flying

SAFETY

FEBRUARY 1986

What Happened In 1985

1986 Flight Mishap Forecast

THERE I WAS

■ . . . the Captain of a B-737 with an airline operating in the Pacific. I was jump seat deadhead crew on this flight with a midnight takeoff at max gross brakes release weight (BRW) for the 5,600-foot length island runway — dark night conditions. The computed EPR was 2.18 max bleeds off thrust; V1 128, Vr 132, and V2 135; and BRW approximately 49,900 Kgs, 30°C. The computed N1 was 101 percent, flaps 10.

During takeoff by the first officer, I got the impression of lower-than-expected acceleration (as did the other two pilots after later discussion). All needles were pointing in the correct, expected direction, and instrument lighting was very low because of the dark night. I noted 2.18 on both digital EPR gauges, both thrust levers parallel, and no stagger. The 80-knots call was normal. At 105 knots, the end of the runway was approaching very quickly, and it was obvious acceleration was not fast enough to get to Vr until close to the threshold. A quick check of engine instruments showed 2.18 EPR and all needles parallel.

At 10 knots below Vr, the Captain urgently called "rotate quick" and simultaneously firewalled both thrust levers on the 737 — resulting in very positive thrust increase. The aircraft rotated just in time. We found out later that the jet blast angle at rotation blew stones and coral from the overrun onto the runway. It was *that* close. The EPR was set at 1.96 for the climb. Slow airspeed acceleration was apparent, and the aircraft was only at 15,000 feet at 50 miles instead of 25,000 feet.

During climb, all parameters were equal except N1 on both engines seemed lower than required for climb. The N1 read 88 percent on both engines. We should have expected 94 percent for the set EPR. No one suspected double EPR gauge failure or malfunction. I suspected fuel contamination.

The Captain decided to return to base to investigate the problem of lack of power in the climb.

There was no icing problem since the temperature was 30°C, but a check of anti-ice engine switches gave an 0.28 EPR drop instead of 0.09 EPR drop with engine anti-ice on momentarily.

After landing, ground investigation revealed Pt2 tubes (EPR) to both engines were blocked by coral debris, insects, and dust. This caused both EPR gauges to read high by 0.18 resulting in 2.00 EPR actual thrust, not the 2.18 desired!! The N1 gauges must have read about 91 percent on takeoff (in the green), but because of dim lighting and parallel needles on all engine instruments, we did not suspect lower-than-expected N1 on *both* engines simultaneously.

We had previously experienced an occasional single EPR gauge malfunction because of the Pt2 tube blockage causing a high reading. This stands out quickly because of the parallel thrust levers, with one EPR needle obviously reading high. However, we were completely unaware of the problem of simultaneous double EPR gauge malfunction with equal needle readings.

The lesson is to treat EPR readings with caution and always doublecheck *closely* the N1 on both engines. Ensure you know exactly what N1 you should get.

The Captain made the correct decision to firewall the thrust levers regardless of overboost danger to salvage the situation. An abort would have been fatal due to V1 being invalid because of low acceleration and V1 farther along the runway.

I tried to focus my eyes on the N1 readings when I first suspected poor acceleration, but did not have my glasses on and could only see approximate needle readings. Approximate readings were simply not good enough. Although 91-percent N1 may be OK on a long runway, it was critical on a short runway. ■

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SPECIAL FEATURES

REGULAR FEATURES

DEPARTMENT OF THE AIR FORCE • THE INSPECTOR GENERAL, USAF

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What Happened In 1985




"It was a very good year." The fliers and maintainers deserve a pat on the back for this, but remember we are all in this together. Each person in the Air Force should take pride in our safety record for 1985.

LT COL JAMES M. CARNEY
Directorate of Aerospace Safety

■ The USAF flight safety success story continues. The 1985 flight Class A mishap rate is the lowest ever — a tribute to the superb efforts of all involved in safe flying operations. And although this article will address shortfalls, you in the flying and fixing business can take pride in the new safety record your professionalism has achieved. Airmen have clearly demonstrated that readiness and combat capability demand the discipline of safety, which is nothing more than being effective, smart, and responsible in every task or operation.

Special recognition is warranted for the following MAJCOMs and their 1985 flight Class A mishap rates: AFCC for another zero rate year, PACAF for their first zero rate, TAC for a record low of 2.1, and USAFE for a record low of 2.7. Excellent!

To gain perspective on 1985, let us briefly "check six" on the USAF flight Class A mishap rate for the last 10 years (Chart 1). Note the relatively sharp decline from 1982 to 1983 (2.3 to 1.7). Suspicion that this sudden drop may have been a fluke was readily dismissed by a comparable rate of 1.8 in 1984, and a new rate plateau or threshold was suggested. The 1985 rate of 1.5 confirmed a new plateau, proving the existence of a more effective mishap prevention program.

Chart 2 breaks out the operations and logistics mishap rates for 1981-1985. The new plateau shows the ops rate averaging 1.0, decreasing .2 from 1984 to .97, while the log rate has been hovering in the .5 regime, down .15 from 1984 to .40. Subsequent decreases to a best possible overall Class A rate (now believed to be in the 1.2 - 1.3 regime) will most likely progress in similar, small increments. Nonetheless, there is room for progress.

There were 53 Class A mishaps in 1985, resulting in 51 destroyed aircraft and 78 fatalities, totaling $272 million in lost resources. A general review of those mishaps will identify deficient areas requiring increased emphasis. Due to incomplete data, a more detailed review of 1985 mishaps will be provided by

Chart 1

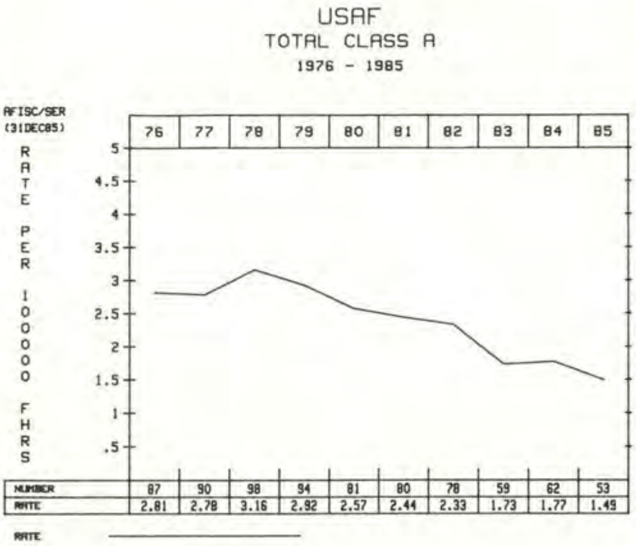
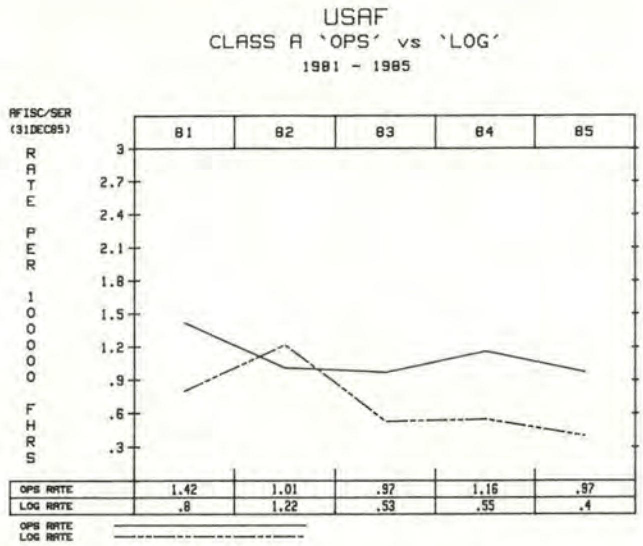


Chart 2



AFISC weapons system project officers in subsequent issues of this magazine.

In 1985, there were 34 operational Class A mishaps resulting in 33 destroyed aircraft and 61 fatalities. A listing by type mishap (Figure 1) shows collision with the ground (nonrange) and control losses continuing to be the major problem areas, comprising 65 percent of total ops losses.

Ten of the collisions with the ground were fighter/attack aircraft, four involving formation maneuvering, all involving fatalities, no successful ejections, and only three attempts. One mishap had suspected spatial disorientation as causal, another had suspected G-induced loss of consciousness, while a third mishap indicated the possibility of either one or both.

Of the nine control losses, three involved air-to-air activity; the remainder were varied. The collision-with-the-ground range category is down five from 1984, a significant improvement. Fighter/attack aircraft accounted for all the midairs, with three of the four occurring at night or dusk. All but one of the landing mishaps were under instrument meteorological conditions. With current (incomplete) data, the only prominent cause condition (alias second-level cause) for ops mishaps is channelized attention.

The operations mishap distribution by aircraft category (Figure 2) shows the fighter/attack force accounting for two-thirds of the total, but a downward trend continues. In fact, the fighter/attack community established record lows in their overall, ops, and log Class A mishap rates with 3.0, 1.9, and .9 respectively.

Of the five cargo mishaps, three were C-130s, equaling their number of 1984 mishaps. The C-130 types of mishaps in 1985 were landing, collision with the ground, and control loss.

Since fighter/attack aircraft constitute the majority of mishaps, a breakout by aircraft and type mishap is provided (Figure 3). All aircraft are within one loss from 1984, except the A-7 which decreased by three. The only significant change in type mishap was range loss. The A-7, A-10, and F-16 decreased their range losses from two each in 1984 to none in 1985.

Considering pilot flying-time ex-

continued

Figure 1
1984 Operations Type Mishaps

TYPE MISHAPS	1985
Control Loss	9
Collision W/Ground	13
Range	1
Midair Collisions	4
Landings	4
Ops Other	3
Ops Total	34

Figure 2
1985 Operations Mishaps

ACFT CAT	1985
Fighter/Attack	23
Cargo	5
Trainer	3
Observation	1
Helicopter	1
Other	1
Total	34

Figure 3

1985 Operations Type Mishaps
Fighter/Attack

ACFT	CONT LOSS	COL W/GND	RANGE	MIDAIR COL	LAND-INGS	OPS OTHER*	TOTAL
F/RF-4	2	2	1	1	1		7
F-15	1	1				1	3
F-16	1	4		1			6
F-106				1			1
A-7		1				1	2
A-10		1		1		1	3
A-37		1					1
Total	4	10	1	4	1	3	23

What Happened In 1985 continued

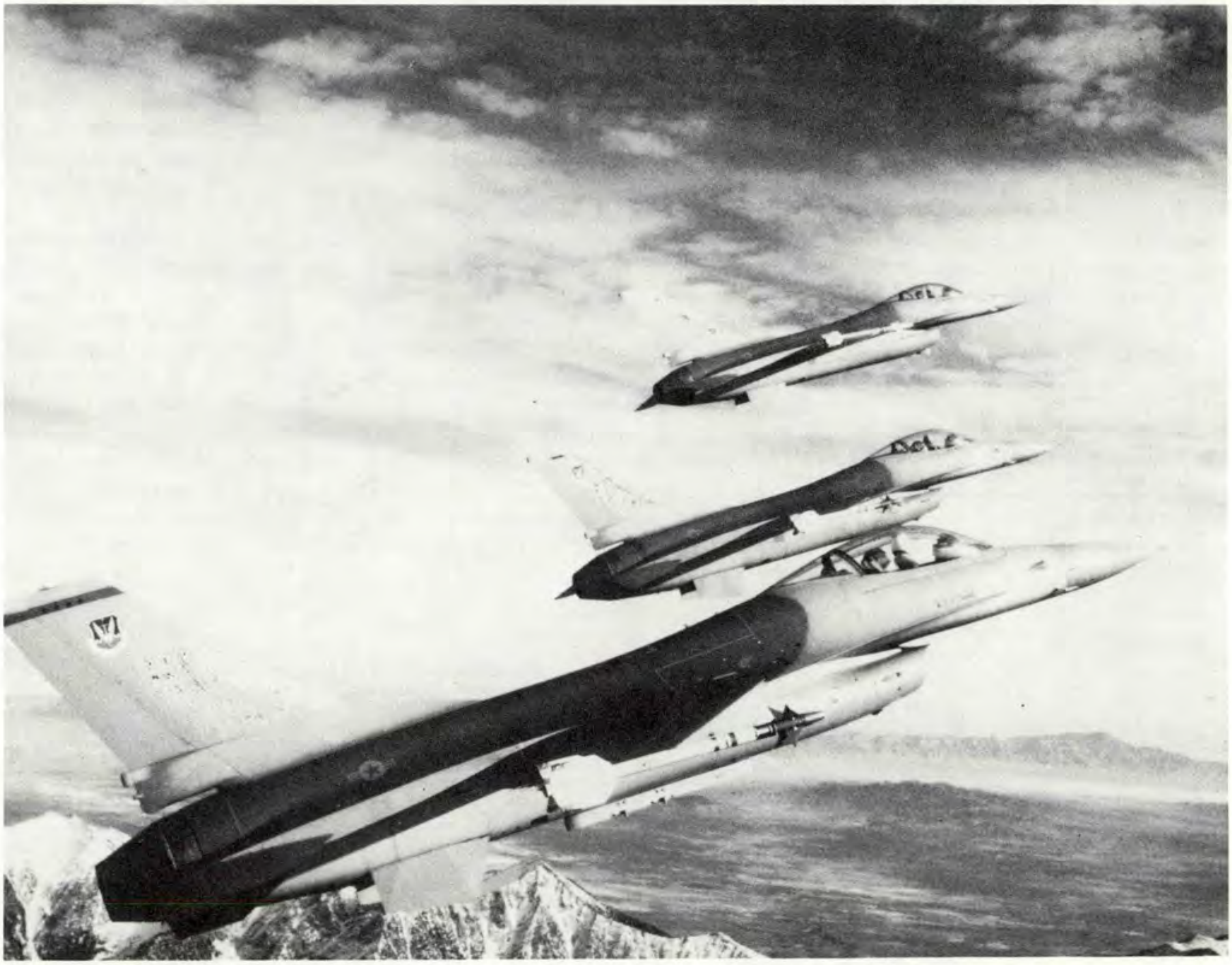
perience as a possible function of mishap potential, Figure 4 data depicts the fighter/attack pilot population distribution, total versus operational mishap pilots for 1983-1984 combined and 1985. Regarding total time, increases of mishap pilots occurred in the 0-500, 500-1,000, and 2,500+ hour groups, 6.5 percent, 11.4 percent, and 6.8 percent respectively, while notable decreases were realized in the 1,000-1,500 and 1,500-2,000-hour groups, 10.2 percent and 12.3 percent respectively.

