AEROSPACE

SAFETY • MAGAZINE FOR AIRCREWS MAY 1980

FOD--it could be hazardous to your health

BY CAPTAIN DENNIS STORCK
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■ Everyone knows what FOD is, right? Foreign Object Damage, that's what. It's those stones and other debris laying around the flight line. Ever think of your clothing as FOD? How about those protectors you wear to save your ears? Your watch, gloves, even you? Well, if you haven't considered all of the above as possible sources of FOD, the time to start is now.

During 1979, several pieces of clothing and equipment (headsets, intake covers, cords, streamers, flashlights, screwdrivers) were ingested into aircraft engines, costing the Air Force thousands of dollars. But, most alarming, one crew chief lost his life when he was ingested by an engine.

FOD—yes, pilots, this means you, too.

Now, I know you're all thinking, "Who would do a thing like that?" But, believe me, these engine FOD incidents occurred at a rate of one every two weeks at an average cost of over $23,000 each. What can the crewmember (yes, pilots, this means you, too) do to prevent what many would term carelessness?

First, check the immediate ramp area during preflight. When you start your engines, start your clearing. If an engine run becomes necessary, clear the front (yes, front) of the aircraft as well as the aft. Believe it, the jet engine produces enough force to actually suck standing water off the ground and through the engine. And you guys up North, beware of ingesting loose chunks of ice. Ice can significantly modify turbine blades beyond repair. Most of all, ensure verbal coordination with the ground crew. Be sure they make no attempts to traverse the front of the affected engine. Additionally, ensure all their articles of clothing and equipment are secure.

If you find yourself needing maintenance while engines are running (i.e., oil pressure problem, hydraulics, etc.), requiring the installation of a downlock or safety pin and its associated "remove before flight" streamer, be sure you get it back just the way it was before installation.

When you have the fire department or transient alert monitor your engine start, be sure their hat isn't going to end up as confetti from your tailpipe.

The fact is, there is a lot of preventable damage being done. Damage that many times can go unnoticed until the aircraft is airborne, when the circumstances could be catastrophic. Most of all, it's not necessary to lose a life because of carelessness. And it can happen fast. Make the FOD check a permanent part of your duties. Don't let FOD be hazardous to your health, or anyone elses. ■

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SPECIAL FEATURES

REGULAR FEATURES

DEPARTMENT OF THE AIR FORCE • THE INSPECTOR GENERAL, USAF

Betting The 50

■ Breathes there a group of fighter pilots gathered where the conversation didn't get around to the last rat race where??? Let's finish that with some words we've heard too frequently of late: "I was pulling on the pole for 7.2 G and then I hit his jet wash and rang up a 9.0 on the meter." "That's okay, those birds are designed to take a lot more than that!"

As a pilot and an engineer, I am bothered by that sort of conversation. I wondered how such a conclusion was reached. It seems to have come about for two reasons. First, everyone knows about the guy who pulled 12 Gs and still stayed in the air; and, second, some of the jocks who are a bit more technically knowledgeable have taken the trouble to explain to those less knowledgeable that the *structural design engineer put a 50 percent margin of safety into the design*. The last part is the kicker, and I'd like to talk about that "margin of safety."

Yes, structural designers do use a 50 percent cushion, but it is darned important that all of you WBFPs* understand just how this 50 percent figure is arrived at and how it is divided up. One way to look at it is as sort of a non-replenishable rainy day emergency fund set aside years ago. One day you decide to use it and find that it is gone. When you ask your spouse where the money went, she says, "I never took more than $5 at a time!" A reasonable

**World's best fighter pilots*

BY MR. JOSEPH F. TILSON
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approach, perhaps, but irrelevant to the intended purpose.

Before we talk too much about the margin of safety, we need to have a mutual understanding of a couple of engineering terms:

Limit Load: The highest load the pilot is normally expected to impose. (You can exceed it but, when you do, some part of the bird may be permanently deformed. It can no longer be considered "like new.")

Ultimate Load: The load point expected to cause complete fracture of some part of your aircraft. (This usually is the point at which you and your bird will part company.)

The designer tries to assure the ultimate load is 50 percent above the limit load. There are several reasons for why he does this but the most important thing for you to remember is – HE DID NOT DO IT TO GIVE YOU A 50 PERCENT CUSHION TO WORK WITH! He knows that there will be *some* intentional and some accidental overshoot when the going gets hot and you start really honking it around up there. Part of the 50 percent margin of safety is budgeted for that sort of thing. But, there are many other claimants for a share of the pie before you ever get to strap on the bird. Some of the real world things that eat away at the 50 percent include:

- Misdrilling of critical fastener holes.
- Tool nicks at critical fastener points.
- Improperly heat treated metal in structure or fasteners.
- Corrosion paths opened by damage to protective coatings.
- Internal (not inspectable) corrosion cracking.
- Improperly torqued fasteners.
- Structural damage induced by bending and stretching. (You know, that other jock that pulled the 12 Gs and got away with it.)
- Fatigue induced by excessive high G counts.

The list is by no means complete. It could go on and on. I participated in one mishap investigation where our analysis showed the actual designed margin of safety was only 23 percent. Given the usual wear and tear, the bird failed even though the pilot at the time was operating within prescribed limits.

Let me also explain something else about the structural designer. His fondest dreams are realized when his airplane is put through a static loads test and two things happen. First, the bird reaches *limit load* without any permanent deformation after the load is released. And, second (now pay attention you guys who frequently bet on that 50 percent) the aircraft falls apart catastrophically when the load reaches 1 percent past *ultimate load* (1.5 x limit load)!

Why, you ask, does he cut it so close? Well, the reason is those were the figures he was given to design to. If he actually achieved a 60 percent margin of safety (1.60 x limit load), odds are that you are going to carry around 10 percent more weight than you need. One of the best ways a designer can give you high performance is to keep aircraft weight to a minimum. Just in case, at this point, you're thinking of the new lightweight, high strength materials now available, rest assured the designer uses them also but he still keeps weight to a minimum for a given required strength! Now, what do you think about that?

No matter how you cut it, if you are one of those who bet on that 50 percent all being there for you personally to use, you are making a sucker bet. If you and your fellow jocks take good care of your bird, chances are your margin of safety will be there when you really are closing in for a kill and you need to reach down for just a little more. But, if you insist upon spending your emergency fund a little at a time, day after day, when you really don't need to, I suggest you take your money to Las Vegas. The odds are better there! ■

OPS topics

Another Sweeper

■ A sweeper was needed to clear some gravel from a runway after normal working hours. The driver dispatched "was fully qualified to operate the sweeper but had never driven it on the runway or flight line. The Base Ops dispatch crew failed to refer to existing checklists and local forms to be accomplished before releasing the sweeper to continue with his duties. The driver departed Base Ops without a radio-equipped escort or hand-held radio and made his way to the approach end of the runway. Base Ops personnel did notify the tower that a sweeper was enroute to the runway but when the tower crew requested a means of communication with the sweeper they were told to stand by. The tower crew did not see the sweeper vehicle enter the runway. It was dark and the tower is approximately 7,000 feet from the approach end of the runway. Although the sweeper vehicle is equipped with all lights required by appropriate tech orders it was not seen against the background of runway and obstacle marked lights. All vehicle lights were on at the time. A transient A-4 was beginning his final approach. In coordination with RAPCON, the A-4 was cleared by tower to continue at 7 DME. The runway appeared to be clear. At 4 DME, tower cleared the aircraft to land and the runway was checked again. The driver was clearing the approach end of the runway after each sweep across the runway. He became aware of the approaching aircraft and turned toward the tower to exit the runway. At approximately 1.5 DME the pilot asked RAPCON if there was a vehicle on the runway. RAPCON queried the tower. Simultaneously, the sweeper's headlights were spotted and the tower directed a go-around. The pilot initiated a go-around at 1 DME. The sweeper cleared the runway and a second approach was flown to a full stop without further incident."

There have been several similar incidents in recent months. This is one hazard we can do without—easily, by making sure procedures are adequate and rigidly observed.

CAT Encounter

Clear air turbulence can still sneak up on us, as a KC-135 crew reported recently. The sky was clear and no turbulence was forecast for the altitude at which the encounter occurred. The aircraft was in a climb, four degrees nose up and 30 degrees left bank when the turbulence was encountered. The aircraft climbed 6,000 feet at 4,000 fpm, although the pilot had adjusted pitch to four degrees down. Wing roll was from 40 degrees left bank to 40 degrees right. Apparently there was no damage to the aircraft, but the experience was no fun for the crew.

. . . What the left hand doeth

One thing that can be said for jet engines is that they'll eat anything. *Anything* includes aircraft forms left where the engine can vacuum them up. A crew discovered this the hard way when an engine compressor stalled on takeoff. After a few busy moments they got the bird back on the ground where maintenance found some 781 pages in the intake. This was a two-man operation, the kind most likely to produce such a situation. One pilot placed the 781 on the nose gear scissor door then climbed into the cockpit. Nr 2 pilot did the preflight but missed seeing the forms. There's an old saying about the right hand and left hand . . .

Gear Up

If your head is up, you may land gear up. Seems we've had several of these in the past year—which is a dumb thing for smart pilots to do. For more see "With The Wheels Up" in the March 1980 issue. ■

GOING ON LEAVE

BY MAJOR ROGER L. JACKS • Directorate of Aerospace Safety

■ With the advent of gasoline shortages, reduced operating hours of service stations and rising gasoline costs, more and more Blue Suiters are seeking an alternative to the automobile when making their travel plans. One alternative rapidly gaining popularity is travel by light aircraft. With several persons or families sharing expenses, it can be advantageous to rent a small aircraft for your travel needs.

As with any type of transportation there are associated pitfalls that, if not avoided, can turn a beautiful vacation into a nightmare. Recently, several Blue Suiters, their families and friends have experienced this situation. Five Air Force fatalities and one individual listed as missing were recorded in non-USAF light aircraft mishaps last December alone. The pitfalls can be avoided by being aware of the hazards and using good judgment in dealing with them.

For many years, the Air Force has recognized the value of strictly adhering to proven flying regulations, flying well maintained aircraft and using competent pilots. In the civilian light aircraft world, this tight control over man and machine is not as predominant. The FAA is just as concerned as the Air Force that aircraft are maintained and flown in the safest possible manner; however, civilian light aircraft pilots are given a larger degree of latitude in self-regulation. Some pilots take this responsibility very seriously; others abuse it.

Whether you are the pilot or the passenger of a light aircraft there are some do's and don'ts that can improve your odds of reaching your destination. It is not a comprehensive list, but rather some basic considerations.

DO

Do make sure the pilot is qualified and current in the aircraft.

Do check that the pilot had adequate rest for the flight, is not on medications and is sober! (Accidents suggest this isn't always the case.)

Do ensure the trip has been well-planned. Winds, enroute and destination weather have been checked, alternate airfields planned— adequate fuel reserves for each step correctly calculated.

Do give yourself extra travel time for winter flying conditions. Low clouds, blowing snow and icy runways can cause extended delays to your travel schedule.

Do ensure the aircraft is ready for flight, i.e., full of fuel, oil checked, surfaces clean and the craft has been cleared for flight.

Do let good judgment prevail over friendship, pride, and ego.

