Flying SAFETY

Damage-Adaptive Flight Control Systems

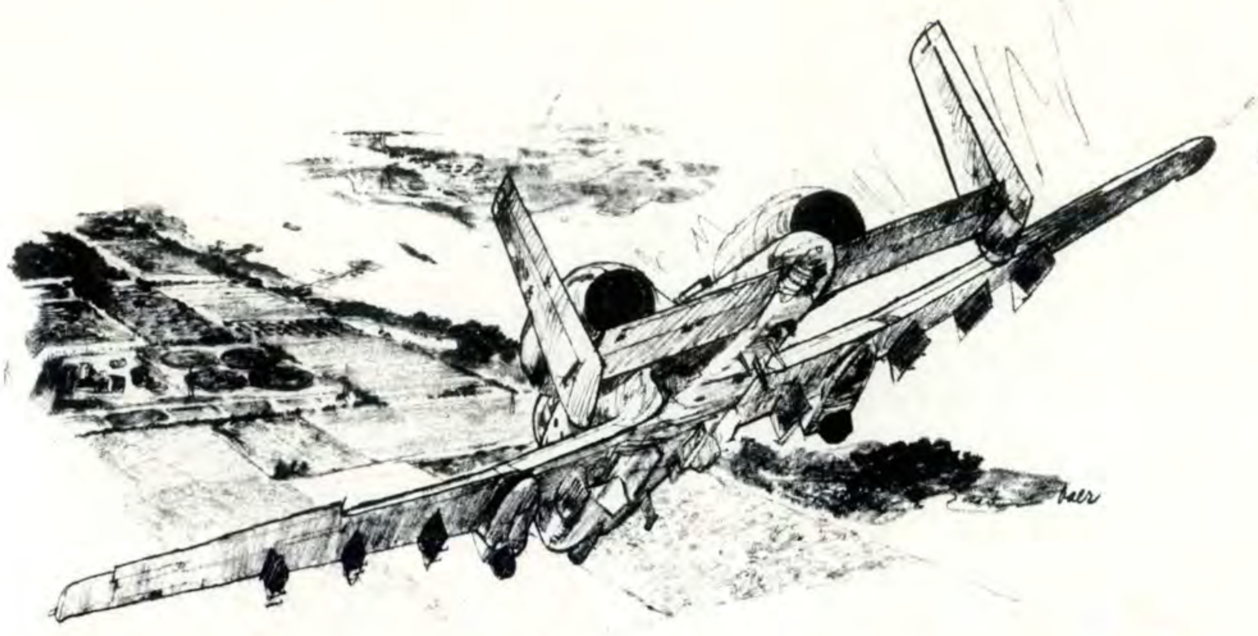
Wake Turbulence Behind Small Aircraft

Controlled Flight Into Terrain

Why Can't We Talk to Each Other?

OCTOBER 1993

SYSTEM SAFETY



THERE I WAS

■ There I was, flying a ho-hum Saturday morning functional check flight on an A-10. The jet was approaching hangar queen status, so we'd ginned up a weekend flight to get it airborne and, if our luck held, released. It wasn't meant to be.

Ground ops were normal. I had the working area to myself once I got clear of the control zone and a large adjacent airport. The jet was doing fine until I got to the manual reversion check.* After controlling the initial pitchup during transition from normal flight controls, all indications looked good and pitch trim seemed to be working.

I pulled up to check out the low speed flying characteristics, then pushed it up to military and lowered the nose into a 20-degree dive to check out the high speed end. Terrain elevation normally kept me from getting very close to the 390 KIAS manual reversion limit but I normally saw 360 to 370 during any pullout which avoided the ground by a comfortable margin.

Pulling back on the stick, I felt the normal heavy-nose characteristic of manual reversion and put in a click or two of trim to help start the pullout. The nose didn't move. I held the trim button aft. Still nothing. The airspeed was approaching the 390 KIAS limit, so I whipped the throttles to idle and tried to extend the speed brakes (they stayed in since hydraulic power is not available in manual reversion).

The ground was becoming more and more of a factor as I grabbed the stick with both hands and pulled as hard as I could. The nose wouldn't come up. I couldn't quite believe it, but apparently I'd have to eject. I moved my left hand from the stick to the ejection handle. As I looked down to confirm I had the handle, the last thing I saw in my peripheral vision was my nose starting to drop, even with full back pressure from the one hand I still had on the stick.

As I reached for the ejection handle with my ejection decision made, a thought popped into my head — get out of manual reversion! I'd gone from a boring FCF to a real scary situation in about 5 seconds, and by now, my mind was racing. In the one additional second it took me to get from the ejection handle to the manual reversion switch, I had time for an amazing number of coherent and disturbing thoughts.

First, I'd made an ejection decision which probably would have let me survive, but had reversed it at the instant I grabbed the handle, which didn't seem wise. Second, the prescribed airspeed range for transition to and from manual reversion was 180 to 210 KIAS, and I was approaching 390 with no clue as to what gyrations the jet would go through when I threw the switch. Third, I'd found the manual reversion switch more quickly than ever before. When I threw the switch, I got an instantaneous negative 3 Gs due to aileron movement toward powered flight position, but was rewarded with immediate resumption

continued

* Manual reversion allows the A-10 to be flown mechanically. The ailerons and elevator are moved by a cable from the stick to a flying "tab" which positions the control surface. Cables are connected directly to the rudder surfaces without the aid of a tab. — Ed.

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There I Was continued

of hydraulic power and normal pitch authority.

I pulled back on the stick till it felt right and avoided the ground by 500 to 1,000 feet. It was several minutes before I could talk well enough to declare an emergency and get a RAPCON clearance back to the field, but there were no other flight control problems, and the landing was uneventful. The maintenance line chief was not pleased with a nonrelease but got off my back when I told him why I wasn't pleased with the jet either.

It turned out the trim motor was intermittent in manual reversion, and even extreme pilot inputs without operative trim may not be able to deflect the elevator into the airstream at high speed. I'm not convinced to this day I'd done an adequate in-flight check of the trim in manual reversion, but the trim had seemed to change slightly when I'd put in a click to test it right after I'd transitioned. It had definitely checked good during the preflight manual reversion checks.

In any case, my in-flight manual reversion trim checks improved greatly on subsequent FCFs. So did my awareness of the possibility of quickly switching out of manual reversion if problems developed, even after I'd transitioned successfully and begun to wrestle the airplane through the zoom and dive required to quickly check the low and high speed ends.

Despite the excitement in the area, the most chilling part of this whole episode happened on the way home for landing. My heart was still going a thousand miles an hour, but everything at least seemed to be under control, and I even sounded coherent on the radio. But as I looked around the cockpit, I discovered I'd forgotten to arm the ejection seat prior to takeoff.

I never did that again. ■

Send Us Your "There I Was"

■ Our readers tell us you like our "There I Was" feature. You have some great stories out there just waiting to be told, so how about jotting them down. You can duplicate the sample outline (including the address on the back) found in this month's issue of *Flying Safety*. Don't tear out the page — there are more readers who have a great story to tell.

This is a totally anonymous program. It is not meant to encourage reporting of other peoples' shortcomings, not a grievance system, and there will be no retribution or confidentiality breaks. The inputs will receive the immediate personal attention of the Editor, and any items which may be useful to the operators and maintainers of our aircraft will be disseminated as soon as possible.

We'd like to cash in on the lessons learned from the close calls, near misses, errors of judgment, or whatever, which come from your "There I Was" story.

This is an ongoing program, so FSOs, dig out your "There I Was" outlines for local dissemination. You can write to AFSA/SEDP, 9700 Avenue G, SE, Suite 282A, Kirtland AFB NM 87117-5670, or call DSN 246-0950, for additional information. If we are not in, a 24-hour answering machine will ensure we receive your inquiry. ■

THERE I WAS . . .

Provide additional sheet(s) as needed to complete your story.

Fold

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"There I Was"
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"EYES ONLY" for the Editor

FOLD

DAMAGE-ADAPTIVE Flight Control SYSTEM

for tactical fighter and transport aircraft

Using a specialized flight control system, pilots of fighter and civil or military transport aircraft may soon be better able to fly severely damaged aircraft back to safety. This new "damage-adaptive" control concept promises not only greater safety and survivability than current fault tolerant flight control systems, but also greater maintenance efficiency for identifying and repairing failed components.

JIM URNES
Section Chief
Flight Control Reconfiguration
Aircraft Subsystem Applications

Fault Protection in Current Flight Systems

■ Today's fly-by-wire flight control systems are connected with the control surfaces of aircraft through multiple channels. Each channel contains digital processors and feedback motion sensors which are linked with high gain control surface actuators. If any of these components fails, the flight computer's fault-monitoring built-in test logic will automatically switch out the failed component and switch in an identically functioning component.

But what happens if major faults occur beyond the limits of today's fault logic and backup components? Battle damage, midair collisions, or hydraulic actuator failures may result in the loss of critical control and stabilization surfaces, suddenly confronting the pilot with completely different flight responses to control commands. Paramount to survivability in such situations is the pilot's knowledge of the extent of damage and the remaining maneuverability of the aircraft. Unfortunately, current flight control systems do not address these major control damage situations.

Nor are the current systems always helpful in identifying failed subassemblies to maintenance crews. The fault logic used in multichannel systems, for instance, sometimes shows false indications of failures, either during flight or in preflight tests, resulting in additional maintenance trouble-shooting and unnecessary subassembly changes. Figure 1 shows categories of F-15 maintenance codes and the high percentage of unsuccessful fault identification. In addition, intermittent in-flight failures reported by test

continued

DAMAGE-ADAPTIVE
Flight Control System
continued

pilots are not always reproduced on the ground, resulting in continuing flight writeups.

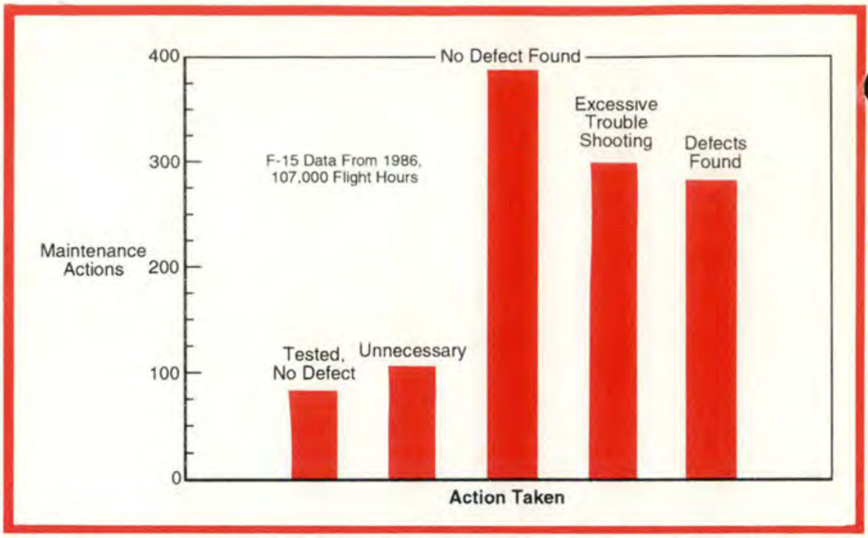


Figure 1. F-15 Maintenance Actions on Flight Control Subsystem Show Difficulty of Accurate Fault Diagnostics

Damage-Adaptive Control Technology

To address these flight control system issues, McDonnell Douglas Aerospace is working with NASA, Air Force, and Navy test centers to develop new damage-adaptive flight control technology which will provide:

■ Accurate in-flight diagnostics of both major as well as minor flight control system failures, together with the resulting flight properties of the aircraft.

