might have saved all concerned a lot of work.

So, remember to pay close attention to the weather forecaster's briefing and always have an alternate plan in case of unexpected diversions. And, oh yes, don't forget who really has to live with the decisions made while *you* are airborne. ■

FSO's: Recommend you discuss diversion plans at one of your next squadron safety meetings.—Ed.

# Why Some People Don't Catch Many Fish...

**OR...**

## No Worries, No Cares, But What Have I Left Behind!

**COL CHARLES MAAS**
Directorate of Aerospace Safety

■ Fishing's a wonderful way to relax. Just being there has its own satisfaction, and the first strike simply yanks the plug on all those tensions built up during the week. The doctors are even telling us we'll live longer if we eat more fish. Great! I didn't need an excuse, but that's even more reason to regularly practice one of Curt Gowdy's hottest angling tips . . . "a wet line catches more fish."

Now in some parts of the country, avid anglers have the opportunity to combine the honorable sport of angling with another great love—aviation.

Everyone needs an opportunity to relax and recharge. That's what recreation is for: An activity that's fun and requires a little less concentration than your regular job. For the aviator, what could be better than checking out an aero club airplane and spending a few hours aloft. No worries, no cares, pure enjoyment. And if a fishing trip can be added to the process, you have an unbeatable combination. But there could be a problem with that line of thinking.

Let's illustrate how this combination may not necessarily be synergistic if approached from the no-worry, no-care angle. Fishing was the prime objective for this trip aboard a Cessna 206 on floats. Most of the preparation for the flight went well; weather was checked, weight and balance carefully computed, a flight plan properly filed. But once at the airplane, prudent planning was overcome by the eagerness to get going.

On this occasion, the airplane was parked next to a dock with the tail toward the shore. Securing the tail was a rope tied to a 4- by 4-inch post embedded in a 120-pound lump of concrete. This mooring point was above waterline and clearly visible. Maybe the pilot had something other than flying on his mind during the preflight ("I wonder if they'll be hitting pink or green Pixies today . . . "), or maybe he was just in a rush to get airborne. Whatever it was, he missed the tail rope—which remained firmly tied to the post. One for the fish.

Everyone in . . . off we go; those fish can't wait any longer. Start up the engine, add some power (well, maybe just a little more to get us moving), and taxi out to the takeoff position. So far, so good. (Not even that undetected shore anchor dragging behind us can keep us from answering the call of the wild.) And here the pattern of omissions begins to take shape. Not only has this pilot missed his anchor, he's also forgotten to adjust rudder trim for takeoff. Two for the fish.

In position now. Push up the power. Sure seems like it's taking a long time to get on the step . . . must be the glassy lake surface on this lovely, calm morning. But what's that sudden, heavy yaw to the left!? That's a problem! Abort!

Okay, everything under control; just forgot to set the rudder trim for takeoff. No sweat. Plenty of waterway left in front of us . . . no need to waste time taxiing back to the start. Those fish are waiting, and I've got my stuff together now. Power up again . . . go for it. Somehow it still doesn't feel quite right; slow on the step; yaw's gone, but not much waterway left . . . . Just when the pilot was thinking of aborting again, he felt a sudden surge of acceleration (amazing what happens to velocity when you decrease the drag of 120 pounds of concrete as it works free) and got airborne just above a stall.

But just as things seem to be going well at last, the nose pitched up wildly—in excess of 45 degrees! Seems the elevator trim was incorrectly set halfway between takeoff position and full nose up! Three for the fish, and that's about all it was going to take.

This airplane just wasn't going to fly today. Frantic attempts to lower the nose (accompanied by the inappropriate response of partially raising the flaps) succeeded only in the aircraft settling back to the water in a power on full stall. And yes, the tail rope and post were still attached! Forward momentum ceased as airplane met bank and associated trees. Luckily there were no injuries.

So what's the moral to this story? One might be that you need to be serious to outsmart the fish. Another might be that flying just isn't an endeavor you can afford to approach casually. Whether it's a sleek fighter with all the latest technology, a state-of-the-art bomber, tanker, or transport, or a seemingly simple recreation airplane that you fly for "fun," if you don't exercise a certain amount of discipline and pay attention to proper procedures, the payoff may be much less than you expected. You might not even have to worry about whether the fish are hitting pink Pixies or green, because you won't be getting your line wet. That's what happened to this aviator . . . don't let it happen to you. ■

# A Lifesaver Called GCAS

**MR AL ENGLISH**
Directorate of Aerospace Safety

■ *This mission should be no sweat. In the hills now, 2 minutes to the drop. Not even a moon outside, and the sweat is beginning to pop out because—damn, these night vision goggles just don't give you very good depth perception . . . "Altitude! Altitude!"*

*Target's in sight. Weapons away! You stay on the deck and snap a hard right turn, your head cranked around to watch for SAM launches. But overbanked, your altitude is slipping away and you don't know it . . . "Pull up! Pull up!"*

Collision with the ground occurs for a variety of reasons. Pilot distraction, task saturation, errors in judgment, optical illusion, just to name a few. Despite everybody's best training and intentions, it happens to military pilots well over a dozen times a year—at a tremendous cost in lives and resources.

### Tactical Maneuvering

Studies estimate that a ground collision avoidance system (GCAS) could prevent between 55 percent and 85 percent of these collision-type mishaps in military aviation, saving at least one aircraft per year. GCAS can definitely help reduce ground collisions.

In 1985, the US Air Force and Navy began to study the problem to find a way to provide the pilot a warning to prevent these types of mishaps. Two key conditions were that the method must be "generic," applicable to a wide variety of tactical and transport aircraft, and it must use only standard sensors already in most aircraft—no costly refits of esoteric black boxes.

### A Software Approach

The basis of GCAS is a software algorithm which fuses aircraft sensor inputs, sensor validity checks, real-time terrain measurement, pilot and aircraft performance, and warning logic into an "expert system." GCAS is not artificial intelligence, but it nevertheless "knows" important facts about the aircraft's situation in real time.

- Attitude (roll, pitch, yaw) and likely changes in attitude.
- Position versus terrain (altitude).
- Terrain type (mountainous, rolling, etc.) and terrain trends (rising, falling).
- Validity and reliability of sen-

sor inputs.

- Response capabilities of pilot and aircraft.

GCAS development proceeded rapidly through use of the air combat mission library and knowledge derived from the Navy and the Air Force's air combat training systems, known respectively as the Tactical Aircrew Combat Training System (Navy) and the Air Combat Maneuvering Instrumentation/Measurement and Debriefing System (AF) (TACTS/ACMI/MDS).

In software, GCAS simulations could be repeatedly exercised from actual missions. In more advanced stages of development, on actual test flights on TACTS/ACMI/MDS ranges, the real-time air and ground range data links enabled engineers to test GCAS in flight without actually loading it aboard the test aircraft.

### GCAS Uses Existing Sensors

Through studies and flight tests, GCAS proved it would work well using existing sensors on most aircraft. These sensors include radar altimeter, barometric altimeter, angle-of-attack sensor, inertial platform, and air data sensor.

GCAS software is unique in that it does not rely on a single sensor input for data but combines and filters several appropriate sensor inputs to derive the best possible data. For example, if the aircraft is rolled to the extent that the radar altimeter antennas are blanked, GCAS would continue to update the altitude information through the use of barometric and inertial sources until the radar altitude comes back on line.

The GCAS algorithm also continually assesses the validity of its computed data to keep its computations free of incorrect or polluted data. For example, the algorithm limits how long it will consider altitude measurement to be valid without the radar altimeter on line.

### False Alarms

Altitude warning devices are not new in aviation, but they do have a troubled history due to high incidence of false alarms and nuisance alarms. Both experience and research have proven that aircrews will turn off or ignore devices that prove unreliable and bothersome.

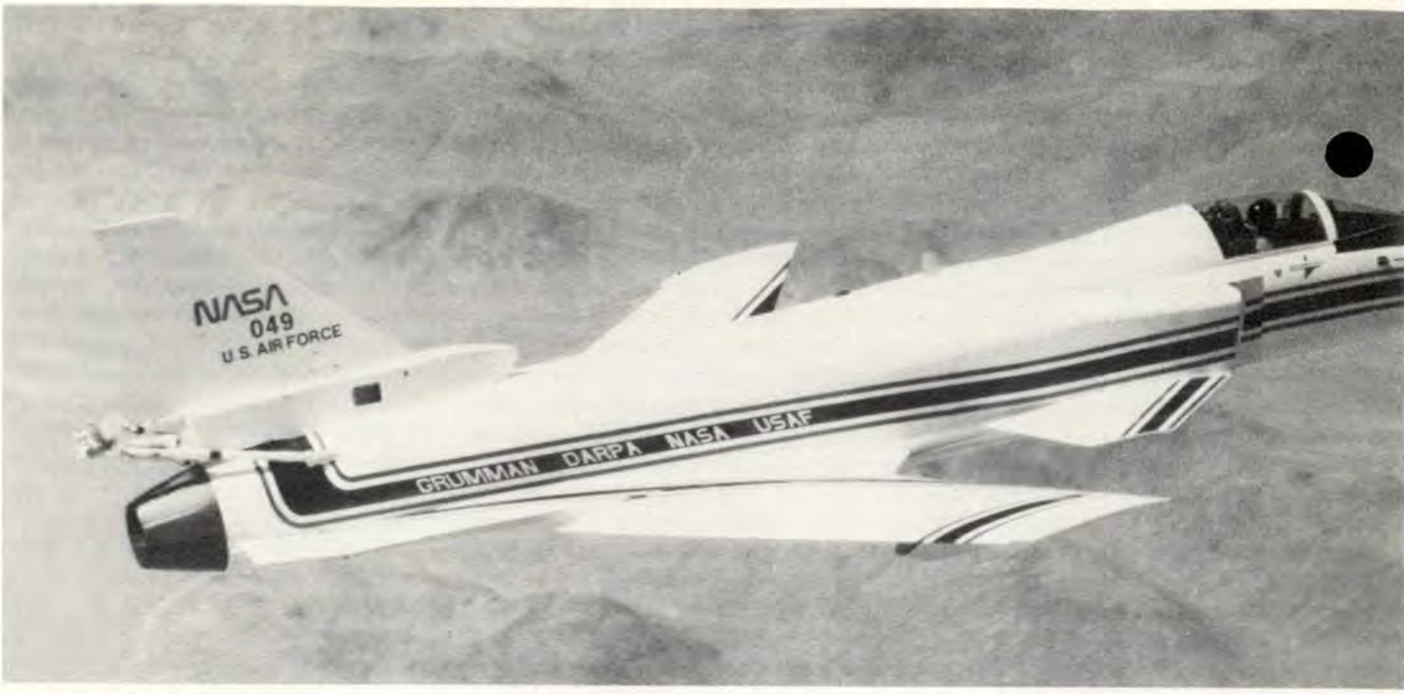
For this reason, a high priority requirement for GCAS is the elimination of false alarms. The complex validity testing and filtering portions of the algorithm were designed to this objective. In final flight testing with tactical aircraft, the false alarm rate proved to be less than 0.1 percent.