DON'T

Don't overload the aircraft with people or cargo.

Don't exceed the pilot's or the aircraft's limitations. Explicitly, don't fly in weather/instrument conditions when the pilot is not proficient and/or the aircraft is not certified for instrument flight. Holding an instrument rating does not necessarily mean the pilot can fly safely in weather. A pilot must be proficient in instrument flying. It's a "use it or lose it" skill!

Don't insist on trying to fly to your destination in marginal or bad weather. Have an alternative travel plan using another type of conveyance. Better late than never!! Get home-itis will buy nothing but grief.

Don't condone flight activities that you know are unsafe!

By being aware of the hazards, doing some wise planning and using some "good old common horse sense" light aircraft flying can be a fun and expedient way to travel. Have a good leave. Fly Smart! ■

G-Tolerance: a case for short pilots

■ Fighter pilots in current and future generation aircraft are destined to have frequent exposures to high +Gz during aerial combat maneuvering. Current efforts in aerospace research and development are centered around enhancing +Gz tolerance, so that pilots will be able to function more effectively while maintaining air superiority utilizing increased aircraft maneuverability. Previous reports have pointed out the hazards of exceeding one's G-tolerance.* The most hazardous outcome from exceeding one's G-tolerance is loss of consciousness (LOC). A minimum of 15 sec of incapacitation is to be expected with G-induced LOC. From our experience on the USAF School of Aerospace Medicine human centrifuge, a pilot who suffers an LOC episode may not even realize it has happened. For these reasons, it is of prime importance to ensure all fighter pilots have the best G-protective equipment and are fully trained in physiologic straining methods to enhance G/-tolerance.

The anti-G suit alone has been shown to increase G/-tolerance by +1.0 to +1.5Gz. Proficient straining maneuvers can increase Gz-tolerance by 2.5 G or more. Protection, wearing an anti-G suit and performing a proficient straining maneuver, therefore, can enhance G-tolerance by at least +3.0 Gz. Currently recommended Gz-tolerance standards minimally require individuals flying fighter aircraft to attain +7.0 Gz for 15 sec. with an onset rate of +1.0 Gz per sec. These are minimal standards, since in a true combat situation it is likely a pilot may go to higher GzZ levels for longer times and even more importantly, may utilize very rapid Gz onset rates (as high as +10 Gz/sec).

In general, Gz-induced LOC is preceded by greyout (loss of peripheral vision) or blackout (complete loss of vision), but with the rapid Gz onset rates these premonitory symptoms may not be present. If greyout or tunnel-vision does occur in flight, it is certain that LOC could be imminent. Pilots who frequently experience greyout at a specific +Gz level should be aware that they are very close to their tolerance limits, and this may even change on a day by day basis.

Several previous studies have shown an inverse relationship between Gz-tolerance and the individual's height. This is not unexpected physiologically, since the vertical distance from the heart to the eye (brain) in direct opposition to the Gz vector is a critical determinant of GzZ-tolerance (Fig 1). The shorter the heart-to-eye distance, the lower the arterial blood pressure necessary to maintain retinal (eye) and cerebral (brain) perfusion. Tilt back seats were designed with this fact in mind, attempting to decrease the vertical heart-to-eye distance, thereby enhancing Gz-tolerance. The M-1 and L-1 straining maneuvers are performed to increase the arterial blood pressure and therefore increase the driving pressure to the eye and brain. In addition, the muscular tensing used in these maneuvers enhances venous blood return from the extremities to the heart. The venous blood return to the heart is important to cerebral and retinal blood flow and prevents pooling of the blood in the extremities.

In the Crew Technology Division of USAFSAM, we have looked at parameters in addition to height which directly correlate with increased Gz-tolerance. These parameters include, in addition to shorter stature, increased age and more experience (both more flying hours and more fighter aircraft time). These findings point out the tall, young, less experienced pilot as being most susceptible to low Gz-tolerance.

On several occasions over the past years, we have evaluated individuals with low Gz-tolerance. They had suffered Gz-induced LOC episodes in flight. Most of these pilots were tall, young, and less experienced and demonstrated a lower than average Gz-tolerance as measured using a specific centrifuge evaluation protocol. In addition, they had an inadequate knowledge of M-1 (or L-1) straining maneuvers and the correct way to perform them. After normal aeromedical evaluation and Gz-training, most of these individuals were recommended for return to flying duties.

For these reasons, it is especially important for individuals with these low tolerance characteristics to have more than the average amount of attention paid to assuring they have full knowledge of methods to protect

**Footnote: The author will furnish on request a reference list to the scientific literature regarding the facts cited in this article.*

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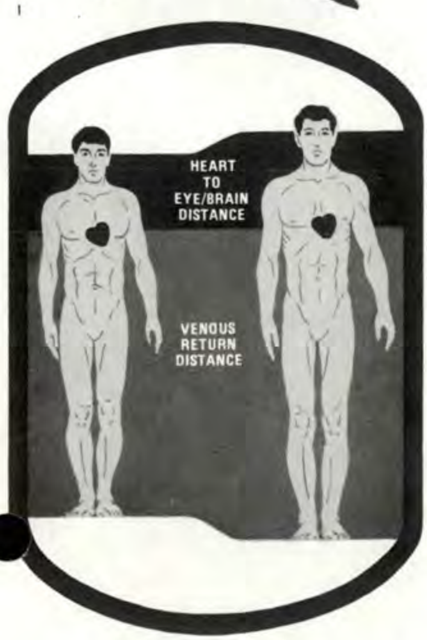
themselves against G_z-stress and are absolutely proficient in performance of M-1 (or L-1) straining maneuvers. This certainly is not to say that anyone is immune from G_z-induced LOC given the appropriate set of circumstances. Everyone should know how to protect themselves from rapid onset high sustained $+G_z$. This training should be very early in pilot training, since several cases of G_z-induced LOC occur in student pilots flying T-37's and T-38's. Re-emphasis of the training would be very advantageous during fighter lead-in.

Anthropometric standards for aircrew selection in general have been set to allow a safe interface between man and aircraft within the cockpit. Current USAF height limits require aircrew to be 76.0 inches (193 cm) or less. From our experience at USAFSAM, low G_z-tolerance individuals have an average height of 71.3 inches (181 cm) whereas high G-tolerance individuals averaged 68.4 inches (174 cm). From a G_z-stress point of view it seems that these height standards serve additionally to prevent putting an individual with physiologic lower G_z-tolerance in an unusually hostile environment. Waiver for exceeding height standards should be carefully considered not only in light of cockpit design limitations, but also on the basis of the inverse relationship of G_z-tolerance and height.

Many factors besides those mentioned above, influence actual G-tolerance. Since height is one factor, taller individuals should make sure they are versed in all methods to enhance G-tolerance including proficiency in M-1 or L-1 straining maneuvers. This could prevent their having a slight disadvantage during high G aerial combat maneuvering. Instructor pilots should be particularly aware of these factors when training individuals who fit the low G_z prototype making sure they emphasize G protection. Most pilots with fighter aircraft experience indicate that much of their ability to cope with G-stress comes with having regular exposure to increased G. Individuals predisposed to low G-tolerance should pay close attention to G protection if they have been out of the cockpit for a long period of time.

Short individuals have a definite physiologic advantage with respect to G-tolerance. This does not mean that taller individuals cannot compensate. It does suggest that enhancement of aerospace safety can be achieved if taller individuals are encouraged to utilize all aspects of G protection. ■







An Inspector's View Of Safety

BY COLONEL GARY R. TOMPKINS
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■ Inspectors, like commanders and safety officers, can't take off their "hats." We deal with the problems of our Air Force everyday and begin to anticipate a worst case scenario – not always without reason. Since the solution to most of our important problems is above our pay grade or won't be fixed on our watch, and since most human errors are sure to be repeated, it is easy to become disillusioned – even cynical. We think we know what's *wrong* with today's Air Force based on our memories of the "good old days." I wonder if we can see what's *right*?

While bemoaning the state of electronic warfare, conventional weapons availability, survivability, experience levels, accident rates, realistic training/evaluation, night CAS and other such pervasive issues, I reflected back to my F-100 days in Europe in the 60s – not that long ago.

ELECTRONIC WARFARE We had never heard of RHAW or PODs (except travel PODs) – much less worked with them. We knew that SA-2s existed and planned to "avoid" them. We thought that going in low and fast would handle the rest (maybe it would have – then).

CONVENTIONAL WEAPONS We had 20MM, MK117s, NAPALM (fill your own type) rockets, a few bullpups (remember radial error? 200 feet at 12 is a bull!), AIM 9s and a super secret "kill all" weapon that a few of us were briefed on – CBU 2. Actually, we never preflighted or flew with these weapons – live or inert – except for an occasional burst of outdated HEI or a one time "gee whiz" AIM 9 shot. There was no dash 34 checklist and we didn't know a fahnstock clip from a fan belt. We did train well tactically (for the time). We dropped MK 76s (a fat version of the BDU 33; for you new heads) and MK 106s; however, release parameters were based on how close you could get to the ground without fouling – who cared about frag patterns?

SURVIVABILITY We had unpainted F-100s lined up on the ramp ala Egypt in '67. Maintenance could never hack it if the jets were dispersed – right? We had gas masks, gold visors (stored in the safe), eye patches and pistols which we dutifully showed inspectors. We even got some tear gas in the squadron to test our mask donning. But it was obviously unsafe to try to operate with the masks on – anyway, lethal gas was against the Geneva Convention and we'd nuke 'em if they used it – right? I had heard of atropine in UPT and I suppose we had some stored somewhere. We ran the TAB Vee tests and discovered that base camouflage made it hard to find the runway and aircraft camouflage made night flying impossible, or so we thought.

LOW EXPERIENCE LEVELS I had a first lieutenant flight commander, captain ops officer and major sq commander (though unfortunately, not at the same time). Of course, it took a lot longer for promotion then (e.g., 7 years to temporary captain). Very few experienced troops came over – there was a PACAF Air Force, a TAC Air Force, and a USAFE Air Force. Most of our captains (about 80 percent) left the service when they PCS'ed (retention isn't a new word!), and we received bright young guys to replace them. They were highly selected (50 percent UPT washout rate; assignments based on class standing) great stick and rudder men, and *very* aggressive. Then came the retreads – FAIPS, B-47 crews, old heads (sound familiar?). Funny thing, they taught us judgment.

HIGH ACCIDENT RATES Our squadron had missing wingman, flybys on my first four Saturdays on the base. Great way to introduce the family to the Air Force! We lost 25 percent of our squadron pilots the first year doing such combat-relevant maneuvers as high G rolls under a 500 foot ceiling and flying under power lines. We worked hard to get our major accident rate below 20 per 100,000 hours for the F-100 fleet but never made it. Of course, we had no tail hooks (at first), rocket ejection seats or sophisticated electronics. Neither did we have to worry about a radar environment. We went uncontrolled through IMC (it's a big sky, isn't it?) in a "local area" which included most of the continent. We found two smoking holes by searching the route of the missing low level MAPs. I stopped counting when 44 of my close associates bought the farm between 1963 and 1968. The last year was combat; however, the line between a combat loss and an accident was fuzzy, indeed.