A look at the UE/PAA pilot experience distribution shows no significant changes of mishap pilot distribution between 1983-1984 and 1985. However, in relation to total pilot distribution, 1985 mishap pilots in the 0-500-hour group increased, exceeding their share of mishaps by 9.2 percent (compared to 7.4 percent in 1983-1984). Conversely, the 1985 1,000-1,500-hour mishap group made a greater reduction from their share compared to 1983-1984, 1.0 percent to 8.5 percent.

Logistics have shown notable improvements in 1985 (Figure 5). Four less logistics mishaps were experi-

Figure 4
1985 Ftr/Atk Pilot Experience Distribution
Percent Ops Mishap Pilots and Population Pilots

EXPERIENCE	TOTAL HOURS				U.E. HOURS			
	Population Pilots		Mishap Pilots		Population Pilots		Mishap Pilots	
(HOURS)	1983-84	1985	1983-84	1985	1983-84	1985	1983-84	1985
0 - 500	15.2	15.9	10.9	17.4	50.8	47.2	58.2	56.4
500 - 1000	12.0	11.6	20.0	30.4	28.2	30.3	27.3	30.4
1000 - 1500	15.0	14.0	14.6	4.4	11.9	12.9	10.9	4.4
1500 - 2000	18.2	16.9	20.0	8.7	5.3	5.3	1.8	4.4
2000 - 2500	14.6	14.7	10.9	8.7	2.3	2.3	0	4.4
2500+	25.0	24.7	23.6	30.4	1.5	1.7	1.8	0



Fighter/attack pilots with 1,000 to 2,000 hours total flying time experienced a significant decrease in mishaps.

Most of the logistics mishaps occurred in fighter/attack aircraft, but the overall rate showed a marked improvement over last year.

enced this year for a total of 15, down 21 percent from 1984. Of the 15 mishaps, 14 aircraft were destroyed, 12 involved fighter/attack aircraft, and there were 14 fatalities. Fifteen ejections were attempted, and all were successful.

As usual, engines constitute the major logistics type mishap (Figure 6) with 7 in 1985; however, this is down from 13 in 1984, a significant decrease. All seven engine mishaps were in fighter/attack aircraft, and four of the seven were accountable to design deficiency and/or equipment failure.

No more than two mishaps occurred in any of the other logistics categories. And with the exception of engines, all categories remained within one mishap from 1984. Of the eight nonengine logistics mishaps, five were fighter/attack (two A-7, one F-4, one F-15, and one F-16).

As a whole, logistics mishaps have been reduced to a point where randomness may be the largest influencing factor, with the possible exception of the engine category. This is a good indication and a tribute to the logistics community in their endeavors to eliminate all deficient areas.

There is still room for progress. A study of the 1985 Class A mishap reports (90 percent available) shows 20 percent were clearly *preventable*. That percentage has remained fairly constant the last 3 years (24 percent in 1983, 23 percent in 1984). These mishaps involved people who were not doing their job effectively, smartly, or responsibly. Preserving our people and aircraft requires *total* participation in mishap prevention by everyone — commanders, supervisors, and individuals — to eliminate all needless losses. It can be done! ■

Figure 5
1985 Logistics Mishaps

ACFT CAT	1985
Fighter/Attack	12
Cargo	1
Helicopter	1
Trainer	1
Total	15

Figure 6
1985 Logistics Type Mishaps

TYPE MISHAPS	1985
Flight Controls	2
Landing Gear	1
Fuel System	2
Engines	7
Hydraulic/Pneumatic	1
Structural	1
Logistics Other	1
Logistics Total	15

Figure 7
1985 Logistics Type Mishaps
Fighter/Attack

ACFT	FLIGHT CONT	FUEL SYS	ENG	HYD/ PNEU	LOG OTHER	TOTAL
F/RF-4		1	1			2
F-15			1	1		2
F-16			3		1	4
QF-100			1			1
A-7	1	1	1			3
Total	1	2	7	1	1	12

1986 Flight Mishap Forecast

MAJOR RICHARD W. MORGAN
Directorate of Aerospace Safety

■ The 1986 flight mishap forecast predicts the Air Force will have 57 Class A mishaps, 51 destroyed aircraft, and 31 Class B mishaps this year. Of the 57 Class As, 39 will be operations related (pilot error), 15 will be logistics related (materiel failure), and 3 will be miscellaneous or undetermined. This translates into an overall Class A mishap rate of 1.61, the lowest forecasted rate ever.

Fighter/attack aircraft will have 26 of the 39 operations Class As, 13 of the 15 logistics Class As, and 2 of the 3 miscellaneous or undetermined Class As. Of the 41 total fighter/attack Class As, 22 will involve F-4s and F-16s. These are some of the events that will happen this year *if* the 1986 flight mishap forecast is correct.

The forecast is, like its predecessors, only a reflection of the mishap potential that currently exists in the way we support, maintain, and operate our aircraft. It is based on three basic assumptions: (1) That we have accurately defined the types of mishaps our aircraft are likely to have, (2) that we have accurately assessed current trends, and (3) that nothing changes in the way we support, maintain, and operate our aircraft in terms of policy, procedures, tactics, modifications, etc. It also presupposes that we actually fly the 3,542,101 flying hours programmed for 1986.

In spite of some past accusations, the mishap forecast is not derived by a room full of fortunetellers with crystal balls, nor is it totally computer generated. It is, rather, the product of a logical process which begins with a computer-generated expression of mishap potential based on the mishap history of each aircraft.

Historical mishap data are biased as a function of recency, i.e., the more recent the data, the more "weight" it is given. A historical weighted average mean rate is projected for each aircraft for each type mishap and compared to its 1986 programmed flying hours. The product of these two numbers becomes the initial mishap projection for each aircraft. This is the only purely mathematical part of the process and involves some 34,398 separate calculations (49 aircraft x 26 mishap types x 3 sample time periods x 3 weight factors x 3 mishap classes).

The next step in the process involves evaluating Class C mishap and Category I materiel deficiency report trends for their reflection of mishap potential. If specific aircraft system trends are changing, the mathematical projection is further biased accordingly. At this point, the last step in the process begins (the "sleight-of-hand, mirrors, and body english" step).

Air Force Inspection and Safety Center analysts and aircraft project officers get together and "murder" the projection for aircraft based on their knowledge of current or anticipated changes in procedures, tactics, missions, restrictions, training programs, and the impact on mishap potential of any ongoing or anticipated aircraft modifications. Only after all of this is accomplished are the forecasts for each aircraft added to arrive at the Air Force total.

The overriding assumption on which the forecast is based is that nothing unforeseen changes. The inevitability of the forecast is totally dependent on that assumption being correct. If something changes to increase mishap potential, the numbers in that area will increase, and if something changes to decrease potential, they will decrease. We know that something changed in 1983 to lower mishap potential to a new level for 1983 and 1984. A similar change occurred last year in 1985. These changes have been taken into account.

The 1986 forecast predicts fewer Class A mishaps than any previous forecast. It also represents the largest annual decrease in the number of Class As predicted. This decrease is tempered by the rate plateau established in 1983 and 1984, but also reflects the new rate threshold for 1985 which we expect will continue into 1986.

Remember, the forecast is not a goal. The goal is to beat the forecast by additional prevention efforts in those areas having high mishap potential. The charts show us where we need to concentrate. The challenge is to continue the downward trend in the Class A mishap rate. ■

1986 MISHAP FORECAST
By Aircraft Type and Category of Mishap

AIRCRAFT		CONT LOSS	COLL GND	RNG	MID AIR	LDG (PLT)	T/O (PLT)	OPS OTH	FLT CONT	GEAR	FUEL SYS	ENG	ENG FOD	HYD/ PNEU	ELEC SYS	STR-UCT	BLD AIR	INST	LOG OTH	BIRD STRK	WX	UND MISC	TOT	FLYING HOURS
USAF	DEST	10	18	2	2	1		2	2		1	10								1		2	51	
	CL A	10	18	2	2	5		2	2		2	10				1				1		2	57	3,542,101
	CL B				1	9	1	1		2		6	6	1	1				1	1		1	31	
A-7	DEST		1						1			1											3	
	CL A		1						1			1											3	82,026
	CL B					1																	1	
A-10	DEST		1	1	1							1										1	5	
	CL A		1	1	1							1										1	5	222,917
	CL B				1							1											2	
A-37	DEST		1																				1	
	CL A		1																				1	29,852
	CL B																							
B-1	DEST																							
	CL A																							4,877
	CL B												4										4	
B-52	DEST		1																				1	
	CL A		1																				1	104,520
	CL B					1																	1	
FB-111	DEST																							
	CL A																							20,637
	CL B																							
C-5	DEST																							
	CL A					1																	1	58,936
	CL B													1						1			2	
C-9	DEST																							
	CL A																							29,490
	CL B																							
KC-10A	DEST																							
	CL A																							29,066
	CL B												1										1	
C-12	DEST																							
	CL A																							32,810
	CL B																							
C-21	DEST																							
	CL A																							57,618
	CL B																							
C-130	DEST	1	1																				2	
	CL A	1	1			1																	3	380,704
	CL B					1																1	2	
C-135	DEST		1																				1	
	CL A		1																				1	269,762
	CL B											1											1	
C-141	DEST		1																				1	
	CL A		1																				1	290,792
	CL B					1																	1	
E-3	DEST																							
	CL A																							29,724
	CL B														1								1	
E-4	DEST																							
	CL A																							1,954
	CL B																							
F-4	DEST	3	2					1			1	2											9	
	CL A	3	2					1			2	2											10	328,257
	CL B					1				1		1							1				4	

1986 MISHAP FORECAST
By Aircraft Type and Category of Mishap

AIRCRAFT		CONT LOSS	COLL GND	RNG	MID AIR	LDG (PLT)	T/O (PLT)	OPS OTH	FLT CONT	GEAR	FUEL SYS	ENG	ENG FOD	HYD/ PNEU	ELEC SYS	STR-UCT	BLD AIR	INST	LOG OTH	BIRD STRK	WX	UND MISC	TOT	FLYING HOURS
F-5	DEST	1	1																				2	
	CL A	1	1																				2	27,360
	CL B																							
F-15	DEST	1	1		1			1				1											5	
	CL A	1	1		1			1				1											5	200,868
	CL B					1		1		1		2											5	
F-16	DEST	1	5	1								4											11	
	CL A	1	5	1		1						4											12	247,488
	CL B																							
F-106	DEST											1											1	
	CL A											1											1	24,131
	CL B																							
F-111	DEST		1																			1	2	
	CL A		1																			1	2	82,679
	CL B																							
H-1	DEST																							
	CL A															1							1	47,254
	CL B					1																	1	
H-3	DEST																							
	CL A					1																	1	27,013
	CL B											1											1	
H-53	DEST		1																				1	
	CL A		1																				1	15,333
	CL B					1																	1	
H-60	DEST																							
	CL A																							4,317
	CL B																							
O-2	DEST																							
	CL A																							28,667
	CL B																							
OV-10	DEST																							
	CL A																							33,067
	CL B																							
T-33	DEST	1																					1	
	CL A	1																					1	49,763
	CL B																							
T-37	DEST	1																					1	
	CL A	1																					1	304,691
	CL B																							
T-38	DEST					1			1											1			3	
	CL A					1			1											1			3	353,855
	CL B					1	1						1										3	
T-39	DEST																							
	CL A																							6,048
	CL B																							
T-41	DEST																							
	CL A																							36,129
	CL B																							
T-43	DEST																							
	CL A																							16,781
	CL B																							
OTHER	DEST	1																					1	
	CL A	1																					1	62,722
	CL B																							

PACAF Perfection

■ For the first time in its history, Pacific Air Forces (PACAF) has completed a full year of flying without a Class A aircraft mishap. This also marks the first time in Air Force history a command with as large a flying program as PACAF has done this.

