flying

SAFETY

MAY 1981

Refueling Boom Damage Assessment Report

ON THE LINE

Sharing the Skies of Freedom

Cockpit Exercises

LIGHTNING AND AIRCRAFT

Loss Of Control
#1 OPERATOR KILLER

■ Last year, pilot-induced control loss was the number one USAF aircrew killer. On nineteen occasions, aircrews put their aircraft in situations where recovery was impossible, although they all tried. In all cases we lost the aircraft, and in most, the aircrew as well. Ten crewmembers bailed out in time to save their lives, but 25 didn't. In 1980 alone, pilot-induced control loss mishaps cost us 25 people and 19 airplanes. That equates to an entire tactical squadron. We cannot accept losses of that magnitude from mishaps which can be prevented.

Fighter/attack control losses were the biggest player, but we also experienced control losses within the trainer, bomber, and cargo communities. Here are some examples:

- An A-7D pilot on a Red Flag mission was rejoining on his element lead because of rapidly deteriorating weather on the low-level route. The element leader decided to abort the low-level and pulled up into the weather. The mishap pilot was uncertain of the element leader's position and of the terrain in the area. He aggressively maneuvered into an extreme nose-high attitude, failing to properly transition to instrument flight. Airspeed bled off rapidly, and the aircraft departed controlled flight. The pilot ejected safely.
- A National Guard EB-57 was performing a heavyweight, simulated single-engine approach immediately after takeoff. During the approach, the pilot allowed his airspeed to drop 20-25 knots below the single-engine minimum directional control speed. The pilot realized that he was too slow and applied power to go around. Because of the asymmetrical thrust, directional stability could not be maintained. The pilot initiated a dual-sequenced ejection. He was killed; the EWO survived.
- On two occasions, T-38s stalled out in the base turn. Futile recovery attempts ate up precious time and altitude. A solo student rode the airplane in, and a dual crew ejected out of the envelope. No one made it.
- An F-4 was leading a flight of two on an ACT mission. During a simulated gun attack by the wingman, the mishap pilot maneuvered into an extreme nose-low attitude. The IP in the attacking aircraft noted the leader's attitude and terminated the engagement by calling "knock it off." During the dive recovery, the mishap aircraft entered an undercast, and the pilot stalled the aircraft. Ejection was attempted just prior to impact, but was unsuccessful.

There were 14 more, and in too many cases pilots who were considered to be highly qualified and respected flew their aircraft beyond controllable limits, often losing their lives. The causes consistently include disorientation, inattention, loss of situational awareness, over-aggressiveness—all factors which, in essence, mean losing trac[k] of primary "stick and rudder" duties.

The best way to prevent those losses is to throughly know and appreciate the performance capabilities and limitations of yourself and your aircraft. There is no such thing as a pilot who knows too much about his aircraft. Know your capabilities, the limitations of your airplane, and fly within both. Our experience so far this year indicates that we will lose another squadron of people and airplanes in 1981 for the same reasons unless we do something to counter. The people in the cockpit are our first line of defense against this insidious killer. No matter what your mission is or what you are doing at the moment, the first rule of the air is to maintain aircraft control. As simple as that is, too many pilots forgot to do it last year. Throw a nickel on the grass. Thanks. ■

Leland K. Lukens

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Director of Aerospace Safety

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SPECIAL FEATURES

REGULAR FEATURES

DEPARTMENT OF THE AIR FORCE • THE INSPECTOR GENERAL, USAF

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Refueling BDA* Report

■ This article will provide a "how goes it" report for receiver pilots and tanker crews. We will look at how the Air Force has fared over the last few years, discuss 1980 trends, and show when you will be most likely to be involved in an air refueling mishap. We evaluated the 1980 refueling mishaps by calendar month, type receiver pilot/boom operator qualifications, brute force disconnects, breakaways, nozzle binding, and signal coil failure. In some cases, combinations of these factors were considered. Opinions were expressed and evaluations were made by safety officers and the author.

*For the purpose of this report, BDA stands for boom damage assessment.

First of all, over the last three years the number of reported air refueling mishaps has dropped significantly. Decreases of 20 percent in each of the last two years is a record that is going to be difficult to match in 1981. The numbers are:

	1978	1979	1980
Total	50	40	32
Mishaps/Mo	4.2	3.3	2.7

Additionally, there were no Class A or B mishaps in 1980 (1974 was the last previous year in which there were no A or B mishaps). Class A mishaps occurred in 1976 and 1979. There were three fatalities in the 1979 mishap between an HH-53C and HC-130 tanker.

A look at the last three years' mishaps by calendar month is shown here:

	J	F	M	A	M	J	J	A	S	O	N	D
1978	4	5	7	4	3	3	4	3	3	8	1	5
1979	2	3	7	0	3	4	5	2	1	7	1	5
1980	6	4	1	3	1	1	1	3	3	2	2	5
TOTAL	12	12	15	7	7	8	10	8	7	17	4	15

A look at the mishaps shows that October has been the worst month for boom mishaps. Also, months from December through March have all been worse than the average month during the three year time frame, The summer of 1980 was the best sustained period for mishap reduction while the greatest single month reductions were in March and October of 1980. The reasons for these reductions are unknown. If you have the answer, let us know what it is.

Here is another way to look at the 1980 data by month.

MAJOR ARTHUR P. MEIKEL
Directorate of Aerospace Safety

1980	J	F	M	A	M	J	J	A	S	O	N	D
	F4E **F4E** **F4G** **RF4C** **RF4C** AC130	**F4D** **F4C** EC135 F111D	**F4G**	**F4D** KC135A A7	**B52D**	C5A	F105	**B52H** C141B **F4D**	**F4D** F111 A7D	**B52** **B52D**	**B52D** **F4**	**B52** **B52** F15 F105 F106

Figure 1

Looking at refueling mishaps by month and aircraft type, we find that the F-4 and B-52 are the major offenders with 12 and 7 mishaps respectively. These receivers, understandably, account for a major portion of our refuelings. The A-7, C-135, F-111, and F-105 had two each. Looking for trends, we see that F-4 refueling mishap numbers improved greatly in late 1980 while the B-52 numbers show an increasing trend. One trend which does not show here is the C-141B. In January 1981, C-141s have had two boom ice shield mishaps. The reports are not complete, but there is a good chance that inexperience contributed to those mishaps. The F-4 also experienced two refueling mishaps in January, which, along with one F-15 mishap, accounts for the January 1981 total.

A closer look at the seven B-52 mishaps shows that six occurred at night. Clouds, marginal visibility, and refueling currency played a part in the seventh mishap. Four of these mishaps could be attributed to lack of proficiency. Two involved student receiver pilots and two involved pilots who had long periods since their last night AR. Of the seven mishaps, a breakaway was called late in four instances and not called at all in two cases. In all seven mishaps, the boom ice shield was damaged.

Some trends can be found by looking at 1980 from a day/night point of view. We find night mishaps rising slightly and day mishaps on the decline. As we have seen, the B-52 has influenced these figures. The F-4 is almost even in this area with seven day mishaps and five night mishaps. Overall, slightly more refueling mishaps occurred during day operations.

A check of SAC's data on air refueling contacts showed these facts.

- Night contacts accounted for 28% of all contacts.
- Fighter contacts accounted for 43% of all contacts.
- Night contacts were up 38% in the fourth quarter of 1980 over the first three quarters' average.
- Fighter contacts were up only 8% in the same time frame.

This would help explain the increase in B-52 night mishaps as well as the increasing trend in night mishaps. Using the same numbers we can make some predictions of risk. Refueling at night is more hazardous since 41% of our mishaps occurred at night and only 28% of contacts were made at night. Fighters were involved in more than their share of mishaps: 62 percent of 1980 mishaps while accounting for only 43 percent of 1980 air refueling contacts. More interesting is the fact that, other than the B-52, which had 86% of its refueling mishaps at night, no other large aircraft had a night AR mishap. In all, 50% of large aircraft mishaps occurred at night while only 40% of fighter mishaps occurred at night. Disregarding several fallacies, the idea that fighter refuelings at night contain the most risk may not be

1980	J	F	M	A	M	J	J	A	S	O	N	D
	D D D N D D	D D N N	N	D D D	N	D	D	D N N	D D D	D N	N D	N N N N D

Figure 2

continued

Refueling BDA* Report continued

completely true. Perhaps the ideas of (1) watch B-52s at night and (2) watch fighters all the time would be more appropriate.

In 15 of the 32 mishaps in 1980, three were related to noncurrency of pilots, four to the inexperience of boom operators, and the other nine to student pilots. (The numbers don't add up because in one case an inexperienced BO met a rusty receiver pilot.) Of course, for student pilot we might say IP error. (The numbers don't show the many instances where the IP did a super job.) Anticipating a student's actions during air refueling has to be one of the toughest jobs the IP has to perform. The students, in most instances, were erratic, and nozzle binding occurred before the boom operator affected a disconnect. Boom operator error? The simple fact is that student pilots on the boom make it tough for everyone. Students get demonstrations, but are IPs requiring the student to be stable in the contact position before being allowed on the boom? Do many receivers expect to feel a contact as they coast through the contact position?

A breakaway was not called in at least four required cases, was called after damage was incurred in four other cases, and called by IBOs twice. In no mishap did a receiver pilot or instructor pilot call a breakaway. Even though the receiver pilots may have their hands full, calling a breakaway will cause both the tanker and receiver to disengage their toggles and perhaps affect a disconnect prior to nozzle binding.

It is difficult to quantify the affect that human factors have on air refueling. The average pilot's ego tends to create a false image of hinself, which is superior to his own capabilities. In the case of a receiver pilot, false pride may cause a reluctance to call a breakaway which would tend to destroy an inflated self-image (and also lead to loss of status among peers). Egos can spur us to high achievements but receiver pilots should be aware that egos can also cause problems, i.e., nozzle binding. Nozzle binding, out of the refueling envelope, was a prevalent problem in 1980 mishaps.

Signal coil problems were a factor in 12 of the refueling mishaps. Results of no contact situations ranged from nozzle binding while in tanker manual operations, closure while too many people were checking their switches and circuit breakers, and receivers departing the envelope without "pickling" themselves off the boom.

There were 12 brute force disconnects resulting in mishaps during 1980. No correlation could be made between brute force disconnects and student pilots, type receiver, signal coils or breakaways. A familiar phrase cropping up in safety reports is, "nozzle binding" as a result of "refueling" out of the envelope. The quality control for each type of receiver "envelope" rests with the boom operator. Pressures of mission accomplishment, real envelope vs published envelope discrepancies, coil problems, and the requirement for a "calibrated" eyeball all make the boom operators' job difficult and contribute to nozzle binding.

In 1980, all air refueling mishaps were in the Class C category. Once again, the numbers have improved during the last two years. Keep up the good work in 1981.

This article contains numerous facts, figures, and opinions. In summary, here are some of the points relevant to 1980 refueling mishaps.

1. In 1980, six out of seven B-52 refueling mishaps happened at night.
2. Receiver pilots seldom call breakaways.
3. If the boom operator calls "no contact," the receiver pilot should continue to fly his aircraft in the refueling envelope.
4. If the boom operator calls "no contact," he may not have a disconnect capability.
5. In 1980, more refueling mishaps occurred during day refueling than at night.
6. During the last two years, the number of refueling mishaps are down significantly.
7. C-141B refueling mishaps show an upward trend.
8. The boom operator does not have a good disconnect ability in the full range of the receiver envelope.
9. A breakaway during actual refueling provides as much training as one called at the end of AR.
10. If you haven't refueled for 40 days; the tanker reports his autopilot is acting up as you arrive near the precontact position; and your hands don't seem to be working during a turbulent, night refueling, you should consider calling it a day. ■

FOUL PITCH

LT COL EDMOND N. DUROCHER · Directorate of Aerospace Safety

■ The disappointment one might derive from pulling back on the pole and having nothing happen is probably like having the steering wheel come off in your hands on the freeway. It's gotta be the pits.