REALISTIC TRAINING/ EVALUATION You bet! In spite of the rules. Of course, DACT was catch-as-catch-can with no tape recorder or debriefs to figure out why the Mirage III ate you for lunch. ("Energy maneuverability curves" were still to be developed.) CAS was an "impress-the-Army" exercise. If you timed the burner light just right . . . Strafe was the biggee; our four-man NATO team averaged 96 percent. How effective it was against a T-54 tank was not the point. ORIs were actually fun – after the first day! We went to the range and filled a gunnery meet square. Of course, there were all those nuclear safety/ release rules but no base "attack," "enemy" fighters or any of the rest.

NIGHT CAS You must be kidding! By '65 we had heard of the Night Owl tests in Florida; however, our night flying consisted of a tour of the NATO capitals at 30,000 feet. We did practice MISQUE (an early version of ASRT) for a while; accuracies of a few miles were achievable.

We have certainly come a long way in the last 15 years, and yet a lot really hasn't changed. The ethic and spirit of squadron life; the importance of flight leadership; endless briefings and additional duties. The basics are just as important as ever. The problem is that we're playing in a different league with different rules. Against today's requirements we may have slipped a bit.

There are real world, important issues for us to work. Nevertheless, it's constructive to reflect on the progress we've made and pat ourselves on the back, occasionally. It may not hurt to help the new banner carriers – and ourselves in the process – place the current turmoil in perspective. ■

Visibility, Safety and You

BY MSGT FREDERICK N. ROTTET
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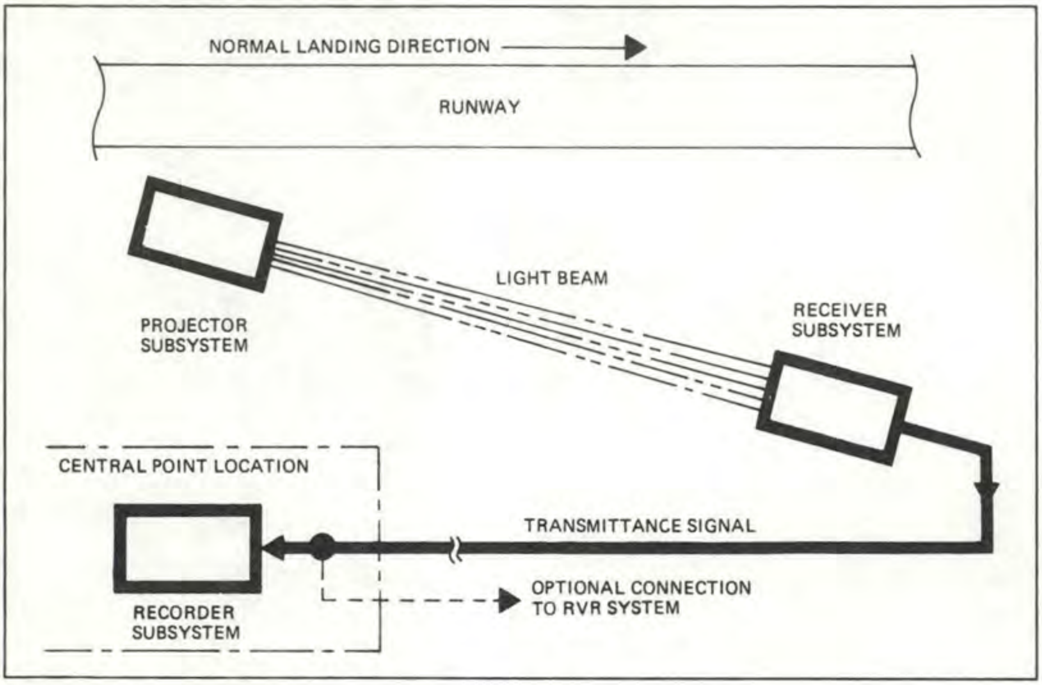


■ Pilots know that visibility is one of the more critical aspects of flying safety. But how many of you are familiar with how visibility and runway visual range are defined and measured? We'll take a look at these terms, discuss how the visibility measuring sets do their thing, and point out some of the capabilities and limitations of the system.

First, the definitions. What exactly is visibility and how is it different from runway visual range (RVR)? Visibility is defined as how far you can see and identify prominent unlighted objects by day and prominent lighted objects by night. For example, being able to see a tree or building against the contrast of the sky. It's a different matter for night situations, when your reference is that of being able to see a 25 candlepower light source. But visibility by itself doesn't take into account the effect that the runway lights have on a pilot's ability to see. Obviously, brighter runway lights let you see farther. This is where RVR enters the picture. RVR represents the horizontal distance a pilot will see down the runway from the approach end. It is based on the sighting of either high intensity runway lights or on the visual contrast of other targets whichever yields the greater visual range. RVR, in contrast to prevailing or runway visibility, is based upon what a pilot in a moving aircraft should see looking down the runway. RVR is horizontal visual range, not slant visual range.

The figure shows the basic siting and components of a visibility system. A constant-intensity beam of light is projected towards a receiving unit which is either 250 or 500 feet away, depending on installation. On a very clear day, the receiver picks up the maximum amount of light and is adjusted to display a 100 percent reading. Any subsequent reduction in the clarity of the air reduces the amount of received light, and thus the percentage displayed. This raw percentage needs to be corrected, because the receiver may be picking up light from sources other than the projected beam. How much "background" light you have can be found by momentarily turning off the light source. Then you subtract this amount of "background" from your original reading, and the result can be converted into actual visibility using a set of tables.

This whole process can be time-consuming, and the possibility of error is always present. To convert this percentage to an RVR reading, a different set of tables for each runway light intensity setting must be consulted. To top this off, there are different sets of tables for day and night!

To overcome these problems, an RVR computer was developed in the mid-60's. A common item at many bases, this small digital set goes through essentially the same procedure as a human operator. It automatically turns off the light source, measures the background light being picked up by the receiver, and stores the result for future use. It then turns on the light source, allows its intensity to stabilize, and measures the raw visibility. Background is subtracted from the data during this phase, and the corrected data is cross-referenced to internally-stored conversion tables. The computer even knows whether it's day or night outside, and knows how bright the runway lights have been set. The RVR value displayed is continuously available and is updated every 51 seconds. Every batch of ten readings is automatically averaged, rounded off and displayed to show trends. The computer warns the operator when the RVR falls below field minimums, when an excess amount of background light is present, or even if the visibility set goes bonkers and puts out an

abnormally high reading!

Sound good? In a way, it definitely is. It can be a more accurate system and is fully automatic, and can certainly relieve a weather specialist of a time-consuming chore. But to get maximum benefit from the data, you have to be aware of the limitations of the system. After all, it's not human like you or me.

First, this visibility set (called a transmissometer) is situated near the end of the runway and adjacent to it. Although dual transmissometers are frequently installed, single systems still exist. But no matter how many you install, they can't be everywhere. Hopefully, a site is selected that is representative of the whole runway area, but some bases have weird phenomena. Thus, you occasionally have a situation where the transmissometer is in clear air and the rest of the runway is rotten! Local pollution, blowing dust, the town dump, the steam plant and a chaotic barbecue can mess up the best of systems.

Second, the light source and receiver units are mounted on metal stands, so that the measurement occurs approximately 14 feet off the ground. If your cockpit is that high, as it is on larger aircraft, you have no problem. But if you're in an A-37 and the layer of ground fog is 10 feet thick, you might be in for a surprise. Certain types of haze and pollution can do just that sort of nonesense, and sometimes nobody notices until you are ready to touch down.

Finally, there are some accuracy limitations in the system itself. The transmissometer loses effectiveness below 1,000 feet, and at the other end of the scale, above 6,000 feet. For example, a 96 percent reading at night converts to 7.0 nautical miles visibility, and a 97 percent reading converts to 9.0 miles. A 99 percent reading jumps up to 20 miles, so the relationship of percent to miles is not uniform. For this reason, the RVR computer is programmed to display a double-minus sign (−−) below 1,000 feet and a double-plus sign (++) above 6,000 feet. Visual observations and direct readings must take the place of computed RVR values on either end of the scale.

Well, gang, does this mean that you take all visibility reports with a grain of salt? Definitely not. The equipment works quite well, the operators are dedicated professionals like yourselves, and the equipment technicians are notorious for keeping the equipment operating at peak efficiency. But being familiar with the system can make the data more meaningful to you and make you a safer, more effective pilot. ■

About The Author

MSgt Rottet is a veteran of 20 years in the Weather Equipment career field, and has spent 13 years of that time in various instructional capacities at the Weather Equipment School, Chanute AFB, Illinois. A graduate of the ATC NCO Academy, MSgt Rottet holds an Associates degree in meterological equipment technology through CCAF and a Bachelor of Science degree in career occupations through Eastern Illinois Univeristy. He is currently the Career Development Course writer for his career field, a subject matter specialist and a technical writer.

It Really Does Use Monkeys And Mirrors

BY CAPTAIN JIM DAVIS • 89th Flying Training Squadron • Sheppard AFB, TX

■ When an aircraft was lost due to a fuel system malfunction, there were few experts who could do other than quote the existing tech orders. As these tech orders proved inadequate, it became evident that a new look at fuel transfer system malfunctions was in order.

So, what follows are some little known secrets of the T-37 fuel system. The T-37 being a ubiquitous airplane, its fuel system idiosyncracies should be of interest to many pilots in several commands. The author wishes to acknowledge the considerable assistance of Major Pat Flanagan, who is currently studying at the Air Force Institute of Technology.

Let's get to the "who dun it" first and then fill in the details later. Under a fuel starvation situation, with rpm between 70 and 80%:

- The fuel boost pump warning light will illuminate 22-25 seconds prior to flameout.
- Near full scale, fuel flow fluctuations will occur approximately 5 seconds prior to flameout.
- The left engine will flameout first, followed immediately by the right.

Flameout will be quick and sudden with no noise or noticeable roughness.

Now, the really sharp ones among you are clamoring, "What about the telltale rise in fuel quantity which precedes flameout?" No doubt your mind is recalling dim memories of how air on the fuselage tank fuel probe causes the fuel quantity to increase – indicating a problem long before the boost pump light comes on. WRONG, JP-4 BREATH. That is an old wives tale and nothing more. The fuel quantity will rise but not because of what you might expect.

Let's start from the top. While there is little doubt that Orville and Wilbur may have dreamed up the fuel system, it is basically a solid design. Here is how it works.

- There are capacitance probes in all three tanks.
- The fuselage tank probe is density compensated.
- There is no fuel quantity transmitter.

What exists is similar to a Wheatstone Bridge based on capacitance. (See Fig 1) As total fuel decreases, the capacitance on the three probes change and the system continually attempts to balance itself through the use of a variable capacitor (the fuel quantity gauge). When you check the fuel in a wing tank, you move the selector switch. This mechanically substitutes a dummy capacitance load for the other two tanks, isolating them from the system. The system balances itself through the variable capacitor (fuel quantity gauge) and, voila, you have the amount of fuel remaining in the selected tank.