A Class A mishap is one in which there is loss of life, loss of an aircraft, or when damages exceed $500,000.

PACAF aircraft flew more than 95,000 mishap-free hours during more than 73,000 sorties.

According to General Robert W. Bazley, Commander in Chief, PACAF, "This achievement is a testament to the high quality of aircraft and people who fly and maintain them here in PACAF.

"Never before has the command enjoyed such a fine combination of people and equipment. In light of the rigorous training, demanding mission, and sophistication of the aircraft we fly, this unprecedented achievement is a tribute to the professionalism and unparalleled dedication of our flying and maintenance personnel."

This year's rate breaks the command's previous record of 1.1 mishaps per 100,000 flying hours set in 1983. ■

PACAF aircraft flew more than 95,000 mishap-free hours during more than 73,000 sorties marking the first time in PACAF history the command completed a full year of flying without a Class A aircraft mishap. This also marks the first time in Air Force history a command with as large a flying program as PACAF has done this.

FLIGHT DATA RECORDERS AND SIMULATION

Aircraft crewmembers have always been suspicious of people who want to put recorders in planes. The crewmembers sometimes feel this represents a lack of trust and is an affront to their professionalism. The purpose of these recorders is not to collect evidence to hang the crew. In this article, Major Kaye explains why flight data recorders (FDRs) are not only desirable, but essential for our modern aircraft.

MAJOR MICHAEL J. KAYE
Directorate of Aerospace Safety

■ Mishap investigation boards, without FDR data, often spend weeks examining wreckage and reconstructing flight profiles to learn what caused a mishap. With the aid of FDR information and simulations developed from this data, the process can be reduced to a few days — sometimes hours. This allows the mishap board to focus its attention on the fundamental purpose of the investigation — why the mishap occurred and what corrective actions can be taken to prevent a recurrence. During this second phase of an investigation, simulations are also being used in an increasingly effective way to find the root cause of the mishap.

Background

The first FDRs used styli to scratch analog signals on a metal foil and normally recorded five to nine primary flight parameters. Although more recorded parameters were desired, this was not practical because of the physical size and weight of the equipment. In numerous commercial mishap investigations, this recorded information proved useful in flightpath reconstructions, but systems operation, since it wasn't recorded, could only be deduced. In time, however, advances in electronics greatly increased the ability to capture and store FDR data.

Current commercial FDRs use integrated circuits to digitize data, process it, and then store it. They are capable of recording more than

60 parameters on a magnetic tape and, in addition to flightpath-related data, record numerous systems parameters as well. Unfortunately, size and weight prevented installing this type of data recorder on aircraft other than transports; the tape recorder alone uses a full 21-inch avionics box.

The development of small, nonvolatile memory chips allowed the beginning of second generation FDRs. These new systems have solved the previous size and weight problems and can preserve data on approximately 100 items. This development is particularly significant for fighter and attack type aircraft. These aircraft account for most of the military aircraft mishaps but, until now, have been restricted from carrying FDRs.

B-1B, F-16C/D, and F-15E aircraft will soon have this type of crash survivable FDR and will be excellent examples of present capabilities. The aircraft will have a recorder with a solid state memory encased in a protective shell that is 4 x 5 x 4.5 inches and weighs less than 5 pounds. Over 70 parameters will be recorded. These include flight parameters, pilot inputs, systems status, engine performance indicators, control surface positions, and additional flight variables.

Importance of Flight Data Recorder Data

In general, the conclusions reached by a mishap board are based on facts — normally derived from two principal sources, the aircrew and the aircraft. Other sources, such as eyewitness testimony, radio transmissions, ground based radar plots, IFF information, and chance photography of the mishap sequence can be extremely valuable. However, they are often not available or their credibility and validity are questionable.

Aircrew testimony frequently provides the key to finding the cause of a mishap, but if they are killed, this vital source of information is lost. Even if anyone survives, the information provided may be unreliable or extremely limited for any number of reasons. Although FDRs can't record what the pilot was seeing or thinking during the mishap, FDR data has been used very effectively to create cockpit simulations of the mishap sequence. This is done by using either computer graphics or actual flight simulators to help the mishap pilot explain or remember what happened. In cases where pilot testimony is not available, this same type of simulation can be viewed by other pilots. They attempt to understand the mishap pilot's environment, thought process, and actions during the mishap sequence.

The second primary source of mishap information, the aircraft, is becoming increasingly difficult to investigate as systems evolve. Older aircraft, controlled primarily through mechanical means (pushrods, cables, pulleys), have easily traceable linkages. In the latest fly-by-wire aircraft, it is impossible to trace input to output. Although investigators can determine the position of a flight control surface at impact, they generally don't know if it was positioned there by the pilot or by a spurious signal from a computer.

Fly-by-wire flight control systems are not the only advances that make post mishap investigations more difficult. The solid state control of engines, navigational systems, weapon systems, and other aircraft systems also reduces the traditional mechanical evidence used by the investigator. Even the often relied on dial analysis used to determine gauge readings at impact is of limited value in aircraft using multipurpose cathode ray tubes (CRTs) to display flight information. In this case, only the standby instruments can be analyzed because the CRT display is not recoverable.

F-16C/D and F-15E aircraft will soon have crash survivable FDRs. The F-16 Signal Acquisition Unit (pictured above — top) records aircraft information and transmits this information to the F-16 Crash Survivable Memory Unit (pictured above — below).

Installing FDRs in today's newest aircraft and follow-on versions is essential. After a mishap, the malfunctioning electrons will not be found in the wreckage, and computer systems rarely leave physical evidence of a malfunction. The importance of using valid data during an investigation and in developing associated simulations cannot be overstated. If the present technological trends continue, FDRs may soon be the principal way to get meaningful information after a serious aircraft mishap.

Data Presentations for Simulations

When the FDR is recovered after a mishap, it is taken to a facility capable of processing the information. The recorder or memory unit is connected to an interface unit which strips the data from the component and dumps it into a computer. The computer provides storage space for the data and a processing unit so it can be displayed in one of three basic formats; tabular, plot, or graphic. The figure shows a diagram of this system.

The tabular data consists of engineering units, digital units (binary, octal, etc.), and raw data (ones and zeros). This is usually the most basic form of presentation and provides a capability for minute detail analysis.

Plot or analog data can be presented in a number of different formats. The principal advantage of analog data is that it provides a much bigger picture or overview of an event or parameter in a given time than is possible with tabular data.

The third method of presenting data is through graphics. Although graphics are not new, advances in technology have provided tremendous capabilities in this field that are just now beginning to be appreciated and applied. Given present technology, it is possible to create

continued

three-dimensional flight simulation from FDR data similar to those provided by an air combat maneuvering instrumentation system. Presently, this capability is still in the research stage, but because it holds so much promise for the future, it deserves close examination.

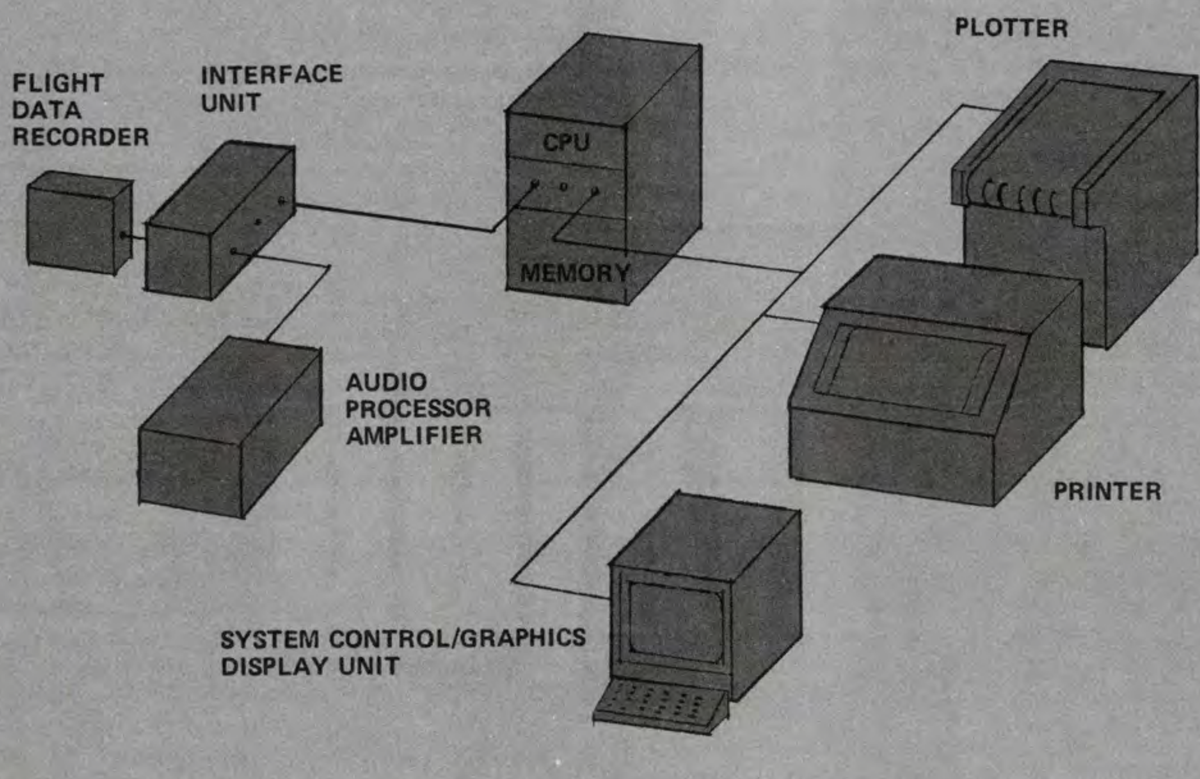
Computer Graphics in Mishap Simulations

There are three primary agencies in North America that can produce computer graphics from FDR information. These are the Flight Research Playback Center in Ottawa, Canada, the National Transportation Safety Board in Washington, DC, and the US Navy Accident Recorder Analysis Center (ARAC) in San Diego, California. There is considerable crosstell between these three groups, and although there are some minor differences, they all have approximately the same capabilities. Computer graphics and the simulations created from them are becoming increasingly important.

The following information comes from a study of the Navy's ARAC system.

Computer graphics are extremely useful for three reasons: First, they are capable of displaying large amounts of data simultaneously; second, they present the data in a form that can be easily understood; and third, they give the big picture, yet at the same time, show details. Depending on the requirement, computer graphics can be used to develop a three-dimensional flight simulation or a cockpit instruments simulation of the mishap sequence. A discussion of the capabilities and limitations of computer graphics will show the usefulness of the simulations.

The ARAC System has six primary flight profile viewing modes, and each has its own unique uses. The system is not limited to these six modes, but these particular modes offer a good insight into the system's capabilities.



BASIC FLIGHT DATA RECORDER PROCESSING EQUIPMENT

■ **Stationary Observer with a Fixed Viewpoint Viewing Mode (Picture 1)** In this mode, the observer's view is from a fixed point in space along a line to another fixed point in space. This mode allows the aircraft to come through the scene and presents a complete three-dimensional relationship. It also provides an understanding of the aircraft's position and what its speed and altitude are relative to the observer. An altitude and ground grid in addition to sampling rates help portray velocities. The major limitation in this mode is that no single view can provide all the information with great detail. Several different viewing points would be required, depending on the complexity of the maneuver, to achieve the desired detail. This could normally be accomplished easier by switching to another mode.

■ **Stationary Tracking Observer Viewing Mode (Picture 2)** This mode simulates the observer's view from a fixed point in space along a line to the center of the aircraft. Different viewpoints can be selected. This mode is very useful in providing a witness' eyeview of the aircraft as viewed from the impact point, edge of a runway, the control tower, etc. Two limitatiions to this mode are that the ability to interpret the flight dynamics depends on the observer's position and a historical record (sampling rates) can't be presented as it was in the previous mode.

■ **Chase Plane Viewing Mode (Picture 3)** This provides an observer's view from a chase plane at a specified position and attitude with the mishap aircraft at the next sampled position and attitude. In other words, since samples are approximately one second apart, the observer is always one second behind the aircraft, and his view is boresighted down the fuselage reference line of the chase plane. This mode is excellent in simulating three-dimensional accelerations and attitude changes; however, abrupt or violent changes in position or attitude can drive the aircraft off the side of the screen. In this case, the viewer can switch to the next mode to reacquire the aircraft.