Our F-15 has a flight control system that flies better on its hydromechanical system (CAS-OFF) than an F-4 Phantom with stab-augs engaged. With electronic augmentation (CAS-ON), the Eagle is an absolutely superb machine that delivers superior performance with minimum tasking to the pilot. We don't achieve all that fine control without entering the world of advanced, complex technology. From day one, Eagle drivers learn there's a lot of FM (fancy magic) in their machines. Acronyms like PRCA (pitch and roll control assembly), CSBPC (control stick boost and pitch compensator), and PTC (pitch trim compensator) become part of the Eagle pilot "lingo."

Despite the shroud of complexity, the procedures required to handle flight control anomalies are fairly simple. With a highly reliable fly-by-wire (CAS) system overlaid on a hydromechanical system, USAF adopted the approach that if the CAS is on, leave it on. This logic has generally proven sound as we have had occasions when the hydromechanical system was disabled, and the fly-by-wire saved the aircraft. While this philosophy is still valid, we have found a need to modify that approach in a special case where the aircraft has a lack of pitch response. This lack of pitch can best be explained by an apparent failure in the stick force sensor, or a failure which acts like a stick force sensor failure.

The Control Stick

When an Eagle driver pulls on the pole, he does more than move a control stick. He also moves the stick grip which, unlike most aircraft, is mounted in a pivotal fashion so that it can move independently of the control stick. It is rather like having two control sticks, one mounted on top of the other. The upper portion (the stick grip) could be viewed as the fly-by-wire (CAS) control stick while the lower portion is the hydromechanical control stick. Normally, these two work together with the CAS comparing, measuring, shaping and smoothing out pilot stick inputs to achieve precise aircraft control. However, they can also work against one another. For example, torquing the stick grip forward (tells CAS nose down) while pulling aft on the control stick will certainly put the CAS system in opposition to the hydromechanical system.

Stick Force Sensor

The stick grip communicates the pilot request through the stick force sensor. As part of the CAS system it senses forces applied to the stick grip and generates electrical pitch and roll signals proportional to the applied force. The sensor is mounted between the pilot's stick grip and the control stick column and is dual redundant like the rest of the CAS system. Although total pitch CAS

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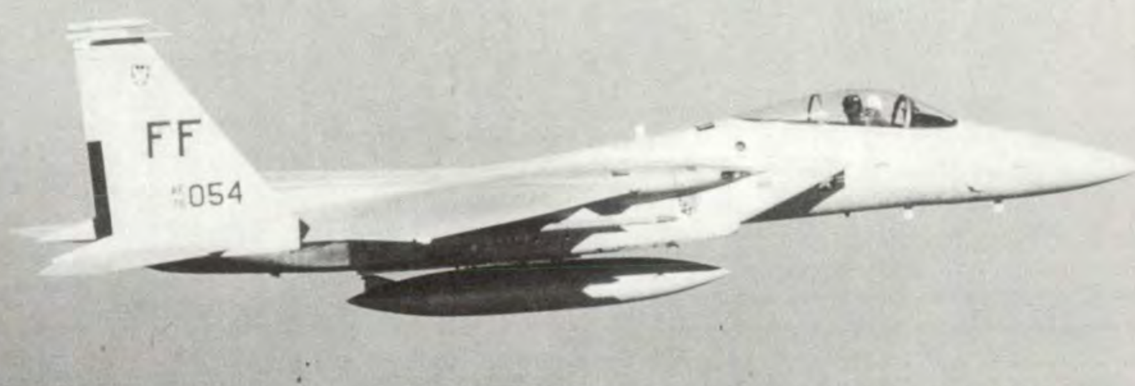


FOUL PITCH continued

authority is 10 degrees of stabilator travel, the stick force sensor can only add or subtract 2.5 degrees within that 10-degree band. In other words, the stick force sensor is a sub-unit within the CAS and does not command the total authority of the pitch CAS system. Therefore, a "sensor failure" cannot totally overpower the hydromechanical system.

The Failure Modes

There are possible failure modes in the flight control system where the CAS fights the hydromechanical system and the pilot senses a lack of pitch response. The first failure can occur if there is a dual failure in the stick force sensor. The second failure can occur in the hydromechanical system, specifically contamination in the pitch boost actuator within the PRCA.

The failures are similar in that the stick force sensor is not detecting any applied force, and it uses its authority (up to 2.5 degrees) to counter the hydromechanical input. The failures are different concerning the forces applied to the stick grip. In the sensor failure scenario, there *is* force applied while in the contaminant scenario there *is not* (until the stick hits the aft stop).

A contaminant in the pitch boost actuator could hold the shuttle valve open. In this case, the control stick would be driven aft, and the controls would probably feel spongy to the pilot. Because the stick is being driven aft, the pilot is not applying the stick grip force normally associated with a given stick position. Hence, the CAS can sense a zero pitch rate request from the pilot, and the stick force sensor will attempt to hold a zero pitch rate. Once the stick hits the aft stop, the pilot does apply stick grip force, and the stick force sensor works with the hydromechanical system to attain the desired aircraft response. In fact, the G onset rate will be smooth and increase rapidly so that the pilot will have to move the stick forward as the desired G is attained. When the shuttle valve closes, the contaminant will be washed clear, and the airplane will feel perfectly normal thereafter. If that smells of a CND, you're right.

With a stick force sensor failure, hitting the aft stick stop will not have this affect. Therefore, the stick force sensor will continue to apply its authority against the hydromechanical system. The affect will be greatest in the flight regime where the hydromechanical system has the least stabilator authority. This happens when the pitch ratio is a minimum. The pitch ratio is the device which adjusts the amount of collective stabilator deflection for a given amount of longitudinal stick motion. The ratio is scheduled by Mach number and altitude to produce essentially the same stick travel per G throughout the flight envelope. We selected parameters where the pitch ratio is extremely low (PR = .06) to graphically portray the affect of a sensor failure. See Figure 1.

Although the graph represents a specific model, other configurations will not cause the curve to change appreciably. The upper curve on the graph represents a normal system when the CAS and hydromechanical system are working together to produce the desired aircraft response. The lower curve shows the affect of the stick force sensor working against the hydromechanical system.

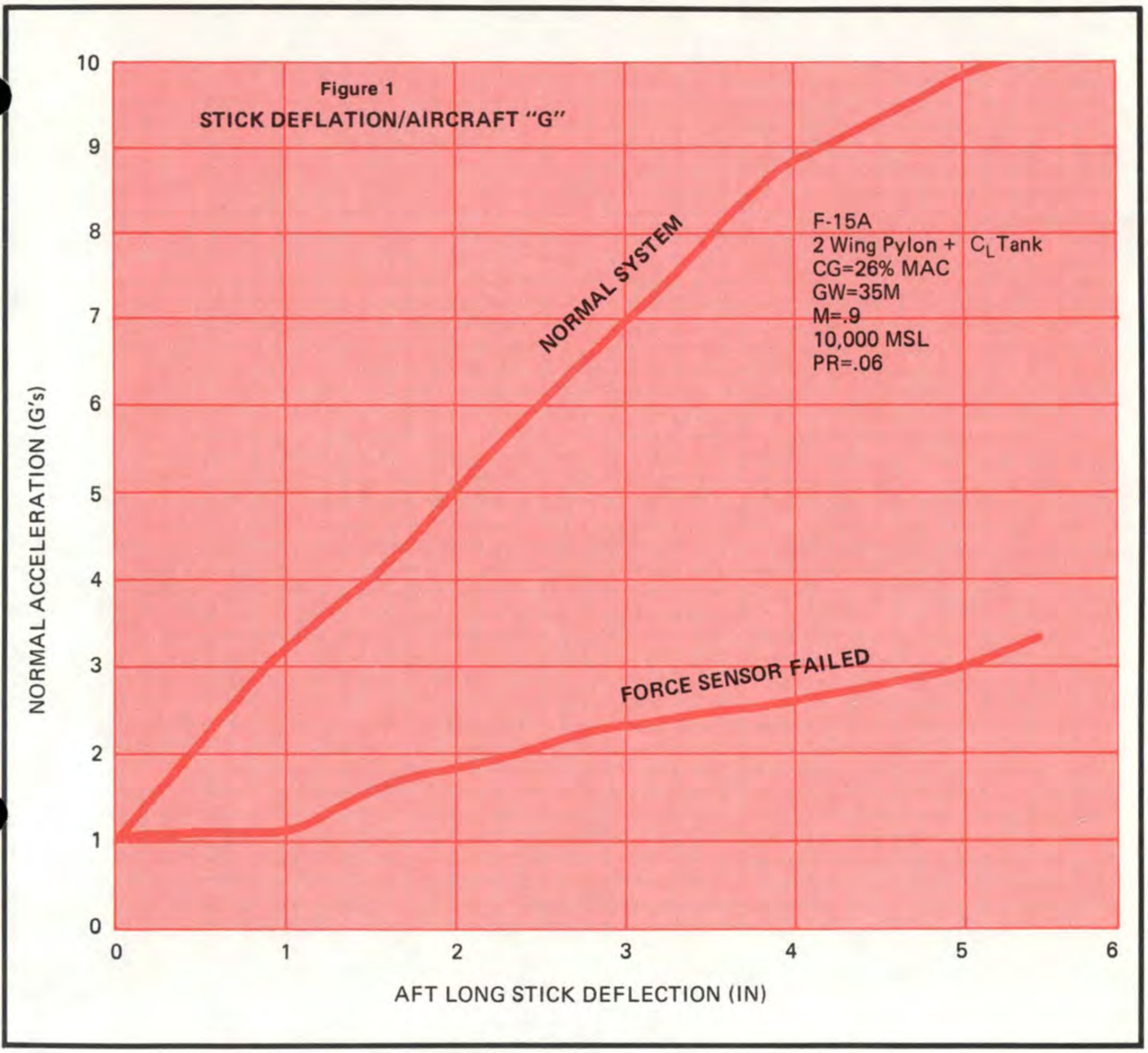
How It Feels

Although the graph is quite explicit with the information presented, there is another way to view the situation which might be helpful. The aircraft is programmed to respond with a specific stick force per longitudinal stick deflection; and, there is a specific relationship between stick deflection and G. Therefore, we have an indirect relationship between stick force and G. With the CAS-On, the relationship is 3.75 lbs per G to 3.3 G's, then 2.0 lbs per G thereafter. With a sensor failure, the stick force per G is changed drastically.

A chart at Figure 2 shows the change. It should strike you that a pilot who pulls to a normal 3 G turn and gets 1.1 G is going to feel like the system has failed completely. If he continues, and snatches to a normal 8 G position, he may or may not realize the small increase to 2.5 G's depending on his pucker factor.

Figure 2

Pounds of Pull	Acft "G" Normal System	Acft "G" Sensor Failed
0	1.0	1.0
3.75	2.0	1.1
7.5	3.0	1.1
9.5	4.0	1.6
11.5	5.0	1.8
13.6	6.0	2.1
15.6	7.0	2.3
17.6	8.0	2.5
19.6	9.0	2.7
21.6+	10.0	3.4



What To Do

All users have received a safety supplement with the proper procedures for handling lack of pitch response. Some discussion might serve to reinforce the validity of the approved solution of centering the stick, turning pitch CAS-OFF, and reapplying aft stick.

First of all, you would do well to remember that this occurrence is rare. While that speaks highly for the flight control system, it also sets the scene for the old complacency trap. Hopefully, it will be a long time before anybody has to resort to this procedure, but when you need it, you'll want to do it right. Having to neutralize the longitudinal stick might seem a bit unnatural, but it is the quickest way to regain the most pitch control. You could hold the stick in your lap and run the trim button but that will only gain a G and a half in a second and a half. Too little and too long.

You could hold the stick in your lap and turn the pitch CAS off. The penalty here is a 10 to 30 second delay for the CAS to remove the 2.5 degree authority against the hydromechanical system. Too long.