But what about this rise in fuel quantity prior to flameout? Yes, Virginia, it does occur. But not at all for the reasons you had thought. The cause of the erroneous increase is not air on the probe. This is a normal occurrence. Rather, it is based on the fact that our type of Wheatstone Bridge is designed with the assumption that the fuselage tank has at least 400 lbs of fuel in it when there is fuel in the wing tanks. Without this situation, the "bridge" becomes unbalanced and the fuel indicator goes bananas (similar to dividing a number by zero). That's the good news, now the bad. The increase can be as little as 100 lbs or as much as 600 lbs and can begin from 5 to 15 minutes prior to flameout. Further, it may take the entire 5 to 15 minutes for the rise to occur. As you can tell, this would not be very noticeable. The best warning is an unusually high fuel quantity indication rather than the actual rise.

So what? As everyone knows, it will take a double failure of the fuel system for a no-notice flameout, due to fuel starvation, to occur. WRONG, AGAIN. Another old wives tale. Let's start with what you've been told all these years.

In the fuselage tank there is a float switch package that consists of three sections. The top section contains the high level float switch. The middle section contains the mid level float switch. The bottom section contains the low level float switch and the fuel low level warning switch.

Here's how it works. Start with a full fuselage tank and begin to burn fuel. As the fuel decreases to approximately 415 lbs in the fuselage tank, the mid level float switch turns on the proportioner pump and replenishes the fuselage tank from each wing equally. Fuel increases until the level reaches approximately 565 lbs where the high level float switch turns the proportioner pump off. This continues until the end of the mission when the wing tanks finally become depleted. At that time, the fuel quantity continues to decrease below 415 lbs. The proportioner pump turns on yet there is no gas in the wings to transfer into the fuselage tank. The fuel quantity continues to decrease. At 380 lbs ± 20 lbs, the level of the fuel reaches the low level float switch. Here several things happen:

- The proportioner pump is turned off.
- The gravity feed valves open, turning on the gravity feed light.

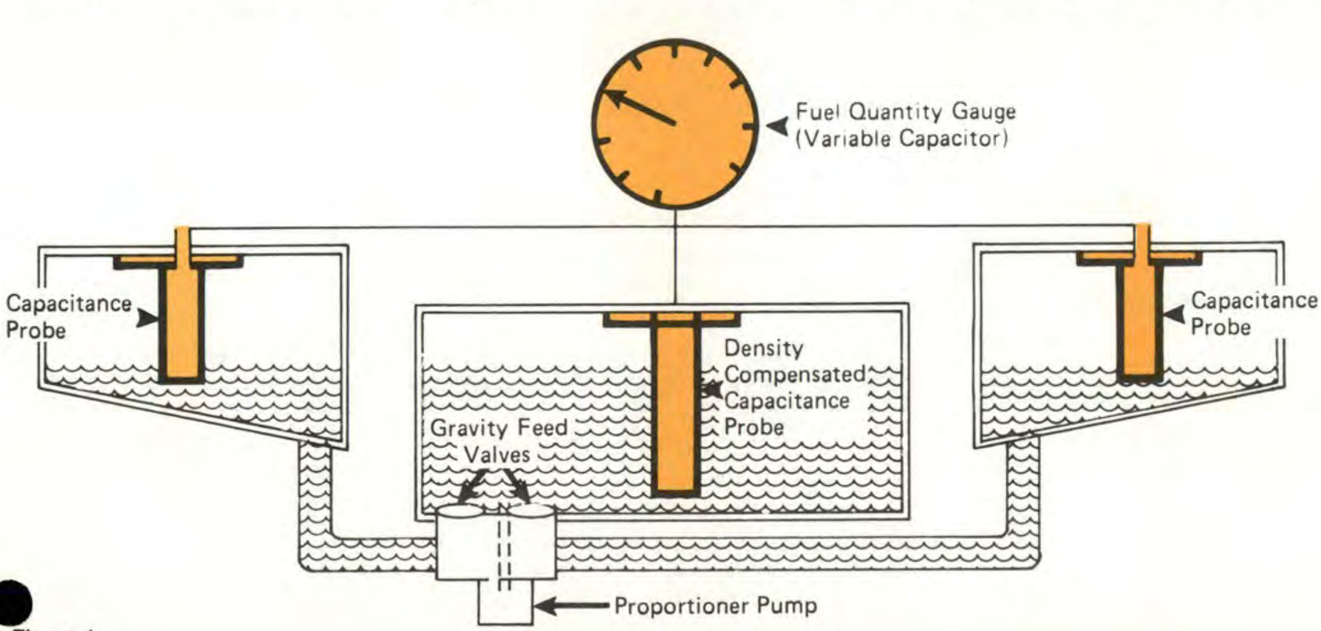


Figure 1

It Really Does Use Monkeys And Mirrors

continued

■ The fuel low level warning light is turned on.

From this final warning, you have approximately 30 minutes till flameout. A quick check of the options (Fig 2) shows that an unannounced flameout can occur under the following conditions:

■ Both the mid level and low level float switches malfunction.

■ Both the low level float switch and the proprotioner pump malfunction.

Let me introduce some new information. There are two types of float switch assemblies in the T-37. (Fig 2) One type has two floats and the other has the three floats (which you were led to believe all along). In the two-float assembly, one float controls the high level switch and the other controls BOTH the mid level and low level switch. A failure of this bottom float and you lose not only your normal replenishment system but you also lose your emergency backup. Let's rock the apple cart one more time. Aircrews have no way of knowing which float switch assembly is installed in a particular aircraft. The stock number of each is identical. One estimate has it that the two types are evenly distributed throughout the fleet. Now you are looking at not a double failure but rather just one sticking float that could have you enjoying a nylon letdown.

On the brighter side, the mean time between failures of the float switch assemblies is over 2,000 hours. Both types fail at approximately the same rate.

It Just Isn't Your Day

Let's say that you have one of those failures that will lead to a no-notice flameout. Clearly, it will show up on your regular 15-minute fuel checks or a level off check, or a before descent check, or an approach to field check. But let's say you've been preoccupied and didn't get around to such trivial matters. The first thing you notice is the boost pump light illuminating. Your memory of the Dash-1 brings a Warning to the front of your head.

WARNING
If the fuel boost pump warning light has illuminated due to fuel starvation in the fuselage tank, continued engine operation is questionable regardless of how rapidly corrective action is taken. Depending on altitude, consideration should be given to immediate initiation of

EMERGENCY AIRSTART procedure.

The boost pump light has illuminated due to fuel starvation. This occurs because you've got air between the boost pump and the boost pump pressure sensor. This slug of air will guarantee that your engines will flameout; but, the T-37 has a pretty rugged engine. For if you select Fuel System – Emergency and Starter-Air, that slug of air will be followed by more fuel and the ignitors will be firing. You have an excellent chance that the flameout will be brief and the engine will immediately restart.

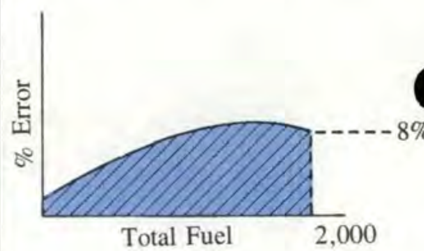
Before you get carried away with this sure-fire cure-all, another WARNING comes to mind.

WARNING
If double engine failure is experienced at or below 2,000 feet AGL, immediate ejection is advisable.

And again, ejection should not be delayed below 2,000 AGL in futile attempts to restart the engines.

First The Monkeys

Two other items come to mind on somewhat related topics. The first concerns the accuracy of the fuel gauging system. A check with the people at Honeywell (who designed the system) yields up the following chart.



Although the graph is not to scale, it shows two useful points. First, the error in the system is at its greatest at the high end of the scale, indicating approximately 8% low. At the low end of the scale, the error becomes significantly less. In fact, the error is proportional to the amount of fuel in the wing tanks and is exaggerated by the pitch attitude of the aircraft. So, as the fuel decreases to the point where it is all in the fuselage tank, the system is most accurate. Tests have shown that as the fuselage tank nears depletion, the percent error decreases significantly. As with the high end of the scale, the percent error is negative, indicating less fuel than is actually on board. Good news for those of you who routinely fly a 1.9.

FLOAT SWITCH ASSEMBLIES

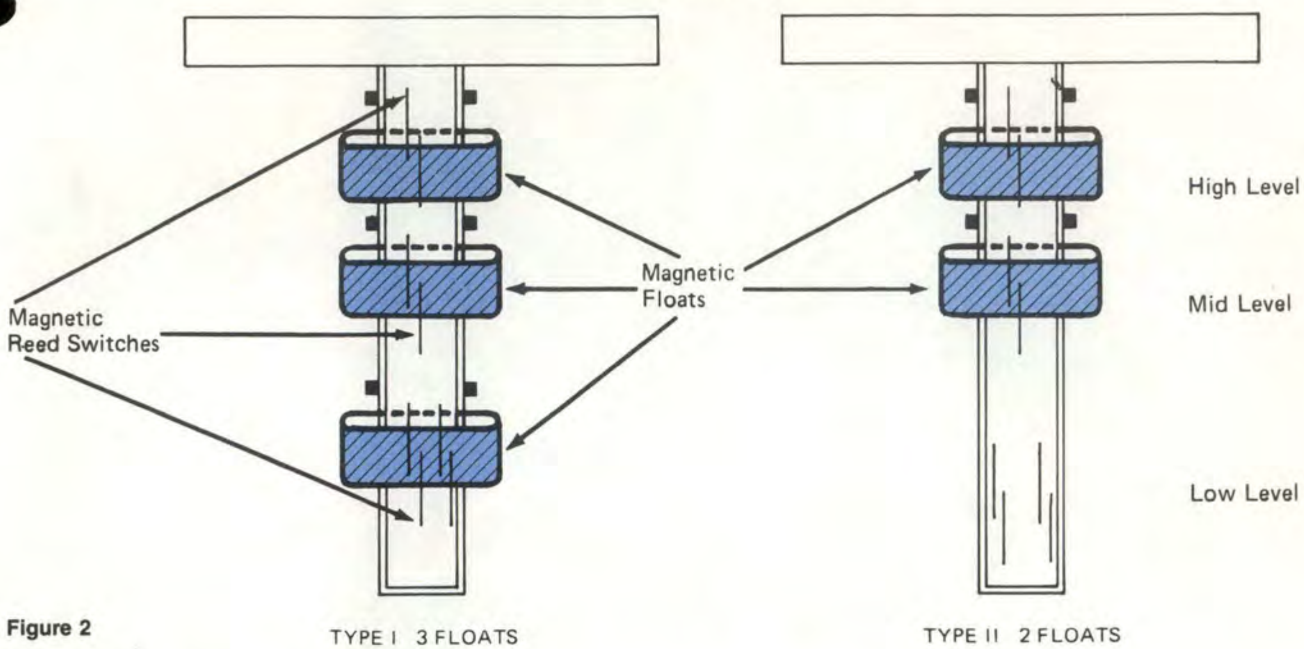


Figure 2

Now The Mirrors

The last topic that I want to cover is one that caused a bit of consternation a few months ago. The situation went something like this:

> While returning from an out base at cruising altitude, a crew encountered boost pump failure as indicated by the fuel boost pump warning light. A check of the fuel total and balance showed all systems, except for the boost pump, working normally. They selected Fuel System – Emergency (gravity feed) and continued the mission heading home. At about 680 lbs total fuel, the fuel low warning light illuminated. Checking the fuel distribution, they found the fuselage tank with 380 lbs and each wing tank containing 150 lbs. They suspected trapped fuel, yet observed the wing tanks to feed normally.