In flight tests, GCAS has been installed in existing avionics modules connected to a data bus designed to the requirements of MIL-STD-1553. This standard establishes the requirements for digital, command/response, time division multiplexing techniques on aircraft. To issue warnings, GCAS used the cockpit voice synthesizer to issue two degrees of alarms: "Altitude! Altitude!" in the case of a dangerous condition with slow onset, and "Pull up! Pull up!" in the event of rapid onset.

Prior to full-scale development, there are choices to make in implementation. GCAS can be deployed as either a hardware or software modification to an aircraft's flight data computer, or as a dedicated avionics box networked to the 1553B or other standard data bus.

### A Giant Step Forward In Flight Safety

Today, the US Air Force is entering tests to evaluate a generic GCAS algorithm that will be considered as a solution to both the DOD's and the Air Force's need for a GCAS on transport aircraft. Already, the collision warning systems in tests for fighter/attack aircraft, specifically for the A-10, has been effective. It is a warning system only and will not maneuver the aircraft to avoid the ground collision hazard. We would look to the future for such an automatic maneuvering capability. For now, until GCAS implementation is complete, it will remain the pilots' vigilance and awareness that will keep them and their machines out of the dirt. ■




**MAJOR H. DUTCHYSHYN**
Directorate of Aerospace Safety

■ Lt Colonel Tom Peters scanned the Air Force Crash Lab and studied the once familiar hulks. It had been almost 10 years since he had his first introduction to the twisted metal airframes that yielded the clues in his Aircraft Mishap Investigation Course. But this time was different. The work crews were painstakingly laying out the rubble trying to recreate another crash site. This one was what the Air Force used to call its Advanced Tactical Fighter. Those clues he had been taught to look for were well hidden this time. "We have truly entered the age of the plastic airplane," he thought as he picked his way through the scattered debris.

### Aircraft Composites

For now, the above paragraph is pure fiction; but how long do we have until this fictional episode becomes reality? Today, more and more composites are being used in aircraft construction. The technology that has been making airplanes lighter and stronger has been slowly evolving for many years. At first, composites were used in those nonessential but nice-to-have components such as gear doors and fairings. But now, composites are being used in much larger, critical structural components such as wings, fuselage bulkheads, and helicopter blades. This large-scale use of composite technology has ushered us into an era where both aircrew and maintainers need an appreciation for the benefits and hazards of these materials.

### Benefits

"With half the weight of aluminum and twice the strength of steel . . . ." Although this almost sounds like an introduction for Superman, high strength-to-weight is usually the first benefit of composites that is exploited by the design engineer.

Composites use high-strength fibers, such as carbon/graphite, Kevlar®, or boron that are held in place by resins, such as epoxy, polyurethane, or bismaleimide to form the composite material. The strength of this material is derived from a combination of the high-strength qualities of these fibers and the strong bond between the fibers and the resin, or matrix, material. As the material is cured, these bonds strengthen and allow the loads of one fiber to be shared by the next. This shared load exploits the high-strength qualities of the fibers such that less material is usually required to maintain the required margin of safety for a given design load. This increased load-carrying efficiency, combined with the generally lightweight nature of the composite, saves weight that can now be turned into increased performance such as greater thrust-to-weight ratios, longer range, or heavier payload capabilities.

Another common benefit is the ability to tailor a composite to either show stiffness or flexibility in specific directions. Generally speaking, composites exhibit strength and stiffness characteristics that are very sensitive to the relationship between the orientation of the composite and the direction of the stressing force. Aligning the fibers of a composite in a way that maximizes the load-carrying performance, design engineers can adjust the amount of stiffness or flexibility they desire in specific directions. This tuning process not only saves weight by eliminating nonessential materials, but also lets the engineer use the structural flexing or stiffening to increase aircraft performance.

### Future Flight Today

The X-29's forward-swept wing and the wing of the Highly Maneuverable Aircraft Technology (HiMAT) demonstrator are examples of this aeroelastic tailoring.

# The age of PLASTIC AIRPLANES

While the X-29 uses this tailoring to stiffen the wing and resist the flexing forces of high dynamic loads, the HiMAT attempted to use flexibility to achieve increased performance. As HiMAT increased G, the composite wing would flex under the load in a way that might be compared to increased camber. This controlled flexing resulted in more lift that HiMAT could turn into increased performance through the increase in available G.

While strength and tailoring benefits have soaked up much of the limelight on composites, we are still learning to exploit many of the other characteristics of composite materials. Developments in manufacturing have led to advances in molding and bonding technologies that allow designers to use complex shapes and smooth surfaces to reduce aerodynamic drag. Corrosion resistance and reduced thermal expansion properties allow engineers to design for harsh environments such as heat, humidity, and salt spray. By controlling the load paths of the structure and the directional characteristics of the composite, engineers can design out fatigue and increase the life of the aircraft. Each of these characteristics, along with the increased strength-to-weight ratios, has led to the development of more capable and safer aircraft.

**Risks**

However, these developments are not without risk. While we enjoy the benefits of the hazards that are eliminated through the use of composite materials, we must be prepared to face some new hazards and maintenance problems as well. Ask the troop who was crawling down an intake and learned about a composite's ability to store large amounts of static electricity. His lesson came in the form of his own personal lightning bolt. How about that misplaced step or dropped tool that doesn't show a surface scar yet causes an internal flaw that will fail under load. These hazards will be facts of life in this new age and will persist from the manufacture and repair of composites to the everyday operational use and maintenance of composite aircraft.

The most publicized of these hazards deals with the manufacturing process and the chemical toxicity of the elements used to make composites. Whether it was due to prolonged direct contact or the inhalation of vapors, medical reports have indicated a sensitization of certain individuals to the manufacturing chemicals. The reactions observed have resulted in ailments ranging from rashes to asthma. While our military personnel are usually quite removed from the manufacturing process, we should be prepared to consider some of these hazards in the area of composite repair.

**Reduced Maintenance**

Although composites should have reduced maintenance requirements, our maintenance crews will still have to contend with the effects of aircraft modifications and battle damage repair. Here our crews may have to protect themselves against chemicals that were irritants in the manufacturing process, as well as the potential irritants in new adhesives or curing agents.

But chemical toxicity of the composites is not the only hazard. Before the repair can be made, the composite will usually have to be cut, sanded, or drilled to prepare the piece for repair. This process results in a composite dust containing fragments of the composite fibers. If these fragments permanently lodge themselves in lung tissue, some physicians feel this will cause lung scarring and may have possible carcinogenic effects for the individual who fails to take proper precautions. As we field more composite aircraft, our maintenance crews will have to adapt to this changing environment and protect themselves from these hazards.

**Into the Future**

With the age of the plastic airplane upon us, it is clear many challenges continue to face us as we learn to harness this new technology. Armed with some baseline knowledge of composites—its benefits as well as hazards—aircrews and maintainers will have to adapt to procedures that will maximize these benefits and reduce the hazards of using these materials. It is only from this perspective will we be able to fully integrate the plastic airplane in today's Air Force and protect our people and their aircraft to meet tomorrow's challenge. ■

# Once Again, Thanks for Your Support


. . . AND THE WINNER
FOR THE SEPTEMBER 1989
DUMB CAPTION CONTEST IS . . .

## Sgt Scott Lucier
83 FWS/DOC
Tyndall AFB FL

Okay, gang, we admit it! Your talents for dumb humor are approaching the pure genius level. We keep thinking these pictures can have only a few possible approaches, and you keep proving this is just *not* the case. So, congratulations, SSgt Lucier—you are our latest winner! Your cheap little prize is in the mail.

Now take a look at the honorable mentions to see how tough the competition is getting. If you really want to be stumped, take a look at our latest contest on the back cover, and see if you can beat it.