All things considered, the best procedure is to center the stick first. That eliminates any TAS delay and also covers the pitch boost shuttle valve contaminant scenario. Turning the pitch CAS to OFF takes the stick force sensor out of the loop. Leaving the pitch ratio in normal (assuming it's functioning normally) should protect against G overshoots and/or PIO's as you smoothly apply back stick to achieve the desired flight path.

Remember that such a simple action as torquing the stick grip can produce unusual responses with a perfectly normal system. If you've altered your sitting position, are flying left handed, or have made some other change in the cockpit, be sure to eliminate torquing as the possible culprit. ■

SHARING THE SKIES OF...

MAJOR CHARLES F. BUKOSKI, USAF (Ret)

■ "Look at that! Did you see that Cessna right in front of us? What's the matter with those guys? Don't they know this is a military low level training route? We're going to have a midair collision one of these days because of them!"

Have you been there? How about this one: "WOW!, look at that jet fighter! He must be going supersonic! I'll bet he didn't even see us. Those guys think they own the sky. They can fly anywhere they please and there isn't a thing we can do about it. We're gonna have a midair collision one of these days because of them."

Well, what do you think? Sounds like a lack of communication, doesn't it? On whose part? Who owns the airspace, anyway?

The Big Picture

Let's take a look at the whole picture and see. In 1956 there was a terrible midair collision over the Grand Canyon which caused the public and therefore Congress to become alarmed over the lack of safety in the airlines. The outcome was the Federal Aviation Act of 1958. It changed a lot of things in the world of aviation, but mainly it created the Federal Aviation Agency (the Federal Aviation Administration came in 1966 with the advent of Department of Transportation) and made it responsible for all of the airspace in the United States (out to three miles offshore).

The FAA is divided into regions which are the administrative equivalent of our major commands and likewise fairly autonomous. They, in turn, are divided into Air Route Traffic Control Centers (ARTCC). It is the Center that, for all intents and purposes, owns the airspace. From there, all approach controls, towers, the military, and anyone else that needs to have airspace must negotiate with the Center to work up Letters of Agreement (LOA). For us in the

Midair collision prevention is one of our most important concerns. The author tells us of some of the actions they have taken at his base, where cooperation between many airspace users is the basis for midair collision prevention. Maybe others can get some ideas for their own application.

Miami area, the Miami Approach, has a LOA with the Miami Center describing the airspace for which they are responsible and the procedures for handoffs, etc. For us at Homestead, we have LOAs for our low levels (Military Training Routes—IR and VR), profiles to and from the range and for Air Traffic Control Assigned Airspace (ATCAA).

I'll get into more detail about this in a moment, but first let me explain the principles of handing out airspace.

If you are also a civilian pilot and are familiar with all the different types of controlled airspace such as Control Zones, Air Traffic Areas, Terminal Control Areas, Continental Control Area, Positive Control Areas, ad infinitum, you'd think it was pretty complicated (obviously the work of a committee). Well, it may seem that way, but the underlying principle is that everybody gets a fair piece of the sky. Simple as that.

Since there are three segments of aviation—Military, Air Carriers and General Aviation—it seems that no matter which one you're a part of, the other two take more than their share. I participate in all three. I fly the Phantom, I own my own twin engine Cessna which I use for pleasure and Air Force business, and I ride the airlines.

When I am jetting along in Big Ugly, I feel I should get a great deal of cooperation from everyone, because I am an integral part of our nation's defense, and people should be proud to contribute in whatever way they can. People should understand how important these training missions are. Everyone knows the military is hard pressed for flying time and, therefore, should know the quality of training we need. Give us a break!

However, what about me and my Cessna? At 25 gallons per hour and at $1.80 per gal ($45 an hour), I don't appreciate taking the scenic route because half of the airspace is reserved for someone else, especially when it's reserved and nobody is in it! That one really gets my gall. ("Center, is R2901 in use?" "No." "May I fly through it? It would save me 50 miles." "No, it's reserved." "When are the planes due?" "This afternoon, sorry.") Isn't that dumb? More about that later. Well, at any rate, how about when I'm riding Biggie Airlines which is probably an hour behind and now we have to go around or hold for a lost general aviation pilot or a diverted F-4? Yep! I'm upset.

A senior airline captain feels he has earned the right to preferential treatment, and when flying from Houston to Miami thinks he should turn only twice. Once out of traffic towards Miami and once to line up with 9 Right at Miami. As a matter of fact, I get to listen to a few tapes at Center as part of my job and I heard a certain L-1011 captain give Center a big harangue about how much it costs to take the eight mile deviation Center just gave him.

I Have My Rights

What is the point of all this? Easy to answer for any freedom loving American. Rights. Every American has a right to the Nation's assets. General aviation pilots have a right to the airspace whether it is to fly their Lear to conduct business or fly loop-de-loops in their homebuilt. And Biggie Airlines has the right to earn a profit, all while the military is obliged to maintain a high state of readiness.

What's the solution to all this? Sharing. And with generous amounts of FACE-TO-FACE public information. Years ago, air traffic was such that any aviator could pretty much fly wherever he felt. Now, however, even airspace has become a scarce resource. Since airspace is finite it effectively shrinks as competition for its use increases.

Resource Management

Let's take a look at some of the ways we at Homestead AFB share airspace with our brother and sister aviators.

The easy way to keep airplanes from running into one another is to mark off blocks for special use. We do this in the form of restricted areas, MTRs, etc. This is called separating airspace from airspace. This is a very safe way to fly, but

Sharing The Skies of Freedom

continued

also very wasteful. For example, we do a lot of air-to-air training over the Florida Straits. We used to schedule the area from 0800-0900 just to be sure or to accommodate fall out, slips and whatnot. What this did was close the area to any other user anytime between 0700 and 1900 even though we only had planes in it for maybe a total of two hours. Now the area is designated a warning area (it's on the charts for all to see) and we schedule on a real time basis, which does not tie it up all day for a few flights.

Why do we do this? Well, it's easy. It doesn't take much effort on anyone's part. You can see that if this is repeated all around the country, all three segments would be spending a large amount of their time flying around the other two's reserved airspace. Besides, what are we doing with all the exotic radar systems we have? Wasting that resource as well, I suppose.

Here's what we do at HST. Unfortunately, Homestead doesn't own any airspace of its own so we have to share some 6,000 square miles of Navy Key West's airspace with them. Even though that is an awful lot of area, careless management of it can cause lost sorties. This invariably results from reserving airspace "just in case."

We used to schedule a certain area for possible backup and hardly ever used it. Sounds like the clever thing to do, but (and that's a big but!) that prevents anyone else from using it, like the Navy who might need it for the same reasons. So there we have a large chunk of airspace that is essentially off limits to everyone, yet no one is using it.

When the Navy started increasing their operations at Key West, we started to run out of airspace. What we do now is schedule what we need in the areas where blank spots are available on a first-come, first-served basis. That is, there could be an Air Force flight in the middle of a Navy period with Navy controllers and vice versa. "Real time scheduling," we call it. In fact, if you don't show up within 30 minutes of your scheduled time, you've lost your area. Normally, in the RTU business, slipping can't be accommodated anyway due to simulator and academic schedules.

There Are Paybacks

Now I realize this concept is not exactly original and it does require cooperation and positive attitudes, but the important point here is that sharing can and should be applied to all areas of flying operations. For example, when no one is on the bombing range, let a civilian fly through it (this takes a thorough understanding between ATC and the range owner). When there is little or no traffic at home, let a civilian fly over the base if it is a shortcut for him. The real benefit of the latter is that if an Air Taxi discovers he can cross a base, say half the time, it will cause him to call GCA or tower every time he flies, thus giving us a chance to at least be aware of the presence. Word of our helpfulness and cooperation has gotten around the general aviation community in the Miami area and, in turn, has paid off in big dividends by having most nearby traffic checking in with us while reaping public good will.

Homestead's Midair Collision Avoidance Program (MACA)

Let's get down to the basics of Homestead's MACA program. It consists of three major parts: airport visitation, speaking, and articles in local papers.

We got together with our counterparts at MacDill and Patrick AFBs and drew some territorial lines for airport visits giving us a little over 50 airports in our area. We try to get to each one every six months. While visiting the FBOs (Fixed Base Operations – aircraft sales and service) on the field we gather up the chief flight instructor and all the students we can and lay on a very informal briefing on our flying activities. Our briefing emphasizes three areas: Low level routes, the bombing range and local traffic around the base.

Now how do you get there? Of course, you could use some mundane, unimaginative method of transportation such as a staff car, but why not add credibility and empathy to your cause and go by Cessna? Cost too much, you say? Actually not. We were quite fortunate in the past since both officers in the Airspace Management Office owned airplanes, and the USAF (the DO actually) paid for the gas. We do not have that luxury any longer, however, and have just looked into renting a plane. Without going into the computations, suffice it to say that the GMV at 21¢ per mile and per diem for two days would cost

$173 for one of our circuits while a rented Cessna 152 at $26/hr would cost only $120 for the day. No per diem is needed.

Speaking to large groups is another way to educate the general aviation pilot. I spoke to over 2,000 pilots last year, and the feedback was very satisfying. To whom do I speak? To any group we can find.

One great opportunity is to team up with the GADO (General Aviation District Office). The Accident Prevention Specialist has a program that requires him to go around and do similar things. I've found that offering him a one hour block takes a load off of him. Other sources for speaking opportunities come from the Flight Service Station, area flying clubs and, of course, from the flight schools.

Writing articles for local newspapers is another great way to get to the local people. This would be especially effective for bases out West where airplanes tend to become more of a necessity than a hobby as here in the East. We haven't exploited this segment of our program as much as we should, but we're going to. Innovative approaches to this are many. For example, the fliers that bother me the most are not the regulars that come to every seminar and belong to clubs, as they are fairly conscientious. It's the people you can't get to my airport visits and briefings. It's the people who don't read flying pubs, go to meetings or otherwise participate in aviation activities other than to use airplanes to get from A to B.

In Summary

Without question, any program has to be tailored for local conditions. The one inviolate rule in the MACA business that is absolutely imperative when dealing with other aviators is that it must be *face-to-face*. In our day-to-day staff paper shuffles, we solve a lot of problems by creating or altering a piece of paper. It's a lot like initialing off the Crew Read File card. Aircrew initials only document the fact. It is a substitute for a face-to-face briefing.

Some commanders send a personal letter to local pilots. Although this is a positive effort, it has limited effectiveness. Paper just cannot produce the same results as people.

Why is face-to-face communication so important? Because it is *two-way*. Some of the comments I get are: "Gee, I didn't know you were restricted to corridors. I thought the Air Force could fly anywhere it felt like," and "If I had known that you always flew over such and such place, I'd always fly the other way," and "We didn't know the Air Force cared about us."

That last one is the clue. They didn't think we cared, but we do. Ask any Air Force aircrew. How does the average civil pilot know we care? We have to tell him. And, while we are out telling him about our flying activities along with some of our problems such as a lack of training routes, lack of flying time and so on, we ask him where he flies.

I found out one day that a seaplane school was using Lake Okeechobee for their school, right on our 500 foot low level. After we both recovered from the shock, he agreed to move to another part of the lake. Also, do yourself a favor and ask the civil flight instructors where they send their students on their solo cross-country flights.

Our shop at Homestead is manned with a full time, excused from flying, major and a full time squadron IP. We feel at times that it is a luxury to have full timers, working airspace, but judging from message traffic it appears that our problems are minimal and manageable compared to those at many other locations. But it takes a lot of work, command support and a sincere interest to get it that way. Good luck. ■

About the Author

When this article was written, Major Bukoski was Chief, Airspace Management, 31st Tactical Fighter Wing, Homestead AFB, FL. He is a Master Navigator with more than 3,200 military flying hours, as well as over 2,000 hours in general aviation. Major Bukoski, retired from active duty, is employed by Eastern Airlines in Miami in Maintenance Management.