They and you have been taught that gravity feed should keep the fuselage tank full. WRONG, AGAIN. Take another look at Figure 1 and then compare it with Figure 1.9 of your Dash-1, page 1-12. They don't agree. Check Figure 1 again for the position of the wing tanks and the gravity feed valves. Putting things in this perspective, their situation seems quite normal. Not quite. I've heard from a lot of would-be-test-pilots who tried to duplicate this situation with mixed results. Here are a few facts that will help put things in their proper perspective.

- Start with positive pressure in the wing tanks from the wing tip vent valves.
- Add the one-way valves between the six fuel bladders in each wing.
- Toss in a bit of occasional turbulence and uncoordinated flight.

Add all these together and the gravity feed will do what you've been led to believe all along. The moral of this episode is: After you've identified a boost pump light as a boost pump – and not a fuel transfer malfunction – return the switch to Fuel System – Normal.

Oh, yes, If you have a rare situation like the one above, don't expect the last drop of fuel to leave the wings until total fuel decreases to 226 lbs.

Finally, a disclaimer. Although the information in this paper is correct, it is not exhaustive and is not a substitute for the existing tech orders. They should be considered accurate until changed. I hope you have learned a little more about the indestructible Tweet and will continue to search for answers. As the system ages, the mysteries will increase. ■

RED FLAG Lessons Learned

BY SENIOR AIRMAN PETER J. CARROLL • Det 2, 3636 CCTW (ATC) • Nellis AFB, NV

■ Red Flag exercises, conducted at Nellis AFB, Nevada, are the testing grounds for many of our tactical systems, equipment, and procedures. Detachment 2 of the 3636th Combat Crew Training Wing is a part of the gamut which makes up the Red Flag exercises, its survival instructors accompany and monitor the performance of every aircrew member who acts as a survivor in the Red Flag Search and Rescue (SAR) exercises.

The SAR scenarios are written to maximize the realism for both the survivors and the rescue forces, as well as other participating aircraft. The survivors choose their own course of action without guidance from the Det 2 instructors.

One of the major roles of the instructor is to compare the actions of the survivors to various ''school solutions'' which are taught at USAF survival schools and during continuation training. From these comparisons, an analysis is being conducted to determine if the problem areas are a result of insufficient emphasis during survival training, insufficient continuity of continuation training, or inapplicability of training to a realistic environment.

This article addresses several of the problems which have recurred, on a frequent basis, and points out some techniques which may reduce potential future problems.

Evasion Survivors very often fail to apply proper evasion/camouflage procedures considering the tactical environment created by the SAR scenarios. Tracks are a dead giveaway to the enemy. By failing to exercise proper discretion for the desert environment, many survivors leave obvious tracks which are easily followed in the loose desert soil. These tracks can be avoided by using hard or rocky ground and by making use of available vegetation. One method is to step or slide the foot beneath available bushes or shrubs to conceal tracks.

Route Selection and Movement A consistent problem for survivors is the route they select for travel. In a desert environment, rapid movement, walking in the open, and skylining (walking on the crest of hills or knolls) can attract unwanted attention. Additionally, traveling the military crest in desert areas can result in the survivor being seen. By using available vegetation and drainages and slowing the pace, the survivor can move from one concealing bush to another, greatly reducing the chances of being detected.

Location Determination (Map and Compass Use) Survivors have difficulty relating the map to the surrounding terrain. Identifying landmarks, interpreting contour lines, orienting the map, and triangulation are observed as frequent weak areas. It is essential for a survivor to know his position in relation to the nearest Selected Area for Evasion (SAFE) area and Forward Edge of Battle Area (FEBA). Additionally, many survivors do not know the procedures for activating the SAFE areas. NOTE: Aircrew members should check their intelligence shops for the correct activation procedures.

Signal Mirror Past experience in desert SARs has proven the signal mirror to be an invaluable tool for directing rescue aircraft to the survivor's position. Yet, a great many of the survivors are unable to utilize this device with or without reading the directions. Many survivors also have difficulty in finding the bright spot which is used to direct the flash toward any given object. Some find it necessary to practice with the mirror, thoughtlessly flashing nearby terrain, thus exposing their position to the enemy.

Compass Vector When using a compass to vector an aircraft to the survivor's position, most of the problems are caused by a lack of preplanning by the survivor. Survivors do not take the time to identify references for cardinal directions and therefore are unable to give vectors to recovery forces on short notice. Another problem is that some survivors use vectors when simple turns would have been more effective.

Two basic concepts have become apparent at Red Flag. First, it is not always advisable to vector rescue forces directly over one's position during the location phase. It is often better from a safety standpoint, especially the survivor's safety, to vector the rescue aircraft to a holding point some distance away to where a mirror flash can be directed. Another concept is that if the survivor takes the time to locate references for the four cardinal directions prior to the arrival of rescue forces, he can generally provide adequate and reliable directions if he disregards the compass heading and directs the SAR aircraft simply to "come northwest."

Security Many survivors do not anticipate an English-speaking enemy nor do they consider that the enemy may have automatic direction finder (ADF) capability. When the survivors communicate over the transceiver, their transmissions are too lengthy and they are easily deceived by the simulated enemy, who can confuse both the survivor and the recovery forces. This results in unsuccessful recoveries and shootdowns. Survivors sometimes unknowingly transmit valuable information to the enemy when they are talking to rescue forces. Additionally, enemy forces may attempt to deceive the survivor and convince him that they are the rescue forces.

Authentication Problems associated with survivors using improper authentication procedures were discovered shortly after the first Red Flag exercise, and an increased emphasis is now being placed on authentication at the survival schools. In the meantime, the aircrew member should consider reverse authenticating the rescue forces before volunteering any sensitive information to them. (Example: "Rescue, what is the sum of the last two digits of my SSAN?")

Directing Strikes Known enemy positions are of extreme importance to any incoming friendly aircraft. Such information, when passed effectively, will reduce the chance of any further downed crewmembers. Very often this information is available to the survivor but is not passed along to the rescue forces. At the time information is needed most, survivors are busy with many distracting duties such as radio operation, concealing themselves, and picking up equipment; however, omitting this information could bring disaster to what can be a successful rescue.

The majority of survivors give away their position prior to rescue. Doing this enables the enemy to choose several courses of action such as surrounding the survivor and waiting for rescue forces to attempt his extraction, then shooting down those forces creating more survivors who will need help, and so on.

At Red Flag, we have been fortunate to observe many a successful rescue, but we have also observed a significant number which may have been unsuccessful if the threat had been real. Increased emphasis on tactical environments during both formal and continuation training may be of substantial benefit in reducing the frequency of observed problems. One point seems to stand out, at least to the observers of Red Flag: *Many of the problems result from the survivor not being prepared for the rescue forces to arrive*. By mentally reviewing all of the actions which may be asked of him, in particular, signaling, vectoring, and communicating, the survivor will greatly increase his chance of a successful rescue. ■

Unchained

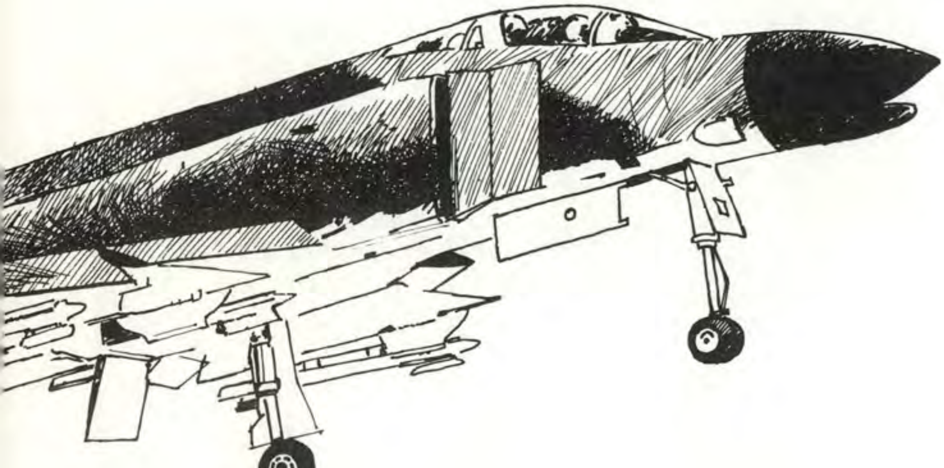
■ Everybody knows that a chain is only as strong as its weakest link. In the safety field we look for such a weak link since mishaps are caused by a chain of events all linked together. Take away one link and there is no mishap. Well, the only link that was missing here recently was a distance of about 75 feet between a landing F-4 and a SOF truck on the runway.

To set the stage for this near-mishap (and a reported HATR). SAC operates at our base as a tenant unit to the host F-4 wing. Working relations are good, and the two flying operations normally run smoothly side by side. But in any operation there is always room for the unexpected (AKA "Murphy") to occur.

Here's what happened.

The SAC SOF was parked in his vehicle alongside the TAC RSU when the TAC RSU Officer (RSO) came up to the truck. He asked the SOF to drive him onto the active to remove an F-4 drag chute which was on the runway and holding up their flying activities. When the SOF said okay, they both drove toward the taxiway, and the RSO informed the SOF that the runway was restricted to low approach only (500 feet AGL).

As they approached the active, the SOF called Tower for clearance. Tower cleared him on to the active, and stated "F-4 on final, restricted low approach." As they drove down the active toward the approach end, they could see the F-4 – three miles – two miles – ONE MILE!!



"HEY, I THINK THIS GUY IS GONNA LAND!!!" The SOF truck took a sharp left and got about 60 feet from centerline when the F-4 touched down practically abeam the truck and on the opposite side of the centerline – that little distance between your reading this here and reading about it in a Class A mishap report.

But let's look behind the scenes at all the little murphies that allowed a mishap to almost happen.

The F-4 was returning from the firing range where a "beeper" had tied up the Guard frequency. He turned it off and simply forgot to turn it back on.

The approach was being flown by the GIB for training, and the radar controller handling the approach was a trainee.

The aircraft was high and to the right of course when the pilot took control at three miles and 1,000 feet. He had planned and requested a full stop and was now concerned that, due to his position, he might not be able to complete the approach to landing. He decided to disregard further controller instructions and fly it visually.

It was about this time that the Tower notified PAR of the clearance for a restricted low approach,

Melody

or How to Amost Run Over Your SOF

BY CAPTAIN JOHN W. McGEOUGH, JR.
66BMW FSO
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"vehicle on the runway," and they cleared the SOF truck on the active.

PAR relayed the clearance to the F-4. There was no response.

When the tower controllers realized that the pilot might try to land, they broadcast go-around instructions over Guard, and PAR again gave him go-around instructions.

The pilot acknowledged neither of these (he couldn't hear tower) and completed his approach and landing. Ironically, the only other individual who might have been able to send him around – the RSO with his flare gun – was out of position on the runway!

If we analyze some of the above actions, one thing is evident. The pilot was so intent on taking control from the GIB and getting the plane down – "landing fixation" – that he was totally oblivious to any other communications about him. And even though he never actually got a clearance to land, he had asked for one. Not hearing (or rather comprehending) any instructions to the contrary, he assumed he had received a clearance.