### Honorable Mentions

1. **Don't get despondent, Ralph. It's only a matter of time before we find the pointy thing that goes through the air first!** MSgt Rocky Cowart, 142 FIG/SE, Portland IAP (ANG), Oregon

2. **I saw Roy Rogers do this with Trigger in a movie and had to give it a try.** SSgt Henry R. Harlow, 907 CAMS/MAAA, Rickenbacker ANGB, Ohio

3. **Wait a minute! I was only kidding when I said this plane is so easy you can fly it backwards!** SMSgt Edward J. Wintermantel,171 AREFW, PA Air National Guard, Coraopolis, Pennsylvania

4. **But Sir, wouldn't it be easier for maintenance to install the engines correctly than to try to fly it backwards!!** Major John Bushko, HQ SAC/DOCSB, Offutt AFB, Nebraska

5. **"I wonder if they'll know I missed Cockpit Familiarization Training yesterday?"** Colonel Stuart C. Bradley, Deputy Commander for Maintenance, Randolph AFB, Texas

6. **Somehow—I don't think this is what they meant by "Hindsight is 20/20."** SMSgt Dave Dashnaw, 6545 TG/ENAM, Hill AFB, Utah

7. **We did okay flying this mission this way, but I would like to be able to read the instrument panel better.** Major Ralph C. Mayton, Jr., 12814 Brockwell Road, Prince George, Virginia

8. **Next time, Jack, don't blow the canopy when I say "Give us some fresh air." Just open it a little.** Major Ralph C. Mayton, Jr., 12814 Brockwell Road, Prince George, Virginia

9. **Man, some party last night! But I think we parked this thing the wrong way. I can't find the instrument panel.** Major Ralph C. Mayton, Jr., 12814 Brockwell Road, Prince George, Virginia

10. **Well, sure, you're going to lose some aerodynamics . . . but this is real heads-up flying!** Major Steve Sward, 93 BMW Intelligence, Castle AFB, California*

*Major Sward's entry came to us on the accompanying drawing instead of the usual photocopy along with the note, "Guy sitting backward on F-4 . . . We're saving money on photocopies."

We gave Major Sward an honorary 10 points and our imaginary gold star for efforts above and beyond the call for sending us the drawing instead of the photocopy. That was a first for us. Nice going Major Sward!

# FSO's CORNER

# See And Avoid Techniques

**CAPTAIN DALE T. PIERCE**
919th Special Operations Group
Duke Field, Florida

■ Out of the 32 FSO's Corner articles published so far, 8 concerned midair collision avoidance. Of these, two were about midair collision avoidance (MACA) posters, one was a business card that provided quick reference to local MACA hazard areas, one covered providing up-to-date information in the FLIP, and another highlighted using television to get the word out. Two articles addressed MACA pamphlets, and the last article addressed MACA program integration.

This article will discuss another important MACA idea. This one was provided by an FSO who is getting rave reviews about his great product.

The FSO at the 513th Airborne Command and Control Wing (ACCW), RAF Mildenhall, England, developed a topnotch MACA pamphlet. It does all the usual things a MACA pamphlet does, and goes one better.

Both the front and back covers are illustrated in cartoon format as an attention getter. Inside the pamphlet is a chart of the local flying area and a description of various points of interest.

Next is a set of aircraft descriptions, complete with illustrations, for the six types most often found at RAF Mildenhall. This is followed by an RAF Mildenhall airfield diagram and airfield information summary and discussions of the local military control zone, arrivals, and traffic patterns.

The last three pages in the pamphlet have a real eye catcher. Here the reader finds a great refresher of see-and-avoid techniques. We all heard most of the information in undergraduate flight training, but not often enough since. The pages cover visual scanning techniques, blindspot accommodation, and a list of things you can do to help yourself see and avoid. Good stuff.

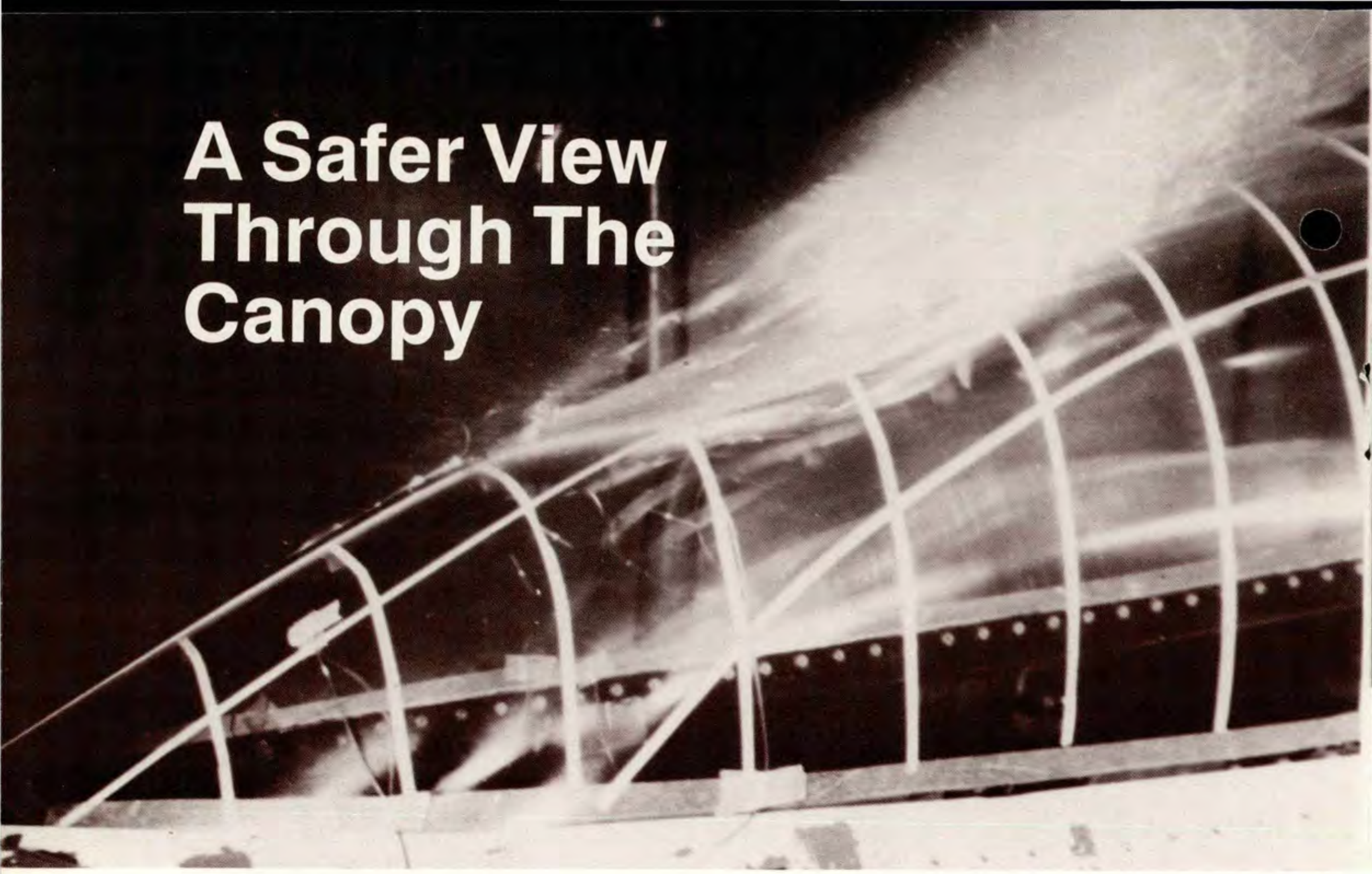
We all need to review this type of information periodically. Putting the information in a convenient place where Joe Silverwings can pick it up and read it is another good way to get the word out. Who knows, a little review of see-and-avoid techniques in your MACA pamphlet might get through where "another standard briefing" at a flight safety meeting might not.

Will it sink in? Maybe. Good MACA practices should be recognized and rewarded because they save valuable combat assets and invaluable aircrews.

Captain John W. Behle, FSO at the 513 ACCW, provided this month's FSO's Corner idea. If you would like a copy of his MACA pamphlet, write to him at 513 ACCW/SE, APO New York 09127-5001.

What are you doing in your program that could help other FSOs if they knew about it? If you know of something, call me (Dale Pierce) at AUTOVON 872-2235 (USAF TAWC), or send a short note to 919 SOG/SEF, Duke Field, Florida 32642-6005. ■


This idea does have great merit! Maybe you can use it in your safety program. (This particular cartoon sure caught our eyes at *Flying Safety* as it is one of ours.) We encourage all of you to use our artwork and stories to promote safety.



# A Safer View Through The Canopy

The new one-piece A-7 windscreen eliminates two large metal frame members. This allows the pilot unrestricted forward vision.

**DAVE HARPER**
Directorate of Aerospace Safety

■ *The flight was briefed as a four-ship surface attack sortie to Avon Park Gunnery Range. The briefing included information on bird hazards and bird conditions for the low-level routes . . . .*

What could be an F-16 jock's recital of how he spent his morning is, in this case, the opening lines to a Class A mishap report. Three hours after this beginning, the pilot suddenly experienced the rude and unpleasant effects of a 500-knot windblast as a large bird penetrated the aircraft canopy.

Medical literature states that above 450 knots, a pilot can expect "certain helmet loss, loss of vision, bleeding around eyes and mouth, tearing of tissue, limb flailing, chill, and disorientation." In this case, the pilot was fortunate enough to be able to eject and was hanging from his parachute risers when his $10 million aircraft exploded on impact 2 miles away just seconds later.