■ Immediate action after a damage incident to reconfigure the control commands to use remaining good actuators or engine response (or both) to restore stable, controllable flight.

This technology development is advancing flight control fault protection well beyond current levels to such events as major airframe damage and hydraulic or propulsion subsystem failures.

To illustrate this new damage-adaptive approach, consider how a deflected aileron will cause an aircraft to yaw and pitch as well as roll. With current flight control systems, the unwanted yaw and pitch are usually countered by commands to the rudder and stabilator. For a damaged aircraft, however, these additional responses may be needed to make up for the loss of a control surface.

Accordingly, the damage-adaptive system will recombine or reconfigure the control actuator and engine commands of a damaged aircraft so the pilot stick inputs will produce nearly the same response expected for the undamaged aircraft. Thus, if one horizontal stabilizer of the F-15 is damaged, the system will command aileron and rudder changes which exactly make up for the missing stabilizer maneuvering force.

In addition to providing added safety to the pilot, crew, and passengers, the new damage-adaptive system also includes diagnostic concepts which will provide more accurate preflight and in-flight fault reports to reduce unnecessary maintenance and flight writeups. The damage-adaptive and fault diagnostic tasks are performed by special control mode software described in the next section.

Flight Test Development

Under an Air Force Flight Dynamics Laboratory program, a Damage-

	Maneuver Conditions	Failure Indication Major System	Subsystem Failed	Cause
1	>3 g	Roll CAS Disengage	Dynamic Pressure Sensor	Connector Fails Under g Load
2	ACM	None	Stabilator Surface – 100% Missing – 80% Missing – 50% Missing	Battle Damage
3	1 g Small Pitch Inputs	Pitch, Roll CAS Disengage	Stabilator Actuator	Hydraulic
4	2 g Turn	Autopilot Disengage	INS	Platform Stabilization Fails Under g Load
5	5 g Turn	Pitch, Roll CAS Disengage	Pitch Computer	Card A Loose Connection Under g Load
6	Pull-Up	CAS Disengage	Right Angle-of-Attack Sensor	Excessive Friction in Rotor
7	Cruise	Right Stabilator Failed	Stabilator Actuator	Locked at Trim
8	Cruise	Right Stabilator Failed	Stabilator Actuator	Locked 6° Away From Trim Position

Figure 2. Test Faults Inserted During Flights of the NASA Test F-15 Aircraft

Adaptive Flight Control System was demonstrated on a NASA F-15 research aircraft. This system was designed by McDonnell Douglas Aerospace and General Electric Aircraft Controls (now a division of Martin Marietta). Twenty-five test flights were used to evaluate new concepts for both in-flight fault diagnostics, as well as flight control reconfiguration of damaged or disabled control surfaces.

In-Flight Fault Diagnostics Key to the success of damage-adaptive flight systems is accurate in-flight detection of faults. In the F-15 flight demonstration, artificial intelligence (AI), composed of a rule-based expert system, was used for subsystem fault reporting, while AI with model-based reasoning was used for major damage identification. Figure 2 shows the faults tested ranged from minor subsystem failures to major battle damage to the stabilator control surface.

Some of the minor faults were programmed to occur as intermittent mechanical, electrical, or hydraulic failures during maneuvers in the test aircraft. Such failures, which normally result in Can Not Duplicate (CND) maintenance and repeat writeups by the pilot, were successfully detected by the expert system software. Two examples illustrate this type of problem and the effectiveness of our approach.

In Fault #1 (figure 2), for instance, a wiring connector pin was programmed to separate contact only under high load maneuvering and regain contact before landing. With the new fault diagnostics software installed in the flight control software, the system successfully detected the problem when it occurred and tracked down its source in the wiring.

A second case (Fault #6) concerned an angle-of-attack sensor probe failure. Two of these probes are used on the F-15, one on each side of the fuselage nose. The fault programmed in the flight software represented friction or binding on the rotating shaft of the right probe, causing a delay in the response. This delay causes a mismatch between the left and right angle-of-attack inputs to the flight computer, resulting in a shutdown of a portion of the flight control Command Augmentation System (CAS). This intermittent, hard-to-isolate failure was also successfully diagnosed by the expert system software.

To program the expert system to diagnose such failures, fault detection rules were related to facts available in the flight system after a failure. Figures 3 and 4 illustrate a portion of the diagnostics system programmed in the flight software of the F-15 for the sensor probe failure.

The facts shown in figure 3 were sequentially activated in the flight control software as True/False questions. This approach is much like

continued

Facts		Rules										
No.	Mnemonic	1A	2A	3A	1B	2B	1C	1D	1E	2E	3E	4E
0829	Pitch CAS Engage	F										
0830	Roll CAS Engage	F										
0831	Yaw CAS Engage	T										
0813	No Pitch and Roll Axes Disengage	=F	F		F							
0837	No Pitch and Yaw Axes Disengage		T									
0838	No Roll and Yaw Axes Disengage		T									
0839	No Pitch+Roll+Yaw Axes Disengage		T									
0802	No Multiple Axis or Other Faults		=F	F								
0835	No Disengage			T								
0801	No Single Axis Faults			T								
0800	CAS Mode System			=F								
0842	Roll CAS Re-Engage				T							
0841	Roll Reset Fail After Disengage				=F	F						
0550	Fault Code 2210C1AZ					=F	=F					
0570	ASP Indicator Not Latched						F	=F				
0001	Fault Code 2210A2A1							F	=F			
0041	AOA Monitor								F	=F		
0028	Right AOA Signal on Bus									T		
0048	Left AOA Signal on Bus									T		
0027 R	Right AOA Mechanical									F		F
0047 R	Left AOA Mechanical									T	T	
0049	Left AOA Not Lagging										=T	
0029	Right AOA Not Lagging											=F

Figure 3. Fault Isolation of Right Angle-of-Attack Sensor Using Expert System Diagnostics in the Flight Control System Software

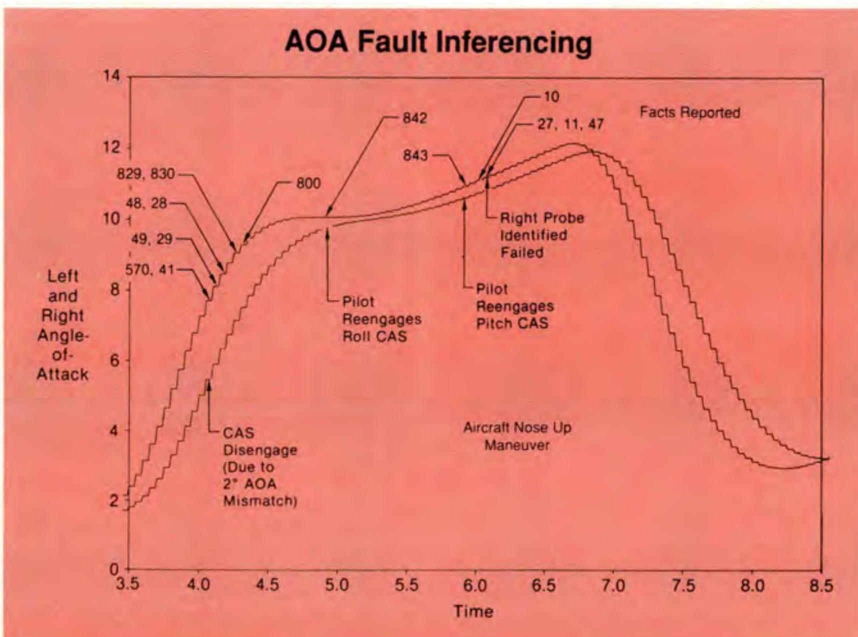


Figure 4. Flight Response With Fault Diagnostics Reporting Failure in F-15 Angle-of-Attack Sensor, Right Side

DAMAGE-ADAPTIVE Flight Control System

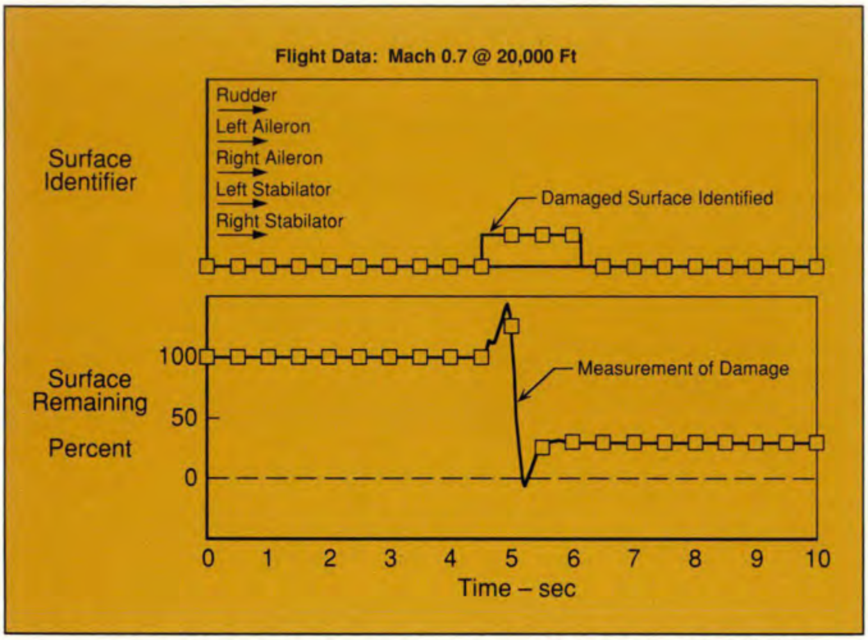


Figure 5. Flight Recording of Damage Detection, Right Stabilator of the Test F-15 Missing 80% of the Span Surface

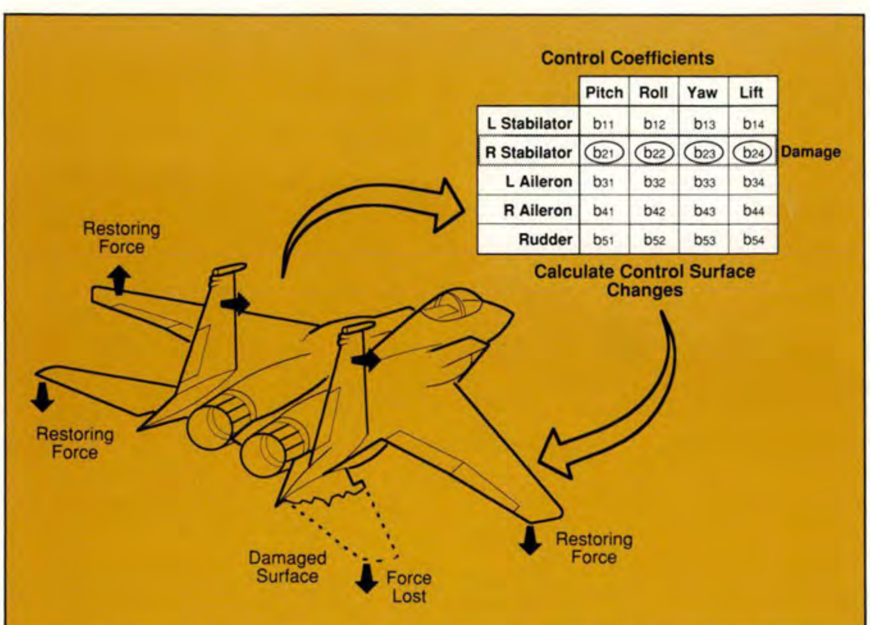


Figure 6. Reconfiguration Software Calculates Stabilizing Control Surface Commands

what a technician would use to search through available information. The answer for each rule is used in another rule to infer the chain of events leading to the cause of the fault. This process happens during flight while the fault is occurring. The CAS disengagement triggers the diagnostics.