Turning to PAR, there is room to second-guess their actions also. Controllers will sometimes request acknowledgment of a CHANGE IN CLEARANCE from the pilot – but not always. Here we didn't even have a change, since landing clearance was never issued! And since it was not required, the controller did not press the pilot for an acknowledgment.

PAR did notice that the F-4 had gone below the 500 foot restriction. However, they took no action since their interpretation of a "Restricted Low Approach" is "500 feet above the field, *at the runway threshold*." It had not been uncommon for pilots to go below that altitude on an approach and then climb up to it before the runway threshold. By the time Tower started calling go-around instructions and PAR picked it up, the pilot was so intent on landing he heard nothing.

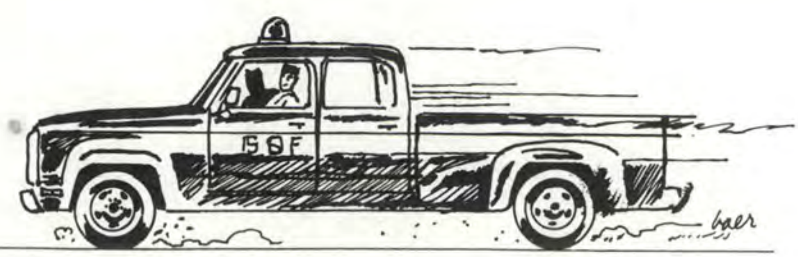
The restricted low approach concept is addressed in neither AFM 51-37 nor TERPS. This is important because if we have no specific definition we will have only interpretations – and these can be dangerous. Is it a decision height or an MDA? And should the controllers notify the pilot if they observe him going below the restricted altitude?

Another area we second-guessed was the tower. They cleared the SOF truck on to the active when the F-4 was three miles on final. They assumed he had received, understood, and would comply with the instructions relayed by PAR. But is that good enough? Is it safe enough? Perhaps it would help if the tower must have a confirmation by the pilot acknowledging the restricted low approach (to either the Tower or Approach Control) before they clear anybody else on the runway. And perhaps PAR should request acknowledgment anytime a clearance out of the ordinary is given to an approaching aircraft.

So what have we learned from the above? That the whole episode was a simple case of a pilot landing without clearance? WRONG!

Everyone of the factors (or Murphyisms) stated above is a link in that chain of events: Guard turned off; RSU unmanned; failure to receive an acknowledgment from the pilot; landing fixation, etc. None of them by themselves are barnburners, but when they all link together you have all the fixin's.

How strong are the links at your base? ■



A Personal Review

When Squadron Leader Peter A. Barratt of the Royal Air Force left his job of publishing the RAF's *Transport Aircraft FS Summary,* he summed up some of his experience concerning flying safety. We think his words make a lot of sense, so we are reproducing portions of his editorial from *Aerospace Safety,* June 1978.—Ed.

■ Let me begin with a rhetorical question—what is Flight Safety? I believe that we should not have flight safety, per se, at all. None of us, except for the occasional psychopath (and I trust that we have none of those) sets out to kill, maim or injure himself or his professional colleagues. It therefore follows that we aim for safety in our daily round, whatever that daily round might entail. It further follows that, for those of us whose daily round is aviation, our primary unstated objective is flight safety.

It has become somewhat fashionable to make "airmanship" the preserve of those who actually get airborne. I disagree; I believe that it is in making this mistaken assumption that we have been forced into creating a generic name such as flight safety. For me, flight safety is simply good airmanship; conversely, airmanship is the practicing of good flight safety principles. The two are as inextricably linked as to be one and the same thing. As an island race we have always depended upon the sea, and our sea-faring traditions go back a long way. Perhaps that is why, with only three generations of airmen, airmanship is far from being on a par with seamanship. And yet I believe it should be. I would like to suggest that we take a leaf out of our nautical brothers' book and instill a spirit of airmanship in all those who have any dealings with aircraft—if you like an "air-in-the-bones" philosophy in lieu of "salt-in-the-bones." We could then dispel any idea that flight safety was a subject in its own right with its own mystique and we could put airmanship back where I believe it properly belongs—in the cockpit, on the flight line, in air traffic control, amongst the support personnel and so forth—in short, with all those whose job is associated with putting aircraft in the air.

A few months ago I wrote . . . about the reason for putting men, rather than machines, into cockpits and onto flight decks. Even as I did so, I realised that I was not stating the whole truth. I stated that the advantages that men had over machines was in their adaptability, their flexibility and their analytical approach to problems. And yet we are in danger of replacing those adaptable, flexible and analytical men with "mechanical" men who merely follow the book by rote. Already we have seen accidents caused by a blind adherence to FRCs (flight reference cards [checklist]) rather than a systematic approach to the problem. You may be lucky, your emergency may appear in FRCs, but on the other hand it might not. Certainly, the secondary effects of any malfunction and any action you may take can only be known by understanding the systems and logically thinking the problem through. Think up "new" emergencies for yourself and follow then through; try them in the simulator if you have one. Every one to which you have given prior thought is one less with which to be taken unawares. Once again this is all airmanship—I believe we must bring back the man who is capable of logical and intuitive thought; we cannot afford automatons in our cockpits. . . .

AIRCREW HAVE FINAL RESPONSIBILITY

Let me now turn to one of the specifics of the flight safety world—aircrew error. To err is human, as we have often been told, and I cannot see anything that will radically alter man's fallibility. Aircrew error has become a very emotive issue. It is the aircrew who have the final responsibility and, more often than not, it is the aircrew who also have the unenviable task of trying to sort out the situation when it is all going to worms. But we have become too accustomed to shooting the pianist even when the piano is out of tune or when the score is wrong. Simply because the accident situation occurs at the final man-machine interface (i.e., pilot-aircraft) we should take more care before we rush in and blame the pilot. Conversely, when the pilot is skillful enough to rescue a situation that was not of his own making, we should be much more ready to heap acclaim upon him. Furthermore, I would like to extend this argument to those other members of the chain referred to earlier.

Virtually every accident has a human cause. The human error can occur when the specification is written, when the specification is turned into a design, when the design is turned into metal, when the product is tested, and finally when the aeroplane is put into service. Even here the human error can be made by any one of a thousand people involved in the aircraft operation, its maintenance and all its other support services. Fortunately, each stage acts as a cross-check, seldom is any one man acting in isolation and, furthermore, we impose a system of controls and feed-back loops, all of which serves to eliminate the potential accident. However, we know from experience that, however small the mesh, sooner or later one will still slip through the net. Even then the accident may be avoided because its potential may be recognized in time and the appropriate remedial action taken. However, the human-being will continue to show its limitations – limitations in perception, limitations in understanding, and limitations in reaction and implementation. No, let us think twice before shooting the pianist, seldom will he not have been giving of his best even if his best still costs us an aeroplane. On the other hand, any breaches of discipline should be dealt with swiftly so the distinction can be made more easily by those on the sidelines.

WHAT IS FLIGHT SAFETY?

Perhaps we should return to the current definitions of flight safety at least as we see them in the Royal Air Force. The aim of Flight Safety is the reduction to a minimum of human and material losses due to aircraft accidents. The chief reason for an active pursuance of such a policy is simply because we can ill-afford either type of loss. Accidents erode our already overstretched finances, they eat into that intangible called morale, and furthermore we have an accountability to the general public who want their money used for their defence rather than for us to throw it on the scrap-heap.

AS PROFESSIONALS WE TAKE PRIDE

Having said that, I believe that few, if any, of us are actually conscious of these factors in our own flight safety philosophy. I said it earlier but it bears repetition – none of us actually wants an accident to occur. The real accident prevention motivators, I believe, are such things as the value we put upon our own and our colleagues' lives, and, furthermore, as professionals, we take a pride in doing the job to the best of our abilities. But it is in this same area where all too often we fall down. As members of the aviation community, flight safety is part of the community spirit. Only a few of us are assigned to fly the aeroplanes but all of us have a responsibility for their safety. It is a small air force these days and when an accident occurs the word travels fast. Often we will know the pilot or a member of the crew. Some of us will look at the cause and say – "I thought that would happen some day" or "That almost happened to me, but . . ." How many people to whom it nearly happened or who thought it would happen actually told someone about their experiences or their fears? Where was their sense of community spirit? Are their consciences clear when the question is asked "Could this accident have been prevented?" Sometimes to voice our thoughts in this way will necessitate an integrity of the highest order. Sometimes to do so will be to appear foolish to our peers and our masters alike. But surely our sense of community spirit can overcome that, surely our commitment to aviation is bigger than that, and just as surely our peers and masters must respect our appearing foolish for the great degree of moral courage it really is. If ever a climate is engendered that tends to keep our mouths sealed we must do all we can to break those seals. A prerequisite of flight safety is commu-

continued on page 22

A Personal Review continued

nication and in an age of ever advancing communications, it is sad to see us performing so badly at the simple art of communicating. By failing to communicate, all we can be sure of is that we are, in effect, condemning a friend or colleague to death. And when the tragedy occurs, those of us who had the knowledge which could have prevented it, but kept it to ourselves, are as the perjured witness, the crooked judge and the biased jurors in a bogus trial leading to the execution of the innocent. . . .

FLIGHT SAFETY . . . WHERE IT BELONGS

Let us, therefore, abolish flight safety and recreate airmanship. Let us put flight safety back where it belongs in our personal approach to our jobs. Do pass on your good ideas all the time, not just when we visit, for not to do so is a form of complacency. Let us recognize that, for as along as men are part of aviation interface, we will have human error accidents, but let us not shoot the pianist simply because he produces cacophony rather than harmony. Let us open up our own hearts and see if they contain any useful pointers towards the causal factors of accidents and then let us tell someone of responsibility to tell us of their mistakes so we may forewarn others. Finally, let us take the broader view so that we all contribute to a learning curve for our profession in toto rather than each having his own. . . . ■

AREA NAVIGATION PRIMER

■ ". . . The aircraft knows where it is at all times. It knows this because it knows where it isn't. By subtracting where it is from where it isn't (or where it isn't from where it is—depending on which is greater) it obtains a difference or deviation. The area navigation system uses deviations to generate corrective commands to drive the aircraft from a position where it is to a position where it wasn't; consequently, the position where it was is not the position where it isn't. In the event that the position where it is not is not the same as the position where it originally wasn't, the system acquired a variation. (Variations are caused by external factors, and the discussion of these factors is not considered to be within the scope of this report), the variation being the difference between where the aircraft is and where the aircraft wasn't. If the variation is considered to be a significant factor, it, too, may be corrected by the area navigation system. However, the aircraft must know where it was also. The 'thought process' of the system is as follows: because a variation has modified some of the information which the ANS has obtained, it is not sure where it is. However, it is sure where it isn't and it knows where it was. It now subtracts where it should be from where it wasn't (or vice versa) and by differentiating this from the algebraic difference between where it shouldn't be and where it was, it is able to obtain the difference between its deviation and its variation, this difference being called error."—Douglas Service Magazine Nov/Dec 78, by way of TWA *Flight Facts* Aug 79. ■

F-4 Rollers: wheels, tires, brakes

BY LT COL HORST GAEDE, GAF
Directorate of Aerospace Safety

■ The Air Force has come a long way, so has the F-4 Phantom. To make that air machine predictable when it's on the ground and give it a smooth ride, we installed a landing gear and subsystems like wheels, tires and brakes (not to mention the nosewheel steering) – things I want to talk about in this article.