Visually acquiring a bird with a 6-foot wingspan from 1 mile would require a pilot to recognize an object smaller than a pinhead on his head-up display (HUD). At 500 knots, while concentrating on the hazards of low-altitude formation flying, spotting even such a large bird in time to maneuver to avoid it would be exceptional. As the mishap report mentioned, preflight briefings routinely include bird strike risk factors for military low-level routes, products of the computerized Bird Avoidance Model. But even with this very serious approach to staying aware of and away from likely areas of flying fowl, evolving military threats necessitate ever more frequent low-level, high-speed flights and mean that bird strikes will remain an increasingly inescapable fact of flight.

## New Technologies

So what can be done to better protect our flying resources from catastrophe? That's where the

Windshield Systems Program Office (SPO) and the Air Force Office for Logistics Technology Application (AFOLTA), both at Wright-Patterson AFB, Ohio, come into the picture. These offices work to use advanced technologies to fulfill user requirements for aircraft transparencies. It is their complex task to develop, test, and apply materials and manufacturing techniques which will enable windshields and canopies to prevent penetration by the USAF standard 4-pound bird at up to 500 knots and maintain optical quality compatible with advanced HUD and night vision goggle (NVG) use. Specifications may also require the transparencies to resist scratches, have low radar reflectance, survive laser weapons, resist degradation from the sun's UV light, maintain all of these properties through years of cycling between subzero and scorching desert temperatures without cracking or delaminating, be lightweight and inexpensive, and require minimal manpower to replace.

### Rewards

It is a challenging task, to be sure, but the potential rewards to the Air Force are great. Consider the F-16 canopy. It is one of the major "costs of ownership" for that aircraft and has an average service life of under 2 years. Repair and replacement of the canopy costs over $7 million per year and necessitates considerable aircraft downtime. It also was designed for head-on bird strike protection to only 350 knots—fine for its original high-altitude mission, but not confidence inspiring in today's increasing high-speed, low-altitude roles. AFOLTA and the Windshield SPO are now working on projects to produce F-16 canopies using advanced polycarbonate laminate construction which will improve bird strike protection to 500 knots, increase scratch resistance, minimize reflectivity, provide laser hardness, and increase service life to 4 years. A longer term project aims to develop a one-piece, frameless canopy.

### Other Improvements

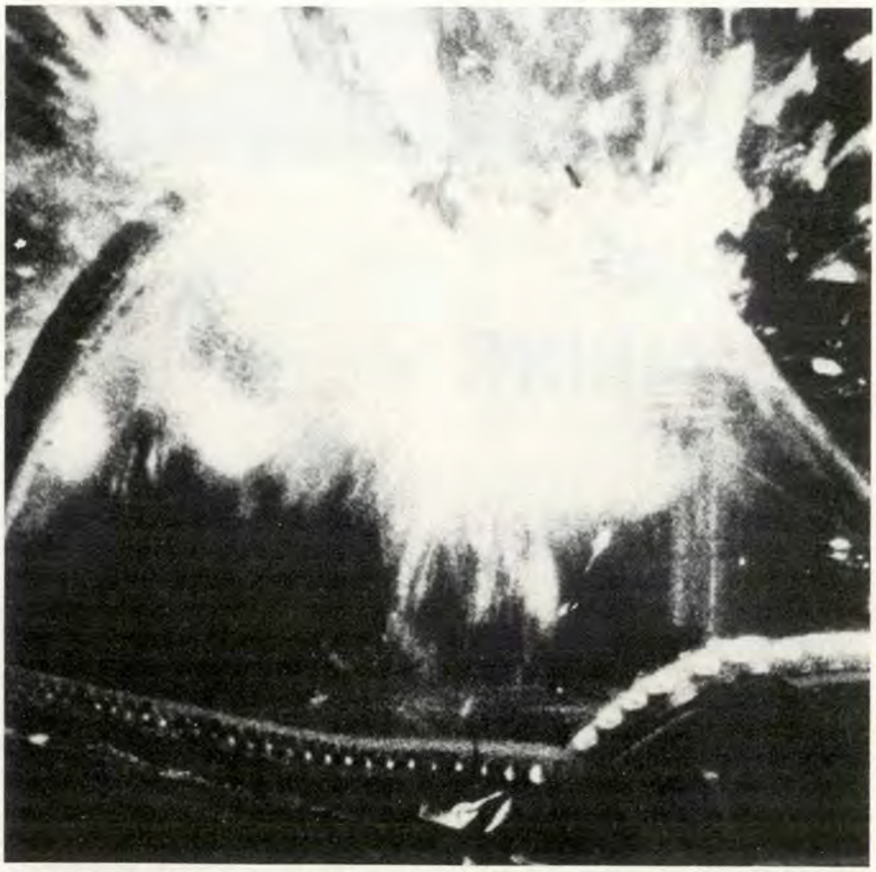
Another transparency improvement effort is underway for B-1B aircraft. Program personnel are investigating the effect of changing from a thermal temper to a chemical temper on the outer glass ply. It is hoped this will lessen thermal cycle stresses on the bond to the adjacent polycarbonate ply and thus reduce windshield delaminations.

Past success stories in the world of windshields include the F-4 windscreen. A production contract has been awarded to replace the three-piece windscreen which provides 290-knot bird strike protection in the center and 190-knot protection on the side panels. The new design is a one-piece, three-ply polycarbonate laminate sandwiched between acrylic outer plies and bolted into a fiberglass frame with a Kevlar® S-glass epoxy composite arch. This high-tech windshield provides 500-knot bird strike protection, removes large vision-obstructing frame members, and is NVG compatible.

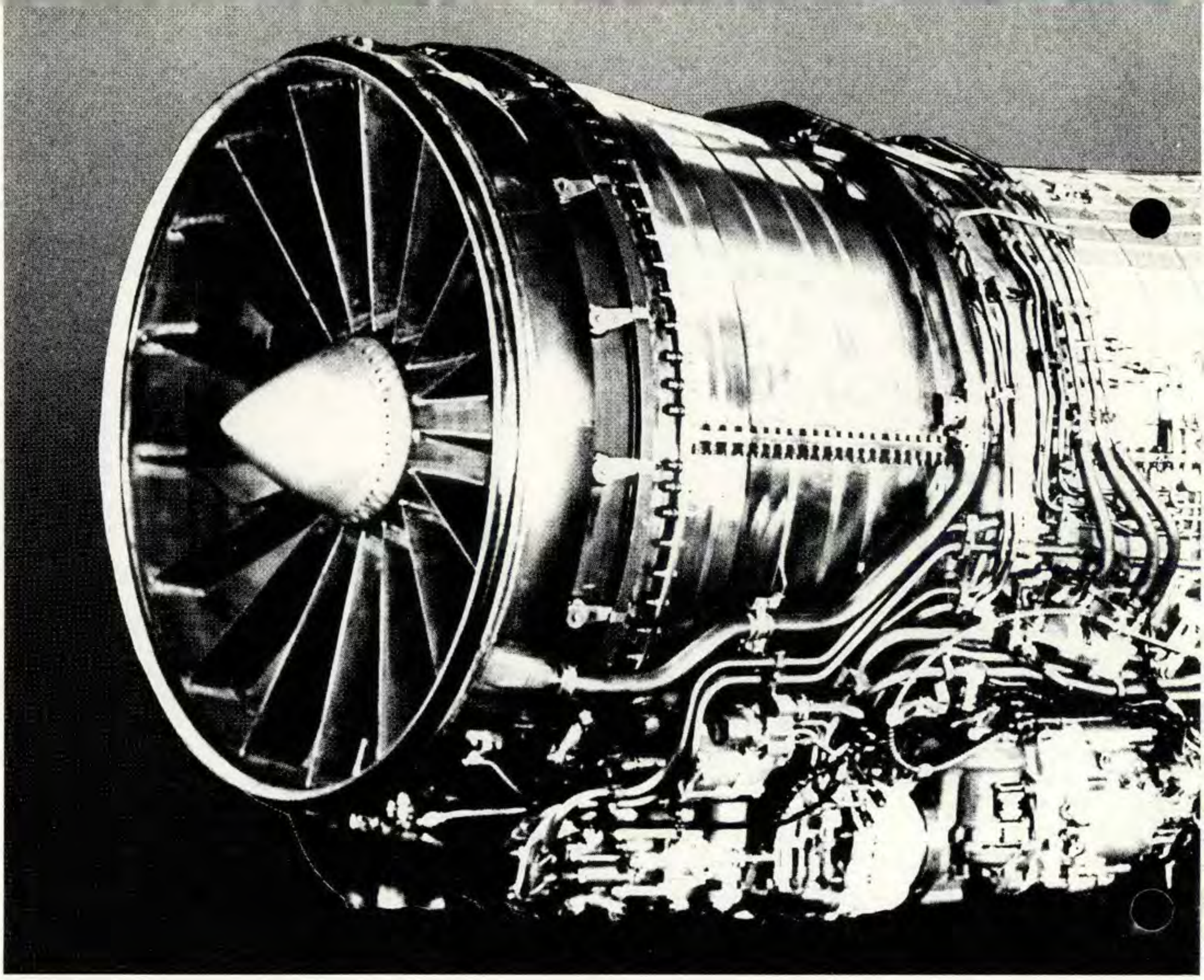
Approval was recently received to begin modification of A-7 aircraft with a one-piece canopy yielding similar benefits, including improvement of bird strike protection to 480 knots from the current 155 knots.

### Costs

Bird-aircraft collisions have taken over 200 lives since birds began sharing the skies with man. The US Air Force experiences approximately 3,000 bird strikes each year, causing an average $65 million in damage. Through application of new and improved methods in the design and manufacture of windshields, USAF pilots will see greatly reduced vulnerability to feathered projectiles while mission capabilities are enhanced. This is just one example of progress in both safety and combat readiness achieved hand-in-hand through advanced technology. ■



Prototype canopies are tested for bird impact resistance by propelling dead, 4-pound chickens from a special gun at controlled speeds and angles. Shown is the one-piece A-7 windscreen.