Figure 4 is a response output of the two sensors during a pitch maneuver, showing the delay of the right probe and the sequence of facts searched to find the bad component.

The major faults programmed to occur in the test F-15 (figure 2) were control surface failures, with the right stabilator used as the flight test example. A special control software module could be triggered by the test pilot to cause the stabilator to fail or represent severe damage conditions, including partial or complete loss of the control surface (such as shown in the airbrushed F-15 photo on page 5). This loss was represented by continually centering the right stabilator aerodynamically, thus eliminating any tail lift from it during a maneuver. This condition resulted in highly asymmetric flight properties with a high degree of uncommanded roll during pitch maneuvers.

To diagnose the major fault damage to the control surface, model-based reasoning logic was programmed into the test aircraft's digital flight processor. This software uses highly sophisticated reasoning logic based on a programmed model of the F-15 to determine the extent of damage. Figure 5 shows a flight test data history of damage detection of the right stabilator surface which has an 80 percent loss of the surface span. The damage estimation identifies that only about one-fourth of this control surface remains attached to the aircraft.

As described in the next section, this damage measurement information was used to reconfigure the

continued

controls to restore close-to-normal maneuvering responses to the damaged F-15. Without this reconfiguration, however, the test aircraft proved very difficult to fly. According to the NASA test pilot in one flight scenario:

"The stabilator locked 6 degrees leading edge down was very uncomfortable, requiring three-fourths left stick and one-half forward stick to hold the aircraft level; I hit the forward stop countering transient."

Flight Control Reconfiguration After detecting the type and extent of damage to the aircraft, the Damage-Adaptive Flight Control System successfully determined correction commands to all the remaining control surfaces. The size of the surface correction commands is determined by comparing a model of the ideal F-15 response to the available force coefficients of each remaining control surface (figure 6). This computation is performed 20 times each second to continually provide the desired response to the pilot stick maneuvering commands.

In the flight demonstration, the responses of the reconfigured F-15 flight control system were compared with both the undamaged and the nonreconfigured damaged flight responses (figure 7). The results show a large uncommanded roll rate for the nonreconfigured damaged aircraft was eliminated for the reconfigured aircraft. Some typical test pilot comments were:

"Five seconds after failure, can go hands off."

"I certainly think the airplane could be flown to a safe place with any of the impairments."

Since pilot awareness of aircraft damage and remaining maneuverability is critical to survival, the head-up display (HUD) provides this information as soon as a failure is detected. On the display (figure 8), a maneuver symbol and allowable maneuver envelope box are presented

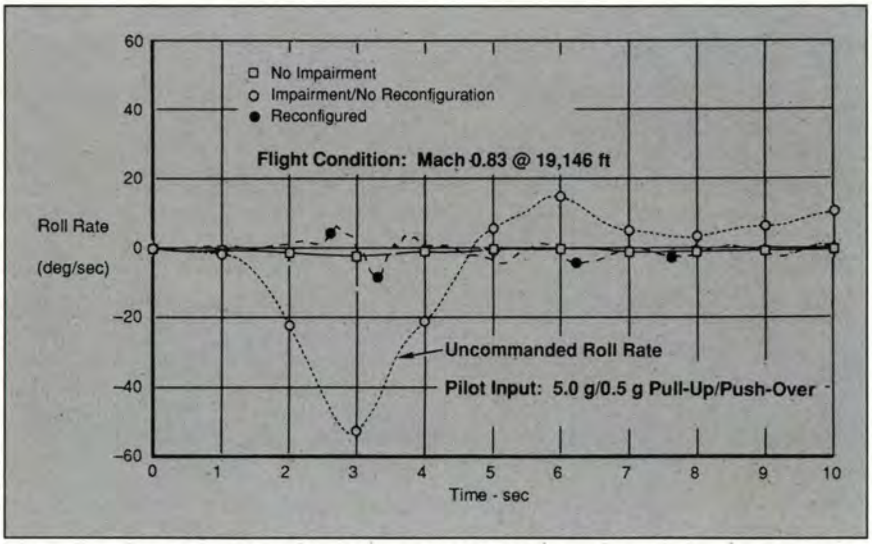


Figure 7. F-15 Flight Response Comparison: Pilot Commands a 5-g Pitch Maneuver With Right Stabilator Failed in Locked Position

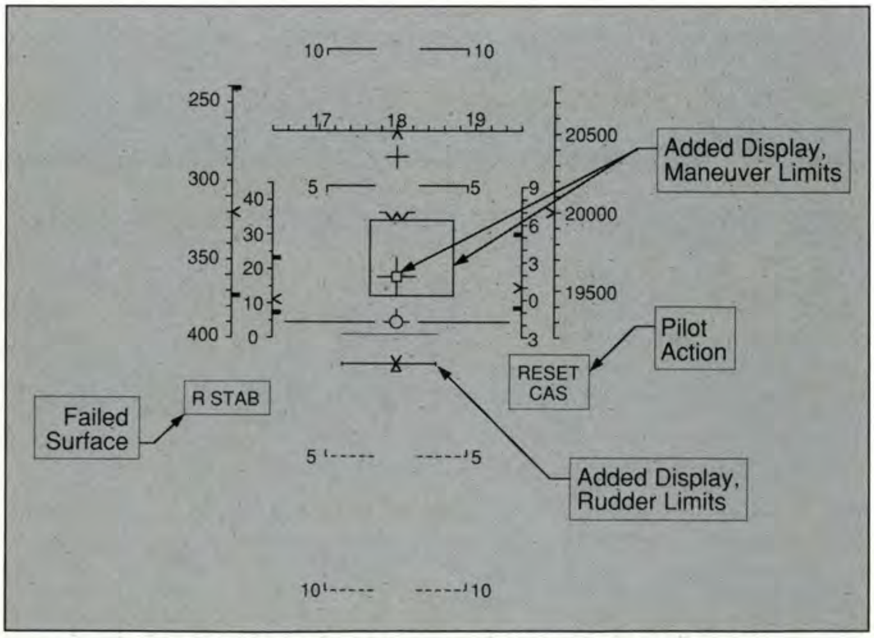


Figure 8. The HUD Shows Maneuver Capability of Damaged F-15

continued

to the pilot based on the roll rate and normal acceleration capability of the damaged aircraft. Also shown on the HUD is the available rudder response.

Advanced Research

Further advancements are in development at McDonnell Douglas Aerospace for both damage reconfiguration and onboard maintenance diagnostics.

In a NASA program, for instance, McDonnell Douglas is developing AI flight systems which incorporate neural network technology to detect wing damage conditions. A neural network is a memory process which is structured to function like the human brain. The connections among its summing nodes are based on pretrained weighting factors designed to process data in certain time-sequenced patterns.

In the wing damage detection application, for instance, the network will first identify partial wing loss due to battle damage. Then, motion patterns measured by the pitch and roll rotate gyros and accelerometer sensors, together with pilot steering commands, will be processed for abnormal maneuver patterns which indicate the extent of damage (span loss) to the wing. To train the network to recognize both normal and damage maneuver properties, F-15 wind tunnel tests were conducted with the right wing cut off.

Figure 9 illustrates the network developed to detect a wing-partially-missing damage situation. This neural network can be programmed in the fault detection flight software of the Damage-Adaptive Flight Control System.

A similar approach to detecting subsystem faults is being investigated for the Navy to advance the ability of flight control systems to find intermittent component failures during flight. The Naval Air Warfare Center Aircraft Division — Warminster — is sponsoring programs which are developing advanced onboard maintenance diagnostics using AI technologies.

Other forms of flight control reconfiguration are also being flight tested. One uses engine thrust changes to steer a multi-engine aircraft which has experienced a complete hydraulic system loss. With the conventional flight control surfaces disabled, precise steering of the aircraft through throttle command changes is extremely difficult for the pilot, due to the lack of any feedback stability augmentation. Reconfiguration software adds this stability feedback capability to the engine commands, thus providing a stable flight path for runway landings.

Such a control reconfiguration system has been developed for an F-15 test aircraft, under a program for the NASA Dryden Flight Research Facility. In April 1993, NASA test pilot Gordon Fullerton successfully landed a test F-15 using only thrust changes to steer the aircraft. Similar tests are also being conducted by McDonnell Douglas for a transport damage-adaptive flight control system in an MD-11 transport flight simulator.

Flight Systems of the Future

Results of flight research show significant promise for control systems which can diagnose and safely control major fault damage situations. These systems will contain fault reasoning logic which can more accurately diagnose a wider range of in-flight subcomponent failures than today's flight systems and also provide the correction commands to restore safe flight.

Several steps remain to transition this research technology to production, including developing flight software for sizing and validation and measuring flight performance using fighter and transport test vehicles. But once in production, this new damage-adaptive flight control technology will make our fighter and transport aircraft much safer to fly and much more cost effective to maintain. ■

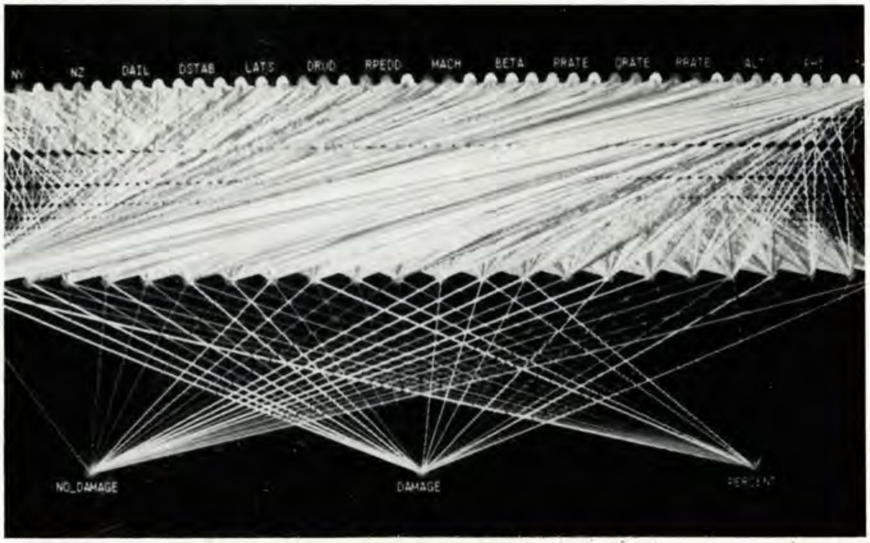


Figure 9. Neural Network Designed to Detect Wing Damage

NEW Electronic Cooling Fluid. . . Better for Less

LOIS GSCHWENDER
Wright Laboratory's Materials Directorate

■ Researchers in Wright Laboratory's Materials Directorate have developed a new cooling fluid for aircraft electronic systems. The payoff is increased aircraft safety and reliability as well as reduced operating costs.

Background

For more than 15 years, silicate ester-based coolants have been used to maintain safe operating temperatures for aircraft electronic systems. The traditional coolant started to cause operational problems for the Air Force's B-1B aircraft. Specifically, the aircraft's radar cooling systems started experiencing electrical arc failures, filter clogging, as well as overheating.

