Aircraft Accidents and Aircraft Instruments

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"In modern military flying, irregularities of knowledge concerning position or direction in flight are causing losses of near-catastrophic proportions. . . . This phenomenon of spatial confusion affects everyone who flies. . . . When it is severe . . . it is one of the most lethal of all occupational hazards."*—Colonel H. G. Moseley, *USAF (MC)

UNFORTUNATELY aircraft accidents under instrument conditions are not rare. During the period of July 1, 1957 through June 30, 1958 the Air Force experienced 116 such major accidents. By far the greater portion of these involved jet equipment with jet fighters being most frequently involved and jet trainers only slightly less so (Table I). Regardless of the aircraft type, however, the losses associated with this type of accident are high. In those considered, 111 aircraft were destroyed and sixty-five pilot operators were fatally injured. Accidents of this kind emphasize the dependence of pilots on aids external to themselves, particularly when visual contact is lost.

TABLE I. HAZARD ATTENDANT TO ACCIDENTS OCCURRING DURING INSTRUMENT REFERENCE, BY AIRCRAFT TYPE
USAF/ANG Major Accidents
July 1, 1957 to June 30, 1958

Aircraft Type	Aircraft or Pilots Involved	Number		Per Cent	
		Aircraft Destroyed	Pilot Operator Fatalities	Aircraft Destroyed	Pilot Operator Fatalities
Jet aircraft	104	92	51	88	49
Fighter	57	50	27	88	47
Trainer	31	28	17	90	55
Bomber	16	14	7	88	44
Non-jet aircraft	22	19	13	90	62
Trainer	2	2	1	100	50
Bomber	6	5	3	83	50
Cargo/Trans.	13	11	8	85	62
Liaison	1	1	1	100	100
Total	126*	111**	64†	88	51

*Includes 10 secondary aircraft/pilots involved in collisions.
**Includes 7 secondary aircraft.
†Includes 4 pilots in secondary aircraft.

The magnitude of the problem is graphically portrayed in Figure 1, where the hazard associated with accidents which occur under instrument conditions is compared with the hazard associated with all major accidents. When all major accidents for the period were considered, 55 per cent

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resulted in aircraft destroyed. As impressive as this figure is, it pales by comparison with the 88 per cent of the aircraft which are destroyed when the accident occurs under instrument reference. The pilot fatal ratio is equally depressing. For the periods considered, one-fourth of all major accidents resulted in fatality to the pilot operator. Accidents under instrument conditions during the same period resulted in the loss of over half of the pilot operators.

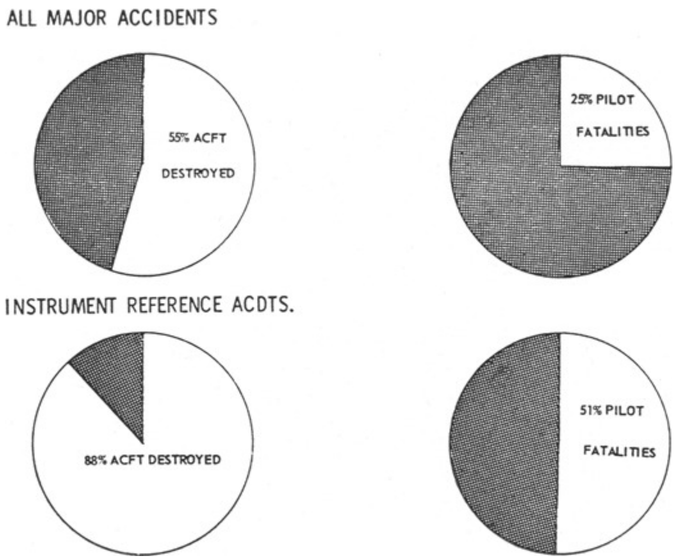


Fig. 1. Relative severity of major accidents occurring under instrument conditions, July 1, 1957-June 30, 1958.