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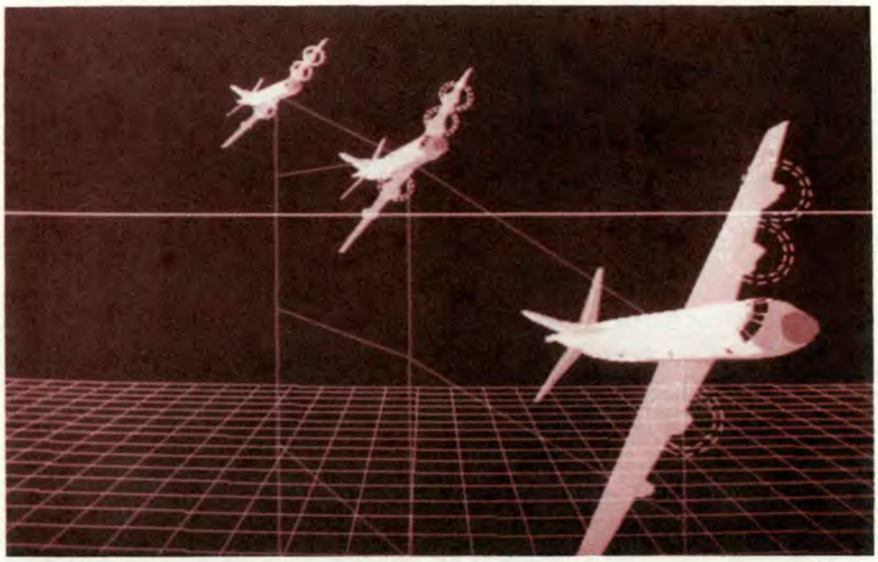
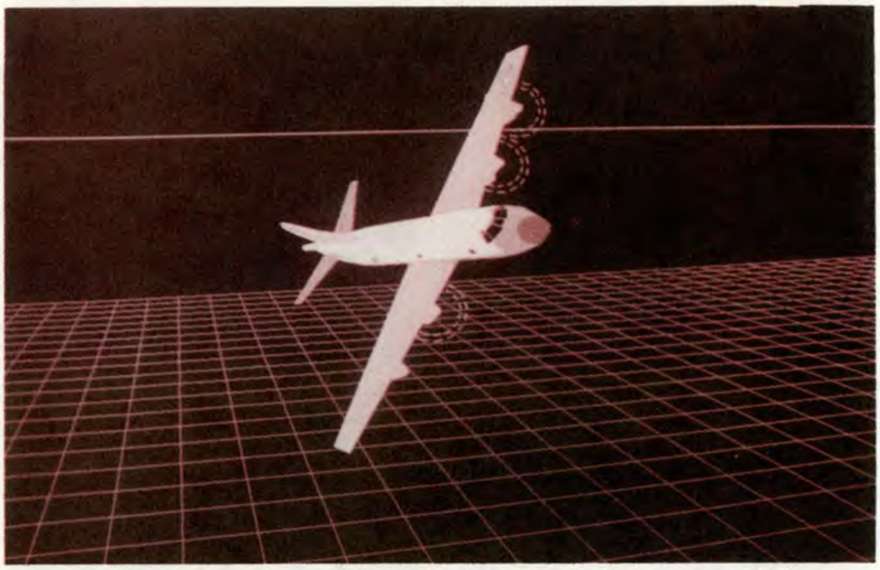
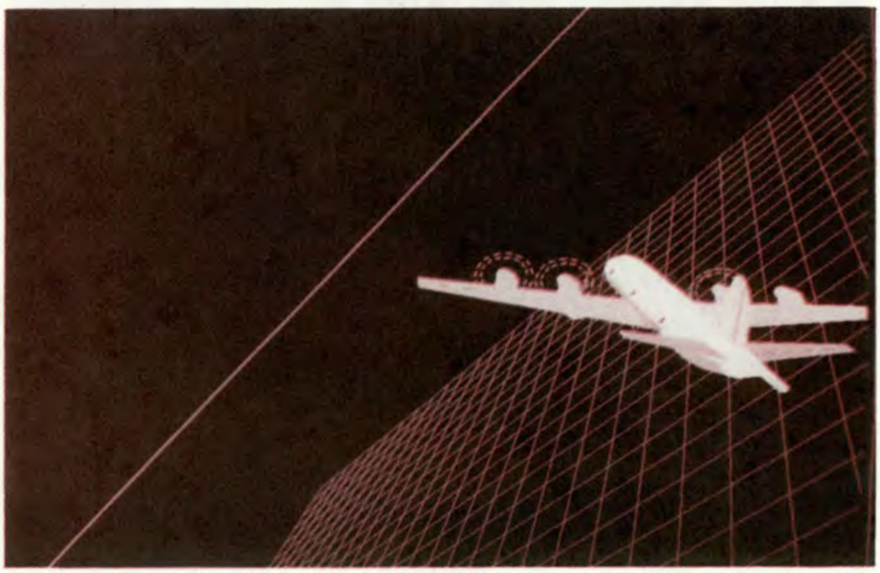


Picture 1



Picture 2



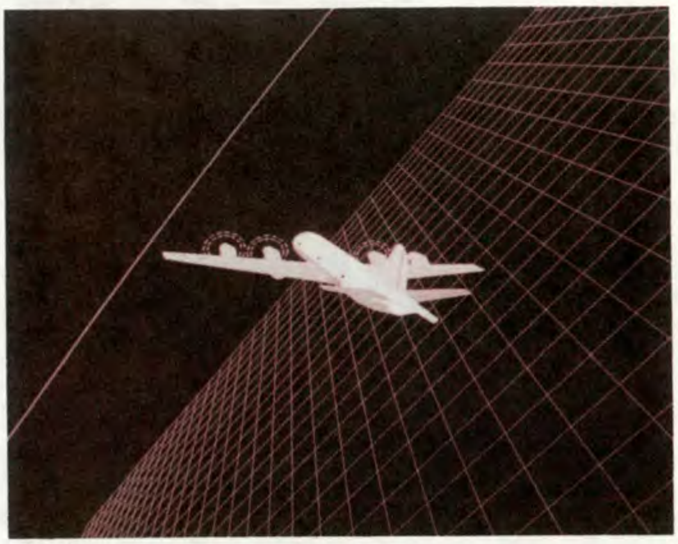
Picture 3

■ **Chase Plane With Tracking Observer Viewing Mode (Picture 4)** In this mode, the observer is at a specified chase plane position with his line of sight centered on the mishap aircraft at the next sampled position and attitude. This mode is similar to the previous mode except the observer is visually tracking the aircraft and not looking straight out in front of the chase plane. As mentioned earlier, this mode provides a scene with the aircraft constantly in view and also a fair representation of three-dimensional accelerations and attitude changes. The major limitation to this mode is that unusual viewing angles are possible and these may cause perceptual illusions. Effectively, in this mode the observer is in a glass chase plane and, if the aircraft he is tracking pitches hardover, he would find himself in the unrealistic position of viewing the aircraft through the floorboard of his chase plane.

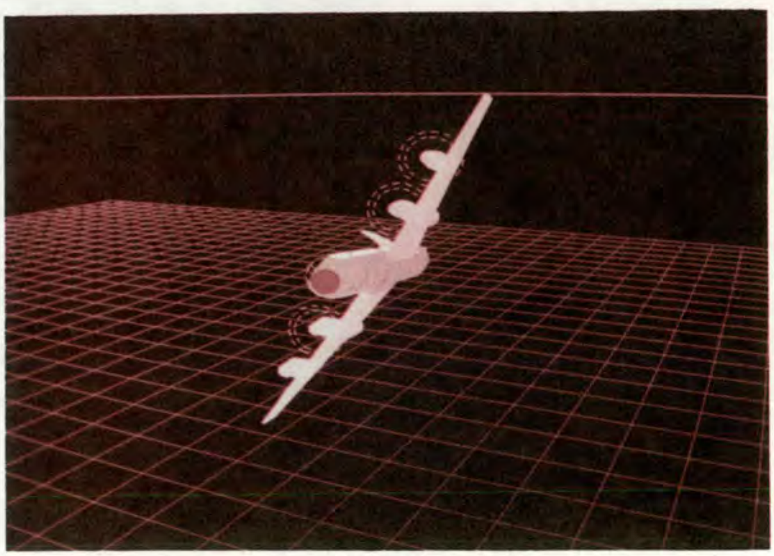
■ **Trimetric/Cockpit Viewing Mode (Picture 5)** This viewing mode provides split-screen views with the aircraft centered and the observer at a fixed distance looking north, west, and down, and also with the observer looking at the world scene along the aircraft centerline. The advantage of this mode is that it presents a simultaneous display of the aircraft's attitude with respect to compass points and the earth's surface. Its two major limitations are that position and velocity must be inferred from ground references and, because the scale is diminished, the detail is also reduced.

■ **Wingman with Tracking Observer Viewing Mode (Picture 6)** In this final mode, the observer is at a fixed point relative to the aircraft center, stabilized in pitch and yaw, with the line of sight to the center of the aircraft. In this case, the viewer selects a distance and an altitude differential which will be maintained regardless of what the aircraft does. This mode also provides for changing viewpoints and flightpath tracking. It offers a potentially good representation of pitch and roll movement and a large aircraft image, depending on the distance selected. The two primary limitations in this mode are that unusual viewing angles and the aircraft frame of reference may cause perceptual illusions and position must be inferred from ground references.

In addition to three-dimensional flight profile simulations, FDR data can also be used to simulate cockpit instruments. These simulations are also derived from computer graphics and can show cockpit instrument displays and additional information, such as the vertical acceleration bar graph in Picture 7. This information is not actually available in the cockpit but can be very useful to mishap investigators. There are four basic presentation formats.



Picture 4



Picture 6

■ **Cockpit Instruments Graphics Display (Picture 7)** This display shows simulated instruments as contained in Picture 7. The instrument groupings are similar to the aircraft cockpit where possible, however, the different groupings are not necessarily in the same relationship to one another. The viewer must understand the instrument readings correspond to parameters the FDR monitors. This means what the simulated instrument depicts is not necessarily what the actual cockpit instrument indicated because there is no way to know if the instrument malfunctioned or if there was a circuit fault downstream from the recorder tie-in.

Picture 5

Picture 7

■ **On/Off Indicators** This includes the display of warning lights, landing gear position indicators, and other indicators of this type. Again, the indicator grouping is similar to the aircraft cockpit where possible.

■ **Bar Charts** The inclusion of bar charts in a cockpit simulation provides for a much easier comparison of parameters, and this is very apparent in the example. Also, bar charts can be included to display parameters not monitored by cockpit instruments but useful to further define the dynamics of the mishap sequence.

■ **Numeric Readouts** This final presentation format provides for the simultaneous display in engineering units of all parameters for a single time sample. The information can be displayed along the bottom of the screen or next to the simulated instrument.

Applications of Simulations

Simulation is just one of many tools available to a mishap board during an investigation. Regardless of how good a simulation may seem or how well it might perform, it is not an end in itself but only an aid in piecing together the total picture. Actually, in many mishaps where FDR data is available, simulation is unnecessary because an analysis of tabular and plot data will provide the cause. In other instances, especially where human factors are involved, simulation can reinforce conclusions or provide key elements in determining the cause of a mishap.

There are many examples of how different kinds of simulations are used in mishap investigations. In May 1979, an American Airlines DC-10 crashed shortly after takeoff at Chicago O'Hare International Airport. In this investigation, FDR data was integrated into a motion base simulator to duplicate the aircraft failure modes and cockpit indications during the mishap sequence. These flight simulations helped determine the mishap aircrew's actions were correct given the information they had available, and emergency procedures were deficient.

In a recent midair, two C-130s collided during an airshow while attempting a tactical pitchup maneuver to downwind. Information available from the mishap FDRs was used to produce a computer-generated simulation of the two cockpit instrument displays during the midair. From this simulation and the use of two C-130 flight simulators to demonstrate the mishap maneuver, it was clear the lead C-130's delay in starting a turn after establishing a 10-degree pitch attitude set up the midair.

These are two good examples of how simulation is applied from FDR information. Many more examples could be given which also show how effectively simulation can be used during mishap investigations. Simulation can't provide the total answer, but when used intelligently, it can help guide mishap investigators to the correct conclusions.

Simulations derived from FDR information allow the mishap investigation board to clarify, in more cases and with better confidence, the cause of major mishaps. This is particularly true for fly-by-wire, high-technology aircraft mishaps where evidence disappears at power down. Fortunately, advances in solid-state technology have provided a vast increase in the capability of FDRs while at the same time making them more dependable and practical.

The use of computer graphics in developing cockpit instrument simulations and computer generated movies of the mishap maneuver is just now coming into being. These new forms of simulations offer tremendous capabilities to a mishap investigator that can greatly simplify the investigation and help put the investigator on the right track.

If the present trend continues, the use of simulation derived from FDR information will play an ever-increasing role in determining the cause and preventing the recurrence of serious aircraft mishaps. ■

GLOWWORM 1,2,3...