Researchers found the silicate ester-based coolant was reacting with moisture to form a silica gel and alcohol. The gel buildup on electrical boards was causing system failures through electrical arcing. It was also clogging coolant system filters causing pump failures and subsequent component overheating. The alcohol formed in the reaction had a flash point dangerously below the operating temperature of most of the electronic system components.

By switching to a synthetic hydrocarbon polyalphaolefin*-based coolant, Wright Laboratory scientists solved the B-1B's cooling system problems.

This new coolant is also nontoxic and costs 75 percent less than silicate ester-based coolants. Since it is compatible with all B-1B avionics and cooling system components, conversion to the new fluid is a simple drain-and-refill procedure.

The entire B-1B fleet has been converted to the new coolant, and other weapons systems are following suit. The new coolant has also been selected for use on the Air Force's low altitude navigation and targeting infrared for night (known as LANTIRN) system. Navy F-14s have already converted, while Air Force F-15s and F-16s, along with Navy F-18s, are being studied for conversion. The Army has also decided to use the coolant in their Patriot missile system.

The Payoff

This new, environmentally safe coolant improves aircraft safety and reliability while reducing operating costs. Life cycle cost savings for the B-1B and F-18 are projected to reach well over $1 billion.

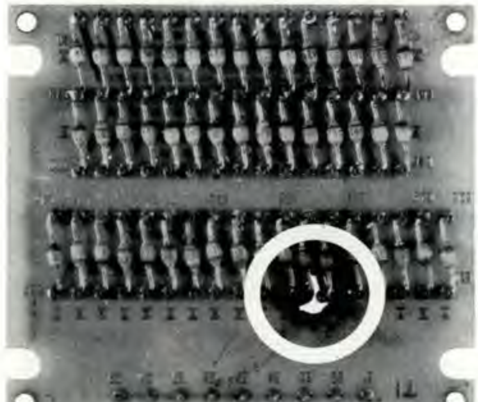
The Defense General Supply System bought the coolant most recently for $9.40 per gallon compared to $70.86 per gallon for the old coolant it replaces. They buy an average of 24,175 gallons per year of coolant. The savings work out to $1,485,795.50 per year for fluid cost alone.

In addition to the acquisition cost savings of the fluid, the new coolant saves maintenance because it does not react with water. The cost of conversion for the B-1 was paid for in the first year by the lower maintenance costs. In the B-1, the old fluid would degrade and clog filters resulting in coolant pump starvation. The pumps would burn out, rendering the radar system inoperative.

Cleaning and replacement as a result of each of these mishaps cost the Air Force $40,000. While not all systems are as sensitive as the B-1 coolant system, all systems the new coolant has been evaluated in to date have had good results.

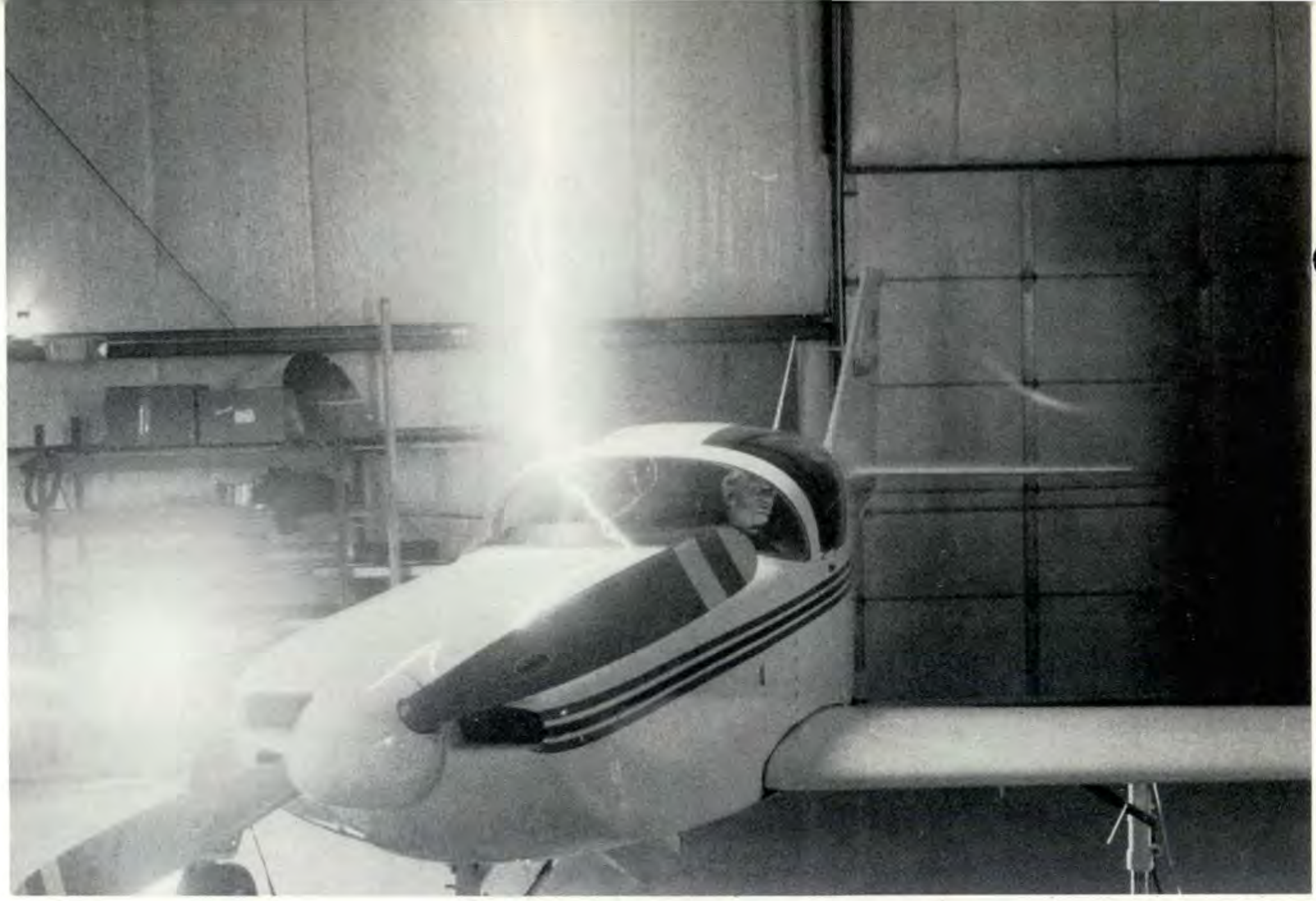
Further, the new coolant has better lubricating qualities than the old. In the F-15, for example, the operators of component tests noticed less "chatter" in the coolant pump loop tests. The new coolant (MIL-C-87252) may eventually be used in almost all systems currently using MIL-C-47220. It may also be used to replace silicone oils which are used in a limited number of applications.

Additional cost savings are anticipated as other systems switch to the new coolant. ■



The silicate ester coolant was reacting with moisture to form a silica gel and alcohol. This gel buildup on electrical boards was causing system failures through electrical arcing.

* The new coolant is composed of this synthetic base.



Lightning Protection
for Light Aircraft

CMSGT ROBERT T. HOLRITZ

■ Commercial aircraft experience the majority of lightning strikes. In fact, on the average, each commercial aircraft experiences one lightning strike per year.

Commercial aircraft experience the majority of the reported strikes for two reasons: because of their size, and because they almost always fly IFR and, therefore, spend a lot of time in the clouds.

Fortunately, most of these mishaps result in little or no damage to the jet or in injury to passengers or crew. This is because the size of the aircraft tends to isolate the inhabitants of the aircraft from the deadly electric field of a lightning strike and, also, because the metal skin of a large jet provides a highly conductive path for lightning to travel. But for a light aircraft, especially an aircraft constructed of low or nonconductive composite material, a lightning strike can be disastrous.

Light Aircraft Problem

A lightning strike on a small aircraft, whether it is of metal or composite, can subject the crew and passengers to an electric field as great as 100,000 volts. If not killed outright, the pilot would almost assuredly be incapacitated and unable to fly the aircraft.

For composite aircraft, the problem is worse because of the high resistance afforded by composite materials. This resistance generates a tremendous amount of heat when subjected to the 200,000 amps of a lightning bolt. And in composite aircraft, the lightning seeks conductors such as flight control cables and bushings.

The New Designs

During the past 10 years, a large portion of the new general aviation aircraft were constructed of composite material. This is because composites are strong, light, and easier to work with than metal. Most of these aircraft were bought as kits, and their owners often invested thousands of hours in their construction.

Most of these kits are considered high performance, and most of their owners are very experienced pilots. Since lightning is not restricted to thunderstorms and can, in fact, occur in any cloud, fiberglass airplane pilots were essentially restricted to VFR fight in spite of their experience.

NASA

Ted Setzer is the president of Stoddard-Hamilton Aircraft, Inc. His company produces the Glasair III, one of the most popular composite aircraft kits on the market. Setzer wanted to be the first to produce a composite aircraft kit which would provide the pilot and passengers with a high degree of protection from the effects of lightning. He led a team of other small businesses — Lightning Technologies, Inc., Analytical Services & Materials, Inc., and Aero-Space consultants. Their goal was to develop and validate lightning protection for fiberglass general aviation aircraft.

Because NASA has been in the forefront of lightning studies since the 1940s, Setzer and his team applied to NASA for funding for their research. They were awarded $50,000 under a NASA Langley Research Center Small Business Innovation Research program established by Congress in 1982. After their basic research proved such technology was feasible, NASA awarded the team an additional $500,000 to build an aircraft using the technology.

The Prototype

The Glasair IIILP (lightning protected) is actually the product of two state-of-the-art technologies: composite materials and digital electronics — both of which make the aircraft highly susceptible to lightning damage. The concept of the Glasair's lightning protection system is actually pretty simple — the technology has been around for years.

To provide conductivity, the final composite layer of the aircraft structure contains a sheet of expended aluminum foil. The foil is perforated to allow it to form a bond with the composite media. Since the foil is on the outer layer of the aircraft, it does not significantly affect the structural integrity of the aircraft but it does keep much of the electrical field from the crew and passengers and provides a conductive path for the lightning to pass.

Inside the aircraft, the team bonded most of the flight control surfaces, bushings, and other moving parts such as trim tabs. Other systems were insulated to provide protection.

The Results

This study proved a composite aircraft, even a fiberglass kit aircraft, can be designed to provide the same protection against lightning as larger commercial jets. It can be built to conform to FAA requirements to maintain structural integrity, protect occupants from shock, and prevent ignition of fuel vapors. It also provides sufficient protection of critical flight systems such as flight controls, propulsion, and avionics systems.

It is important to understand no aircraft is invulnerable to lightning. However, this technology is designed to provide aircrews with the maximum ability to experience a strike and make a safe landing at a nearby airport.

Composite aircraft are here to stay. New designs and changes in the FAA type certification will bring new life to the general aviation industry. The money NASA invested in lightning protection research will pay great dividends in general and commercial aviation safety. ■

Contact the Safety Specialists

Here's your guide to the folks at the Air Force Safety Agency and how to reach them by phone, FAX, or mail.