The impact of these types of accidents on the over-all Air Force accident picture is shown in Figure 2. Jet aircraft accidents under instrument conditions (12 per cent of all of the accidents experienced in jet aircraft during the period) accounted for one out of five of the jet aircraft destroyed and for one out of five of all the pilots lost in jet operation during that period. Non-jet accidents under instrument conditions were more critical. Although they accounted for only 9 per cent of the accidents, they were responsible for one out of five of the aircraft destroyed and over half of the pilot fatalities in non-jet aircraft.

By far the greatest portion of the accidents under instrument reference occurred in flight under normal conditions. Acrobatics, low altitude bombing maneuvers, and other critical types of operation were insignificant in terms of numbers.

The most frequent accident type was collision with ground or water and the second most frequent was the abandonment of the aircraft while it was still in operating condition because of such emergencies as impending fuel depletion or because the pilot was lost (Table II). The collisions with the ground or water, in most instances, were completely unanticipated and gave the pilot no opportunity for escape. This type of accident almost by definition exceeds the structural design limits of both the aircraft and the man and can result only in fatality to the pilot and destruction to the aircraft.

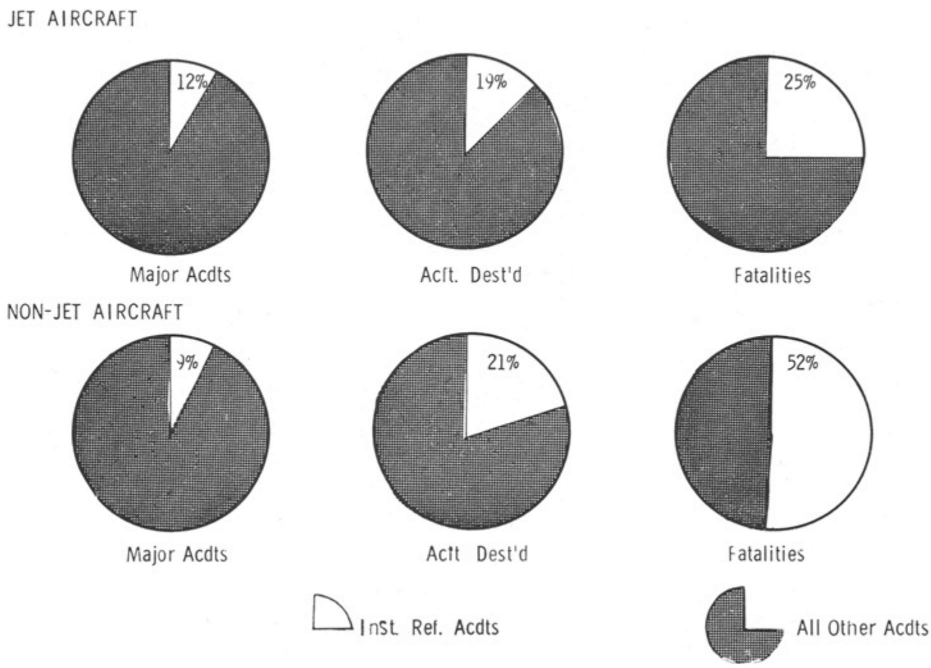


Fig. 2. Impact of accidents occurring during instrument reference flight on the Air Force accident records, July 1, 1957-June 30, 1958.

An accident under instrument conditions involves a breakdown of the equipment, the auxiliary aids, the man, or of the interaction between them. A list of the specific failures is shown in Table III. Here both the factors which were considered the primary cause of the accident as well as all causes are listed. As is usually the case, the pilot operator was responsible most often for the accident, although various types of unsafe conditions were most frequently contributing factors. Since the accidents under consideration occurred under instrument conditions it would be expected that weather would be a major factor. The validity of this expectation is indicated by the sixty-one instances in which weather was implicated. In spite of this, however, in only one accident was weather considered the primary cause.