Cockpit EXERCISES

We recently came across these "body-wakers." They have been recommended in both TWA and Pan AM publications. They look like some excellent calisthenics which may be done within the confines of most cockpits. The obvious cautions apply about care in not bumping switches, flight controls or disconnecting oxygen or intercom connections. Other than that, every little bit of alertness helps!

■ Extended sedentary periods such as during long overwater flights have a way of making the mind and body sluggish. Late evening trips are especially difficult since the body naturally wants to settle into a restful state. A popular way of coping with "sinking spells" involves the consumption of coffee. But some people suffer side effects from coffee such as gastric discomfort and rapid heartbeat, and too much coffee can result in lethargy brought on by caffeine poisoning.

An alternative to stimulants is exercise which increases circulation, stretches muscles and heightens alertness. The following exercises can be done from the flightcrew station, or for that matter at a desk.

There's no particular order of exercise grouping, but greater benefit will be derived by doing as many exercises as possible. It is important that the exercises be accomplished as described.

LOWER LEGS—CALVES

1. Lift For Heels and Toes:
   Lean forward slightly with hands on knees. Strongly contracting calf muslces, lift heels as high as possible. Slowly lower heels and then lift toes as high as possible, keeping heels on the floor. Do 10-15 complete repetitions.

LEG MUSCLES

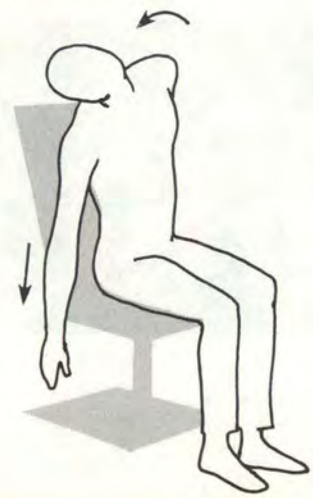
2. Leg Isometrics:
   Cross ankles, with both feet on the floor. Strongly press forward leg backwards against rear leg and vice-versa, but allow no movement. Hold at maximum force for a count of 5, then relax. Do three repetitions, then reverse foot position and do three more.

TORSO

3. Waistline'Lower Back Flex:
   Hold elbows at shoulder level, slowly twist as far as possible to the right. Slowly return to face forward and continue as far left as possible. Keep going at a medium pace, without holding your breath. Do about 10-12 repetitions to each side.

4. Lower and Upper Back Flex:
Sit straight up, feet flat on the floor. As you exhale, bend forward and touch your feet. Immediately sit up, as you inhale, and pull your arms back at shoulder level, as if you were "rowing" your seat. Hold this position with your back arched, for just a moment, then repeat the entire motion. Do 15 repetitions at a moderate pace.

5. Side Stretch:
Sitting up straight, with hands down alongside your seat and abdomen drawn in, slowly lean to one side (no forward motion allowed) and try to touch the floor. The motion is very similar to retrieving something from the bottom of your nav kit, except you should be looking forward. Straighten up, then do to the opposite side. Do about 10 times to each side.



ABDOMEN

6. Abdominal Muscle Trim:
Sit straight up with your hands on your knees. Exhale as you draw in your abdominal muscles as far as possible; relax, letting out muscles as you inhale. Repeat for 15 repetitions at a steady, brisk rate.

CHEST/UPPER ARMS

7. Palm Squeeze:
Put your hands in your lap, palms facing each other. Without holding your breath, push your hands strongly against each other for a medium count of 4. Relax. Repeat 10-15 times.

HEAD/NECK

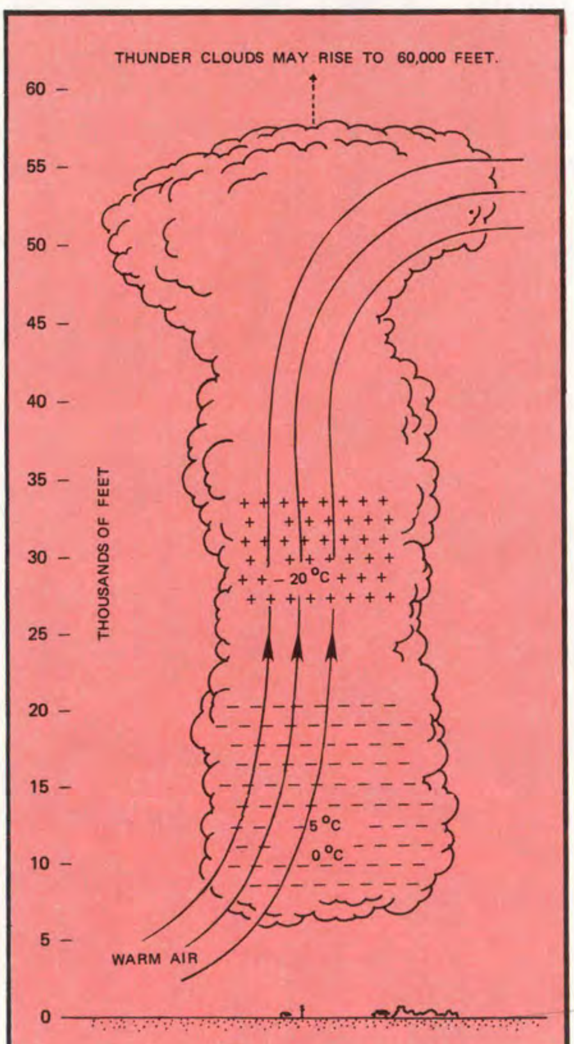
8. Head Rotations:
Sit up, hands in lap, relaxed with your head drooping and chin on your chest. In a slow, relaxed motion, moving only your head, rotate your head around in a large easy circle to the right. After completing one circle, rotate to the left, and so forth, for about 6 repetitions to each side.

9. Shoulder Lift:
Sit erect with hands on knees/upper legs. Inhale, while straightening arms and shrugging shoulders as high as possible. Hold for a moderate count of 4, then exhale in a long sigh, letting shoulders droop, head sag, arms bent and relaxed. Stay relaxed for count of 4, repeat. Do five repetitions, each time trying to feel the release of tension. ■

Even though April, May and June are the worst months for lightning strikes, some are reported in each of the other months, too, and to some of you with many flight hours, these encounters may seem routine. But on very rare occasions lightning has brought a plane out of the sky, and on less rare occasions it has caused some very frightening close calls. Thus, it is well to review what lightning is, why your aircraft sometimes gets involved with it, what to expect from it, and how you can help researchers learn more about it and design even better protection from its effects in the future–Reprinted from Aerospace Safety *magazine.*

Lightning And

FIG. 1

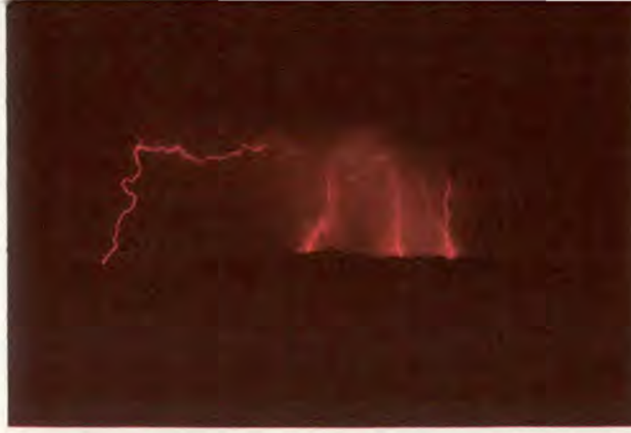


■ A lightning flash is a very long electrical spark which extends between one center of electrical charge in a cloud and another center of opposite polarity charge in the ground, in another cloud, or sometimes even in the same cloud. The energy that produces lightning is provided by warm air rising upwards into a developing cloud as shown in Figure 1.

As the air rises, it becomes cooler and at the dew point its excess water vapor condenses into water droplets, forming the cloud. When the air has risen high enough for the temperature to have dropped to minus 40°C, all of the water vapor will have frozen to ice. Some of the ice crystals coalesce into hailstones which are heavy enough to fall through the cloud, gathering supercooled water droplets as they do so. According to one theory, as these droplets freeze onto a falling hailstone, small splinters of ice chip off, carrying away with them a positive charge and leaving the hailstone with a negative charge. The vertical air currents carry the ice splinters to the upward part of the cloud, leaving the base of the cloud with a negative charge center. The air currents and electrical charges tend to be contained in localized cells, and there may be several such cells in a single cloud.

Surrounding any electrical charge is an electric field which extends outward a long distance from the charge itself. Close to the cloud charge center the electric field is very intense, and when sufficient charge has accumulated, this field may be strong enough to *ionize* the air, creating a conducting path in the form of a luminous spark which jumps outward towards a region of

FIG. 2



uncharged or oppositely charged air. Some of the charge from the cloud flows along this spark, charging up a column of air, perhaps a meter in diameter around the spark, and intensifying the electric field in front of it. This causes more ionization and further extension of the spark, and the process repeats itself for many extensions and forms a zig-zagging, luminous column of ionized air called the *stepped leader*. The leader zigs or zags about 50 meters in each step, travelling

Aircraft

MR. J. A. PLUMER

at about 100,000 meters per second, and pausing for about 50 millionths of a second between steps while it is supplied with more charge from the cloud.

As the stepped leader approaches the earth, it attracts electrical charges of opposite (positive) polarity and produces ionization from sharp objects such as tall buildings and trees. Fed by the attracted charges, sparks called *streamers* emanate from these points and propagate upward a short way to meet the downcoming leader. When the two meet, a conducting path is formed so that the charge in the leader can combine easily with the opposite polarity charges in the ground.

The process thus far takes only a few thousandths of a second to accomplish. When it begins, the leader moves in the general direction of an opposite polarity charge source, but it does not "know" where it will finally strike. There may be several possibilities, and the leader frequently splits into several *branches* on its way, as happened in the flash of Figure 2. The first branch that reaches a source of opposite charge completes the path and wins the race, so to speak. The leader that began the flash of Figure 2 found this opposite charge in the earth, but it might also have found it in another cloud, or even within the same cloud as the original source of charge. When the leader reaches the ground (or other opposite charge center), the positive charge in the ground rapidly flows into the leader, neutralizing the negative charge in it from the ground up. The head of the region in which this neutralization takes place moves up the leader channel at a velocity of 100 million meters per second—creating a current which reaches, on occasion, as high as 200,000 amperes. This current is called the *return stroke* and is responsible for the bright flash and loud noise we associate with lightning.

Once it reaches the cloud, the return stroke dies out but the charge remaining in the cloud may drain off through the conducting channel to ground, forming *continuing currents.* If additional charge centers are present in the cloud, they may also discharge to ground through the same channel, forming additional strokes, called *restrikes.* Neither the return stroke nor the restrikes last for more than a few thousandths of a second. The continuing currents are of lower amplitude—a few hundred amperes—but last for a much longer time than the strokes. Together, the strokes and continuing currents make up the complete lightning *flash* and flashes may persist for up to a full second. If more than one stroke occurs, the main channel will brighten during each one, causing the channel to flicker.