As of October 1993

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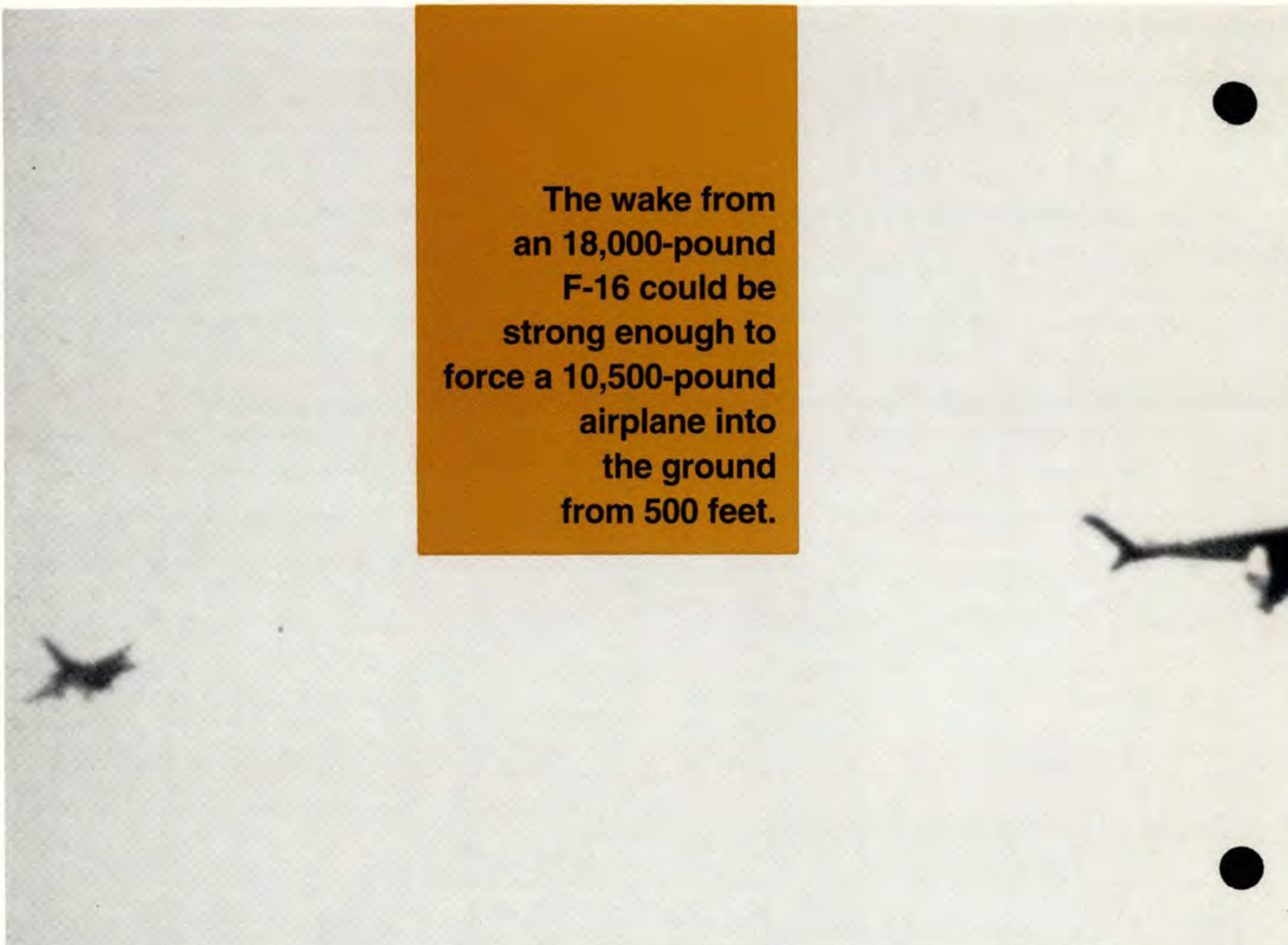


The wake from an 18,000-pound F-16 could be strong enough to force a 10,500-pound airplane into the ground from 500 feet.

Wake Turbulence Behind

CAPT CHRIS HABIG
445th Test Squadron
Edwards AFB CA

■ Two people died when their 10-passenger twin crashed on short final. Wake turbulence from an F-16 had put the twin out of control. Who would have thought the wake from an 18,000-pound F-16 could be strong enough to force a 10,500-pound airplane into the ground from 500 feet AGL? It was.

Few pilots know small airplanes can generate dangerous wake turbulence. We're all aware of the danger behind heavy and jumbo aircraft, but an F-16? In 1979, Mr George Kurylowich of the Air Force Flight Dynamics Laboratory announced a David-and-Goliath syndrome existed among Air Force pilots. While we knew heavy aircraft (Goliath) could flip smaller aircraft (David), we were generally not aware "David can slay David."

I believe this syndrome still exists today. We emphasize safe separation behind large jets, but we don't recognize the dangers of wake turbulence behind smaller aircraft. The fact is, *every aircraft generates wake turbulence.*

In this article, I'll describe wingtip vortices to give you better insight into what you're up against. Then I'll talk about what happens when an airplane flies into that vortex. Finally, I'll summarize some USAF wake turbulence mishaps involving fighters as evidence of the turbulence behind small aircraft and give you some hints for flying safely. First, let's examine the vortex itself.

The Vortex

The strength of an aircraft's wingtip vortices depends upon several factors — the aircraft's speed, weight, and wing shape. Most pilots know the effect of speed — slow aircraft generate stronger wakes. They also know heavy airplanes generate stronger vortices than lighter airplanes. Some, however, know nothing about the effect of wing shape. Yet without this knowledge, it's impossible to accurately assess the danger of an aircraft in front of you.

Take this fill-in-the-blank test. A 25,000-pound airplane with a 25-foot

Small Aircraft

wingspan generates wake turbulence __________ as strong as a 100,000-pound airplane with a 100-foot wingspan. A year ago, I would have answered "one-fourth." Boy, was I wrong!

Let's consider span and configuration when discussing wing shape. For a clean wing, vortex strength is a function of *weight divided by wingspan*, not just weight! This ratio is called span loading. It's a measure of how much weight the wing carries per foot of span. It's also the factor of wake turbulence which isn't well known among pilots.

Simply put, the span loading will tell you more about the strength of the wake than weight alone. Let's answer the question I posed earlier. Divide the weight of each airplane by its wingspan to get span loading. Since the span loading of each airplane is the same, their wingtip vortices have the same strength! Surprised? So was I. But this was for a clean wing. What happens when you lower flaps?

Lowering flaps weakens the vortices. That's good news. Just make sure the airplane in front of you has its flaps down and you'll be all right. NOT! The vortices start out just as strong as those from a clean wing

continued

While pilots of small aircraft are to be wary of turbulence behind both small and large planes, pilots of large aircraft must be just as careful behind other large aircraft. Large aircraft can experience the same violent reactions to wake turbulence as small aircraft — rapid roll and loss of lift — yet pilots of large aircraft are at a disadvantage since they don't have the thrust or roll rate of a small airplane at their command.

From 1971 to date, there have been 27 reported incidents involving wake turbulence, 4 of which were Class A mishaps. These mishaps involved *all types* of aircraft. In one case, maximum roll authority was barely enough to prevent a C-141 from losing control in a C-5's wake. The same rule of thumb applies — if the airplane in front of you is the same size or larger, it is a hazard!

Anytime the aircraft in front is your size or larger, beware of wake turbulence.

Wake Turbulence Behind Small Aircraft continued

(remember the span loading!). Anything hanging from the airplane (flaps, slats, spoilers, speedbrakes, landing gear, etc.) creates turbulence which makes the vortices dissipate faster. But you can't ignore them — they're still there.

Of course, the mere presence of wake turbulence doesn't invite disaster. Another airplane has to fly through the wake before anything bad can take place. Let's see what happens during a vortex encounter.

Flying Into a Vortex

A vortex, by its nature, will eject an aircraft flying into it — you can't get trapped in the middle. Unfortunately, at low altitude, the aircraft may be thrown out in an attitude or direction from which it cannot recover. How does this happen?

Figure 1 shows the vortices produced by a wing. The tornado-like flow of either vortex can quickly put you into an unusual attitude, especially if your wingspan is short enough to fit inside it. Your ability to counter the vortex depends on how well your aircraft rolls.

In the passenger twin's situation, the roll rate caused by the wake turbulence was three times greater than the mishap aircraft's maximum roll rate. Since fighters roll better than most airplanes, you might think they'd be immune from wake turbulence. They aren't! The upset can be so powerful and sudden you may not have the time or the altitude to react. Case in point: The T-38 is the fastest rolling airplane in the Air Force, but the vortex from another T-38 2 miles in front is so strong it takes 70 percent of the T-38's roll capability just to counter it! Scary as this is, you may have to deal with more than just an unusual attitude.

Outside the wingtips is a general upward flow of air, and between the wingtips is a general downward flow. The strength of the flow is surprisingly strong. I calculated the downwash of our 18,000-pound F-16 to be 1,850 ft/min! If you're unlucky enough to get thrown into that downwash at 150 knots (ballpark for a fighter), you will quickly lose 7° angle of attack over most of your wing. This could be enough to put you at negative AOA and send your stomach to the roof of your mouth! In fact, it took our twin only 7 seconds to fall from 500 AGL to the ground!

Statistics

From 1976 to 1987, the USAF had 12 wake turbulence mishaps involving identical fighters (F-15 behind F-15, for example). Fortunately, none of these resulted in destroyed aircraft or fatalities, but each involved a loss of control and aircraft damage. Why don't we have more mishaps? It's because we usually fly the same glidepath as the plane in front of us (figure 2). As the wake sinks, the no. 2 aircraft will be safely above it. Separation criteria usually assure enough time for the wake to sink out of our way. Instances can occur, however, when the standard separation may not keep you safe. For example, a tail wind can blow the vortices forward into your flightpath or a shallow approach (e.g., no flap) may put you in the middle of the wake. In these cases, either increase your separation or go around to give the vortices time to dissipate.

Summary

You've seen the span loading of an aircraft is a better indicator of vortex strength than weight alone. You cannot assume small airplanes don't trail wake turbulence — they do. You also learned you're most susceptible to a wake upset if the airplane in front has a wingspan at least as large as yours (i.e., you can fit inside one of its vortices). Rather than just thinking about wake turbulence separation behind heavy and jumbo aircraft, use your head anytime the airplane in front is your size or larger. Everyday separation rules may not keep you safe. In particular, if you are landing with a tail wind or flying a shallow approach, watch out. Put more distance or time between you and the airplane in front.

Finally, if you remember nothing else, remember this rule of thumb: *If the airplane in front of you is the same size or larger, it's a hazard!* ■

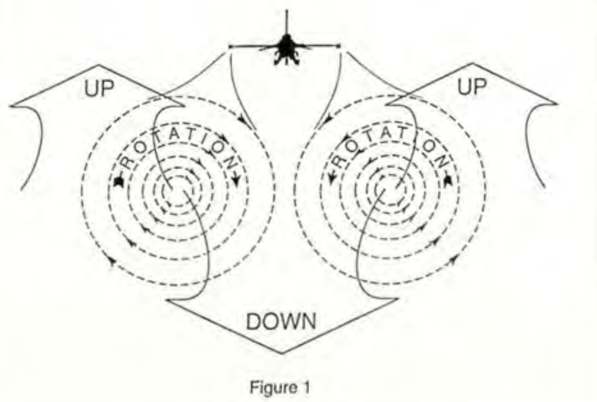


Figure 1


Figure 2

Controlled Flight Into Terrain-

AN AFTI UPDATE

Since 1 January 1976, the Air Force has had 150 fighter/attack Class A mishaps classified as collision with the ground. They have resulted in 170 total fatalities and account for a combined cost of $1,087,079,164.* We have the technology to significantly mitigate this type of mishap!

* All figures are as of 31 August 1993.

PEGGY E. HODGE
Assistant Editor

■ Mishap files at the Air Force Safety Agency show us many mishaps occur where *good* pilots fly *good* aircraft into the ground. We have always had to live with this danger — it's part of being an aircrew member. Or is it?