To a great extent the high portion of pilot failure under adverse weather is a matter of experience. An evaluation of the pilots' weather flying indicates that jet pilots involved in accidents had an average of less than ninety hours of weather flying while those involved in non-jet accidents had an average approximately two times as high, that is, about 185 hours. This limited experience is, however, not only associated with accident pilots since a sample of comparable non-accident pilots had approximately the same levels of experience.

Although equipment failures occur, these are not frequent and seldom are sufficiently devastating to precipitate an immediate action. Likewise there is seldom a complete breakdown of the auxiliary aids. It is rare, for example, that weather personnel fail to relay proper weather information or that there is a breakdown of such auxiliary aids as Ground Control Approach or of landing facilities.

Hence if there is rarely a complete breakdown of any of the fundamental systems, that is, the man or his equipment, most accidents must be the result of a partial failure of the man-machine complex or of the inner connecting links which relate the various parts of this complex. An examination of the actual accidents indicates that this is the case. It is rare indeed that an accident is completely the result of a single failure.

The operation of any system, which involves the man and machine in an integral man-machine combination in its simplest form, involves a machine in operating condition, a man functionally intact, and interconnecting links between the man and machine. These in aircraft pilots are in the form of instruments which give the man information regarding the functioning of the equipment and controls which can be used to modify that functioning once a decision to do so has been made. These interconnecting links are most critical in instrument flying. Unless the instruments which the man must rely upon are completely and immediately dependable and designed so that the information they impart can be gleaned rapidly and efficiently, difficulties are sure to arise. This problem has been recognized for some time and much has been done toward developing instruments which are designed for maximum usability by the human operator. The present attempts, by the Air Force as well as other agencies, to develop improved systems are the result of clear recognition of the problem. Unfortunately the amount of emphasis which has been placed upon the development of basic aircraft performance has not been matched by a comparable amount of attention di-

TABLE II. MOST FREQUENT INSTRUMENT REFERENCE ACCIDENTS*
BY PHASE OF OPERATION BY ACCIDENT TYPE
USAF/ANG Major Accidents
July 1, 1957 to June 30, 1958

Phase of Operation	Total	Type of Accident				
		Collision Grd/Water	Abandon Aircraft	Mid-Air Collision	Fire/ Explosion	Spin/ Stall
In flight	65					
Normal		15	20	2	4	0
Tactics/maneuvers		9	5	7	1	2
Landing	19					
Approach		9	6	1	0	2
Other		1	0	0	0	0
Other	17					
Takeoff		8	0	0	1	1
Go-around		5	2	0	0	0
Total	101	47	33	10	6	5

*Pertains to 101 (87 per cent) of the accidents reviewed.

rected toward facilitating the use of the basic equipment in terms of man's inherent strengths and weaknesses. It would be desirable to state that the current problems associated with instruments were soon to be eliminated, but a critical survey of the current efforts would suggest that all-inclusive solutions are not immediately impending. In this regard, two quotations are presented showing the divergent opinions of members in two major groups working in the instrument area. The first of these states: "The evaluation of this indicator and related tests . . . have resolved irrefutably the 'inside-out' 'outside-in' controversy. The 'fixed aircraft-moving horizon' type display was not only shown to be generally superior to the 'moving aircraft-fixed horizon' type but actually the only acceptable one for maneuvering flight." This appears to be a statement which indicates great progress. A perusal of the second, however, clouds the optimism gained and suggests that the state of development is not as far advanced as could be desired. This states: "At . . ., simulation studies indicate that the moving aircraft symbol presentation produces measurably superior performance with fewer control reversals than does the moving horizon presentation. This superiority is due to the use of psychologically correct display movement relationships in the moving aircraft symbol presentation."