If your aircraft happens to be near a charge center or an advancing leader, the electric field around the aircraft may be intense enough to ionize the air about its extremities. This ionization often occurs in the form of a corona—a bluish glow visible at night and frequently called St. Elmo's fire. If sufficiently intense, streamers may also form and propagate outward from the aircraft toward the leader or charge center. As this happens, the intervening field will become even more intense and the leader may advance more directly to-

continued

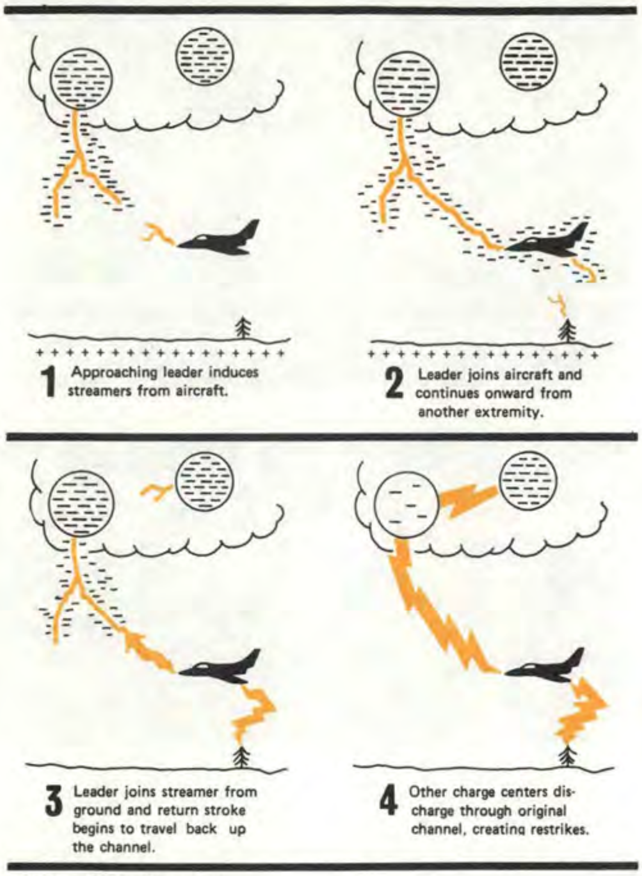


FIG. 3 Strike Sequence

ward the aircraft and meet one of the streamers emanating from it, completing a conducting path through which charge may flow onto the aircraft. Since there is not room for very much charge to remain on an aircraft, charge will "overflow" in the form of intense streamers from other extremities and enable the leader to progress onward, as shown in the sequence of Figure 3.

Thus, your aircraft becomes a link in the conducting channel from the cloud to the ground or another cloud. Whatever strokes and continuing currents pass through the channel will also have to be conducted through your aircraft.

Once within its clutches, you cannot fly away from a lightning flash. When the return stroke passes through the channel, you will experience the bright flash and loud bang so often reported. You will be "let go" only when the flash dies out naturally.

From your perspective in the cockpit, the foregoing events may appear to be caused by the aircraft becoming charged up by some other process and then suddenly discharging itself into the surrounding air, accompanied by a bright flash and loud bang. Sometimes at night the corona and streamering will persist and brighten for many seconds, appearing as a fluctuating column of fire snaking outward from the nose of the aircraft. When the flash finally occurs, the corona and streamering cease because the electric field has collapsed, and it appears as if the aircraft has suddenly discharged. Hence the event is termed a *static discharge* and not a lightning strike. However, a rather large amount of electrical charge is necessary to produce either a bright flash or a loud bang—far more than can be stored on an aircraft, so if either of these symptoms occur, you almost certainly have been struck by lightning. In fact, the loud bang does not even occur on some strikes; only a "whoosh" sound. This is thought to be a cloud-to-cloud flash whose return stroke occurs less rapidly, producing less current and noise.

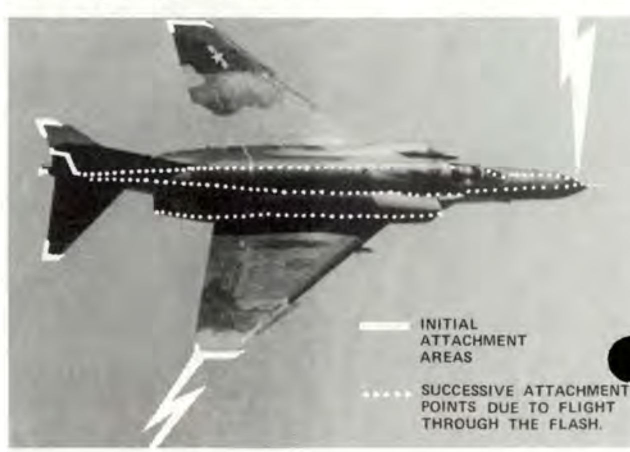
WHAT PARTS OF AN AIRCRAFT GET HIT?

Since it will be part of a path between two charge centers, there will always be at least one entry and one exit point on your aircraft. *Initially,* these are places from which streamers came during the leader phase described earlier, and may be any of the extremities such as the nose, wing tips, horizontal or vertical stabilizer tips, tail cones and, somewhat less frequently, other protrusions such as propellers and blade antennas.

But, an aircraft flies quite a distance during the lifetime of the total flash, and this may expose other surfaces to flash attachment. A flash striking the nose, for example, may reattach at successive points along the fuselage until a trailing edge is reached, where it will then remain until the flash dies. If an initial attachment point was already at a trailing edge, the flash will simply hang on there. Figure 4 illustrates this process and shows other likely attachment points on a typical aircraft.

continued on page 22

FIG. 4 Lightning Attachment Points



How To Save Your Neck

CAPTAIN JIM PORTER
4TFS
Hill AFB, UT

■ You fighter types have been there before, cruising along in your "allotted" area, when a strobe at six o'clock suddenly appears. A quick glance reveals an eager bandit quickly closing to ordnance parameters. Your vast knowledge and experience dictate that very soon you'll be laying on one of your better turns to ensure this intruder learns quickly that he's not dealing with just "anyone" today. In that nanosecond between decision and action, you twist around to get a good padlock and now you're ready to pull the string on this guy. With a snap of the wrist, he's looking at a 7-9 G target and you're looking at . . . oh! *-#:@/?*!

What happened? When you laid that turn on your body, your body came back with "idiot, you're not ready for that turn." You succumbed to an equally lethal bandit—pain—and now you're just another strafe panel. Your neck failed you miserably and left you with little interest in the ensuing air-to-air engagement.

This pilot experienced a sensation which I have heard described best in two ways: (1) somebody stuck a knife in my neck and slashed it down my back; or (2) a thin wire about 2 feet long was heated to 800 degrees, and pressed into a line joining the neck and back. No wonder he's ready to RTB (or pull the handle, if it's for real).

Transition of the tactical fighter force into high G aircraft is well under way. In the 5-6 G environment, most people held up well and neck problems were uncommon. However, with the introduction of aircraft that can sustain 9 Gs until they run out of gas, the limiting factor is the pilot, specifically his neck.

What can you do to minimize neck injuries and ultimately better

How To Save Your Neck

continued

prepare yourself physically for the air-to-air arena? The first objective should be strengthening those muscles, which will increase your G capability and lessen your likelihood of neck injury. How do you best accomplish this? By making exercising convenient. The chances of getting your average fighter jock to the gym for the purpose of hitting the neck machine lie somewhere between slim and none. However, if that neck machine is in one of the squadron briefing rooms or in the lounge, guys might just use it.

The neck exercise machine must be expensive and hard to build? Wrong on both counts. Note the accompanying photo. The first requirement is a solid foundation to attach the hardware. Your base sheet metal shop can help with items such as angle iron and cutting/drilling. Tack on miscellaneous parts such as a couple of pulleys, some rope, a wooden dowel, a few weights, and the machine comes together easily. A little negotiation with the fabrication shop will yield a head harness and you've got it. The total expense is minimal.

Now that we've discussed a simple way to work the "problem," consider a couple of additional tips which will reduce air combat related neck injuries. In the arming area and then again as part of your fence check, limber up the neck by twisting around in both directions to check six. Once you're involved in the fight, set your neck and think about when high G onset will occur.

Fighter pilots who work with high G aircraft know that an unconditioned neck can transform them from a 9 G killer to a 3 G target. Simple neck conditioning in the squadron environment can significantly improve the pilot's ability to beat this painful adversary. Also, don't forget to limber up your neck before the fight and set your neck during the hassle. In the end, he who can check all aspects at 9 Gs has a considerable advantage. ■

Neck exercise machine was fabricated locally for F-16 pilots at Hill AFB. Location where pilots congregate encourages its use.

ON THE LINE

MAJOR BRIAN D. HUDSON
Directorate of Aerospace Safety

■ We continued to make headway against FOD in 1980, but success was primarily in numbers and not so much in dollars. The number of damaged engines decreased by 32 to 346 from the 1979 figure of 378. This was approximately one-half the decrease of 61 between 1978 and 1979.

The most notable improvements in actual count were seen in SAC's FB-111 and KC-135 fleets, USAFE's F-111s, MAC's H-1s, [A]DC's F-106s, and ATC's T-38s. In fact, the T-38 decrease from 33 in 1979 to 7 in 1980 leads the pack and is a remarkable achievement. On the backside of the coin, we find USAFE F-4s and TAC F-15s significantly contributed to general increases over their 1979 total of engines damaged and rates per 100,000 engine hours.

In reviewing the 1980 rates, we've selected the high six for 1979 and 1980 as published in the monthly HQ AFISC Mishap Summary, in accordance with AFR 66-33. The F-105 is a newcomer to the top of the list, but of greater significance might be the F-16's rates. With over five times the 1979 engine hours in 1980, the rate was more valid, and it continued to be one of the highest. The position of the F-16 intake certainly appears to present considerable potential for FOD from both ramp and personnel sources. However, we suspect the age old learning curve may also be keeping the rate up. The sharp decline in SAC's FB-111 FOD mishaps, while increasing engine hours, dropped them from the top six, along with the F-106 which decreased its rate from 18.04 to 3.02.

Moving away from the engine count to the dollar totals, we saw a moderate decrease of $648,858 from the 1979 figure. However, due to ground mishap reporting time limits, this figure may change significantly (i.e., in 1979, cost increased over

continued

TOTAL INSTALLED ENGINE FOD (except ice)
COMPARISON BY MAJCOM/AIRCRAFT*
1979 VS 1980

INCREASE				DECREASE			
MAJCOM/ ACFT	1979	1980	CHANGE	MAJCOM/ ACFT	1979	1980	CHANGE
TAC A-10	10	14	+4	AFRES T-37	4	1	−3
AFRES C-130	1	4	+3	SAC FB-111	8	1	−7
ANG	7	10	+3	AFRES C-123	4	1	−3
TAC	42	45	+3	TAC C-130	3	0	−3
USAFE	17	23	+5	SAC KC-135	10	5	−5
TAC	19	24	+5	USAFE F-15	8	5	−3
TAC	2	6	+4	ADCOM F-106	4	0	−4
ANG F-105	3	7	+4	TAC	4	1	−3
MAC Test Cell	1	4	+3	AFLC F-111	5	2	−3
				USAFE	10	5	−5
				MAC H-1	9	3	−6
				MAC H-3	4	0	−4
				AFSC T-38	3	0	−3
				ATC	33	7	−26
				TAC	9	4	−5

*Reflects only those MAJCOM/ACFT combinations showing + or − changes of 3 or more.

see inside front cover July 81 for corrected chart

FOD RATES (HIGH SIX)

1979* MDS	MISHAPS	RATE**	1980 MDS	MISHAPS	RATE**
F-16	3	37.45	F-105	8	38.95
F-111	43	27.73	F-16	7	25.27
H-1	9	24.84	F-111	39	24.34
FB-111	8	21.94	F-5	12	19.46
F-5	12	18.99	F-15	35	17.07
F-106	8	18.04	F-4	123	15.85

*AFLC lost one F-102 engine in a total of 64 hours. The resulting 999.90 rate was excluded because a single mishap and low hours were considered insufficient to provide a valid data base.

**Rate per 100,000 engine hours.

$1.2 million from initial figures available in Jan 80). Best advice is to use the $648,000 figure with caution. Although our costs appear to be lower, a decrease in the number of engines lost to FOD will not have as great an impact as in the past due to the sharply rising cost of modern propulsion units.

Of course, all these figures don't reveal cause factors. In an effort to improve our prevention efforts, we categorize mishaps by cause. The high six aircraft in 1980 are presented along with a percentage comparison for all aircraft between 1979 and 1980.

The figures generally indicate where emphasis should be placed in our prevention programs. Hardware, equipment and metal objects (which may be either) inflict most of the damage for most aircraft. They are where our greatest efforts must continue; however, the undetermined category has presented an increasing problem.