The Great Seat Belt Lesson

A SAFETY WARRIOR ARTICLE

This month's Safety Warrior article is written in a humorous way and is fun to read. But, there are several safety messages in it that we can all learn from. So, enjoy the story, and see how many safety tidbits you can find.

LCDR T. COPELAND
Dartmouth, NS Canada

■ In the early 1950s, the Canadian Navy's Avenger aircraft were used to conduct an antisubmarine tactic called Glowworm.

Glowworm was a hair-raising nighttime maneuver in three parts: (1) A dive to increase airspeed followed by (2) a sharp pullup to loft rocket flares high into the night sky, and (3) a quick pushover to attack visually the submarine illuminated by the flares.

My startling introduction to this roller coaster tactic came one night in 1952. In those days, I flew in Avengers as a backseat radio/radar operator. My crew station was deep inside the lower fuselage of the aircraft with only two small perspex windows looking outside.

I was away on leave when my squadron adopted Glowworm so I missed all the ground lectures and the daylight practice flights. And on my very first night back from leave, I found myself in the back of an Avenger flying seaward into the blackness to practice Glowworm with an exercise submarine. My pilot was new to the squadron so I didn't know him well. I knew less about Glowworm.

En route to the exercise area, we investigated a few radar contacts but not in a very aggressive manner. This lulled me into believing that the new pilot might be a bit conservative. I didn't realize he was adapting himself to his nighttime surroundings. Since the radar compartment was not used for takeoff and landing, I had neglected to strap myself into my seat.

As we approached the exercise area at 1,500 feet, a submarine-like contact appeared on the scope. I dutifully reported it to the pilot, fully expecting a gradual run-in not unlike the kind we had just been making.

I should have guessed something would be different this time for, instead of getting an acknowledgement, I heard an ominous increase in engine RPM and felt a slight yaw as my "conservative" pilot pushed against the rudder pedals to wedge himself more firmly into his seat. Concentrating on the target, I kept my face pressed into the rubber visor of the radar scope and continued to report the decreasing range. Then, I uttered the fateful words the pilot was waiting like a coiled spring to hear. "Range — 2 miles."

Before the last syllable was out, three things happened all at once. On came the power, over went the nose, and upward shot the writer, propelled toward the roof of the pitch-black compartment by negative G.

Part 1 of Glowworm had begun!

As my seat and I parted company, my helmet with its short cord was instantly torn from my ears, adding the engine's howl and the roaring slipstream to the shock of my sudden dislocation. And just as my eyes assumed the shape and size of dinner plates, the airplane steadied in the dive allowing the dissipated G to drop me painfully onto the cabin floorboards, somewhere in the blackness behind the seat I had just seconds ago occupied. Totally disoriented, I groped for something to cling to and had partially regained my feet when three things happened all at once: (1) We reached the bottom of our dive, (2) we hit our maximum airspeed, and (3) we commenced Glowworm, Part 2!

As suddenly as he had pushed the nose over, the pilot now wrenched back on the pole to send the airplane zooming skyward at a fearful angle, buckling my knees and throwing me back onto the floorboards. My heart was now racing at about 300 beats per minute. In my frantic search for something to hang on to, I unwittingly grabbed the elevator control cable that ran exposed along the fuselage wall. I didn't know what I had seized, but I wasn't about to let go even though I could feel my arm moving oddly back and forth each time the pilot moved the controls.

Suddenly, I sensed a slight change in attitude and some reduction in airspeed. Were we about to level off, all safe and sound? Not on your life! We had just reached the apogee of our upward zoom, and Glowworm, Part 3 was only a microsecond away.

With the nose of the aircraft still high above the night horizon and the airspeed falling off at an alarming rate, the pilot triggered off the Glowworm rockets and simultaneously pushed over for the attack sending the rockets skyward, the airplane seaward, and me once again toward the cabin roof. But this time, I had a death grip on the elevator cable and floated only as high as the bilge window that gave onto the underside of the wing. Unfortunately, my startled face appeared at this small opening just as the rockets suspended on the wing rails suddenly belched out their fiery innards. And at this precise moment, my fingers, moving smartly along with the elevator cable, jammed painfully into the small tunnel that guided the cable into its recessed pulley. All this proved too much. I let go.

Down we hurtled toward the submarine, the night sky now alight with flares and me sprawled again on the cabin floor convinced the rockets had misfired and were now burning off the wings.

Just as suddenly as this wild roller coaster had begun, level flight was restored followed by normal engine power and a kick by the pilot on the rudder in accordance with lost intercom precedure. I recovered my helmet and said in a voice I didn't recognize, "Y-Yes, Skipper?"

And Skipper cheerfully replied, "Sorry Radar, we can't make a second run. I had the rocket switch on SALVO and shot off all four!"

To which the unrecognizable voice replied, "Aah, too bad . . . too bad!" ■

LT COL JIMMIE D. MARTIN
Editor

A Lucky Break

■ The pilot of a single-seat fighter took off on a single-ship instrument proficiency sortie. The mission was to fly to a satellite base for multiple instrument approaches and return to home base. The weather was good for this type of mission at 1,100 feet overcast, 7 miles visibility, and layered clouds to 25,000 feet.

All operations were normal until about 15 minutes into the flight. The pilot was flying a TACAN arc while descending in instrument conditions. The initial penetration and left turn to establish position on the arcing approach were uneventful.

As the pilot banked to the right to maintain a correct position on the arc, he diverted his attention in the cockpit to program reference points into the inertial navigation system (INS). He quickly cross-checked the attitude indicator several times while working with the INS.

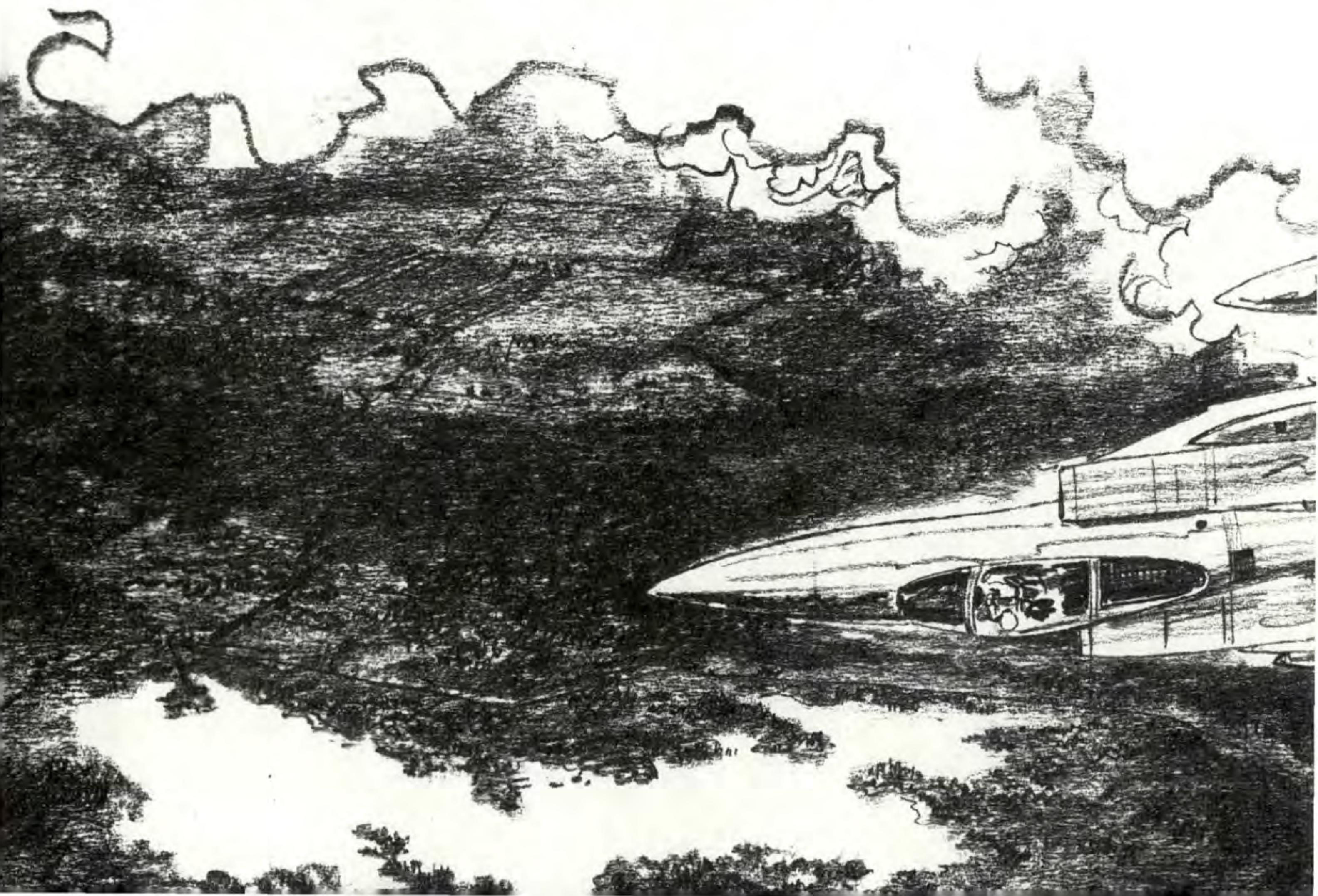
Each time he did so, it indicated straight and level, so the pilot added more right aileron input. As he descended through 5,000 feet, the pilot once again looked at the attitude indicator, which still showed straight and level.

Just as the pilot started to cross-check his backup attitude references, the aircraft entered a small, clear area between cloud decks. The aircraft was in approximately 110 degrees of bank and in a slight descent. The attitude indicator still showed straight and level with no "OFF" flag visible.

The pilot recovered to level flight in the clear air and notified the supervisor of flying of his problem. Another fighter in the instrument pattern was vectored to join up with the mishap aircraft. The mishap pilot then flew an uneventful wing approach back to the home field.

Maintenance troubleshot the aircraft and was able to duplicate the malfunction. The attitude indicator intermittently failed in both pitch and roll. The indicator was submitted for a Category I MDR.

The pilot didn't recognize the malfunction immediately because of



its insidious nature and because of his divided attention in the cockpit. He was working with the INS and using the attitude indicator as his sole instrument reference. The pilot deviated from the concept of pitch, power, and performance instrument flying as described in AFM 51-37, *Instrument Flying.* The instrument cross-check must never be allowed to deteriorate to just one instrument.

This pilot was very lucky. Had he not broken out of the clouds when he did, he could have flown into the ground. He had rolled the aircraft almost two-thirds inverted, thinking he was straight and level. Even though the nose apparently had not dropped much by the time he broke out of the clouds, how much longer would it have taken for him to enter an extremely nose-low attitude? Probably not long. Also, once past the vertical position, any back pressure the pilot applied, without rolling out of the bank, would pull the nose even lower.

Recovering from a nose low, extreme bank angle unusual attitude in the clouds on the standby attitude indicator is definitely an emergency procedure. If you're proficient in unusual attitude recoveries, quickly recognize the situation and take the correct action, it's no real problem. No problem, that is, if you have enough altitude available and if you don't hit another aircraft during the recovery. In our crowded patterns, a midair is a very real possibility in such a situation.