If sufficient interest is aroused

TABLE III. CAUSE FACTORS IN ACCIDENTS OCCURRING UNDER INSTRUMENT CONDITIONS
USAF/ANG Major Accidents
July 1, 1957 to June 30, 1958

Cause Factors	Total		Primary	
Pilot operator		107		52
Poor technique in flight	55		33	
Poor technique in pattern	17		11	
Incorrect operation of misc. equipment	10		1	
Improper flight preparations	5		2	
Incorrect operation of procedure, power plant	3		2	
Incorrect operation of wing flaps	2		—	
Incorrect operation of fuel system and controls	2		1	
Incorrect operation of electrical equipment	1		—	
Mistreated airframe	1		1	
Poor technique in takeoff operation	1		—	
Miscellaneous unsafe acts	10		1	
Supervisory personnel		52		13
Inadequately supervised aircrew training or operation	40		9	
Inadequately provided aircraft maintenance	11		4	
Weather personnel failed to relay weather conditions	1		—	
Unsafe conditions		183		26
Weather	61		1	
Engine (turbine)	16		10	
Instruments	11		2	
Airbase, landing aids and areas	10		1	
Airframe	8		1	
Electrical system	7		2	
Fuel (out of)	5		0	
Power plant components	5		2	
Communications	5		1	
Fuel system	4		1	
Landing gear	4		0	
Oxygen system	3		0	
Flight control system	3		2	
Airways system, navigation aids	3		1	
Survival and personal equipment	2		0	
Heating, ventilating, pressurization	1		0	
Ordnance	1		0	
Engine, reciprocating	1		1	
Miscellaneous conditions	33		1	
Cause undetermined		25		25
Total		367		116

and enough effort expended, major innovations in instrument concepts will undoubtedly result. Pending this, however, there are many problems with individual instruments which need to be considered if present-day flying is to be made as safe and effective as possible. Evaluating the accidents which occurred under instrument conditions indicated it was usually not possible to define the focal point of the breakdown. This was particularly true when the problem was associated with such factors as interpretability or instrument interrelationships. There are instances of actual instrument breakdown which are known to have been contributing factors.

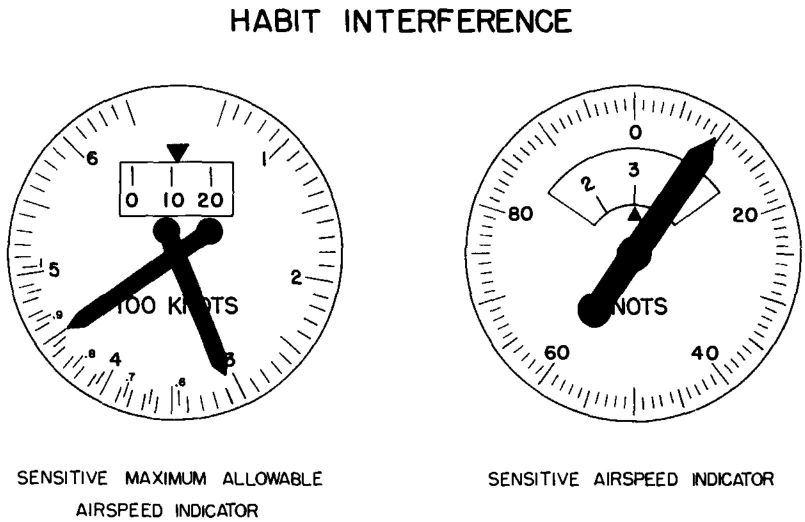


Fig. 3. Habit interference.

Historically the single instrument which has been recognized for the longest time as being inadequate is the altimeter. The need for a presentation of greater accuracy giving a more immediate response and having greater interpretability was documented many years ago. Current efforts to improve this situation involve both the drum type altimeter and the tape type. The drum type altimeter which is being developed will effectively prevent 10,000 foot misreading errors but still allows 1,000 foot misinterpretation errors at critical altitudes. It also may prove to be basically incompatible with the airspeed indicator with which it is often used. Whereas the outside dial of the airspeed indicator is in units of 100 and the drum in units of 10, the outside dial of the altimeter is in units of 100 and the inside dial in units of 1,000. This may well lead to difficulty in interpretation.