Many factors enter into causes, but most of the categories are consistent between the two years. The most notable exception is the undetermined class. This class rose from a little over one-third of all FODs in 1979 to nearly one-half in 1980. Within the high six aircraft, the C-130s, F-4s, and F-111s have increased or maintained a high percentage of undetermineds. Why? We're not sure. Mission environment, investigator experience, and engine design can enter into the equation. However, we do know that in the past two years, 93 percent of C-130 FOD mishap causes were undetermined; the F-4s increased from 15 to 30 percent, and the F-111s moved from 30 to 54 percent. These figures might be a one-time deviation; however, the situation continues to warrant close attention. It's difficult to prevent something unknown.

Overall, it appears that 1980 was an improvement over 1979. The battle isn't over yet! Although AFR 66-33 centers the FOD program management responsibility with the Chief of Maintenance, preventing loss of resources through foreign object damage is a task for operators as well as maintainers. "Eyes open" is a good motto for all! As operators, you may be in the best position to see and report actual foreign objects in the flight line area or potential FOD hazards. Pick it up or report the hazard! ■

FOD MISHAPS (HIGH SIX)

1979				1980			
MDS	GND*	FLT*	TOTAL	MDS	GND*	FLT*	TOTAL
F-4	6	106	112	F-4	13	110	123
T-38	4	40	44	F-111	5	34	39
F-111	7	36	43	F-15	5	30	35
F-15	4	25	29	C-130	7	20	27
C-130	7	14	21	A-10	2	18	20
F-5	1	11	12	F-5	0	12	12

*GND: Discovered during ground operations
FLT: Discovered during intent for flight

ENGINE FOD COSTS

	1979**	1980
CLASS A	None	None
CLASS B	$1,376,851	$1,568,473
CLASS C	$4,309,162	$3,653,385
GROUND	$2,006,364	$1,821,661
TOTAL	$7,692,377	$7,043,519*** = − $648,858
	(Total FOD 378)	(Total FOD 346) = − 32

**Mishap Cost Categories Changed—Jan 79
***Incomplete Due to Ground Mishap Time Limit.

FOD CAUSES (HIGH SIX—1980)

MDS	Undetermined	Hardware (screws, rivets nuts, wire)	Metal Objects	Equipment (headsets, pins, flags, tools)	Ramp Debris (rocks, asphalt)	Ricochet	TOTAL
F-4	37	54	22	8	2	2	123
F-111	21	9	4	3	1	0	39
F-15	12	9	5	7	0	1	31
C-130	25	1	1	0	0	0	27
A-10	4	11	3	0	0	2	20
F-5	1	7	3	1	0	0	14

FOD CAUSE PERCENTAGES
(AF Total except ice-1979/80)

1979%	36%	33%	17%	7%	3%	4%	100%
No.	(137)	(125)	(64)	(26)	(11)	(15)	(378)
1980%	45%	32%	12%	8%	1%	2%	100%
No.	(155)	(111)	(42)	(28)	(3)	(7)	(346)

THERE I WAS

■ . . . often misunderstood and berated. We in helicopters live in a different world from other flyers. Recently, I thought I had found a kindred soul in an Air Traffic Controller at an ATC base in Texas. On a cross-country flight from Tucson, Arizona, to Fort Walton Beach, Florida, the following ensued: After four long, vibrating hours in zero-zero instrument flight at four to six thousand feet (the CH-3 doesn't like to fly very high), we were approaching our first refueling stop. We, in this case, were a flight of two midair recovery equipped Sikorsky helicopters about five miles apart. As we approached the field, we were notified of intensive student training to the runways. Apparently the air traffic controller was familiar with our call sign or deduced our aircraft type from the low altitude and airspeed. He questioned if we were helicopters. Ah ha, thought I, he knows our limitations and capabilities and will let us get below the clouds to approach the field VFR at an angle to their traffic. Not so.

"There I was at four thousand feet with less visibility than the inside of a simulator and hear the next ATC request, 'Jolly 26, please hover until the current traffic clears out.' "

Needless to say, we politely declined the honor of being the first crew to successfully hover a helicopter at four thousand feet with no outside references. After a slight pause, the undaunted controller made the same request of our sister aircraft five miles in trail. Unsurprisingly, he also declined.

This story underscores the fact that controllers cannot be "expert" in all types of aircraft they are called upon to control, and that pilots must use their common sense and judgment before blindly following instructions. While this is especially true in helicopters, it is also applicable to other aircraft with unusual requirements and capabilities. Thanks to the author. His story may save a comrade in arms. ■

Brig Gen Leland K. Lukens
Director of Aerospace Safety

ORDER OF DAEDALIANS

■ The Order of Daedalians, Inc., the National Fraternity of Military Pilots, will conduct its 47th annual convention on 4-6 June in the Marriott Hotel facilities in downtown (on-the-river) San Antonio, Texas.

The presentation of five prestigious awards will be the highlight of the final evening's awards dinner. The United States Air Force in Europe has been selected to receive the Major General Benjamin D. Foulois Memorial Award (flying safety) which is the oldest of these awards. The other coveted awards to be made are the Admiral James S. Russell Naval Aviation Flying Safety Award, Brigadier General Carl Hutton Memorial Award, Weapon System Award (Colonel Franklin C. Wolfe Memorial Award) and Daedalian Civilian Air Safety Award. The awards dinner will be held in the Alamo Ballroom of the Marriott Hotel. ■

LIGHTNING AND AIRCRAFT

continued from page 16

CAN YOUR AIRCRAFT TRIGGER A STRIKE?

A question often asked is, "If an aircraft cannot produce its own lightning flash, can it trigger a natural one?" Stated another way the question might be, "Would the lightning flash have occurred if the aircraft were not present?"

While there is still much we don't understand about lightning formation process, most researchers conclude: (1) that aircraft are usually struck by flashes that would have occurred anyway, but (2) the aircraft, being conductive, is attractive to a nearby leader and causes it to divert towards the aircraft rather than continue on in some other direction. There is some evidence that jumbo-jets sufficiently "squeeze" and intensify the electric field around a nearby charge center to cause a stepped leader to form before it otherwise would have, thus triggering a strike; but this seems improbable for smaller aircraft.

WHEN IS A STRIKE MOST LIKELY?

Erratic as they are, it is impossible to predict just when or where a lightning strike will occur, but some idea of when to be on the alert for one can be obtained from study of past experience.

Figure 5 shows flight and weather conditions summarized in a recent survey of 200 commercial airline strike reports, and Figure 6 shows the flight altitudes at which most of these aircraft were struck. The outside air temperature reported in most instances was within a few degrees of the freezing point (0°C). From this data one might draw the conclusion that a strike is most probable to an aircraft flying at an altitude between 10,000 and 15,000 feet, within a cloud, experiencing rain and light turbulence and with the outside air temperature near 0°C. Strikes have been reported under many other combinations of circumstances, however.

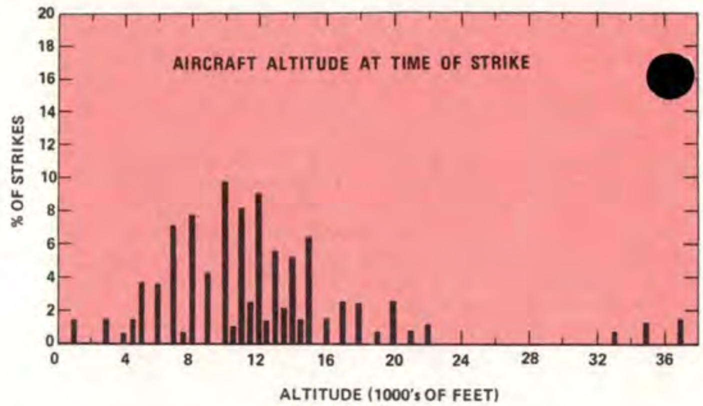


Fig. 6 Altitude Where Most Strikes Occur

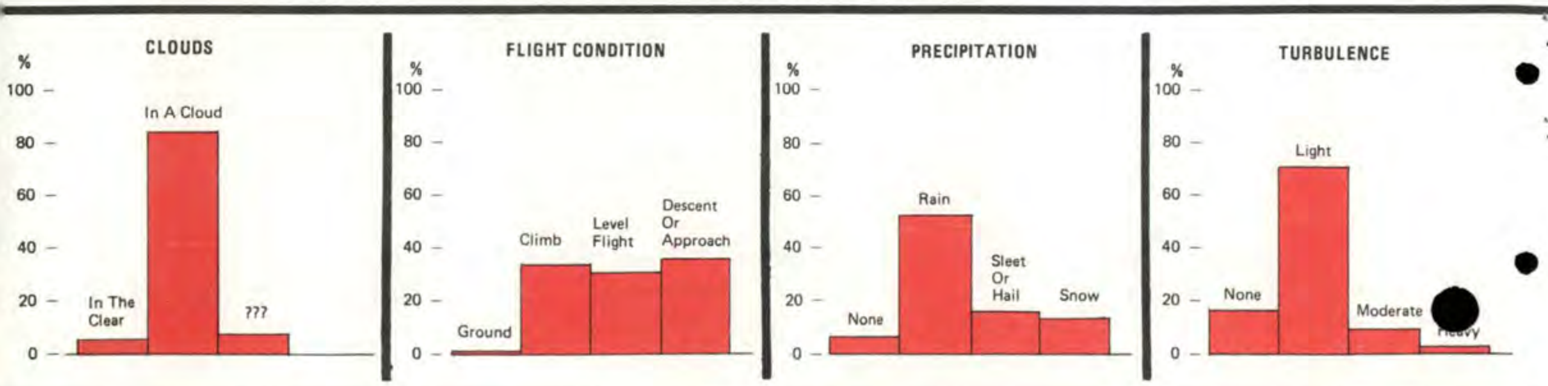
WHAT ABOUT AVOIDANCE?

Good flying practice and USAF flight manuals call for avoiding thunderstorms at all cost—not only to avoid lightning strikes but also to avoid the other manifestations of a good thunderstorm: turbulence, hail and rain. Careful study of weather reports and use of radar can help you avoid areas of precipitation, but unless you can circumnavigate these by well over 25 miles, an occasional strike may still reach out to greet you. There are many reports of strikes occurring to aircraft operating between clouds or in other areas where no thunderstorms were forecast, and a few pilots have even reported "bolts from the blue." Thus, even if you fly diligently by the book, you can probably expect to be "zapped" sometime during your flying career.

WHAT EFFECTS CAN YOU EXPECT?

As we said before, electric currents of up to 200,000 amperes will flow through your aircraft between lightning entry and exit points when you are struck. Owing to its short duration, most of this current will remain in the skins, with relatively little of it diffusing into interior spars and ribs. Fortunately, aluminum is a very good electrical conductor and there is enough of it in most aircraft to conduct this current.

FIG. 5 Commercial Aircraft Lightning Strike Experience



In most cases the only noticeable effect of this current having passed through your aircraft will be small pit marks where the lightning flash momentarily attached, as shown in Figure 7. At trailing edges or other places where the flash can hang on longer, a hole might be melted. Holes can be prevented by making the skin thick enough (0.080 inches will usually suffice) but skins that thick are heavy and are usually used only over fuel tanks or other critical places where penetration of the hot arc cannot be permitted.

Lightning may do a lot more damage to nonmetallic structures such as the fiberglass radome shown in Figure 8. In this case, a streamer induced from the radar dish probably punctured the radome wall and reached the approaching leader. Then when the return stroke followed this path, its explosive blast pressure shattered the radome. The radome contained the blast until its pressure had built to a very high level, resulting in a "violent explosion," forcing the crew to eject.