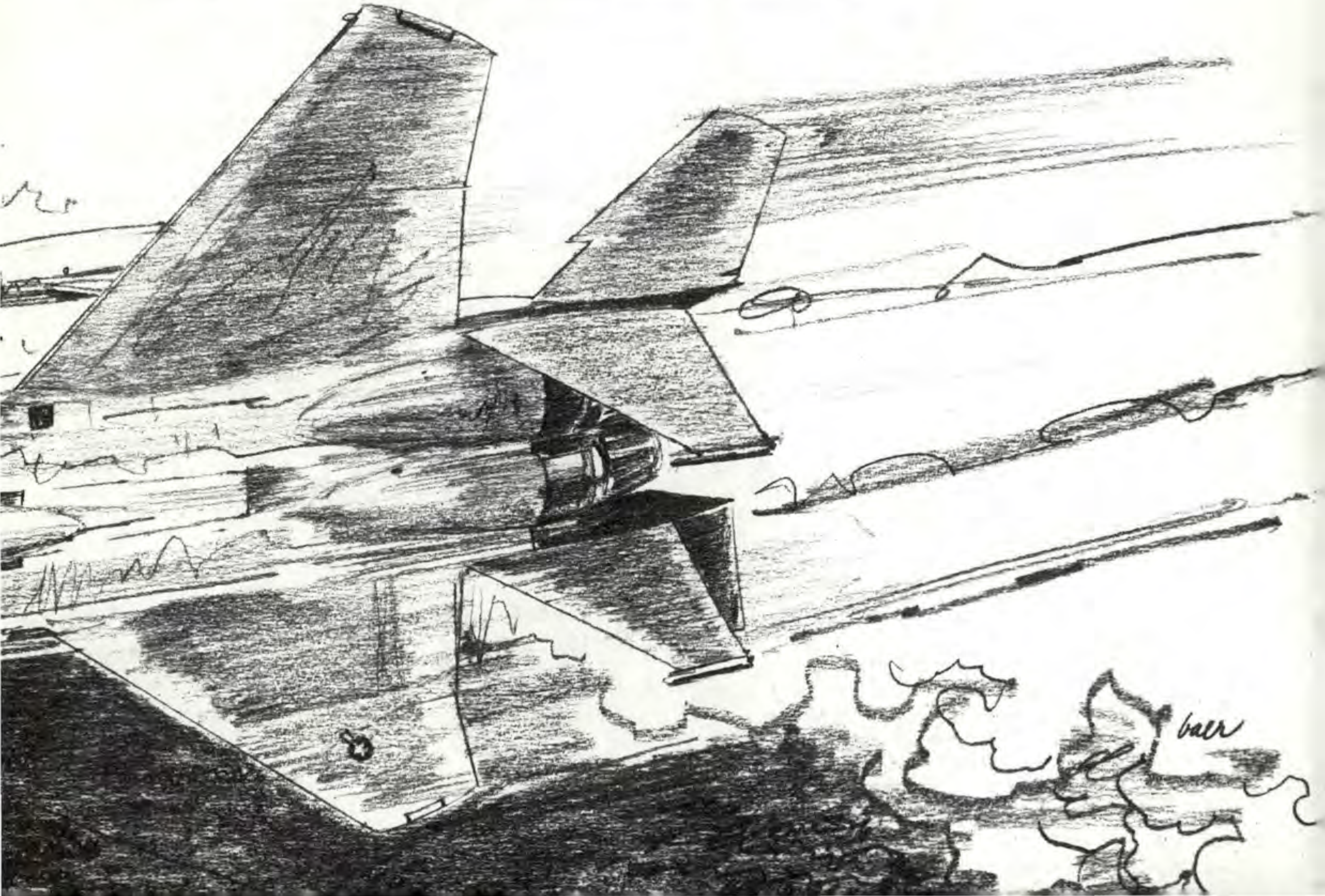
Naturally, we teach recovery from unusual attitudes in our instrument training. It's important to know how to recover from such situations. But, it's even more important to avoid getting into such situations by following the proper instrument flying procedures that are also taught. A regular, systematic instrument cross-check is essential to maintaining aircraft control.

The subject of proper cross-checks was covered very well in an excellent article entitled "Critical Triangles of Agreement" in the September 1983 *Flying Safety* magazine. Since it is a natural follow-on to this incident, we have reprinted the article in this issue. Please read it and take the message to heart.

This incident could have resulted in a fatal mishap. If it had, an extensive investigation would have followed. I'm sure the investigators would have attributed the cause to spatial disorientation. But, we still wouldn't have known exactly *why* it happened. Thus, prevention of a similar mishap would have been more difficult.

As it was, we came out winners this time. We didn't lose a pilot. We didn't lose an expensive aircraft. We didn't have to launch an expensive and time-consuming investigation. And, we know exactly how and why this incident happened, thanks to the pilot. We can point to the dangers of channelized attention (working with the INS) as well as neglecting to perform a proper instrument cross-check.

We were all lucky on this one. Whether you're in a single-seat fighter or a multiplace aircraft, the lessons are here for you. Don't depend on luck. Make your own luck. Fly safe! ■



As you scan your crowded instrument panel, you are presented with instantaneous yet precise data on what (and how) you and your aircraft are doing. But, if one of those instruments goes haywire and is feeding you misinformation, your welfare may depend on whether or not you're checking on those . . .

Critical Triangles of Agreement

CAPTAIN JAMES D. PRICE
Vance AFB, OK

■ After a few tours on static display duty, you know exactly what the visitors are going to ask.

"Is that the gun?," referring to the pitot tube, and "Gee, look at all those instruments! How do you keep them all straight?"

I don't know about you but, at one time, that last question made me feel almost super human for a moment. When you think about it, the engineers who design our aircraft with "all those instruments" are pretty darn smart. There are backup instruments to the backup instruments in some aircraft, each driven by independent sources of information and various forms of power. You may not realize it, but all these instruments form corners of triangles called critical triangles of agreement.

To emphasize my point, I will refer to some very unfortunate mishaps which could have been averted, if someone in the cockpit had applied the principle of the critical triangle of agreement. I'll also refer to some incidents which did not turn into mishaps because the critical triangle of agreement was employed.

Back in 1974, a Northwest Orient flight crew departed New York in a Boeing 727. They were on a charter flight . . . the first leg was to be flown deadhead to Buffalo where they were to pick up a chartered group of passengers.

On the climbout, through rain and turbulent clouds, the flight was routine until after passing through the freezing level. The crew then began experiencing a problem with airspeed control. It was high. The rate of climb was also higher than normal. They were light, so they expected the aircraft to perform better than usual, but not this well. They thought they had gotten into some weird upward gust, so they eased back on the yoke.

The rate of climb went even higher, as one would expect, with back pressure and increasing pitch. However, the airspeed also increased mysteriously. They thought it was a phenomenal gust they were experiencing and pulled back on the yoke even farther. They fixated on the airspeed indicator and pulled harder on the yoke.

The crew violated the most basic premise of attitude flying by disregarding both the main and standby attitude indicators, and following one performance instrument.

Even through the buffet, the pilot increased pitch in an effort to reduce the airspeed. Why would anyone do something so ludicrous? As you know, the 727 is not exactly the SST, so in addition to the stall buffet which most aircrews experience in training, there is also mach buffet, which occurs when the 727 reaches .9 to a .93 mach. Not many crews have experienced this buffet since it is difficult to achieve.

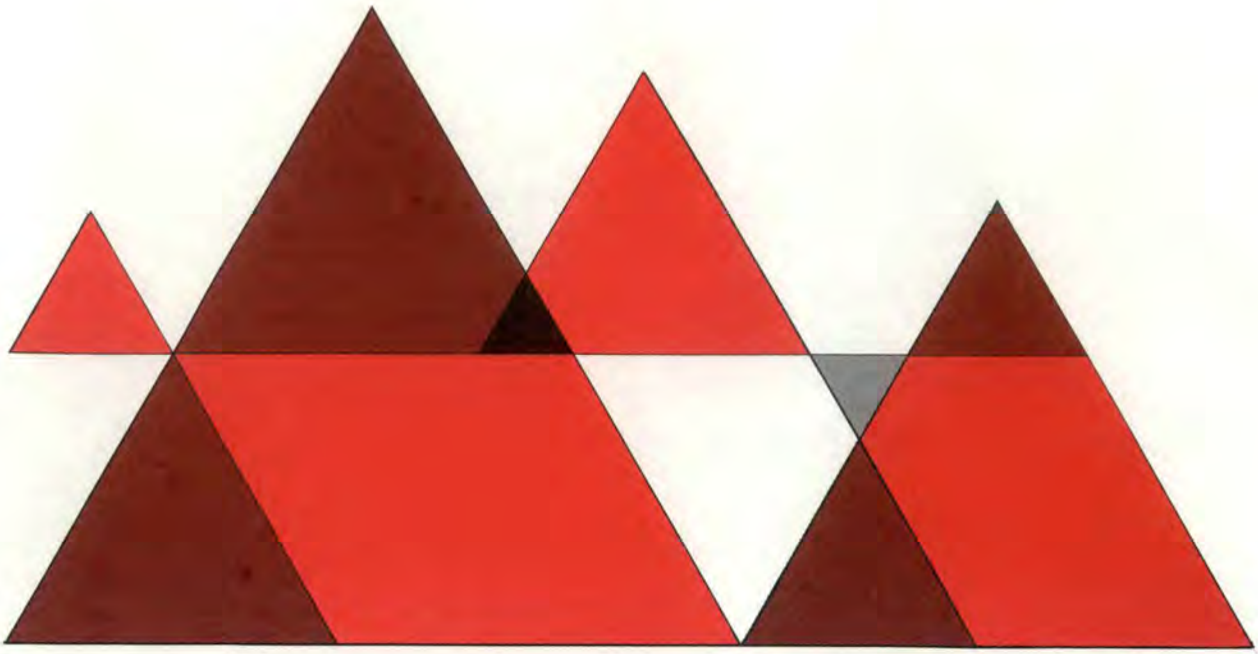
The airspeed had "increased" so much they were certain their aircraft was in mach buffet, so they increased the pitch more and even reduced power. When the aircraft entered a full stall, there were only seconds to spare, and they had wasted valuable minutes concentrating on the airspeed indicator.

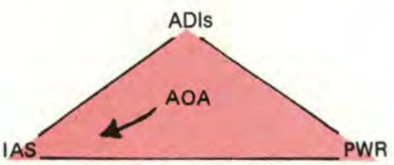
The principle behind critical triangles is nothing new. More than 200 years ago, a wise man observed, "If you desire to give a friend a clock, do not give him one, give him three so he will know the hour."

Think about that. With one clock, you only think you know what time it is. With two clocks that disagree, you may not discover which one is telling the correct time until it is too late. With three clocks, you can be reasonably sure of the time if two agree. That is true in an aircraft as well, whether it is a Cessna 152, Boeing 727, or T-38.

A critical triangle of agreement must be predicated on three totally independent sources of information, and it must derive the information from performance and control instruments with agreement at all times. Sometimes, in addition to the three clocks, there is an alarm clock which brings us back to reality. Let's examine the clocks available to the 727 crew.

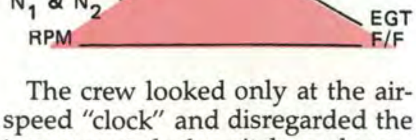
They had both the Main and Standby ADIs, climb power, and indicated airspeed available for the triangle. The one bad clock, the air-





speed indicator, was confirmed bad by two other independent sources of information (control vs performance).

Even if the climb power, which is set by engine pressure ratio (EPR), was incorrect, the critical triangle of agreement for power in the 727 would have allowed them to detect the bad power clock. That triangle is fan and turbine speed (N_1 and N_2 known to most of us as RPM); EPR fuel flow; and EGT.



The crew looked only at the airspeed "clock" and disregarded the two correct clocks, pitch, and power. This added to an already confusing situation. Also, they had an alarm clock to wake them up: Angle of attack.

The buffet started, but they reacted like some of us react to an early launch time. They reached over and shut off the alarm, disregarding its life-saving message, and went back to sleep.

They continued to be just as confused and frightened about the "increasing airspeed" and stalled. They entered a spin and crashed. That mishap held a lesson for all of us, including me. But I missed the part about the critical triangle of agreement.

I separated from the Air Force in 1976 and while training at TWA's facility in Kansas City, this mishap was part of the course material. We discussed the mishap board findings, and the instructor pointed out that checklist discipline had broken down.

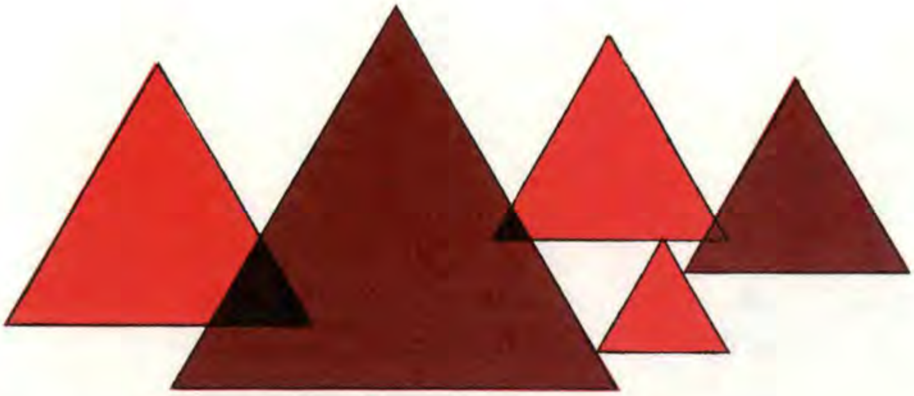
Not only did the first officer fail to turn on the pitot heat, but the second officer did not back him up! As the aircraft climbed through the freezing level at 16,000 feet, ice formed on both pitot tubes. Sometimes that will cause the airspeed to drop to zero, but ice in the pitot system can also seal certain passages and turn the airspeed indicator into an altimeter. That's what happened to the 727. The higher they went, the faster they thought they were flying.

Throughout my career as a second officer on both the 707 and 727, this mishap lingered in my mind as I backed up the captain and first officer while they played with their switches. If they missed something, I was on them like "white on rice." Such an impression did that mishap leave with me. Another point that we discussed concerning the mishap was it is extremely improbable to experience mach buffet in a climb.

When I was an AC on the KC-135, I learned that when something went wrong, the best thing to do was to check the applicable OFF-ON selectors in the "ON" position and command, "Check the circuit breakers." This usually solved the problem, but if it didn't, it gave me time to think of which checklist to call for. Had the 727 crew done that, the pitot heat switch would have been found off — problem solved.