The members of the Advanced Fighter Technology Integration

continued

Controlled Flight Into Terrain continued

(AFTI)/F-16 Joint Test Force at Edwards AFB, California, don't think so. They have been flight testing an automatic recovery system for the past 8 years — a system making most of these mishaps something we will not have to deal with in the future.

CFIT

Roughly one out of every four fighter/attack aircraft lost is due to controlled-flight-into-terrain (CFIT) mishaps where the aircraft inadvertently hits the ground. (See the chart below.) *

Since 1 January 1976, 18.4 percent of fighter/attack Class A mishaps resulted from collision with the ground.

	Mishaps	*CWG*	*Percent*
Fighter	658	112	17.0%
Attack	153	38	24.8%
Total	**811**	**150**	**18.4%**

Ground collision avoidance systems (GCAS) are being developed today to handle CFIT mishaps. Most of these mishaps result from the pilot losing track of where the ground is and where the aircraft is headed. Typical examples are the pilot who is distracted during low level flying and starts a shallow descent toward the ground, or the pilot who is well above the ground during air-to-air flying but is looking behind and doesn't realize the aircraft is in a steep dive.

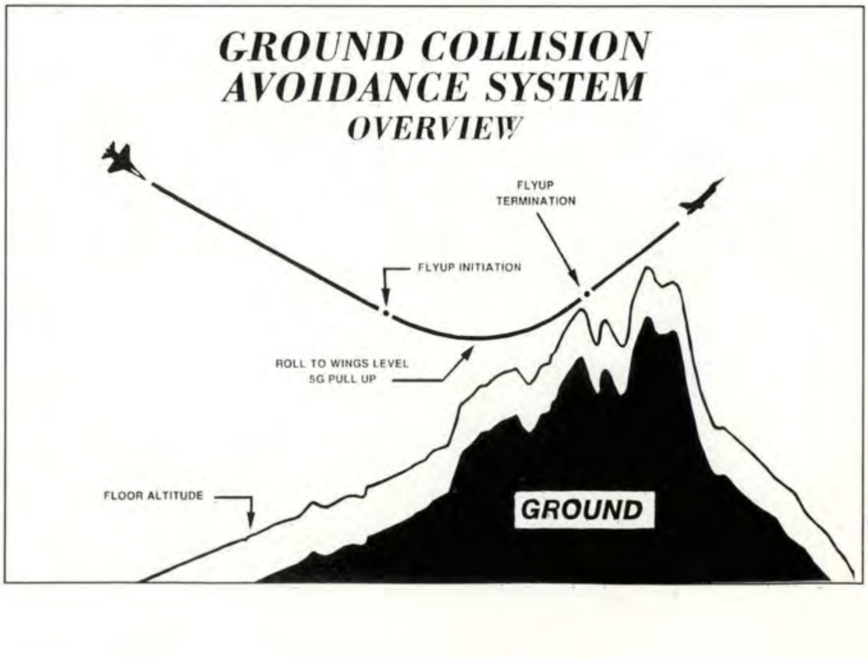
"The difference between the AFTI/F-16 GCAS and other ongoing efforts is we use an automatic recovery," said Mark A. Skoog, Chief Engineer on the AFTI/F-16 Program. "Other systems are designed to warn the pilot. We do that also, but, if the pilot does not react, our system will wait until the last possible moment and then take over and recover the aircraft."

In recent years, there has been much publicity on a new, although smaller, category of CFIT mishaps — those caused by G-induced loss of consciousness (GLOC). Because the AFTI/F-16 GCAS automatically recovers the aircraft, it can be used to prevent ground collision during GLOC.

Flying Safety first visited the AFTI people in 1987 when their GCAS could prevent 80 percent of CFIT

The difference between the AFTI/F-16 GCAS and other ongoing efforts is that it uses an automatic recovery. The system warns the pilot but if the pilot does not react, the system takes over and recovers the aircraft at the last possible moment.

The GCAS computer constantly calculates altitude needed to recover above the floor altitude. The system begins warning the pilot visually and aurally 5 seconds before taking control. If the pilot doesn't respond, the GCAS performs a flyup maneuver at the last second.



** For your information, the AFTI people at Edwards AFB, California, use the acronym CFIT for controlled flight into terrain. The Air Force statistics people at the Air Force Safety Agency use CWG for collision with the ground.*

mishaps. Today, with the use of a digital terrain data base, their automatic All-Terrain Ground Collision Avoidance System (ATGCAS) is the technology almost eliminating this deadly and costly mishap category. Here's how it works.

A Digital Terrain Data Base

In July 1985, when testing began, the AFTI people used the simple altitude sensing system available on most of our aircraft. This allowed flat terrain avoidance. Today, the system employs a digital terrain data base where all of the terrain and known obstructions, such as towers, is digitized and entered into computer memory on board the aircraft.

This system can almost eliminate CFIT mishaps. Flight testing of the current All-Terrain Ground Collision Avoidance System design began in September 1991 and is still ongoing. (See "AFTI/F-16 Update" on page 22 for the most current status of the AFTI program testing.)

The digital data base is a series of numbers corresponding to the terrain elevation at various points arranged in a grid pattern. This data is stored on a removable optical disk. The data base covers an area of approximately 40,000 square miles, but the optical disk is capable of storing an area 10 times this size.

The data base is scanned ahead of the aircraft similar to a terrain following radar. The scan region grows in length with increased speed, dive, and bank, while it expands laterally and shortens in length due to turn rate. (See figure 1.)

The three-dimensional model of the local terrain contained within the scan is then reduced and compressed to end with a simplified two-dimensional representation of the local terrain. Figure 2 shows the compression techniques used to increase computational efficiency.

The Autorecovery Maneuver

The pilot controls the autorecovery system operation by setting above ground level (AGL) altitude, or floor, which is the minimum for the planned flight.

During flight, the GCAS continuously compares the aircraft flightpath (altitude, airspeed, and attiti-

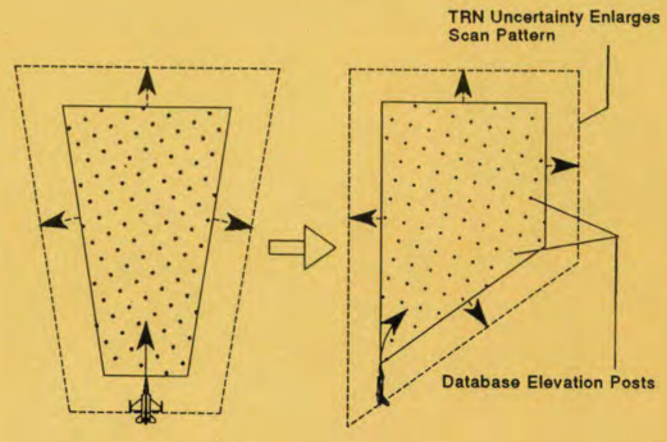


Figure 1 Terrain Scan

The data base is scanned ahead of the aircraft similar to a terrain following radar. The scan region grows in length with increased speed, dive, and bank, while it expands laterally and shortens in length due to turn rate.

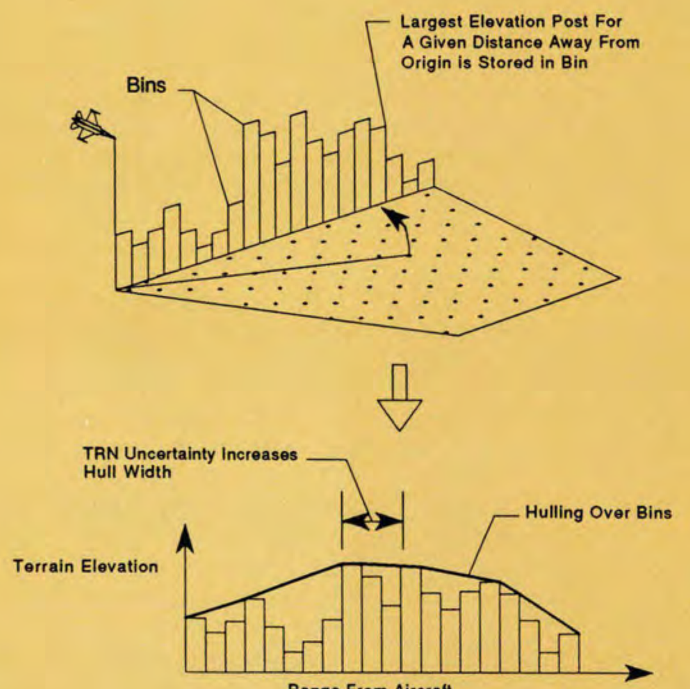


Figure 2 Binning and Hulling Process

Binning and hulling are methods used to simplify a complex, three-dimensional model of the local terrain contained within the scan region into a two-dimensional representation of the local terrain.

continued

AFTI/F-16 UPDATE

MARK A. SKOOG
AFTI/F-16 Joint Test Force Chief Engineer

■ Since last visited, the AFTI/F-16 project has achieved many goals and begun many new ones.

In January 1993, the project completed Close Air Support (CAS) Block II/III phase. This phase was the key driver for ground collision avoidance testing and single seat, low altitude night attack demonstrations.

The milestones achieved were:

■ All terrain GCAS recoveries down to 150 feet AGL.

■ Covert automated terrain following down to 200 feet AGL.

■ Demonstration of the first 4-G capable maneuvering TF system.

■ Demonstration of a fully automated terrain and threat avoidance system.

■ Demonstration of the improved data modem in a close air support environment.

■ Multiple night close air support demonstration flights down to 500 feet AGL.

Since January 1993, the AFTI team at Edwards AFB, California, has been deeply involved in analyzing and reporting on the results from their flight testing. Other involvements have included their use of the GCAS on AFTI to aid in a number of mishap investigations.

In the meantime, the AFTI Program Office at Wright Laboratories has been aggressively pursuing the transition of GCAS into the production F-16 fleet.

Current plans are to have a fieldable GCAS similar to the one demonstrated on AFTI/F-16 ready around 1997. AFTI will be involved in developing their system into a production configuration. A manual recovery system should be available sooner. ■

Controlled Flight Into Terrain continued

tude) to the set floor altitudes. According to Mr. Skoog, "The GCAS is always calculating how much altitude it would take to roll the aircraft wings level and pull 5 Gs to clear the near horizon. The pilot is given audio and visual warnings as the GCAS senses the aircraft running out of altitude. When the GCAS has just enough altitude to recover, it takes over."

The actual maneuver the aircraft performs is very simple. When the autorecovery is commanded, the aircraft rapidly rolls to wings level and pulls 5 Gs until the near horizon is cleared. The pilot is reminded to take over by the voice warning which announces "you've got it."

Ability to Override

One of the important parts of the AFTI/F-16 GCAS is *the pilot's ability to override the automatic controls.* The pilot is always capable of completely overriding the automatic controls and can temporarily disconnect the system with a paddle switch on the control stick. Switches are also available in the cockpit for the pilot to select a warning only (no automatic recovery) or completely turn off the system.

The ability of the pilot to override and turn off the system is considered important because the automatic recovery would not be wanted when the pilot is aware and can prevent flying into the terrain. The system may also be turned off to intentionally descend below the floor altitude. The pilot can easily override the automated recovery through the control stick. According to Mr. Skoog, "Our basic design philosophy is the pilot must have ultimate control of the aircraft. We're not trying to take the pilot's place. We're trying to help."

When the GCAS is in operation, it takes over only when it has *just enough* altitude to recover.