If there is a pitot probe on the radome, as is the case on most fighters, the probe forms a good lightning rod. Usually the pitot probe is grounded to the airframe by a wire inside the radome. Sometimes these ground wires are too thin to carry severe lightning currents and have exploded on several occasions, with damage similar to that of Figure 8. Sometimes the aluminum tubes which bring pitot static pressure back to the instruments have acted as the ground conductor, but the intense magnetic fields surrounding lightning currents often crimp such tubes, cutting off instrument air. To make matters even worse, the cord which brings electric power out to the probe heater is also susceptible to the lightning magnetic fields. These fields may induce severe surge voltages in the heater power circuit. Since the heater is usually powered from the essential bus, other equipment powered from this source is exposed to the same surge. The immediate result has been damage to a variety of other electronic equipment, and has led, in a few cases, to loss of the entire aircraft. Figure 9 shows typical lightning damage to pitot static lines and a heater power cord. Much more is known today about how to protect against these effects, so that radomes and pitot systems in the aircraft now being built are not likely to be as vulnerable.

Because they are usually located on wing tips or other extremities, navigation lights are frequently struck. Normally, the flash attaches to the metal lamp housing and does little damage, but once in awhile it will break the globe and light bulb, as happened to the

continued

FIG. 7 Pit marks where flash attached

FIG. 8 Radome shattered by glass effect

FIG. 9 Typical lightning damage to pitot static lines and heater power cord

FIG. 10 NAV light globe broken by lightning, leaving a path for lightning current to enter aircraft's electric system.

lamp in Figure 10. If this occurs, a portion of the lightning current may get into your aircraft's electric power distribution system and damage electronic equipment powered from the same bus. This, like the pitot heater situation above, is another of the more hazardous lightning effects for it may cause loss of instruments or communication equipment you rely on in bad weather. The circuit breakers for this equipment will usually pop, but not before the lightning surge has already passed through and done whatever damage it can. Surge arrestors are available to suppress these surges before they get this far, but they are not found on all aircraft. If this happens to you and some circuit breakers pop, try to reset them, but be aware that some equipment may be permanently damaged.

FUEL SYSTEMS

The vapor over a partially filled tank of JP-4 can be explosive at the flight altitudes and temperatures where lightning strikes most frequently occur, as indicated by the flammability limits of a JP-4/air mixture shown in Figure 11. The overpressure which such a mixture can produce when ignited is shown in Figure 12, and these figures show that the maximum degrees of flammability and overpressure occur near the flight altitudes and temperatures at which most lightning strikes to aircraft are reported to occur.

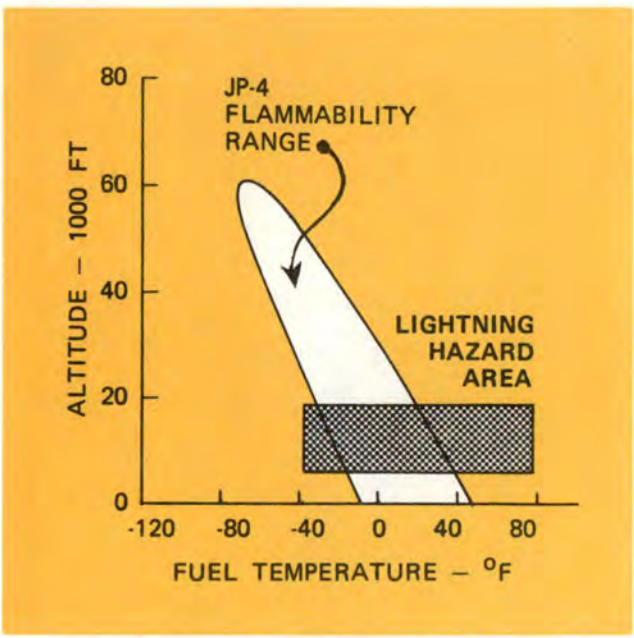


Fig. 11 JP-4 flammability range.

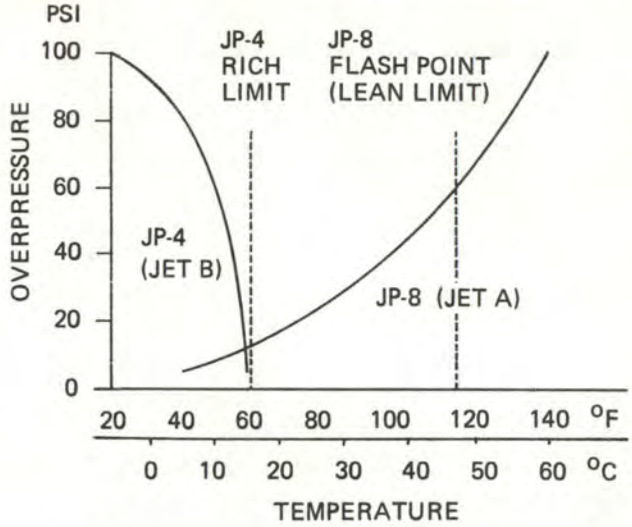


FIG. 12 Pressures generated on ignition of partially fitted fuel tanks under sloshing conditions.

There have been many laboratory studies made of the ways a lightning flash might produce a source of ignition within an aircraft fuel tank. Flashes attaching to access doors and filler caps have been found to cause sparking across inadequate joints or bonds; and flashes attaching to the surface of an integral tank skin have been shown capable of burning a hole if permitted to dwell long enough at one place or if the skin is too thin. Also, simulated lightning flashes have been shown to be capable of igniting vapors at fuel vent outlets under certain airflow conditions—conditions that almost certainly would not exist in flight. Protective measures for each of these situations have been developed, however, and incorporated into today's aircraft, so that the probability of fuel ignition from a lightning strike is remote.

Since the causes of some in-flight fuel tank explosions have never been found, there may still be lightning-related ignition mechanisms which are not fully understood. This is another reason why thunderstorm areas should be avoided, and why operations involving the fuel system, such as in-flight refueling or dumping of fuel, should be avoided while flying in conditions where lightning strikes may occur.

INDIRECT EFFECTS

The lightning effects discussed thus far are frequently termed the *direct effects* because they involve some sort of physical damage. In recent years it has become apparent that there are other *indirect effects* produced by lightning strikes. Flight and engine instruments and other electronics have occasionally malfunctioned even though no direct connection with any part of the lightning flash existed. Because electronic systems are being increasingly depended on to perform critical functions in military and commercial aircraft, the Air Force Flight Dynamics Laboratory (AFFDL), National Aeronautics and Space Administration (NASA), and some of the manufacturers have initiated research programs to find out more about these indirect effects. Thus far, it has been learned that the electromagnetic fields which accompany lightning stroke currents may find their way inside an aircraft, where they induce transient voltages and currents in the aircraft's electrical wiring. This occurs even if the aircraft is all metallic, because there are still a lot of nonmetallic windows through which these fields may enter, and the fields themselves can be very intense.

WHAT ABOUT YOU?

The most hazardous effect you are likely to receive from a lightning strike to your aircraft is temporary blindness from the bright flash, if the strike occurs near the cockpit. This blindness usually (but not always) occurs at night and may persist for up to 30 seconds, during which time you may not be able to read your instruments. If you have a copilot, one of you may minimize this problem by keeping your eyes lowered when you think a lightning strike is imminent. Turning up your instrument lights may help by reducing your eye sensitivity before the flash occurs and making the instruments easier to regain afterwards. Keeping one eye closed is another technique.

Some pilots also report receiving a mild electric shock when lightning strikes occur. Since you are inside a conducting enclosure, the electric potentials of everything around you remain very nearly the same with respect to one another—even during the lightning stroke—and you are not in danger of being electrocuted. The strong electric fields which can pass through the windows as the leader approaches, however, may give rise to streamers from your head or shoulders, causing a slight shock as the minute currents which feed these streamers pass through your body. Just as often though, the shock is simply your startled reaction to the loud bang accompanying the strike.

The effects on you may be much more serious, however, if you are flying in a nonmetallic airplane, such as a glider. In such a craft, the control cables may be the only electric conductors and place you in a direct path between attachment points, with fatal consequences.

PRECIPITATION STATIC

Our discussion thus far has dealt with lightning strikes. Another electrical phenomenon which may be even more annoying is precipitation static, more commonly called "P-static." When an aircraft is flying through rain, sleet, hail, or snow, the impact of these particles on the aircraft will cause a charge to separate from the particle and join the aircraft, leaving the aircraft with a preponderance of positive or negative charge (depending on the form of precipitation) and thereby elevating its potential with respect to its surroundings. Since the aircraft has room for only a small amount of this charge, some of it will begin to leak off in the form of ionization at sharp extremities. This ionization continues as long as the aircraft is flying in P-static charging conditions (precipitation) and is visible as a bluish corona (St. Elmo's fire) at night. Unfortunately, this ionization radiates broadband electromagnetic radiation (EMR) throughout the low and high frequency radio bands. This EMR is often received as interference, or "static" by the aircraft communications or low-frequency automatic direction finding (LF-ADF) or communication receivers, and may render this equipment temporarily unusable. The static dischargers usually found on tips and trailing edges reduce this interference by making it easier for the charge to leave the aircraft, but they are not always 100 percent effective, especially in heavy precipitation. Since the conditions that produce P-static may also produce lightning, a strike should be considered possible when P-static appears, but except for providing an easily replaceable attachment point, the static dischargers provide little protection against lightning strikes.

continued

LIGHTNING AND AIRCRAFT
continued

We have reviewed the conditions where lightning is most prevalent and discussed some of the more common things to expect when you are struck. There are new structural materials and electronic devices becoming available whose susceptibility to lightning effects is not known, and there are still aspects of lightning itself which we do not fully understand. Therefore, a considerable amount of research is under way at present to learn more about lightning and its effects, and how to design even better protection into new aircraft.

To date relatively few serious incidents or accidents can be attributed to lightning, but there are two trends in aircraft design which promise to aggravate the problem unless positive protective measures are utilized. The first of these is the increasing use of miniaturized, solid-state components in aircraft electronics and electric power control systems. These devices are more efficient, lighter in weight and far more functionally powerful than their vacuum tube or electromechanical predecessors, but they operate at much lower voltage levels and thus are inherently more sensitive to overvoltage transients such as those induced by lightning.

The other trend is toward the use of nonmetallic materials in place of aluminum in skins and structures. This reduces the amount of electromagnetic shielding which the airframe provides and increases the exposure of wiring to electromagnetic fields. Nonmetallic materials may also aggravate some of the other effects noted earlier. Streamers may be drawn from conducting objects inside plastic wing tips or radomes, for example, puncturing them on their way out to meet an oncoming leader. The stroke current may then do extensive damage to the plastic sections. Fortunately, most manufacturers recognize this problem and provide *diverter* strips to minimize punctures of plastic extremities which enclose vulnerable items such as fuel cells or electrical wiring. Together, these two trends present a challenge to the designer of lightning protection for aircraft of the future, but the challenge can be successfully met if it is recognized early in design.

FIG. 13 Simulated lightning tests on wing-tip fuel tank at the GE High Voltage Laboratory, Pittsfield, Massachusetts.

Usually, the vulnerability of new materials or devices to lightning, and the adequacy of protection systems, is determined by subjecting them to simulated lightning strikes in a laboratory. The Air Force Flight Dynamics Laboratory has recently installed a lightning simulat[illegible] facility for this purpose, as have some of the aircr[illegible] manufacturers. Others utilize facilities such as the GE High Voltage Laboratory pictured in Figure 13. The GE Lab was originally built to help design lightning protection for electric power systems, but much of its equipment is applicable to aircraft testing as well.