So, they missed that lesson in life. But, had they been aware of the critical triangle of agreement for pitch attitude or Chapter Two of AFM 51-37, Instrument Flying, the mishap would have been only an incident. There was, however, no indication on the cockpit voice recorder that anyone on the flight deck had cross-checked the ADI. In fact, the

continued



CRITICAL TRIANGLES OF AGREEMENT continued

dialogue on the tapes was so unprofessional that Northwest Orient management did not want their crews to hear the tapes. Had the captain lowered the nose to level flight and set cruise power, safe flight would have been possible.

The lessons from this mishap went much deeper than the improbability of mach buffet, the importance of proper crew coordination, checking switches and circuit breakers, and good attitude flying. Critical triangles of agreement could have been discussed, but they weren't. If the mishap had happened after the crew had boarded their charter passengers, the Buffalo Bills, that would have sold newspapers, and a discussion of the critical triangle of agreement may have followed.

The critical triangle finally found me on 15 May 1981, when another IP and I were taking a T-38 to Fairchild AFB for a static display. Weather in Colorado and Utah was miserable, so the only way to fly from Vance to Spokane was through Mexico and California — Washington State the hard way.

The first two legs through Albuquerque and March AFB were uneventful. I had flown both of these legs and was getting acquainted with the idiosyncracies of the baggage pod. The SID at March required that we fly south, about 45 miles out of our way to Oceanside, then we could continue on to the north and our next stop, Beale AFB.

The climb was normal, and as I leveled off at FL 390, I set cruise fuel flow for .9 mach and noted that the RPM and EGT agreed with the fuel flow. This was my cruise power triangle.

Right then, my partner commented that he had never seen Los Angeles. Just think, this was his first time over L.A., and I was the guy who had made it all possible. He seemed excited, so I threw back the "bag." I wanted to share in this memorable experience.

As we peered through the smog looking for Disneyland and Farrah Fawcett's house, I noticed that the aircraft didn't feel right. It wanted to descend when the ADI was placed in normal attitude. Level flight required two degrees nose-high on the ADI, which was the last used climb attitude. At first I thought it was just precession, but I felt a very light buffet when I applied the slightest amount of back pressure.

We wondered if the pod had something to do with the buffet. Could it have come undone or

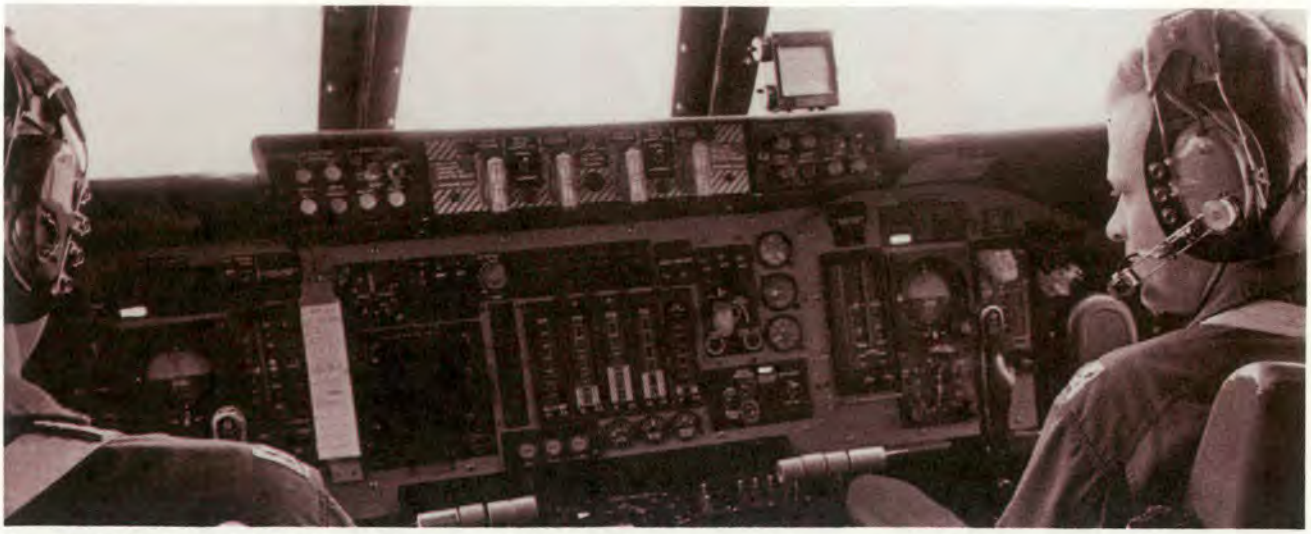
swiveled sideways? We were indicating .95 mach now. Could that be too fast for the pod causing the buffet?

Since this was our first trip with a pod and not much information had been written about it, all those questions were very rational in our minds. We checked the front speed brake switch — centered and up — and checked the pitot heat switch — on (although we had not flown through any visible moisture). We had checked the switches and the circuit breakers. What else could we do?

Both the main and standby ADIs agreed that we were indeed 2 degrees nose high. All the power instruments agreed we had plenty of power. Then the alarm clock rang loud and clear. The AOA was reading .6 (approach). With 2,800 pounds of fuel and no flaps, that equates to about 188 KIAS and .6 mach; not the 295 KIAS and .95 mach that the airspeed indicator was showing. We concluded that the AOA was right. The ADIs and the light buffet confirmed it in my mind.

My first instinct was to add power, and as I did, we heard two muffled pops, then nothing but wind rushing over the canopies. We began to pressure breathe oxygen and set up for a glide to 26,000 feet and the restart.

All during the glide I was mad at myself. How could I have taken so long to figure out such a simple problem? Now I had no engines and a suspect airspeed indicator, and I never did find Farrah Fawcett's

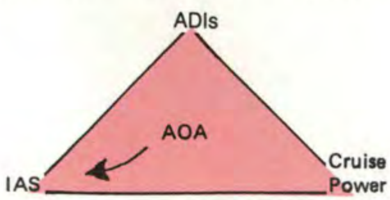


Both pilot and copilot should be looking for the critical triangles of agreement. A basic cross-check and proper crew coordination will guard against misinterpretation of aircraft performance.

house. Then I began to feel thankful that I was VMC for I had never done a needle, ball, and "wind rush" descent before. I hoped I could approximate 270 KIAS for the airstart. Both engines restarted easily using 270 KIAS, and during the approach and landing at March AFB, the AOA agreed with the airspeed indicator. Why?

As we later learned, the AIM's computer static line had cracked. Since that line was in a pressurized portion of the jet, it told the computer we were cruising at about 18,000 feet instead of 39,000. When both engines quit, the cabin depressurized and now the static line was reading the correct atmospheric pressure providing the correct airspeed indication for the restart.

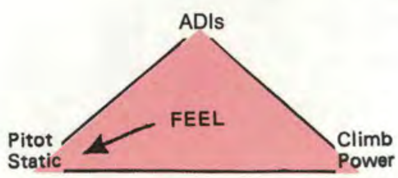
During the approach and landing at March, the cabin pressure agreed with the outside pressure, so the IAS agreed with the AOA and ADI's. Neither my partner nor I had



noticed anything unusual about the climb to FL 390 since all the pitch attitudes were normal and there wasn't the slightest hint of buffet.

Initially, I had followed the same faulty reasoning that the Northwest Orient crew had, thinking about mach buffet. Then I realized that with my cruise power, it was ridiculous to suspect such a phenomenon especially with a pod. For a tie breaker, I used the AOA, but had the AOA not been working, I would only have had feel as my alarm clock.

Let me expand on the feel theory with another story. Years ago, a United DC-6 departed Chicago's Midway Airport into a low ceiling. After entering the weather, all the performance instruments began to read in reverse. The VVI, altimeter, and airspeed all indicated a descent and stall. The captain, as you might imagine, had become quite familiar with the pitch and power requirements for a normal climb. The pitch and power that he saw were the same indications that he had always used, but his performance instruments were in complete disagreement with the control instruments.



The copilot's independently driven attitude indicator confirmed the captain's pitch indications were correct. With no AOA installed in his aircraft, he depended on feel. The low airspeed indicated he should be in a stall, but there was no buffet. Feel was his alarm clock, had he needed it.

The captain held his usual pitch attitude and broke out of the weather at 6,000 feet. This flight crew handled themselves professionally, exercised the principles of good attitude flying, and used the triangle of agreement to turn a confusing situation into confident control. Critical triangles of agreement not only exist for climb, cruise, and approach, but they also exist for takeoff.

Like me, two other pilots missed the critical triangle lesson of the Northwest Orient mishap. They were at the controls of an Air Florida Boeing 737 during takeoff from Washington National Airport on 13 January 1982. The mishap which developed produced fatalities and heroes.

It was a terrible day, with snow and slush covering the runway, and it was snowing hard. The first officer was to make the takeoff. He set the target takeoff EPR of 2.04, and as they started the takeoff run, something seemed unnatural.

The engine anti-ice, which also heats the inlet EPR probe, was not on, and the EPR probe in the engine inlet had iced over. (EPR uses an inlet and exhaust probe to find the pressure ratios.) The probe in the exhaust has "natural de-icing," so the EPR gauges received lots of thrust pressure and very little in-

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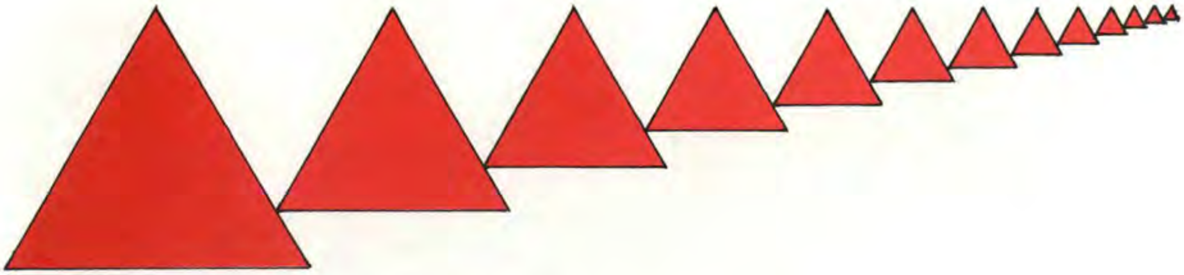


CRITICAL TRIANGLES OF AGREEMENT continued

let pressure information causing a higher-than-actual EPR reading — this was like attempting a takeoff in a T-38, single engine, at military power.

At 14 seconds into the takeoff run, the first officer said to his captain, "That don't seem right, does it?"

Aside from the poor use of English, did you pick up anything from the first officer's statement? His feel was telling him that the critical triangle of agreement wasn't in agreement!

Of the several engine instruments available, only the EPR gauges looked right, and performance didn't confirm that. Had they looked at other engine instruments, such as N_1 and N_2 RPM, EGT, and fuel flow, they would have discovered a low power setting.

Three seconds later, he repeated, "Ah, that's not right." His captain replied, "Yes, it is; there's 80 (knots)."

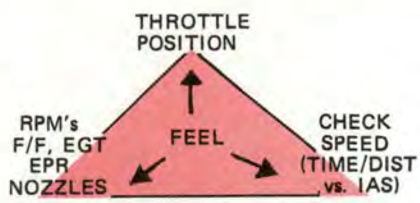
Nine seconds later, the first officer said, "Ah, maybe it is," believing that the EPR and the more experienced captain were correct. Then, only 4 seconds after that, "I don't know."

The 737 lifted off but would not climb. It hit a bridge three-fourths of a mile off the end of the runway.

When the mishap reports were final, we learned many causes for the mishap: Ice and snow on the wings, slush on the runway, improper de-icing procedures, and the engine anti-ice was not used resulting in unreliable EPR indications.

They relied on *one* control instrument, and disregarded the critical triangle of agreement for takeoff power, when so many independent sources of engine thrust information were readily available. If they had recognized the problem at any time prior to the impact and increased power, they would have flown out of the situation safely.

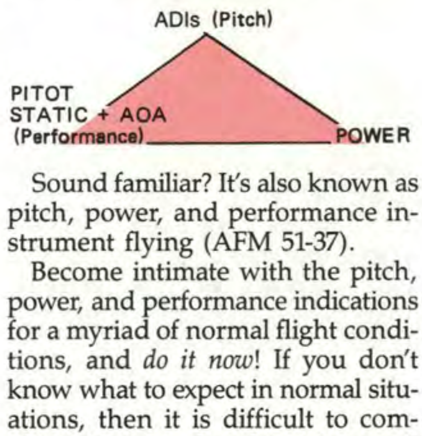
In the 737, as in the 727 and T-38 during takeoff, there are several independent control sources for the critical triangle of agreement and performance source. Graphically, the triangle would look like this:



The alarm clock in the center of the triangle rings when things don't feel right. When that happens, don't shut it off — your feelings are trying to save your life! Check the triangle!

Outside references can either complete or confirm the triangle.

Let's tie this all together with a general, all-purpose triangle of agreement for all in-flight conditions. The three points of the triangle are the pitot static instruments and AOA vs the power instruments vs the attitude instruments.