# ENGINE PLUMBING

## How can you safeguard it?

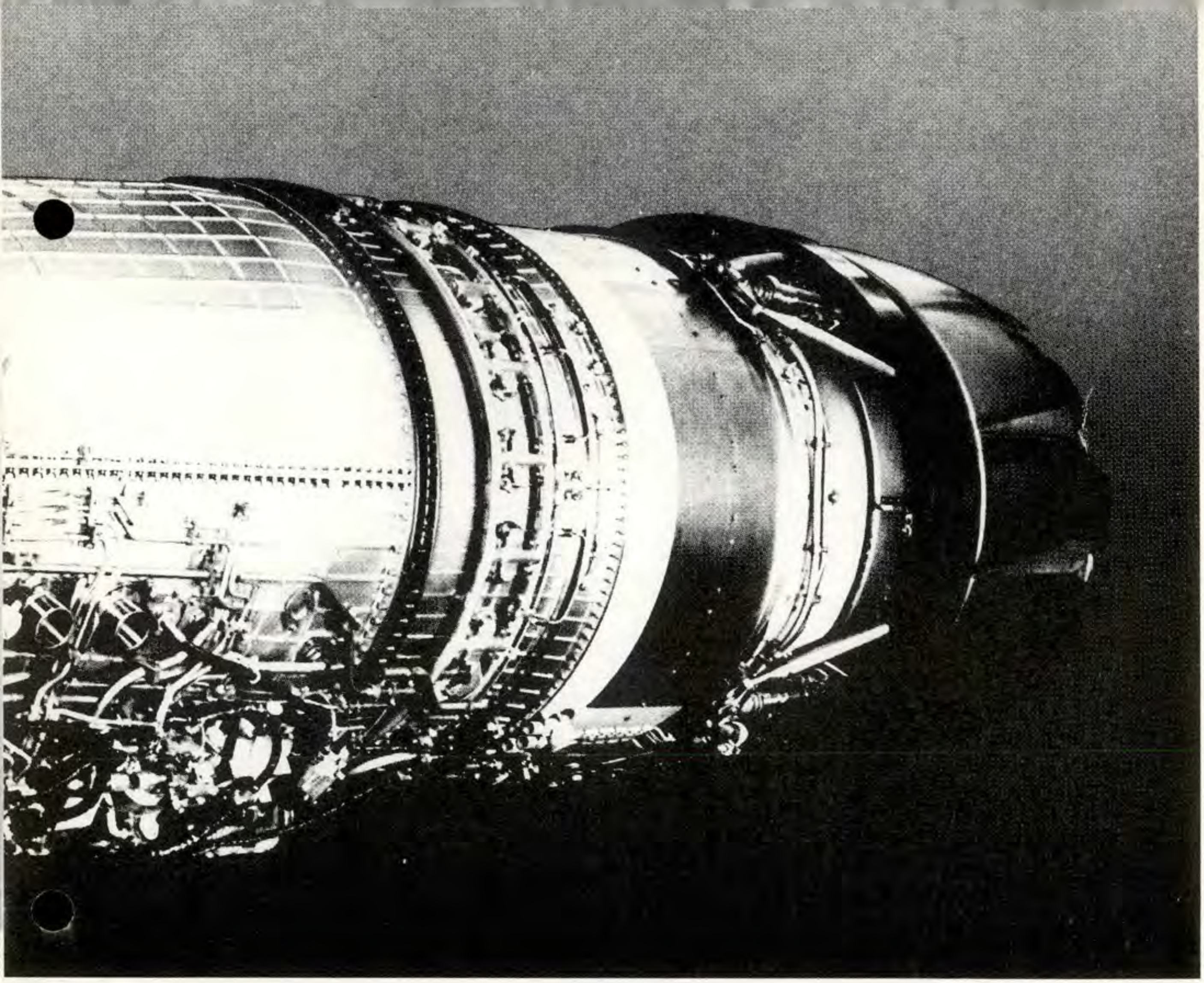
**WILLIAM D. BRADFORD**
Directorate of Aerospace Safety

■ Go out and take a look at any of the newer engines in the Air Force inventory (F110, F100, TF34, TF30, F101, F108, etc.). One of the first items you are going to notice is all of the external plumbing on the engine. These lines carry fuel to the combustor and augmentor, oil for the bearings, and air for control signals. If any of these lines is not performing as designed, the ability of the engine to operate will be affected and compromise the safety of the aircraft.

### Lightweight and Durable

These tubes are designed to be exceptionally lightweight and durable. To accomplish this, it is necessary to ensure the tube has enough strength to perform its function, plus have some additional strength for safety margin. However, this safety margin can quickly be eroded by even small amounts of chafing or nicks. These types of damage must be repaired or the tube deemed unserviceable to ensure the safety of the aircraft. Therefore, it is important to inspect the tubes for damage because even a very small amount of damage can be critical.

Some damage can be fairly easy to fix. If a tube is chafed or nicked, you can see the damage; and if it exceeds TO limits, you either repair or replace the tube. However, there are other types of damage that can occur to the tube that are not as easy to detect, and they can lead to very serious consequences. An example of this is a bent or misaligned



tube—the damage cannot always be easily seen but it can cause the tube to crack while the engine is operating.

**Stresses**

How can a bent or misaligned tube crack while the engine is running? Well, let's discuss various stresses that can be applied to a tube and perhaps then we will better understand what's going on.

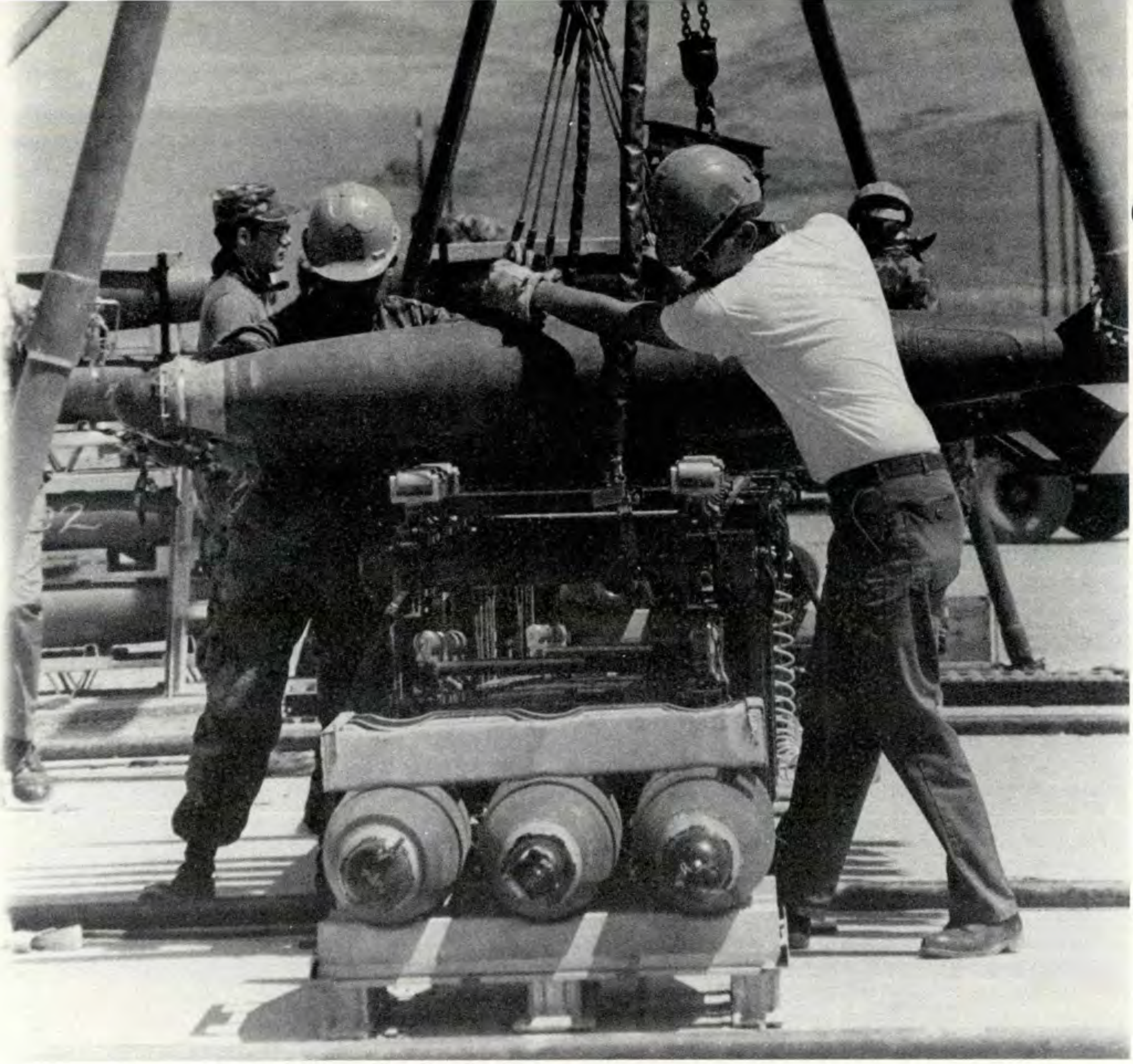
Basically, there are two types of stress that a tube must endure. They are dynamic stress and static stress. A dynamic stress is induced by engine vibrations which are continually applied and released on the tube. They will cause a tube to crack due to fatigue after hours of operation. Static stress, on the other hand, is a stress which is constant, much like the stress induced by the pressure of a liquid in a tube. If that fluid pressure is increased beyond the limit of the tube, a sudden failure will occur, and the tube will rupture.