The tape type altimeter appears to offer advantages. When it incorporates a servo-driven mechanism to increase its sensitivity and a non-linear tape to promote accurate interpretation during critical altitudes, marked improvement in usability should result. The major disadvantage of such a presentation is that unless used in conjunction with a fail-safe feature which will continue to provide information in the event of an electrical failure or with an auxiliary instrument, the pilot may find himself without altitude information at a critical time.

A reverse presentation which has caused difficulty involves two airspeed indicators which were in the Air Force inventory at the same time. This situation has been corrected. However, in at least one instance before this was done an expensive aircraft and a flight crew were lost, probably as the result of the conflicting presentations. Indications are that the pilot who used the position of the airspeed indicator rather than actually reading its value as a means of determining whether or not performance was normal at certain phases during takeoff and climb-out noted an unusual configuration and misinterpreted its meaning. He apparently then lowered the nose in order to gain airspeed which he assumed was low and in the process lost control of his aircraft. An examination of the two airspeed indicators (Fig. 3), both of which are indicating 310 knots will show the ease with which this error could occur. In the accident in question, the pilot had been informed of the change in indicator presentations but this was his first flight with the alternate presentation as opposed to over 500 hours of experience with the one to which he was accustomed.

Other instruments are also known to have contributed to accidents when there was an actual malfunctioning of the instrument itself (Table IV). As suggested previously, if it were possible to make accurate determination of other instances in which the presentation itself contributed to accidents, the numbers would undoubtedly be much higher. Attitude indicators, for example, are instruments which are known to have precipitated accidents even though there was no malfunctioning of the instrument itself. One of the problems which has been documented in regard to this instrument is that of its lag in reflecting the correct attitude, particularly during critical portions of the flight such as immediately after takeoff under instrument conditions. The tendency for the instrument to indicate erroneous turn and bank information during high speed maneuvers is also critical. Both of these design limitations have been recognized and are well known to pilots but remain contributing factors in accidents.

TABLE IV. INSTRUMENT INVOLVEMENT IN ACCIDENTS
USAF/ANG Major Accidents
Jan. 1, 1956 to Dec. 31, 1958

Malfunction or Failure	Reported Instances	Aircraft Destroyed	Fatalities
Fuel quantity	23	17	13
Airspeed indicator	15	9	5
Attitude indicator	11	9	5
Gear position indicator	10	1	0
Gyro compass	7	4	3
Altimeter	6	4	3
Tail pipe temp. indicator	3	2	8
Other	8	6	7
Total	83	52	44

A cockpit deficiency which has proven particularly serious from the standpoint of fatal accidents relates to the channel or mode selector and the frequency indicator which are standard parts of aircraft communication equipment. The location of these rather than the basic reliability of the equipment has been the demonstrable cause of aircraft accidents. Repeatedly under instrument conditions accidents have occurred when the pilot was required to change channels or modes at a time when maximum concentration on instruments was essential. In order to use this equipment in some aircraft, the pilot is required to change control of the aircraft to the left hand and to then lean forward and downward while turning his head in order to complete the channel changes. The reflex action of the body is such that it is very difficult to maintain the aircraft in a prescribed attitude with the body in this position. Additionally the quick straightening of the body is conducive to a Coriolis type disorientation. The combination of this with an unexpected instrument presentation when time is at a minimum is directly conducive to loss of control and hence accidents. This particular problem of diversion is fortunately being alleviated by retrofit and relocation of the communication equipment and by improved design of new equipment. This is a specific example of faulty location. It documents a general principle however; namely, that no piece of equipment in the cockpit should be placed so that diversion from the primary task of flying is required of the pilot, particularly during critical phases of flight.

Other presentations which are particularly important to the pilot are the various warning systems (Table V). There is no presentation demanding greater reliability than one which indicates that a basic malfunctioning has developed; in a matter of seconds immediate action may be required either to initiate corrective procedures or to part company with the aircraft as expeditiously as possible.