Audio and Visual Warnings

The AFTI/F-16 GCAS audio warnings are computer-generated voice commands similar to other GCAS systems. The pilot hears "pullup, pullup" prior to the recovery and "flyup, flyup" when the GCAS actually takes over.

The traditional GCAS visual display is a "break X" — where a flashing "X" appears in the headup display (HUD) to warn the pilot to recover. "The problem with this type of display is it appears suddenly and does not give any trend information," said Mr. Skoog. "A pilot is expected to rapidly understand the warning and maneuver correctly."

The AFTI/F-16 program elected,

instead, to split the "break X" into two chevrons appearing in the HUD at 5 seconds prior to flyup. They move smoothly together to form the "break X" at flyup. Members of the test force say this display has met with universal approval from pilots who have flown both displays.

GCAS Operation

The operation of GCAS begins prior to takeoff. All that is required is to turn on the system by selecting the automatic or manual recovery mode. If a floor altitude other than the default 400 feet is desired, a new one can be selected at this, or any other time, during the flight.

The system automatically goes into a standby mode while the aircraft is still on the ground. The system then automatically arms after takeoff and the aircraft has climbed above the floor altitude.

There are indicators inside the cockpit and in the headup display informing the pilot of the GCAS status. During flight, the system automatically goes into a standby mode while the gear are down, the refueling door is open, or if the radar altimeter or navigation systems fail to give accurate information.

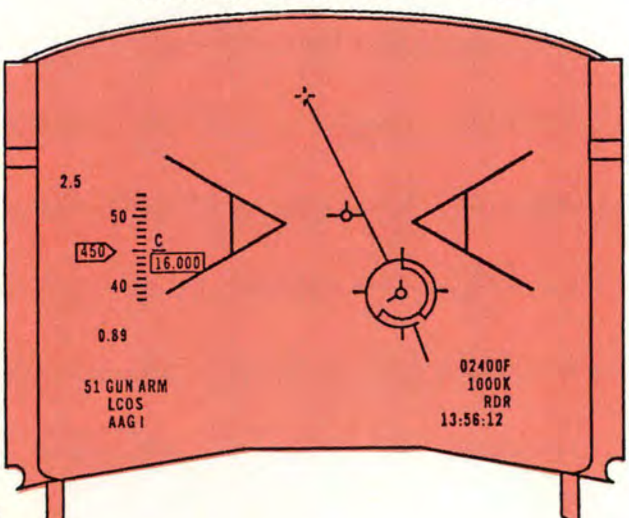
Mr. Skoog added, "Due to budgetary constraints, there are additional self-imposed limits. Currently, the system does not work at dive angles above 60 degrees, Mach numbers above 0.95, and airspeeds below 265 knots. We've shown in simulation the system will function beyond these limits. Our auto GCAS was designed with limited ability, purely for the support of testing other AFTI/F-16 systems. The auto GCAS should be expanded to full envelope when funding is available."

Is It Worth It?

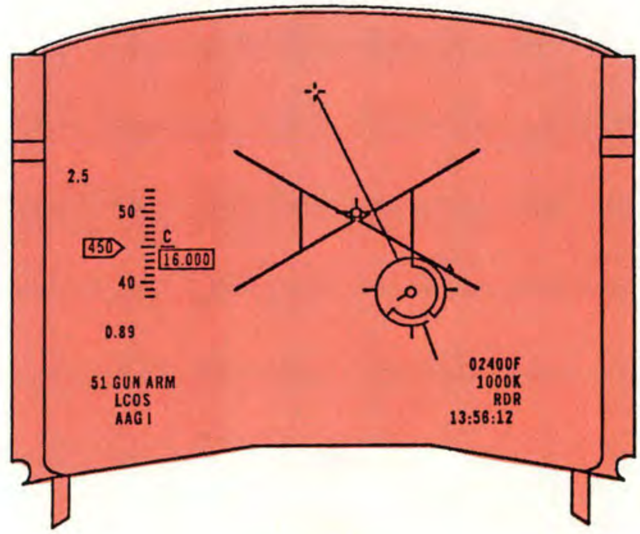
Since 1 January 1976, the Air Force has lost 128 pilots with 170 total fatalities due to fighter/attack CFIT mishaps! According to Mr. Skoog, "With the technology currently available on many aircraft, we could integrate this system effectively. With shrinking defense budgets, we can't afford to lose aircraft or pilots. With auto GCAS, we can save lives, project lower expected losses, and decrease total procurement dollars." ■

Rather than have a flashing "break x" suddenly appear in the headup display to direct a flyup, the AFTI/F-16 uses two chevrons. The chevrons appear 5 seconds prior to flyup and move together to form a "break x" at flyup.

A. Headup Display, 5 Seconds to Flyup



B. Headup Display at Flyup



Why can't we talk to each other?

Regardless of the level of sophistication the air traffic system achieves by the turn of the century, the effectiveness of our system will always come down to how successfully we communicate with each other.

Whether we are talking about the "good old days" of light guns or the futuristic world of data link, we always focus on the same thing — the system cannot work unless pilots and air traffic controllers communicate effectively.

Thomas Lintner and James Buckles
Journal of ATC, Jan-Mar 93

Failure to Communicate

■ When we examine today's incidents, we find a significant percentage results from poor communication. In 1990, there were 872 operational errors (defined as an event where minimum separation between aircraft is not maintained). Approximately 254 of these involved some type of communication deficiency.

Although exact information is not available to us, we could speculate a significant number of the 2,352 pilot deviations filed in 1990 may also have been the result of failures to communicate.

It is not the intent of this article to assess blame on either controllers or pilots, but to present some different thoughts behind the problem. Perhaps, by viewing the problem from "inside," the people most closely involved in the errors (both the pilots and controllers), we can see ways to help reduce these occurrences.

Hearback-Readback

A review of past communication errors indicates the most common contributing factor in an incident is a hearback-readback error. These errors occur when a controller issues an instruction to a pilot, the pilot misunderstands it and, as part of the confirmation process, reads back the WRONG instruction to the controller.

The controller, not expecting to hear a mistake, does not hear the error or correct it, thus "confirming" the incorrect instruction. This generally results in the crew of the aircraft not doing what the controller had instructed them (or at least *thought* he had instructed them) to do. Hearback-readback errors create confusion or, in extreme cases, operational errors and pilot deviations.

When we begin to look at the unique world of hearback-readback errors, we should note two important points. First is the belief no one sets out to make a mistake. When we get up in the morning, it is rare for any of us to say, "Let's see what I can do today to really screw up." Second, today, as in the past, the aviation industry contains some of the most professional and capable personnel in the world.

Whether operating from the cockpit or an air traffic control facility, we all try to do the best we can in the world's most complex ATC system. Why, then, do we allow something as "simple" as communications to result in 254 errors?

One facility in particular, Salt Lake City ATCT, has initiated efforts to

reduce communication errors. The facility conducted a review of hear-back-readback errors in conjunction with the University of Utah. Their report provided some interesting reading.

Findings revealed the number of communication errors, or "miscommunications," where a clarification is required or an instruction is questioned, increased along with traffic volume. The number of "miscommunications" per hour varied from 7 during light to moderate traffic to 12 during heavy traffic. However, the *range* of errors is even more telling. Based on raw data, the range went from a low of 3 miscommunications per hour in light traffic to a high of 30 per hour during heavy traffic.

For those of us who have been exposed to traffic volume as controllers, these numbers are not surprising. However, if we look into some of the idiosyncrasies behind how controllers learn and do their jobs, we may see, from the "inside," why it occurs.

Behind the Controller's Mic

Controllers are taught from the beginning one of the most important traits of the job is decisiveness. They must be in "total control" of the situation at all times. When the new developmental controller (specialist in training) first observes the "seasoned journeyman," they are no doubt impressed with the rapid, concise instructions which appear to be issued effortlessly. There are few pauses or hesitations, and clearances appear to be spoken automatically. Needless to say, this then becomes their goal.

Consider the many other tasks controllers must perform: landline coordination with other controllers and facilities, flight data posting, and review of other current or pending traffic. It appears expediency is an absolute necessity. However, this expediency can play a role in putting the controller in a position to experience a hearback-readback error.

As traffic builds, the controller begins to feel the need to "work faster" because there are more and more aircraft to handle. A thought develops which says, "If I talk faster, I'll have more time to do other things, and then I can work more aircraft." Unfortunately, this can set the stage for error.

When the controller begins speaking faster, the transmission may become clipped. Phraseology, the main communication tool of the controller, suddenly seems too long and cumbersome. Sometimes the controller begins to "shorten" the phraseology instructions to "speed up" transmissions. The phraseology which worked fine 10 minutes ago for five aircraft is suddenly too long when there are nine aircraft on the frequency.

Additionally, when we speak as fast as possible (remember there is a belief among controllers "the faster I talk the more aircraft I can work"), there is a tendency for a person's regional accent to become more of a factor in the transmissions. Just ask any pilots from the southern states if they *really* understand a busy controller from New York.

The end result is a transmission which might be so confusing the crew will ask the instruction be repeated. Generally, this is preceded by one pilot turning to the other and asking, "Do you have ANY idea what he said?"

As the situation develops, we begin to experience the classic catch-22 of pilot-controller communications. The controller receives the request to "say again," or, the even more obnoxious, "BLOCKED," and then re-

continued

Why can't we talk to each other?

peats the same clearance. Now, since this has cost additional time, and the controllers now feel as though they're falling behind, words are spoken even faster to try to make up the time.

The result is either a pilot who thinks he heard everything correctly and says "Roger" or "guesses" at what he thought the controller said. The controller, never realizing or accepting a role in the confusion, wonders how the pilot could misunderstand such simple instructions.

Although the preceding narrative seems to place all of the "blame" on the controller, this is far from the complete story. Let's take off the headset and slide into the left seat to try to see how the pilot might play a role in miscommunication.

Using the Pilot's Mic

One of the more interesting observations from the report out of Salt Lake City was the relationship of aircraft location to communications. The report indicated the further the aircraft were from the airport, the MORE miscommunications occurred between the controller and aircrew.

To many of us, this was surprising until we thought about how many times we have been at altitude, autopilot on, seat back, right foot on panel, and discussing "nonflying" issues. A transmission from ATC becomes an "interruption" and, perhaps, is not heard completely.

We put the coffee cup into the holder, reach for the mic, and sometimes, instead of asking for a clarification, read back a "guess" of what we thought we heard and hope the controller corrects it if it's wrong. This way, it doesn't appear we weren't paying attention. Now, if the controller misses the pilot's incorrect readback, whose responsibility should it be?

As we get closer to the airport, the controller and pilot cease their *individual* efforts and begin to work together to create a potential for miscommunication. The rapid, clipped voice of the controller leads us, as pilots, to feel the pressure of heavy, complex traffic. Not wanting to "take up valuable air time," we abbreviate our readback.

In many cases, incorrect call signs are used. Eastern 1402 calls themselves "1402," and Pan Am 17 asks if "... that was for 'The Clipper.'" The instruction for Eastern 1402 to "turn right heading zero four zero, descend and maintain four thousand" is read back as "right to forty, down to four, fourteen oh two."

The pilot, who long ago moved the seat forward for total concentration, unkeys the mic and thinks, "Boy, that will help the controller. I gave him a good short transmission and didn't clutter the frequency with useless junk." Meanwhile, somewhere in a dark radar room, there is a controller who is thinking, "Who the hell is fourteen oh what?"