Now it is important to understand that stresses are additive, both dynamic and static. When tubes are designed, they are designed such that they will withstand the normal stresses that they will incur during engine operation. However, a tube that has been twisted or bent during engine maintenance or overhaul will have an additional static stress that will be locked into the tube. Although not great enough to fail the tube alone, the locked-in stress, when added to the vibratory stress (dynamic stress) incurred while the engine is operating, may cause the tube to fail in fatigue.

There is no way to accurately predict exactly when the fatigue crack will be initiated, and as you maintenance folks are all aware, it is extremely difficult to inspect all of the tubes on an engine for a failure of this type.

**Handle With Care**

If we want to prevent these tubes from being bent and misaligned, we must rely on good, sound maintenance practices. Do not force or bend these tubes when installing them on the engine. Whenever you bend one of these tubes, you will also increase the likelihood of failure of the tube. You won't be able to determine when the failure will occur, but sooner or later, it will occur. Therefore, take extra care and precautions whenever you handle these tubes, and they will continue to perform the way they are supposed to for the life of the engine. ■



# The AIR FORCE COMBAT AMMUNITION CENTER

CMSGT ROBERT T. HOLRITZ
Technical Editor

■ By 1965, it became obvious the Vietnam War was going to be a long one. It was also apparent the Air Force's ability to fight an intense, long-term conventional war had suffered from years of emphasis on strategic nuclear defense. The Air Force not only lacked the equipment but, even worse, because of the attrition of armament and munitions specialists during the years of relative peace since the Korean War, it lacked the skills and experience to fight a sustained war using conventional munitions.

In an attempt to catch up, new munitions support equipment was hastily designed to support the new aircraft that were added to the inventory since the end of the Korean War. As a result, much of the new equipment was actually useless to the people in the combat zone. This unfortunate situation not only hampered combat sortie production during the early years of the Vietnam conflict but, in several incidents, nearly led to disaster.

It took several years for the munitions part of sortie production to come up to speed. Only toward the final years of the Vietnam conflict did conventional munitions employment evolve into a technically advanced and effective program.

## AFCOMAC's Formation

The Pentagon learned its lesson and was not about to make the same mistake again. Vietnam-era aircraft, such as the F-4 and F-105, were able to fly a maximum sortie rate of 1.5 to 2. However, sortie rates as high as 5 are not uncommon for the newer aircraft such as the A-10 and F-16. The Pentagon wanted to know if the ammo community could support the higher sortie rates of the new generation combat aircraft. So, in 1984, more than 9 years after the last American bomb fell in Southeast Asia, a tiger team was formed at the direction of Lt Gen Leo Marques, the Air Force's top logistician, to evaluate ammo's ability to support the high sortie capabilities of our modern combat aircraft.

The team, consisting of 20 "Blue Suiters" from across the Air Force, conducted several tests in PACAF, USAFE, and at Nellis AFB, Nevada. The results of the tests clearly showed the munitions community was not ready to adequately support modern combat sortie production. The team validated a whole new approach to munitions planning and employment was required to meet the needs of modern combat scenarios. At the recommendation of the tiger team, the Air Force Combat Ammunition Center, or AFCOMAC, was formed.

According to AFCOMAC's superintendent, CMSgt Jerry Modlin, its goal is to "teach large-scale production and effective combat munitions planning. We teach our students how to develop a viable munitions employment plan—one that identifies what munitions are available, how to get them out of the structure, assemble them, and deliver them to the aircraft."

AFCOMAC is located at Sierra Army Depot at Herlong, California, approximately 50 miles northwest of Reno, Nevada. According to Chief Modlin, this location was chosen because it not only had existing munitions storage and maintenance facilities, but it also had a runway and a qualified workforce capable of supporting munitions disassembly, repackaging, and restorage.

When Air Force personnel first arrived at the depot in October 1985, the facility left much to be desired. What was to become the academic area was then an abandoned bomb renovation plant. The living quarters were unimproved WW II barracks. With the help of a PRIME BEEF team from Wright-Patterson AFB, Ohio, RED HORSE from Nellis AFB, and CE from Beale AFB, California, the facilities were refurbished in record time, and the first class graduated in March 1986, only 6 months after Sierra was chosen as AFCOMAC's home.


Handling a load of 2,000-pound bombs in close spaces requires practice. AFCOMAC provides ammo specialists with a chance to gain this skill and be "Combat Ready."


Chief Master Sergeant Jerry Modlin: "At AFCOMAC we provide a very realistic wartime scenario. We use live munitions, and there are virtually no simulations."

Today, AFCOMAC is a model training facility which, among other things, houses the sophisticated combat ammunition system (CAS-B) munitions computer which is designed to interface with Air Force major command munitions accountability systems.

AFCOMAC has a staff of 28 people, which is not only responsible for training students, but also maintains 7 supply accounts, 120 pieces of rolling stock, 33 storage igloos, and 50 explosive line items.

Attendees come from all commands with a munitions commitment. Each command earns its allocation based on the percentage of the worldwide population of munitions personnel (461X0/465X0) assigned. The course is open to 5-level senior airmen and above. Each class is composed of a "heterogeneous" group of 70 munitions specialists. This number was chosen because it represents a balance of the number of munitions specialists that would deploy with a 24-primary aircraft authorization (PAA) F-16 or 6 P-AA B-52G unit.

continued

AFCOMAC stresses a realistic scenario. Here the students get a chance to test their skill downloading a load of 2,000-pound bombs from a railcar. (Top left)

AFCOMAC training emphasizes teamwork. This multicommand team will become part of a cadre of munitions specialists the Air Force can rely on to meet any conventional munitions tasking. (Left)

Munitions Control: Strictly bare base operation, the students must establish their munitions control setting up status boards, electrical power, and a radio communications network. (Top right)

# AFCOMAC

continued

Crosstalk between personnel from different ranks and commands is a very important part of the academic training. Specialists, some with combat experience, and assigned AFCOMAC personnel interface with less experienced munitions specialists to contribute to the total learning experience. In this environment, the younger, less-experienced people often provide a new and improved approach to old methods.

### Academics

The 3-week course is divided into two phases. The academic portion is 2 weeks long and covers subjects such as combat and support plans, mobility planning, and air tasking orders. During the academic phase, students also receive refresher training on how to assemble the basic munitions which are common to current combat scenarios. Fondly called AMMO 101, this part of the academic phase stresses hands-on training as the best way to become familiar with the mechanics of munitions assembly. Students are given a pre-test at the beginning of phase one to measure what they already know about munitions when they begin the class. At the end of the academic phase, they are given a posttest. This is not a pass-or-fail exam, but it is given simply to measure how much the student has learned. Typically, the posttest scores are 10 to 30 points higher than the pre-test.

### The Frag

The final week of the course is devoted to realistic hands-on training. During this phase, the students use what they learned during the academic phase to implement the munitions employment plan they developed during phase one as the students assemble and deliver live munitions to meet the requirements of a combat scenario. The emphasis of this portion of the course is on realism. There are virtually no simulations.

The munitions are live. Supplies, support equipment, and rolling stock are packed and marked just as they would be when they rolled off an aircraft had they actually been mobilized.

The exercise usually begins early on a Sunday morning when the battle staff, made up of AFCOMAC advisors, presents an air tasking order to the student senior munitions supervisor. For the next 4 days, the ability of the students to operate at a deployed location is tested to the maximum.

Using the munitions employment plan, the students must set up munitions buildup equipment and assemble the munitions to meet the Frag. Usually for the first 2.5 days, the Frag is a tactical-oriented sce-

nario with sortie rates for a 24-PAA F-16 squadron starting at 4.5 plus. This tasking requires the students to assemble a variety of CBUs, GBUs, and MK 82/84 general purpose bombs. Sometime on the third day, the scenario is changed to a strategic-oriented scenario to support a six-PAA B-52G unit. The SAC scenario requires the students to build M117, 750, and MK82 500-pound bombs in both high and low drag configurations.

**RAMS**

The Rapid Assembly Munitions System (RAMS) is an important part of training at AFCOMAC. RAMS is a mobile munitions buildup system that allows a 15-person team to assemble general-purpose bombs at the impressive rate of one bomb per minute. The entire RAMS assembly can be mobilized on a single MHU 110 munitions trailer. It can be assembled and operational in less than an hour. RAMS not only provides rapid munitions assembly, but it also has the advantage of being quickly moved to any munitions assembly location. This eliminates the time needed to transport the munitions to a separate buildup area. RAMS is only one of many munitions handling items that has been tested at AFCOMAC.

During the entire employment phase, the AFCOMAC advisors challenge the students to use their ingenuity by introducing unscheduled requirements and frag changes. For example, they may be tasked to support A-10s that made an unscheduled stop at the deployed location with 30mm ammunition. Or they may be tasked to change fuse settings, delay times, or even change the kind of munitions to make the mission.

Real-world problems must also be dealt with. One class had to battle a snowstorm that dumped 8 inches of wet snow on their site. But their resourcefulness carried them through. They improvised by using empty munitions containers on the front of the all-terrain forklifts to plow the area.

**The Result Is What Counts**

After 4 days of hard work, the exercise comes to an end. The new munition specialists are tired, their lips are chapped, and their faces are weathered. In spite of these discomforts, morale remains high because they have the satisfaction of knowing that in just a few days, they became an effective combat team.