Sound familiar? It's also known as pitch, power, and performance instrument flying (AFM 51-37).

Become intimate with the pitch, power, and performance indications for a myriad of normal flight conditions, and *do it now*! If you don't know what to expect in normal situations, then it is difficult to complete the triangle when abnormal and confusing situations arise. Practice the principles of the critical triangles of agreement on each aircraft and simulator sortie. You'll avoid the mistakes that sometimes catch even the old pros.

I finally made it to the static display at Fairchild AFB, WA, and some little old lady remarked, "Look at all those instruments!" I just smiled and humbly thought, "Yup, and I need every one of 'em." ■

Reprinted from Sep 83, *Flying Safety* Magazine.

— Some of the information for this article was taken from "Critical Triangles of Agreement" by Archie Trammell, *AOPA Air Safety Journal*, March/April 1983.

A Break In Routine

LT COL JIMMIE D. MARTIN
Editor

■ The C-23A had been airborne for about 35 minutes on a routine airlift mission with 6 passengers on board. They were cruising at 9,000 feet on autopilot at 135 knots indicated airspeed. The aircraft was in and out of the clouds, and the anti-ice equipment had been operating for about 8 minutes. The crew observed an estimated 1/8- to 1/4-inch buildup of rime ice and activated the de-ice boots.

Ten seconds later, the aircraft yawed right, pitched up, and rolled into an uncommanded hard right bank. The aircraft entered a full stall in a spiraling descent in the clouds. The stall warning system never activated.

The pilot checked the autopilot was disengaged, neutralized the controls, and applied power. He noticed the controls were very heavy during the recovery. The aircraft broke out of the clouds at 4,500 feet and recovered at 4,200 feet. A quick controllability check confirmed the aircraft was flyable. A check of the cargo showed all was still in place. The six passengers were uninjured and definitely wide awake.

The pilot left the autopilot disengaged and got a phone patch with the squadron to discuss the situation. They then diverted to another base for landing and declared an emergency. The crew performed a complete controllability check and made two fly-bys of the field for visual checks. They then made an uneventful landing.

After landing, the aircraft and cargo were impounded for maintenance inspections and reweigh. (I suspect the passengers were happy to seek less exciting transportation.) The cargo weight was accurate, and comprehensive ground checks and inspections found nothing that could have contributed to this incident. They discovered the stall warning system was inoperative.

An extensive analysis of the weather conditions in the area at the time of the incident is being conducted. The flight data recorder information is also undergoing thorough evaluation. Initial review of the flight data recorder information revealed the following.

continued

A Break In Routine

continued

■ **Airspeed** Ten minutes prior to the incident, the airspeed was steady at 152 KIAS. A linear decay then began. By 1 minute prior, it had fallen to 124 KIAS. From that point, the airspeed rapidly fell to 88 KIAS at the time the aircraft stalled. (A check of the performance data confirmed the stall speed for the existing parameters was 88 KIAS.)

■ **Pitch** Ten minutes prior to the mishap, the aircraft was 2 degrees nose high. From that point, the pitch attitude slowly increased to 12 degrees nose high at the time of the stall.

■ **Altitude** The aircraft was level at 9,150 feet until the stall. It then descended to 4,150 feet — a loss of 5,000 feet in 30 seconds.

The investigation into this incident is still continuing. In the meantime, an interim airspeed in icing conditions for the C-23A has been set at 120 KIAS. Also, a new operation supplement (1S-7) to the C-23A Dash One has been released entitled "Advisory Information for Flight in Icing Conditions."

This incident is a graphic illustration of the old adage used by many fliers over the years, ". . . hours and hours of boredom interspersed with moments of stark terror." In this case, the outcome was a safe landing with no damage or injuries. It could have been a disaster.

Even though we don't know the cause of this incident, we can still learn from it. The immediate lesson is simple. *Flying is never routine*. The autopilot is a great invention for relieving pilot fatigue, but it can't think. The pilot and crew must be constantly aware of what the aircraft is doing and not be lulled into a false sense of security by a *routine* flight just like many others before it. The routine can suddenly become very exciting through no fault of your own. ■

Cost-Saving Savvy


Lieutenant Boskovich demonstrates the placement of the rib stiffener she helped develop.

ROSS DAY
San Antonio ALC
Kelly AFB, TX

■ In her first major assignment, Second Lieutenant Jan Boskovich, San Antonio Air Logistics Center, Kelly AFB, Texas, recently helped develop a simple piece of milled aluminum which will save the Air Force approximately $630,000 and make flying safer for T-38 Talons subjected to high stress flights.

Lieutenant Boskovich was given the task of preventing the recurrence of an incident in which a T-38, out of Holloman AFB, New Mexico, lost a wingtip during a high stress maneuver. The rib where the honeycomb wingtip joins the main part of the wing had cracked and failed, she explained.

Lieutenant Boskovich, an aerospace engineer assigned to the Center's Fighter/Tactical/Trainer System Program Management Division, said preliminary tests determined that stiffeners added to the rib would *reduce* the stress that caused the crack and ultimate failure.

Another analysis with stiffeners added indicated that they would work, she said. Subsequently, an Austin, Texas firm manufactured four prototypes.

Meanwhile, nondestructive testing of the T-38 fleet at Holloman AFB revealed cracks in the wing rib of seven additional aircraft at the wingtip/main wing juncture. "Our supply of these specific ribs was nearly exhausted by the requirement to replace these cracked ribs," the Lieutenant said. "It would be approximately 2 years before we could get improved ribs from Northrop," she added.

According to officials at Kelly AFB, Texas, the stiffeners are a satisfactory alternative to rib replacement for the T-38 fleet. Officials estimate the rib replacement would cost approximately $630,000.

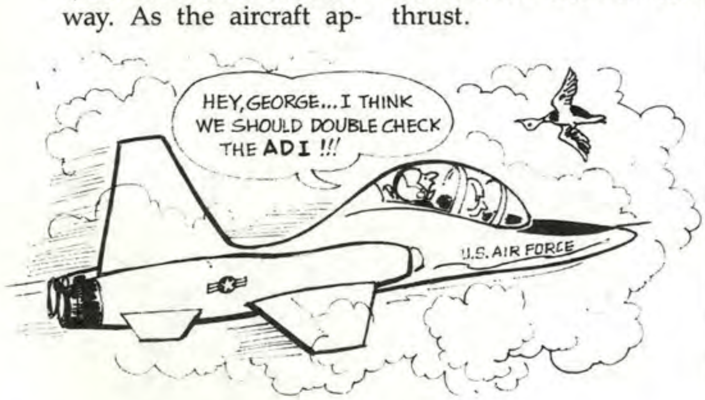
Installation of the four prototype stiffeners — two in each wing — demonstrated, as expected, that the process is relatively fast and simple and can easily be done in the field.

There are approximately 140 T-38s in various commands subjected to high stress flights. These aircraft are now scheduled to receive reinforcing stiffeners within the next 6 months. Meanwhile, their ribs will undergo nondestructive testing every 300 flying hours rather than the standard 900. ■

OPS TOPICS

Slow Falcon

■ During a mil power takeoff, the F-16A pilot noted the aircraft was 11 knots slow passing the acceleration checkpoint. A quick check of engine instruments showed normal readings. The pilot initiated rotation at 145 KIAS, 3,500 feet down the runway. As the aircraft approached takeoff speed at 4,000 feet (2,800 feet computed takeoff roll), the Master Caution light illuminated momentarily. The pilot aborted takeoff. Maintenance never found out why the Master Caution light flashed on, but they found the engine was out of trim and produced lower than normal thrust.



No Gyros

Two pilots were flying a proficiency sortie in a T-38. On initial climbout from a cross-country base, and in instrument conditions, the main attitude indicator (ADI) in both cockpits indicated an increased climb rate. So, the rear cockpit pilot pushed the Talon's nose down. At that time, the main ADI in both cockpits tumbled, and the heading indicator (HSI) in both cockpits began to spin. The front cockpit instruments read 350 knots indicated airspeed, 2,000 feet mean sea level altitude, a descent rate of 2,000 feet per minute, and the standby ADI showed 45 degrees of left bank and a slight descent.

The front cockpit pilot took control of the aircraft and made a gradual climb to visual conditions at 14,000 feet. All attempts to fast erect and fast slave the instruments were unsuccessful. There were no caution lights, "OFF" flags, or popped circuit breakers. In level flight, the standby ADI indicated a 20-degree left bank.

Since the standby ADIs were unreliable, the front cockpit pilot flew a no-gyro, nonprecision radar approach. The aircraft entered the clouds at 4,000 feet and broke out on a 2-mile final. The pilot made an uneventful minimum roll landing on the wet runway. Both main ADIs and HSIs slaved to the correct indications during taxi back to parking.

Extensive maintenance troubleshooting revealed a defective platform gyro. No other discrepancies were found, and the aircraft has flown several times since gyro replacement with no instrument problems.

Are Emergencies Contagious?

An FB-111 escorted another FB-111 with an inflight emergency back to the home field. The two FBs flew a wing approach. The emergency aircraft landed safely.

As the pilot of the escort aircraft advanced power for a missed approach, he noticed the left engine didn't respond — it remained at 70 percent RPM. After completing a single-engine missed approach, the pilot ran the compressor stall checklist which led to shutting down the affected engine. When he tried to restart the engine, it wouldn't start. He then accomplished an uneventful single-engine landing.

Maintenance found a broken throttle cable. A pattern of broken throttle cables in F/FB-111 aircraft has prompted designing a new cable with an estimated delivery date of June 1986. ■

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.

MAJOR

Larry E. Faber

17th Reconnaissance Wing

■ On 20 February 1985, Major Faber was flying an operational mission in a TR-1 aircraft. While cruising at high altitude approximately 3 hours into the flight, Major Faber noticed a low frequency vibration of increasing intensity. After 15 seconds, RPM, EPR, and EGT began to decrease rapidly. Major Faber opened the bleed valves and held the ignition on, but the engine continued to unwind. At this point, Major Faber established recommended glide speed, turned toward the nearest suitable landing field, and advised ATC of his situation. While descending, he attempted several airstarts without success. Arriving over his intended recovery base, Major Faber lowered the landing gear using emergency procedures. At 13,000 feet, another starting attempt resulted in a relight, but the engine did not achieve normal idle RPM and severe vibrations were still present. Major Faber elected to leave the throttle in idle for possible emergency use and continued the descent to set up for his flameout pattern. Departing 4,000 feet, he selected 20 degrees flaps. At 3,000 feet, vibrations increased, and a violent jolt threw him against the right side of the cockpit. He immediately shut the engine down and concentrated on his flameout landing, achieving a high key altitude of 1,900 feet AGL. Because of heavy fuel weight with required higher airspeeds, the pitch attitude was considerably steeper than normally flown during simulated flameout landings. Expertly adjusting his pattern for the unfamiliar parameters, Major Faber established an aim point halfway down the runway and flew a tighter pattern than usual. Over the overrun, Major Faber lowered what remaining flaps he could get with windmilling hydraulic pressure and made a perfect landing 1,000 feet down the runway. Major Faber's professional reactions to a potentially catastrophic emergency, combined with exceptional flying skills while encumbered by a bulky full-pressure suit, prevented the loss of a valuable aircraft. WELL DONE! ■

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UNITED STATES AIR FORCE

Well Done Award

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

CAPTAIN

John F. Painter

140th Tactical Fighter Wing
Buckley ANG Base, Aurora, Colorado

■ On 9 February 1985, while flying in a four-ship A-7 air refueling/SAT mission, Captain Painter's aircraft experienced an engine rollback to idle power thrust. Airspeed was 450 knots at 2,000 feet AGL at the time. Captain Painter immediately climbed to trade airspeed for altitude, in an attempt to make an emergency landing at Pueblo Municipal Airport approximately 45 miles to the northeast. The A-7 engine did not respond to any throttle movement as exhaust gas temperature (EGT) remained at 300 degrees. Flight members joined up, adding suggestions and providing help as airspeed and altitude began to bleed off. Additional forward throttle movement further reduced EGT, and ejection appeared imminent. Fuel was dumped to extend range, and preparation was made for a heavyweight landing. As Captain Painter neared Pueblo, it became apparent the best traffic pattern would be to approach the field from the southeast to avoid the heavy population center in the event of an ejection. The aircraft was positioned for a precautionary landing pattern and turned a close-in base for landing. Due to partial closure of Pueblo's runway and the lack of barriers, Captain Painter delayed configuration and used variable trailing edge flaps to adjust airspeed because the engine would not respond to throttle movement. On landing, the generator failed leaving no antiskid braking or nosewheel steering. Using differential manual braking, Captain Painter brought the aircraft to a safe stop. Captain Painter's calm, quick, and proper reaction coupled with his exemplary flying ability saved a valuable aircraft. WELL DONE! ■

CONGRATULATIONS Air Force

on the ALL-TIME LOW MISHAP RATE

1.49