Looking at the statistics, we were not always too satisfied with our three "goodies." Over the last decade, we destroyed or extensively damaged four airplanes on the ground due to tire/brake failures, losing directional control and running off the runway. We "graded" another three mishaps under the Class B file and, last but not least, counted hundreds of Class C's. We improved considerably, however, over the last five years, bringing the antiskid mishaps down from about 40 in 1975 to less than 20 for 1979. Tire failures (sometimes hard to separate from brake failures) are down from 49 (1975) to 12 (1979).

We were lucky not to lose an airplane for one or a combination of the above failures for over three years now, but let's face it, the potential is there! And, you could be the next one to run into it. So, read on. Let's look at some of the problems that we've got and what to expect.

An on-wheel tire gage will assist in keeping proper main gear tire pressures.

Wheels The F-4 MLG wheels were holding up pretty well over the years, but signals are they don't last forever. Prior to 1979 there were only one or two isolated failures that were attributed to heat damage or machining defects in the lockring groove. Otherwise, the current configuration wheel has been trouble-free.

Over the past 12 months, however, there have been 28 deficiency reports. Of these, 14 failed on the aircraft, and the other 14 were found in the NDI shop. All failed wheels were manufactured between 1971 and 1974. If the current trend continues, we should see about 20 fatigue failures this year. But wait, don't get frightened all the way! The item manager and commands are well aware of the situation and an improved inspection method has been introduced to condemn the bad ones early enough. Additionally, it looks like all wheels are going to be replaced as they reach 10 years of age. The wheel itself probably will not change since the current design is still considered optimum for the operational envelope. Besides that, it might make you feel better to know that these kinds of failures generally occur at taxi speed, because that's when they are subject to the highest stress. So, let's keep 'em rolling!

Tires Tires don't last forever, either. But tires are usually changed before they can hurt you. Still, we have had times when tire failure rates were overall unacceptable, each of them bearing the potential for a run-off-the-runway situation. Anyway, today's "Goodyears" can be taken for the best you could probably ask for, and even retreads are found to do their job.

The primary tire failure mode, therefore, is considered to be underinflation, a condition almost impossible for you, the aircrew, to detect (even crew chiefs have a hard time doing that). In order to cope with the underinflation problem, you can expect a permanent on-wheel tire gage to be added to the main landing gear wheels. This gage is presently designed, or, better, redesigned, and when installed will provide a good means of ensuring adequate and equal pressures inside your

continued on page 24

F-4 Rollers: wheels, tires, brakes continued

"rubbers" before you take your bird up into the sky.

Brakes/Antiskid Provided wheels and tires are in good shape, you still want to have a good selection of braking options on hand to keep you on the "straight and narrow" in more than one way. True? After all, it took some years to upgrade "big ugly" with the "state-of-the-art" Hydro-Aire Mark III Antiskid System, but you've now got it!

It provides several distinct advantages over the old Mark II, namely touchdown protection and crossover locked wheel protection. In addition, the Mark III System exhibits better reliability, simplified maintainability and shorter stopping distances. From the standpoint of pilot "feel" the new system differs little from its predecessor except that the sensitive pilot will probably notice a greater smoothness. Brake pressure is controlled more closely and modulated at a level which maximizes aircraft retardation force.

What the system won't do for you? It won't prevent hydroplaning. Differential braking still results in longer landing rolls. And, be assured that all engineering genius and black boxes cannot replace your pilot skill and judgment once the wheels are on the ground.

Talking about that, I don't consider it very smart to step on the brakes in order to check 'em out right after touchdown, when still at high speed. Some folks seem to have a habit of doing so, at least that's what you read in the mishap reports. Fact is, that braking effectiveness is reduced with increasing velocity. Particularly with a "smooth" system like the Mark III the reduced braking effect, at let's say 150 knots, could easily be misinterpreted as a system problem and a wrong course of action could result (off with the antiskid, down on the pedals again and boom – goes the tire!). Furthermore, many brake operators don't realize how little pedal deflection it takes at 150 knots to lock a wheel if the antiskid is not functioning as advertised. As little as one-quarter inch may already be too much under some conditions. So, why take a chance on ruining your day by getting into the blown tire-directional control loss-depart the runway game? Let the drag bag do the job for you when speed is high (that's when it works best, by the way). Slow down below 100 knots if at all possible before you check the brakes. A malfunctioning antiskid won't hurt you then because it takes almost maximum system pressure at that speed to skid a tire. Should you at that point find out that there aren't any brakes, you still have plenty of time to go through your procedures.

Keep "big ugly" straight, get down the hook, come off the brakes before you select the emergency brake system. Those things are strong but touchy. There is no need to blow the tires now, and after all, you still have a cable or two waiting for you.

To make a long story short: Your Mark III antiskid is a well designed, reliable system, capable of controlling landing roll and stopping distance of your bird. Use it wisely, but be prepared for malfunctions. Expect the unexpected! There are still many things which can go wrong (and they will now and then). A faulty valve could block off braking pressure, a speed sensor could be installed improperly or malfunction, a little wire could be broken.

Sometimes the ANTISKID INOPERATIVE warning light will not tell you the true story.

To summarize again what you can do to avoid surprise from your "rollers":

Check your system thoroughly at preflight (tire condition, wire and connectors, brake stacks, emergency brake lever position, etc).

Plan on using all runway available for your landing roll.

Know your procedures and have a plan of action prepared in your mind ahead of time.

Happy landings! ■

Four F-4 Class A mishaps in 10 years have resulted from tire/brake failure.

Fatigue In Aviation Operations

BY CDR ALAN STEINMAN
Special Medical Operations Branch
United States Coast Guard

■ Fatigue can be operationally defined as a condition characterized by a deterioration in skilled performance resulting from the combined effects of physical, physiological and psychological stresses. Such a definition avoids the strict, narrow usage of the term found in scientific literature and instead permits a discussion of the condition in the total context of the aviator and his environment. Many factors contribute to the development of crew fatigue: sleep loss, physical exertion, altered work/sleep cycles, boredom, anxiety, task oversaturation, hypoxia, discomfort, dehydration, hypoglycemia, recent illnesses, emotional problems, etc. These factors can be present individually or in various combinations. The important element throughout is a resultant degradation in crew performance.

The signs and symptoms of fatigue fall into three general areas: (1) Decrements in psychomotor functions, manifested by decreased coordination, inappropriate aircraft control inputs, etc; (2) Narrowed attention span, manifested by omitting steps in sequential tasks, failure to completely scan instruments, fixation of attention on a single item to the neglect of others, etc; (3) Acceptance of a lowered standard of performance, manifested by decreased concern for flight safety, "cutting corners," increasing preoccupation and distraction by minor discomforts, irritability, etc.

The treatment or relief of fatigue necessitates correcting each of the precipitating factors. Often times, however, the symptoms are reversed by a sudden change in performance requirements. An in-flight emergency, for example, may, for a brief period, eliminate all signs of fatigue, allowing the crew to function at or near their pre-fatigued capacities. The same phenomenon may occur in preparations for a difficult landing or in other psychomotor skills requiring a brief period of maximum performance. Eventually all of the relevant physical, physiological and psychological stresses must be relieved before fatigue can be completely alleviated.

Fatigue can be further subdivided into acute and chronic states. Acute fatigue usually implies single mission performance degradation, and it is manifested by any or all of the symptoms listed above. A common precipitating factor in acute fatigue is participation in a mission during normal sleeping hours. Such an upset in the working/sleeping cycle creates a physiological stress which is often compounded by accompanying physical stresses, as may be found in foul-weather operations, wearing a tight wet suit, etc. Chronic fatigue is the accumulation over a long period of one or more stress factors without adequate time for recuperation. Sleep loss and psychological stresses are often the most precipitating factors. In addition to causing the typical signs and symptoms of fatigue in its own right, chronic fatigue lowers the threshold for the development of acute fatigue among air crews.

Broadly defined in this manner, fatigue is probably the most common factor in pilot caused aircraft accidents. This is particularly true in Coast Guard operations where instant response capabilities are maintained throughout the day and night. Crew rest regulations offer only partial remedy to the problem, since these regulations address only a few of the possible precipitating stress factors. In order to minimize the effects of crew fatigue on aviation operations, aviation personnel must be continually aware of its potential, must be frequently reminded of its manifestations, and must be willing to admit that occasionally they are fatigued and hence are unable to perform to safe standards. Ultimately the responsibility for minimizing fatigue and maintaining maximum performance rests with *each* aviator and aircrewman. This supposes that all aviation personnel are familiar with the causes, signs and symptoms of fatigue in general and with fatigue's specific manifestations in themselves, unfortunately this is rarely the case. Therefore the problem of fatigue will always be a part of aviaiton operations, and will always be a major item of concern for flight surgeons and for flight safety officers (and Commanding Officers – Ed). – Courtesy DOT Coast Guard *Flight Lines*. ■

Mail & Miscellaneous

Send your ideas, comments and questions to:
Editor, *Aerospace Safety* Magazine, Norton AFB, CA 92409

PW ARTICLE

■ In response to Mr. William E. Hardy's article (PW: Encounters of the Worst Kind) in the January issue of *Aerospace Safety*, I would like to relate some observations based on my personal experiences as a PW.

The training received in our survival schools can, in fact, save your life. Not just in learning how to survive in the forest, the jungle or the frozen wastes of the north, but in learning how to cope in a situation that seems endless in a war that is fought 24 hours a day, every day for years: captivity.

When I went through the PW portion of survival training many years ago at Stead AFB, I entered a phase that was to be repeated for real less than a year and a half later but would last considerably longer than those three days of training—in fact, it lasted almost seven years.

My initial interrogation in Hanoi was quite similar in many ways to my first round of interrogation at Stead. The first few months were just like survival school—only for real. During initial interrogation sessions the North Vietnamese grilled me for and got unclassified military information, the validity of which was highly questionable, but satisfied their demands. Interrogation sessions a few months later and the events surrounding them are an example of what Mr. Hardy talked about in his article.

One by one, the men in my camp were pulled out and asked to write a war crimes confession. Eventually it was my turn, and my immediate reaction was to say no. For the next couple of hours, the interrogator and I talked about it as he attempted to appeal to my intellect. After that time, I was put in a side room and told to think about it as I sat on a cement stool while a guard watched me.