This scenario has occurred 30 times since AFCOMAC started. The students are not the only ones who learn at AFCOMAC. Each class helps the school sharpen the training by offering suggestions and using different approaches to overcome problems. The first class produced 700 complete rounds of munitions. The production rate per class now exceeds 1,800. Since the course began in March 1986, students have assembled over 44,000 bombs supporting more than 6,000 tactical and strategic sorties.

**Just the Beginning**

In its fourth year, AFCOMAC is still in its infancy. Plans are being developed to strengthen and extend Sierra's runway to accommodate fully loaded tactical fighters. According to Chief Modlin, "Our ultimate goal at AFCOMAC is to create a combined operations and maintenance training program. As with munitions, there are skills to be learned managing aircraft and load crews to produce combat sorties. Those skills can be taught here in a very realistic and safe environment. We have to bring it together here. We can't afford to do it after the balloon goes up."

In slightly more than 3 years, AFCOMAC has trained over 2,000 munitions students Air Force-wide. AFCOMAC graduates already provide the Air Force with a valuable cadre of munitions specialists to draw on. AFCOMAC's philosophy is echoed by the following words: "If you are not ready on the first day of the war, there may not be a second," and in their motto: "To keep the peace, prepare for war." IYAAYAS! ■

# THE BIG SWITCH

## The Air Force is Converting to a Safer Fuel

GREGORY W. GANDEE
Directorate of Aerospace Safety

### Explosions Can Be Very Costly!

■ Here are some mishap scenarios which will get your attention:

■ During the ground refueling of an aircraft, the tank ruptures, spilling a massive quantity of jet fuel. Within seconds, there is a massive fire and explosion which destroys the aircraft!

■ While flying through weather, a lightning strike causes an explosion of the external fuel tanks. The wingman loses control and ejects. The first aircraft recovers, and the investigation confirms lightning-induced fuel tank explosions.

■ On touchdown, a fuel tank explodes, destroying the aircraft.

■ During ground refueling, leaking fuel/vapors are ignited by arcing electrical equipment. The following explosion destroys the aircraft.

These examples are real, not just projections of what can happen with the highly flammable JP-4 fuel. In addition to lost hardware and combat capability, there has also been the irreplaceable loss of life and experience. The track record with JP-4 fuel over the last 18 years indicates that, based on Air Force Inspection and Safety Center mishap data, we are destroying about one aircraft each year. We have also destroyed several storage tanks and refueling vehicles.

### The Problem

What is the problem and the challenge? There are many reasons for these mishaps, and corrective action may avoid future ones. For the fire to start, we need air, an ignition source, and flammable vapors. Once the fire starts, there is not much that can be done. There is, however, something that can be done with the fuel to reduce the chances of a fire starting.

JP-4 (MIL-T-5624), the Air Force standard, is quite volatile. This volatility is dependent on the temperature of the fuel. JP-4 begins to form flammable vapors at fuel temperatures as low as 20 below zero! Thus, whenever JP-4 is spilled, we have flammable vapors present. Increasing the fuel temperature increases the quantity of fuel vapors.

All fuels have an upper flammability limit based on laboratory data. This suggests that at higher temperatures, there are too many vapors, thus the fuel is too rich to burn. This could be true, but don't believe it! Heating and cooling of the tanks and changes in altitude result in a high probability that there are pockets of flammable vapors. Even a fuel spill on the ground is always flammable. Somewhere above the surface of the fuel, there are flammable vapors mixing with the air.

All it takes to ignite these vapors is a very small spark; the static discharge as one reaches for the doorknob after walking on a carpet in the wintertime is sufficient to ignite JP-4 vapors! Other potential ignition sources in the aircraft or on the flight line include hot engine manifolds and exhausts, electrical arcing, or frictional sparks. All of these have been identified at one time as an ignition source in a JP-4 fire.

### Why JP-4?

Why does the Air Force use such a flammable fuel? Well, it is based on factors such as cost, availability, and operational requirements. However, times are changing, and it looks as if all the Air Force will be switching to a safer kerosene-type fuel designated JP-8 (MIL-T-83133). This change has been in process for years and has operational and safety benefits.

***All it takes to ignite those vapors is a very small spark; the static discharge as one reaches for the doorknob after walking on a carpet in wintertime is sufficient to ignite JP-4 vapors.***

### Safety Benefits of JP-8

JP-8 is quite similar to the commercial JET A1 kerosene fuel. The main difference is the special additive package required by the Air Force. The typical JP-8 fuel has a flashpoint of about 114 degrees Fahrenheit. Put another way, we don't have the flammable vapors present unless the fuel temperature exceeds the flashpoint of the fuel, and this does not happen too often. Even if we spill JP-8, there will not be enough vapors to be flammable. In essence, we have eliminated fuel vapors from the fire triangle of fuel, air, and ignition source.

JP-8 has a long history of development dating back to the time of the Vietnam conflict. The JP-4 fuel fire or explosion was contributing to well over 50 percent of our combat losses. Air Force gunfire testing established the susceptibility to fuel fires could be reduced by changing to a kerosene-type fuel. The initial thought was to switch to the Navy JP-5 with its high flashpoint of 150 degrees Fahrenheit. This, however, was not possible since JP-5 fuel is not available in the quantities necessary to support the Air Force requirements of about 3.7 billion gallons per year. Therefore, the commercial JET A1 kerosene was chosen. The JP-8 fuel has a minimum flashpoint of 100 degrees Fahrenheit and is available. It has properties similar to JP-4 except the freeze point and the flash point. For Alaska-type operations, a special low temperature version of JP-8 will be required.

Following the decision to change to JP-8, it was recognized much effort would be required to assure the fuel did not cause any other problems. Concerns were low temperature starting and restarting an

continued

With JP-4's flashpoint below 0° F, there is always the potential for flammable mixtures in the aircraft fuel tanks. JP-4 leaking from a line coupling into a compartment containing electrical equipment and an arcing battery charger caused this disastrous KC-10 explosion.

Safety is the big payoff by converting to JP-8. Based on an analysis of peacetime aircraft losses, there should be future avoidance of the yearly loss of at least one aircraft.

engine at altitude following an engine flameout. Testing by the air logistics centers, engine contractors, and Air Force Flight Test Center at Edwards AFB, California, established this change could be made without any compromise to safety. Although the engine relight envelope was reduced and the low temperature operation was reduced to about -50 degrees Fahrenheit (not -65 degrees as with JP-4), the benefits far outweighed these concerns.

### JP-8 Conversion

In the mid-70's, DOD Directive 4140.3 was issued. This required all aircraft engines to be suitable for either JP-4 or JP-8. Things looked good, but the energy crisis of the 1970's delayed the change. The first change to JP-8 occurred in England in 1978. Since then, all aircraft stationed in England or transient aircraft receiving KC-135 tanker support out of RAF Mildenhall, United Kingdom, have been using JP-8. NATO wanted to standardize on JP-8 but it did not come about until 1987 and was completed in 1988. There have been no problems. The Pacific conversion will start in a couple of years. It will be followed by CONUS conversion over a 5-year period.

Why the delay in the conversion within CONUS? It is a matter of cost and availability. The best guess for the cost increase, based on recent purchases of JP-8 for Europe, is about 5 cents per gallon. Although the fuel is available, a gradual CONUS conversion is required to permit the suppliers to accommodate this change.

The switch to JP-8 has a positive effect on the environment. The volatility of JP-4 contributes to the evaporation loss of about 35 million gallons per year! The change to JP-8 will eliminate over 90 percent of the vapors released.

The switch to JP-8 will also benefit the Army. The Army plans to phase out all gasoline vehicles by 2010 and replace them with diesel engine vehicles. Both aircraft and diesel engines can operate on JP-8, thus a single battlefield fuel for the Army and Air Force.

### Big Payoff

Safety is the big payoff by converting to JP-8. In peacetime, we should avoid losses such as the ground and flight fires leading to the destruction of costly aircraft. The avoidance of peacetime losses assures adequate combat resources are available. The use of JP-8 fuel will also reduce the vulnerability of the aircraft in combat. Testing at Wright-Patterson AFB, Ohio, indicated the combat losses due to fuel fires and explosions could be reduced by about 21 percent. Ops will also benefit from the higher density of JP-8. This increased density translates into about a 5-percent increase in range for fighter aircraft.

This change does have its down side. As mentioned previously, the JP-8 fuel costs more, and it does not have the -65 degrees Fahrenheit capability of JP-4. However, a special arctic grade JP-8 can be developed where it is required. The increased cost may be offset by the reduction of future aircraft losses and environmental considerations.

Quantification of the savings from future mishaps which will be avoided by the use of JP-8 fuel is difficult. However, the Air Force aircraft costs range from $10 to $500 million. The saving of one aircraft alone could well offset the fuel cost increase for that year! ■

# HYDRAZINE

■ The F-16 has been with us for more than 10 years. Its superior performance and ease of maintainability have made it the weapon of choice for many nations of the free world.

Although the Falcon is an extremely reliable and durable aircraft, its single engine and fly-by-wire design demanded a system that would provide emergency electric and hydraulic power. To provide backup power, the engineers came up with an emergency power unit, or EPU, that could operate either on bleed air from the engine or from hot gases produced by the decomposition of a propellant called hydrazine.

The EPU is extremely reliable and has brought many a sick Falcon safely home. The EPU's main drawback is the hazard of its hydrazine fuel. At F-16 home stations, emergency response teams and flight line personnel receive extensive training on the hazards and cleanup of hydrazine spills. However, F-16s can transit just about any base, and for this reason, it is a good idea for all flight line people to have a basic knowledge of the hazards of hydrazine.