Perhaps the next transmission Eastern might hear would be, "Eastern fourteen zero two, I say again, turn right heading zero four zero, descend and maintain four thousand." No doubt the crew looks at each other, says "Roger," and wonders how someone could misunderstand such a simple readback.

What We Have Here is ...

The end result is two people, the pilot and the controller, who are both striving to do the best, most professional job they can, hinder each other's performance. Two professionals, each with the best intentions, create communication errors for which they must both accept fault.

No doubt this is an oversimplification of a complex human factors issue and perhaps even overly critical of pilot and controller roles. It is certainly not intended to be critical of the people within the profession but perhaps just another example of how "no good deed goes unpunished." However, this article is intended to let both the controller and the pilot look at their role in communications in a slightly different way — from behind the other person's microphone.

If you have to take a deep breath after a transmission, maybe something is wrong.

Something We Can Do

Maybe the controller can slow down the speech rate of the transmission. Perhaps, instead of issuing a clearance, route, altitude, airspeed restriction, and a traffic advisory in one transmission, these instructions can be broken into separate messages. Aren't two short transmissions better than one long one which might have to be repeated twice?

Maybe pilots who are not sure what they heard can ask for a confirmation instead of acting on "I think he said to descend to four thousand." Perhaps the pilot can remember the *quality* of a readback is important to the controller's confirmation process. With call signs, there is a major difference between "Eastern 1402" and "1402," especially if the controller has a flight strip for a Cessna 11402.

Luckily, most of these miscommunications only result in frustration or embarrassment. We normally provide an effective system of checks and balances which preclude small mistakes from becoming larger ones. Unfortunately, this is not always the case, and significant incidents may continue to occur. We must be willing to accept some errors are caused solely by our inability to communicate and understand each other.

There is little doubt more work must be done before these problems can be solved. In the long term, human factors research, changes in phraseology, readback procedures, and radio-microphone limitations should all have additional study. In the short term, we will consider this article successful if it results in just one pilot or controller communicating and NOT having to say, "But I thought you said ..." ■

OPS TOPICS

Keep Trying ... Something's Got to Go Right

■ Did you ever have one of those days when nothing seemed to go right? It's one of those times when your whole day is about to be ruined unless you come up with something "creative." Hey! Don't give up yet! Something's got to go right!

An electric jet was practicing approaches at the aux field (Of course, it couldn't have been home station.), when the landing gear didn't all indicate down and locked.

This was a single-ship mission. (Naturally, where's a good wingman when you need him most?)

The local airfield people all belonged to another service. (It sure would have been nice to have an aircraft-qualified SOF to help with the checklist.)

Every normal and emergency checklist procedure was accomplished — some of them twice — without changing the status of the landing gear. (Of course, now's the time to discover an "unknown" malfunction.)

On a "conference" radio call, the manufacturer could only offer a word of caution about the impending system B hydraulic failure as a result of alternate landing gear extension used IAW checklists. (Oh, great, follow procedures and things keep getting worse.)

Faced with an emergency, gear-up landing, the BDU-33s are dropped over the range, but one hangs on. (Just what we needed, a little extra excitement.)

By now, the jet is back on final for home base with hook extended for an approach arrestment. The approach-end engagement is perfect. The BDU-33 breaks free and skips down the runway and comes to rest in the grass off the edge. (We knew if we just kept trying, something had to go right.)

It may not always seem obvious, but the proper procedures usually give the pilot and crew the best chance of success. ■

Shopping Cart

■ Did you ever get stuck on a commissary run and wind up with one of those shopping carts with defective wheels? You know. One of the wheels is so out of alignment it shakes the milk hard enough to churn butter — and no amount of weight or change in speed will help. You could be passing the canned beans at warp 7 and still be in heavy buffet.

Not too long ago, one of our electric jets encountered the shopping cart effect. Preflight was all normal. The last-chance troops gave a thumbs up. The formation mission went as briefed.

On the wing, the landing was smooth and normal until the nosewheel touched down. Then, it began to shimmy like the mother of all shopping carts. It got even worse as the speed slowed to taxi parameters. By the time the jet was brought to a stop, the nosewheel tire had shredded itself to tire heaven.

The first thing the pilot, the mechanics, and the safety officer discovered was the nosewheel steering scissor was not connected. The bottom link of the scissor was hanging down. Clearly the connecting pin wasn't connected.

However, the pin was inserted through the holes in the top link. Apparently, on Block 40 and later aircraft, the pin can be inserted, the lower link can be raised, and the upper link can be lowered to hold it in place. Obviously, this "assembly" can even work well enough for taxi and takeoff.

This incident also showed the link won't remain "connected" after the strut extends during the takeoff sequence. A closer look at the linkage and pins will replace the general condition/no leaks approach to preflight inspections.

Many crews and maintainers take the "general condition" approach to sections of aircraft preflight checklists. That is, check for the obvious leaks or disconnects and trust in quality maintenance and component durability.

There's nothing wrong with this as long as it's not your eyes which become conditioned.

Conditioned to looking for glaring problems, you might train yourself to miss the not-quite-right goof. Make sure you're seeing — not just looking. ■

FIRST LIEUTENANT

Christopher S. Babbidge

8th Flying Wing
Kunsan AB, Republic of Korea

■ First Lieutenant Christopher S. Babbidge experienced catastrophic engine failure while piloting his F-16C. Lt Babbidge was no. 2 of a four ship, air-to-air continuation training sortie. Approximately 45 minutes into the flight, while returning to his assigned cap at 9,600 feet, Lt Babbidge heard a loud bang. He immediately noticed a rapid decrease in engine RPM and an increase in fan turbine inlet temperature (FTIT).

He responded by snapping the throttle to idle, zoomed his aircraft to 16,000 feet, and turned toward Kunsan AB, 15 NM to the east. As the FTIT continued to rise about 900 degrees, Lt Babbidge shut the engine off and selected Jet Fuel Starter Start 2. Two unsuccessful attempts at emergency air starts were made. Having exhausted all other options, he now placed emphasis on a flameout approach.

Lt Babbidge successfully maneuvered his crippled aircraft to a low key position, extended his landing gear, and accomplished a flawless flameout landing. He successfully landed on speed, well within the first 1,000 feet of the runway.

Lt Babbidge's superior airmanship culminated in a picture-perfect landing. His skillful manipulation of his crippled F-16 led to the preservation of a valuable USAF combat resource.

WELL DONE! ■

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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.

CAPTAIN

Mark E. Kennedy

56th Flying Wing
MacDill AFB, Florida

■ Capt Mark Kennedy, an instructor pilot at MacDill AFB, was in the rear seat of an F-16D during an afterburner takeoff of a transition syllabus sortie. This was his student's third flight in the F-16. Making a right-hand turn out of the traffic pattern at 400 feet AGL and 300 knots, the student pilot deselected afterburner. A loud bang and a noticeable reduction in thrust soon followed. Capt Kennedy immediately took control of the aircraft and continued the turn toward a low key position for a possible flameout landing.

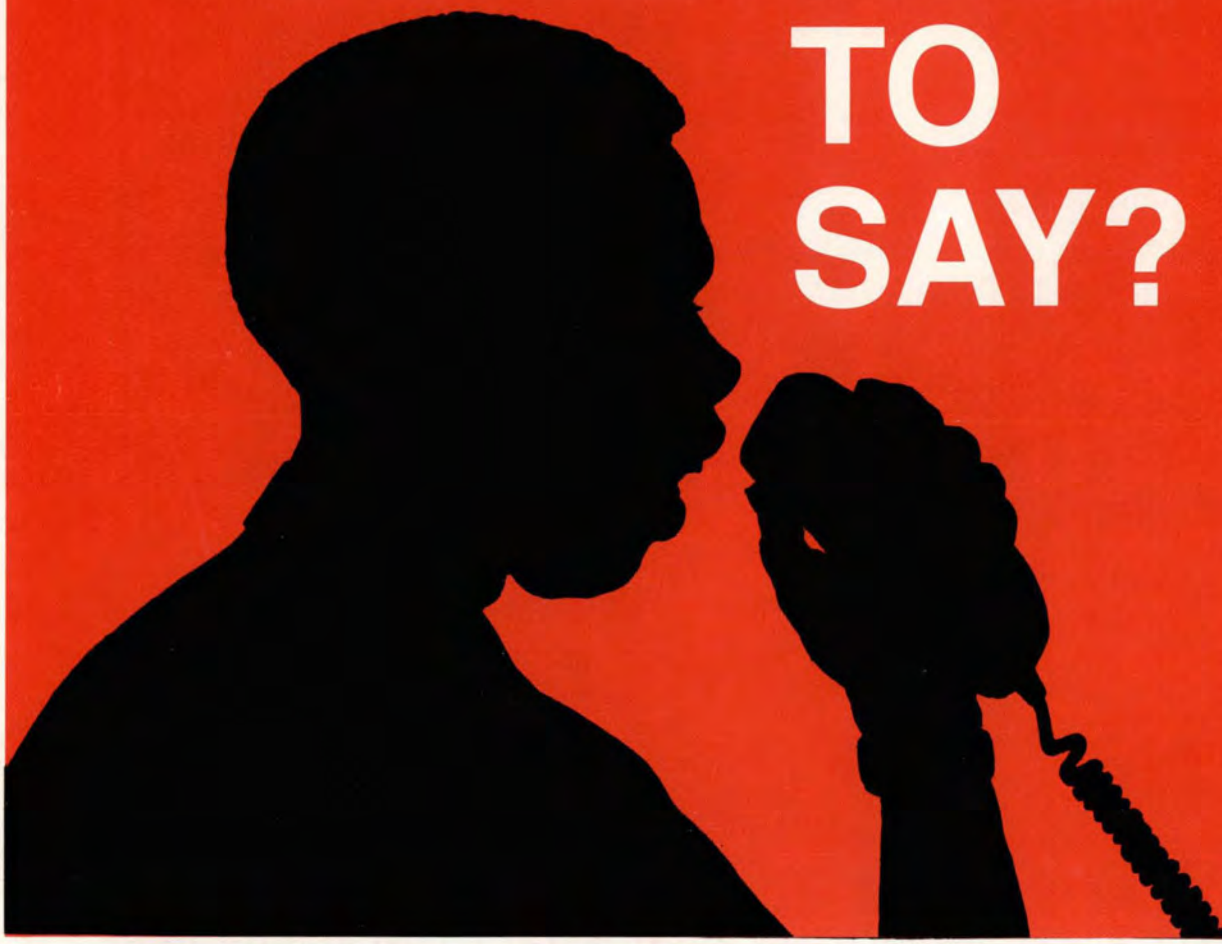
With both cockpits filled with smoke, engine warning lights illuminated, and decreasing RPM, Capt Kennedy quickly evaluated his seriously deteriorating situation. Cognizant of his position over the base, Capt Kennedy elected not to jettison his full external fuel tank. Converting what little excess airspeed he possessed into maneuvering altitude, he realized a flameout landing on the runway was impossible. However, a quick assessment of the airfield revealed an unoccupied taxiway as a possible landing surface.

Continuing his turn, Capt Kennedy radioed the tower with his situation and landing intentions. Despite smoke in the cockpit and visibility restrictions from the back seat, Capt Kennedy was able to maneuver his powerless jet to a rear-seat flameout landing on the taxiway. Using aerodynamic and wheel braking, Capt Kennedy stopped the aircraft and both pilots safely ground egressed. Total time from takeoff to touchdown was less than 1 minute.

Capt Kennedy's superb airmanship, prompt action, and coolness under pressure allowed him to recover a valuable Air Force resource.

WELL DONE! ■

GOT SOMETHING TO SAY?



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