By late afternoon after thinking about it for almost eight hours, I was called in and again asked to write. I politely—yes, politely, because one gains absolutely zero from being antagonistic—answered no. That answer infuriated the interrogator, who then called in two of the guards to administer the punishment he had promised earlier in the day if I refused to write, as I had just done. I had called his bluff, but very quickly was questioning the wisdom of that decision. The guards forced me on to my stomach, pulled my hands behind my back and up around my shoulder blades. One cuff was placed on my wrist and tightened down as tight as humanly possible. The other handcuff was twisted and applied to the other wrist cross-wise. In this position it would cut into the sides of your wrists. This cuff was also cinched down as tight as possible. To ensure this (to get the cuff as tight as possible) the guard stood on it to apply as much pressure as possible. In this particular position if you relax your arms and start to drop them to the small of your back the twisting of the cuffs causes the cuffs to cut into your wrist, causing excruciating pain. I was then placed back into the side room with the cement stool and told not to move. They had a guard watching me most of the time. Whenever the guard

was not there I would use a table in the room to lie on my chest so that my arms could rest on my back and release some of the pressure. I could only do this for a minute or two since the guard continually monitored me. Several times I was caught standing up and the guard would come in and slap me around. After three days my feet had swollen to the point that I could not see my ankles. My hands

were like balloons. They would take me out periodically and ask if I had changed my mind and would write, I'd say no. On the next day, after I again declined to write, the guard took a piece of rope and tied each end above my elbows and tightened it until my elbows touched. I was still in the cuffs. I was placed back in the side room on the cement stool. Six days with no sleep; I passed out, hit the floor and opened a gash on my head. The noise brought the guard who was mad because I was not in the sitting position. He came in and began to knock me around. I agreed to write a statement of apology for bombing in North Vietnam.

It wasn't what they wanted, but they got a statement, and I was really feeling low. I felt, as Mr. Hardy said, that I might have "avoided" that statement had I "resisted harder, longer," even though I had resisted and didn't have the attitude of Bill Hardy's Missourian who did not resist.

What I'm saying is, even when a PW has resisted "to the utmost of his ability" there can be a conflict within oneself. My conflict was relieved, however, when I realized that if they want something badly enough, they can get it—but make them work for it and don't hand it to them on a silver platter.

Let me leave you with something I tell audiences that listen to my experiences and who say they could never do what I did. "Never sell yourself short; you don't know what you can do until you have to do it."

(Drawings are based on originals supplied by Cmdr Gerald L. Coffee.)

Jerry D. Driscoll, Lt Col, USAF
AFISC/SEF
Norton AFB, CA 92409

HAIR BARRETTE

I have enjoyed your magazine for over 20 years. It is a valuable management tool for Ops frogs and maintenance toads.

I just wanted to bring to your attention an observation that is becoming more evident with the increased influx of females into the maintenance workforce. I direct your attention to the back cover of the Jan 80 issue of *Aerospace*. A female is shown launching an aircraft, which is okay, but, in her hair is a large barrette. Not only is this a violation of the uniform wear reg, it is a definite potential for FOD.

I realize that the photo credit was given to the USN *Mech* magazine. Is it possible that the Navy needs some FOD awareness training?

Keep up the good work in producing an excellent magazine.

Donald D. Stockhoff, CMSgt, USAF
Quality Assurance Superintendent
Griffiss AFB, NY

MORE ON HAIR BARRETTE

My pals and I were reading the Jan 80 issue of *Aerospace Safety* and wondering if the maintenance type on the back page really typifies safety with a hair barrette on the flight line around operating F-4 aircraft in violation of AFM 127-101, para 8-24. Thanking y'all.

SMSgt Buck Schlum Bohm
(960MS Maint Super)
4718 Edgemont Dr., Abilene, Texas

You sharp-eyed devils! Thanks for keeping us on our toes. We'll try to do better. –Ed.

YOU'VE COME A LONG WAY NAV!

Congratulations on your excellent magazine. While it is directed toward aircrew operations, many of the safety principles illustrated can be, and are, applied to ground safety.

As an old Nav myself I enjoyed Captain Riolo's article "You've Come a Long Way Nav!" (Sep 1979). Unless my memory is failing faster than I would like, I believe Captain Riolo might have better luck DRing for Guam in the North Pacific than in the South Pacific. Probably it was just a typographical error.

Please continue your excellent work.

Lt Col Richard W. Money
Commander, RBS Det 1
1 Cmbt Eval Gp
La Junta, Colorado

ERRATA

Reference the article "Fuel Density," *Aerospace Safety,* January 1980, page 23. The values for BTU gal in the chart are in error. They should be 118,989 for JP-4 and 125,594 for Jet A.

THE ORDER OF DAEDALIANS

The Order of Daedalians, the National Fraternity of Military Pilots, will conduct its 46th Annual Convention on 5-7 June in the Del Webb's Towne House at Phoenix, Arizona.

The presentation of five prestigious awards will be the highlight of the final evening's Awards Dinner. The Air Force Reserve has been selected to receive the Major General Benjamin D. Foulois Memorial Award (Flying Safety) which is the oldest of these awards. Senator Barry Goldwater will be the guest speaker. ■

MAJOR

Gary A. Matthes

6512th Test Squadron
Edwards Air Force Base, California

■ On 9 November 1979, while Major Matthes was taxiing back to parking from a ground abort in Last Chance, the number one and number two brake systems failed when he attempted to slow down. At idle power the F-16A will taxi in excess of 50 knots without brakes. Approaching a Y-intersection, Major Matthes turned left to parallel the parking ramp, shut down the engine and started the jet fuel starter. However, when he shut down the engine the main generator dropped off the line and he lost nose wheel steering. The aircraft turned toward several aircraft parked on the ramp. Major Matthes then restarted the engine to regain nose gear steering, and did a tight right 270 degree turn narrowly avoiding the parked aircraft. While notifying the tower of his problem, Major Matthes proceeded to the middle taxiway and out onto the runway for an arrestment, but the tail hook failed to lower. Major Matthes then skillfully maneuvered his aircraft into a clear area between the ILS antenna and the runway approach lights, using nose gear steering, and shut down the engine so the aircraft could coast to a stop. No damage to the aircraft or airfield and related equipment was incurred. The skill and quick actions of Major Matthes saved a valuable aircraft and prevented personal injury. WELL DONE! ■

☆U.S. Government Printing Office: 1980—683-214/7

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

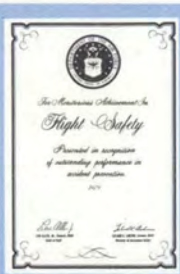
Terence L. Casteel

7575th Operations Group

■ On 12 October 1979 Captain Casteel was scheduled for a local pilot proficiency and low level terrain following mission in an MC-130E. All preflight checks and takeoff were normal until just after lift off when Captain Casteel was forced to use full right aileron to maintain wings level flight. Right turns were possible only with large rudder inputs; however, left turn could be made by releasing right aileron input and using coordinated left rudder. Captain Casteel directed a visual scan of the flight controls and flight control hydraulic booster packs and was informed that both ailerons were deflected upward. An emergency was declared and a left hand pattern flown to a successful landing. Postflight inspection revealed that the left aileron actuator linkage had not been reconnected after maintenance was performed in the left flap well area. Through skillful airmanship and prompt analysis of the situation, Captain Casteel performed the proper steps in handling an inflight emergency: Maintain aircraft control; Analyze the situation and take proper action; Land as soon as conditions permit. With the application of these sound principles in a timely, expert manner, Captain Casteel successfully landed the aircraft. WELL DONE! ■

1979 USAF SAFETY PLAQUES

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



FLIGHT SAFETY

AAC
21st Tactical Fighter Wing

AFCC
1866th Facility Checking Squadron

AFLC
Sacramento Air Logistics Center

AFSC
Detachment 27, AFCMD, AFPRO, General Dynamics

ATC
12th Flying Training Wing
47th Flying Training Wing
71st Flying Training Wing
323d Flying Training Wing
557th Flying Training Squadron
Officer Training School

AFRES
94th Tactical Airlift Wing
913th Tactical Airlift Group
917th Tactical Fighter Group
928th Tactical Airlift Group

MAC
71st Aerospace Rescue and Recovery Squadron
Detachment 5, 38th Aerospace Rescue and Recovery Squadron
62d Military Airlift Wing
76th Military Airlift Wing
314th Tactical Airlift Wing
375th Aeromedical Airlift Wing
435th Tactical Airlift Wing
436th Military Airlift Wing
443d Military Airlift Wing, Training
463d Tactical Airlift Wing

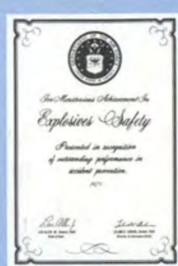
NGB
109th Tactical Airlift Group
116th Tactical Fighter Wing
154th Composite Group
170th Air Refueling Group
188th Tactical Fighter Group
191st Fighter Interceptor Group

PACAF
3d Tactical Fighter Wing
18th Tactical Fighter Wing

SAC
6th Strategic Wing
28th Bombardment Wing
42d Bombardment Wing
97th Bombardment Wing

TAC
1st Tactical Fighter Wing
1st Special Operations Wing
24th Composite Wing
31st Tactical Fighter Wing
57th Fighter Interceptor Squadron
347th Tactical Fighter Wing
479th Tactical Training Wing
507th Tactical Air Control Wing
552d Airborne Warning and Control Wing
602d Tactical Air Control Wing

USAFE
26th Tactical Reconnaissance Wing
32d Tactical Fighter Squadron
86th Tactical Fighter Wing
601st Tactical Control Wing



EXPLOSIVES SAFETY

AAC
21st Equipment Maintenance Squadron

AFSC
Air Force Weapons Laboratory

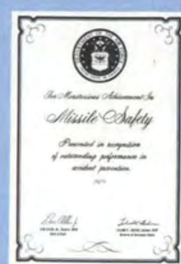
AFRES
919th Special Operations Group

NGB
123d Consolidated Aircraft Maintenance Squadron

PACAF
15th Air Base Wing
18th Tactical Fighter Wing
51st Composite Wing (Tactical)
400th Munitions Maintenance Squadron (Theater)

TAC
33d Tactical Fighter Wing
67th Tactical Reconnaissance Wing
366th Tactical Fighter Wing

USAFE
20th Tactical Fighter Wing
48th Tactical Fighter Wing
406th Tactical Fighter Training Wing
513th Tactical Airlift Wing



MISSILE SAFETY

AAC
5010th Consolidated Aircraft Maintenance Squadron

AFSC
Eastern Space and Missile Center
Western Space and Missile Center
Armament Division

MAC
2d Weather Squadron

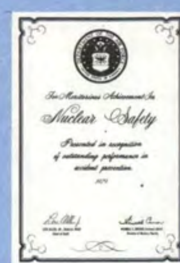
NGB
144th Fighter Interceptor Wing

PACAF
3d Tactical Fighter Wing
51st Composite Wing (Tactical)

SAC
5th Bombardment Wing
28th Bombardment Wing
42d Bombardment Wing
319th Bombardment Wing
44th Strategic Missile Wing
91st Strategic Missile Wing
351st Strategic Missile Wing
381st Strategic Missile Wing

TAC
33d Tactical Fighter Wing
57th Fighter Interceptor Squadron
84th Fighter Interceptor Squadron

USAFE
52d Tactical Fighter Wing
401st Tactical Fighter Wing



NUCLEAR SAFETY

AFLC
3097th Aviation Depot Squadron

MAC
6th Military Airlift Squadron

SAC
28th Bombardment Wing
44th Strategic Missile Wing
91st Strategic Missile Wing
416th Bombardment Wing

TAC
Detachment 3, 425th Munitions Support Squadron
366th Tactical Fighter Wing

USAFE
20th Tactical Fighter Wing
52d Tactical Fighter Wing