While hydrazine may be new to the flight line, it is not new to the Air Force. It has been used by SAC for years as a propellant in the Titan II ICBM. It is a clear, oily liquid with an ammonia-like odor. The propellant used in the F-16 is H-70 which is a mixture of 70 percent hydrazine and 30 percent water. As you might expect, the properties of H-70 are somewhat less volatile than pure hydrazine. In fact, it has a flashpoint of a little over 100 degrees Fahrenheit which is comparable to JP-8 jet fuel.

The Falcon carries 60 pounds of H-70 propellant in a compartment on the right side of the aircraft, just forward of the wing root. The majority of mishaps involved leaks which occurred after the EPU was operating. In these incidents, the H-70 is usually found in a puddle under the right side of the fuselage. There have also been incidents where the EPU was inadvertently activated, dumping hydrazine on an unsuspecting crew chief or blasting him with the exhaust. For this reason, it is a good idea to avoid the EPU exhaust duct area which is located in the right wing root.

### Response

So what do you do if you see or smell a suspected hydrazine leak? The first thing to do is clear the area for at least a 50-foot radius. Personnel should evacuate upwind of the spill. Then get the word to the emergency response team. If the aircraft is in a hangar, open the doors to provide maximum ventilation. Unless you have received special training and have the proper equipment, evacuate the area and leave the cleanup to the experts.

### Health Hazard

Hydrazine can enter the body through the skin, through the respiratory system and, if you can get it past your nose, by swallowing. Short-term exposure can cause dizziness and irritation of the eyes, nose, and lungs. Contact with the liquid can cause severe skin burns. Repeated exposure to sufficient concentrations of hydrazine can cause damage to the kidneys and liver dysfunction. Fortunately, in most cases, the liver will return to normal when the person is removed from the exposure.

How much exposure is dangerous? According to AFOSH Standard 161-13, Occupational Health Exposure to Hydrazine, the maximum safe exposure to hydrazine in a vapor is a mere 0.1 part per million (PPM) for an 8-hour period and exposure for 0.3 PPM for brief periods, not to exceed 15 minutes. However, it is important to note that the odor threshold for hydrazine (minimum concentration that humans can detect an odor) is about 3 to 5 PPM. Since the maximum allowable concentration is 0.1 PPM, any concentration that can be smelled is well above the safe level. It is also important to understand that hydrazine tends to affect the olfactory nerves and can hamper or prevent the detection of even a

continued

# Hydrazine continued

strong odor after a short period of exposure.

### First Aid

First aid for hydrazine-induced injuries is not much different from that of other corrosive chemicals.

The eyes are particularly susceptible to permanent damage from hydrazine. They must be washed with large amounts of water immediately for a minimum duration of 15 minutes.

If hydrazine liquid comes in contact with clothing or the skin, remove the contaminated clothing and rinse the skin with water for a minimum of 15 minutes. For symptoms as a result of inhalation, remove the victim to fresh air immediately.

In the improbable case that hydrazine is ingested and the person is conscious, induce vomiting.

In all cases, it is important to get the victim medical attention as soon as possible. If you have any reason to believe you may have been exposed to hydrazine, seek medical attention immediately!

### Here to Stay

In the past 10 years, the F-16's EPU has proven hydrazine is a reliable fuel, and by following sound safety procedures and adhering to directives, its hazards can be avoided. AFOSH Standard 161-13 contains useful information on the properties of hydrazine. The success of hydrazine in the F-16 has all but assured it will be used in future aircraft designs. Hydrazine is here to stay. ■

We apologize for our mistake in "Emergency Blown Tire," December 1989, page 23. We stated "If an aircraft is taxied or towed with an underinflated tire, the wheel and tire must be condemned." Change 23 of TO 4T-1-3 amends this requirement to direct the removal of both the wheel and tire but **only the tire is automatically condemned.** Our apologies. Change 23 slipped by us.

# MAIL CALL

EDITOR
FLYING SAFETY MAGAZINE
AFISC/SEPP
NORTON AFB, CA 92409-7001

Sir:

■ In your July issue on page 15, "Aviation Heritage," you listed 12 July 1957 "The first test of McDonnell's RF-101 took place. The Voodoo was active in Vietnam from 1961-1967."

You are in error. I was with Det 1 45 TRS at Ton San Nhut until February 1969, and we were still flying RF-101 aircraft then. At that time, I was crewing 56-211, an RF-101C named "Miss Joyce Ann" for my wife. In 1981, while on a safety awareness trip from HQ TAC to D.M., I found 56-211 at MASDIC. I was glad to see my bird made it through.

I receive your magazine monthly at Edwards AFB. I am retired and work for Planning Research Corp. We maintain nine A-7s for the test pilots' school and the AFFTC mission. We now stand at 14-1/2 years with no FODs and no Class A or B mishaps.

Keep up the good work.

Sincerely

***David A. Sandstrom, MSgt, USAF (Ret)***
***PRC QA Rep***
***Edwards AFB, California 93523***

*Thanks for the update. We are pleased you are a regular reader of Flying Safety magazine. Ed.*

Dear Sir:

(Reference *Flying Safety*, July 1989 issue.) I was **very disappointed** to find that the "single-seat" mentality also extends to the Air Force Safety Office. The Koren Kolligian, Jr., Trophy is awarded to the USAF aircrew member who most successfully coped with an in-flight emergency situation. This award for 1988 was given to one aircrew member of a two-seat aircraft. I suppose the Weapon System Officer (WSO) was along simply for the ride. Since both crewmembers were mentioned in the WELL DONE award, (May 1989 issue) and both crewmembers' superb airmanship prevented the loss of a valuable combat resource, why, then, is the WSO not included in the award of the Koren Kolligian, Jr., Trophy? Could the pilot alone of the F-111D have prevented the loss of such a valuable resource if the WSO was not performing his job as a crewmember? I think the Air Force Safety Office needs to reexamine its "second class" citizen mentality.

***F-4 Weapon System Officer***
***APO NY 09283***

*Your statement concerning the Koren Kolligian, Jr., Trophy being awarded to the USAF aircrew member who most successfully coped with an in-flight emergency situation is true enough—open to all ranks and MAJCOMs, but is awarded to one crewmember, regardless of the size of the crew. In fact, only 7 "single-seat" pilots have won, whereas 11 pilots of multiplace tankers, transports, bombers, and helicopters have been chosen.*

*In the past 31 years, the award has been given to two copilots and also two navigators, both F-4 WSOs, whose exploits are well known in the fighter community.*

*There are different nomination procedures for the WELL DONE and Kolligian awards. The Kolligian award is given to only one person. We know each crewmember will perform their respective job to the best of their ability. They are professionals, and without everyone's help, a recovery may not be possible. But for this award, it is the person most responsible for orchestrating the emergency response that receives the nomination. -Ed.* ■



☆ US GOVERNMENT PRINTING OFFICE: 1990:679-051/20003

UNITED STATES AIR FORCE

# Well Done Award

Presented for outstanding airmanship and professional performance during a hazardous situation and for a significant contribution to the United States Air Force Mishap Prevention Program.

MAJOR

## Frederick R. Griese

**58th Tactical Training Wing**
**Luke AFB, Arizona**

■ On 5 August 1988, Major Griese was flying in an F-16D as the instructor pilot and flight lead of four on a conversion syllabus air-to-air training mission from Luke AFB. The flight proceeded normally until he flew a simulated flameout approach (SFO).

Following the low approach, Major Griese advanced the throttle to military power, and at approximately 180 knots, he retracted the landing gear and felt a loss of thrust. He rapidly compared his engine instruments to expected values—RPM 75 percent versus 94 percent, FTIT 550 degrees Centigrade versus 940, and nozzle 75 percent open instead of 20 percent or less.

Major Griese quickly reviewed his options—accomplish the critical actions for low thrust on takeoff which would take about 10 seconds, or extend the landing gear and prepare for a departure end cable engagement. Using superior judgment, he instinctively reduced backstick pressure to reduce angle of attack, so as not to get into a slow speed stall, and trade what little altitude he had to maintain airspeed, while simultaneously lowering the landing gear.

After he confirmed all three gear were down and locked, he increased backstick pressure to regain the landing attitude. He touched down approximately 1,500 feet prior to the departure end cable. At this point, he lowered the hook and shortly thereafter engaged the cable at about 150 knots.

Investigation revealed a fuel control problem. Recreating like conditions in the operational flight trainer, it was shown that the time needed to regain usable thrust was not available. If Major Griese had attempted to continue the takeoff, he would have eventually been forced to zoom the jet, jettison his stores, and eject.

Major Griese displayed exemplary knowledge of F-16 capabilities and outstanding aviation skills under extremely challenging conditions. The superior performance of Major Griese saved a valuable combat asset and prevented untold collateral damage to the nearby civilian community. WELL DONE! ■

# Write A Dumb Caption Contest Thing


There's no way you people are going to continue to beat our dumb humor geniuses who've come up with another truly sensationally funny caption. Yeah, I know you've been able to top us every month so far, but you can't keep up with this killer pace. Of course, if you could, you'd win our fabulous and most revered cheap little prize and be toasted throughout the free world as a true legend.

Write your captions on a slip of paper and tape it on a photocopy of this page. DO NOT SEND US THE MAGAZINE PAGE. Use "balloon" captions for each person in the photo or use a caption under the entire page. Entries will be judged by a panel of experts on humor in April '90. All decisions are open to bribes.

Send your entries to: "Dumb Caption Contest Thing" • *Flying Safety* Magazine • **HQ AFISC/SEPP • Norton AFB CA 92409-7001**