Much is being learned in the laboratory, but our progress there is only as good as our ability to simulate the real-life environment. Thus, we continually seek reports from you who experience the real thing in flight—reports especially of incidents that seem unusual for some reason, or ones that cause a malfunction of some piece of equipment. You can help by providing complete information on these incidents to the Air Force Inspection and Safety Center. Those of most importance are the ones involving electrical or electronic equipment malfunctions. Describe the malfunction as you experienced it and try to follow up with maintenance and repair personnel to see if you can find out what exactly burned out or malfunctioned. Photographs of unusual damage will also be helpful as will retention of damaged parts for further inspection. Of course, many lightning strikes are "routine" events and need not be elaborated upon except as requested in AFR 127-4. But the extra time you take to re[illegible] the unusual ones will help designers provide better lightning protection in the future. ■

RADAR CONTACT

LT COL NICHOLAS O. GASPAR • Directorate of Aerospace Safety

■ As the CT-39 climbed on takeoff, I flipped the gear lever up and called for the after takeoff checklist. Everything was looking good, and I settled back with pride and knowledge that my copilot and I had done another professional job; thorough flight planning and preflight, smooth taxiing and a beautiful takeoff were just the beginning of another successful VIP mission. *The VIP in the back should be impressed with our performance,* I thought. *Maybe that's why they picked me for this flight.*

Lately, I've had several "challenging" missions. The airport—the one we had just left—is nestled in the mountains of the great Northwest. The runway is long enough, but there is no radar, no tower, not even a Base Ops there to help you get in and out—those niceties many military pilots take for granted. It was a "challenge" all right.

Well, anyhow, I took the initiative, made the long distance call to make sure the passenger knew where to meet, got the manifest straightened out, took care of fuel, weather, takeoff data, etc . . . a thousand things to check, and double check. Lt Bud Hill has really come a long way. Six months ago he was a brand new copilot and seemed reluctant to take the initiative. Today he is sharp and even caught my mistake when I misset the altimeter.

At 6,000 MSL we entered the overcast. The forecaster's crystal ball said we should be in the clear passing FL 200. Because of the high peaks, I intended on climbing to MEA (12,000 MSL) in a holding pattern before proceeding on course; those hills out there have claimed many a life, but this kid wasn't going to be one of them. I did my homework—I had flight planned every detail!

Passing 8,000 MSL, Center called me. Bud was handling the radios. He responded and flicked the ident switch as requested. The controller said "radar contact," confirmed our assigned flight level and advised us that our automatic altitude readout was inoperative.

His next transmission was: "Beebe 51, your destination airport is 170 degrees, report leaving one two thousand."

Boy, that's service! I hadn't thought about it for a good while, but those two words "RADAR CONTACT" conjur up a lot of comforting feelings. *You're not alone, you now have another set of eyes penetrating these clouds, watching over you like a guardian angel.* With these thoughts passing through my mind, I rolled out on

continued

Radar Contact continued

heading 170 and mentally calculated the drift correction—plus two degrees. But, deep inside an uneasy feeling haunted me, so I checked the airspeed: 250 KIAS, altitude 8,700 MSL, engines O.K. That inner voice kept nagging, so, reluctantly, I reached for the Sectionals (which Bud had brought along just in case) and double checked the chart.

Sheer panic gripped me as I realized we were headed for the peaks! A sharp bank to the right and pull on the yoke pinned us to the seats—smoothness didn't count at this point. The throttles responded to my insensitive jab as the slatted wings groped for higher altitude. Bud's blank stare belied his disbelief and bewilderment that I would do a chandelle with PAX on board! I didn't care. *I'll gladly explain to the brass, but time for that later*. I called for climb power. Anxiously I watched till finally the instruments indicated we were back on the desired racetrack and airspeed was O.K.

We'll never know how close we came to that deadly peak, but, for certain, much closer than I'd ever want to be again. Slowly, anger and resentment boiled up inside me as I reflected on what almost happened to my Beebe 51 flight. *What in the h . . . was that controller trying to do to me–kill me?* I swore at him under my breath. Had it not been for double checking . . . nay . . . had Bud not brought along the sectionals . . . well, by now we'd be strewn alongside old rocky ridge. I'd be plucking on a harp somewhere in the great beyond rather than sitting in my trusty old T-39 fretting because of what almost happened!

Passing 14,000 MSL we broke out of the clouds and I called Center with resentment frosting my voice. I accepted the 165 vector heading Center gave me only because I could see that we were clear of the mountain peaks; otherwise I'll never trust controllers again! My faith in ATC has been shaken! I wonder what the safety board would have found as the cause of Beebe 51's demise—pilot error? Failure to clear terrain? Inadequate flight planning? Other causes: who knows? Would the controller be blamed for what he almost did to me?

The above story highlights one of the biggest problems we all share—miscommunication. It shouldn't happen, yet it does, over and over again. Take a survey among your pilot acquaintances and see what the term "radar contact" means to them. The wrong definition could cost them their future.

Let's discuss some of the answers you may have come up with. "Aircraft will be provided (radar) terrain avoidance vectors. . . ." False. Controllers are not allowed to vector an aircraft below the MVA (minimum vectoring altitude). Unfortunately the MVA information is not normally available to pilots since it's contained in the air traffic control facility documents. In the above incident the MVA was the same as the MOCA (minimum obstruction clearance altitude) (12,000′ MSL) for part of the sector (2,000′ above the highest terrain within five miles). Though the pilot didn't know the MVA, his clues were the MOCA and the lack of published approaches. The Airman's Information Manual, Section 9, para 412a(4) states: "At airports where instrument approach procedures have not been published, hence no published departure procedure, determine what action will be necessary and take such action that will assure a safe departure." That clearly places the terrain avoidance responsibility in the pilot's lap. The term "radar contact" served no useful purpose in the above case. The controller's statement "destination airport is 170 degrees . . ." was meant only as an advisory, but our friend misinterpreted it to be a "radar vector" and almost bought the farm. Who made an erroneous assumption? The pilot! The controller didn't know the pilot was IMC but even if he had, he could not have vectored him until the aircraft was at or above the MVA.

If you answered: "Aircraft will be provided traffic advisories," you're almost right. The correct answer is MAYBE. The controller's first responsibility is to provide SEPARATION of IFR traffic from other IFR (and certain VFR traffic). Time permitting, he/she will provide traffic advisories about known or observed traffic.

Did you answer "ATC will provide radar service?" Once again you came close, but . . . before you get frustrated, take out the AIM and open it to the Pilot/Controller glossary and check the definition of Radar Contact, Radar Service, Radar Advisory Service, etc. To avoid falling into the trap of miscommunication you DO NEED to know what those terms mean. If you don't have an Airman's Information Manual, get one! ■

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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 Accident Prevention Program.

CAPTAIN
Ernest L. Harris, Jr.

CAPTAIN
Samuel K. Byers

FIRST LIEUTENANT
Roger L. VanZee

STAFF SERGEANT
William B. Spiece

MASTER SERGEANT
Edward Acosta

435th Tactical Airlift Wing (MAC)

■ On 11 July 1980 Captain Harris and crew were on a night, shortfield training mission in a C-130E. On the return to home base, the nr 2 engine oil quantity suddenly dropped from 10 to four gallons and the engine low quantity light illuminated. The loadmaster, Sergeant Acosta, quickly scanned the engine and reported a heavy stream of oil flowing from the drain mast. Captain Harris directed the copilot, Captain Byers, to perform an emergency engine shutdown. Captain Byers completed the shutdown, coordinated a level-off at FL120 and assisted the flight engineer, Sergeant Spiece, with the post-shutdown checklist. Scanning the engine to assure a safe shutdown, Sergeant Acosta reported that the nr 2 engine was now on fire and trailing 20-foot flames. The crew discharged the nr 1 fire agent bottle and isolated the left wing bleed air system. The navigator, Lieutenant VanZee, quickly pinpointed Nurnburg Airport, some 25 miles to the southwest, as the closest suitable recovery base. Captain Harris rapidly descended to accelerate the aircraft to extinguish the fire. He leveled at the assigned altitude of 6,000 feet with the engine fire still burning fiercely. He then directed Captain Byers to discharge the second (and last) fire agent. When it became apparent that the second fire extinguisher had had no effect on the fire, Captain Byers coordinated an immediate descent to a lower altitude. The fire appeared to go out but soon reignited and continued to burn out of control. With no time available to review the approach procedures, Captain Harris directed the copilot and navigator to talk him through the approach. Prompt, professional action on the part of each crewmember prevented the fire from spreading to nearby fuel tanks. Captain Harris' skillful airmanship averted possible injury or loss of life and saved a valuable aircraft. WELL DONE! ■

1980 USAF SAFETY PLAQUES

The Safety Plaques are awarded for outstanding safety achievement and mishap prevention in four areas: Fight, Explosives, Missile and Nuclear Surety. Recipients retain permanent possession of the plaques.

FLIGHT SAFETY

AAC
21st Tactical Fighter Wing

AFCC
1867th Facility Checking Squadron

AFLC
Oklahoma City Air Logistics Center

AFSC
3246th Test Wing

PACAF
3d Tactical Fighter Wing

ATC
47th Flying Training Wing
12th Flying Training Wing
80th Flying Training Wing
323d Flying Training Wing

USAFE
48th Tactical Fighter Wing
50th Tactical Fighter Wing
401st Tactical Fighter Wing
513th Tactical Airlift Wing

AFRES
931st Air Refueling Group
304th Air Rescue and Recovery Squadron
908th Tactical Airlift Group
920th Weather Reconnaissance Group

SAC
410th Bombardment Wing
55th Strategic Reconnaissance Wing
6th Strategic Wing
93d Bombardment Wing

ANG
132d Tactical Fighter Wing
104th Tactical Fighter Group
184th Tactical Fighter Group
147th Fighter Interceptor Group
165th Tactical Airlift Group
123d Tactical Reconnaissance Wing
102d Fighter Interceptor Wing
144th Fighter Interceptor Wing

MAC
39th Aerospace Rescue and Recovery Wing
89th Military Airlift Wing
463d Tactical Airlift Wing
41st Rescue and Weather Reconnaissance Wing
317th Tactical Airlift Wing
314th Tactical Airlift Wing
375th Aeromedical Airlift Wing
54th Weather Reconnaissance Squadron
435th Tactical Airlift Wing
436th Military Airlift Wing

TAC
405th Tactical Training Wing
1st Special Operating Wing
58th Tactical Training Wing
57th Fighter Interceptor Squadron
552d Airborne Warning and Control Wing
33d Tactical Fighter Wing
49th Fighter Interceptor Squadron
67th Tactical Reconnaissance Wing
84th Fighter Interceptor Squadron
31st Tactical Fighter Wing
87th Fighter Interceptor Squadron

EXPLOSIVES SAFETY

AAC
5010th Consolidated Aircraft Maintenance Squadron

AFRES
910th Tactical Fighter Group

NGB
125th Fighter Interceptor Group
184th Tactical Fighter Group

PACAF
51st Composite Wing (Tactical)
400th Munitions Maintenance Squadron

SAC
43d Strategic Wing
380th Bombardment Wing (M)

TAC
USAF Tactical Fighter Weapons Center

USAFE
20th Tactical Fighter Wing
81st Tactical Fighter Wing
7551st Ammunition Supply Squadron
50th Ammunition Supply Squadron

AFSC
3207th Munitions Maintenance Squadron
Air Force Weapons Laboratory

MISSILE SAFETY

AAC
5010th Consolidated Aircraft Maintenance Squadron

AFSC
3207th Munitions Maintenance Squadron

NGB
107th Fighter Interceptor Group

PACAF
51st Composite Wing (Tactical)

SAC
320th Bomb Wing
390th Strategic Missile Wing
381st Strategic Missile Wing
341st Strategic Missile Wing

TAC
56th Tactical Fighter Wing
57th Fighter Weapons Wing
48th Fighter Interceptor Squadron

USAFE
52d Tactical Fighter Wing

AFSC
Armament Division, Eglin AFB
Space and Missile Test Organization, Vandenburg AFB

NUCLEAR SURETY

AFLC
3098th Aviation Depot Squadron
HQ AFLC Nuclear Surety Office

MAC
6th Military Airlift Squadron
36th Tactical Airlift Squadron

NGB
107th Fighter Interceptor Group

SAC
319th Munitions Maintenance Squadron
379th Bombardment Wing
321st Strategic Missile Wing

TAC
Det 5, 425th Munitions Support Squadron
Det 3, 425th Munitions Support Squadron

USAFE
7520 Munitions Maintenance Squadron
20th Tactical Fighter Wing