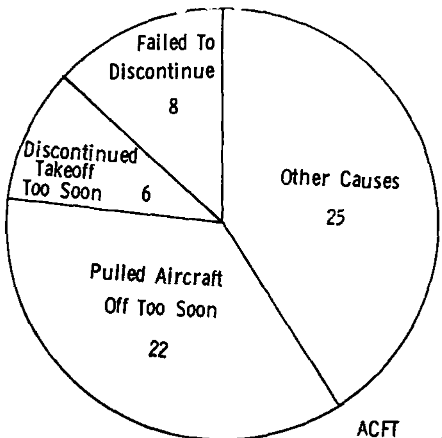
TABLE V. WARNING SYSTEM FAILURES
USAF/ANG Major Accidents
Jan. 1, 1956 to Dec. 31, 1958

Unsafe Conditions	Number Accidents		Aircraft Destroyed		Fatalities	
Fire warning systems		20		18		10
False warning	7		6		2	
Indicator	6		6		4	
Wiring	5		4		1	
Detection	2		2		3	
Gear warning system		19		2		0
Fuel warning lights		6		2		0
Total		45		22		10

The problem of false fire warnings has been a particularly obnoxious one. A failure to indicate a fire produces an extremely critical situation as does a false fire warning which may (and has) resulted in the loss of aircraft and pilots.

Gear warning systems are also a continuing source of difficulty. Fortunately, either a failure of the system or of the pilot to respond to the warning usually results in damage to the aircraft but seldom results in major injury except to the individual's pride.

The previous discussion has been centered to a great extent around individual instruments and their location. A more basic problem presents itself when the inter-relation of instruments is considered. The Air Force, together with other groups including the Navy as well as representatives from several of the NATO countries, some years ago decided upon an instrument arrangement called the "basic six." While this may not have been the best arrangement in all instances, a great deal of advantage has accrued from its use because of the standardization from one cockpit to another.



	ACFT DESTROYED	FATAL INJURIES
PULLED AIRCRAFT OFF TOO SOON	17	44
FAILED TO DISCONTINUE	3	6
DISCONTINUED TAKEOFF TOO SOON	1	0
	21	50

Fig. 4. Pilot factor takeoff accidents, January 1, 1958-December 31, 1958 (total major accidents: 61).

When standardization is considered, one always faces a dilemma. Complete standardization impedes progress and at the same time perpetuates known errors in new equipment. On the other hand, individual arrangements result in such a confusion of presentations from one cockpit to another that any advantage gained from a unique presentation may be lost in terms of the overall use of the equipment. Any change which would serve to create greater confusion for the pilot should be weighed very carefully against the proposed advantages and unless these are marked should not be implemented. Extensive block modifications and retrofit programs are practical methods of circumventing this problem.

Utter confusion would result if all of the many suggestions regarding new instrument warning systems or other presentations were incorporated in modern cockpits. In view of the changes in aircraft functioning, however, it is obvious that at times there is need for new presentations. The selection of these must be made very critically.

On the basis of accident histories there appears to be at least three areas in which the information supplied to the pilot by current instruments is inadequate. These are related to the phases of flight in sequences. During takeoff the pilot has to determine the point at which the aircraft must be either lifted from the runway or the takeoff run discontinued. The requirement for this judgment in aircraft loaded to capacity on marginal runways has resulted in errors which have contributed to accidents. The aircraft may be pulled off too soon, the takeoff run may be discontinued too soon, or there may be a failure to discontinue the takeoff run until the point of no return is reached. Thirty-six accidents during 1958 were attributed to these errors. These resulted in twenty-one aircraft destroyed, in many cases highly strategic aircraft, and fifty fatal injuries (Fig. 4). This record indicates the need for a takeoff monitoring device which will assist the pilot in this flight phase.

Another problem relates to the in-flight necessity for avoiding collisions with other airborne aircraft. With only minor reversals from 1947 to 1958, the portion of all Air Force major accidents which are mid-air collisions has increased. Although the decrease in 1958 is heartening, repeated evaluations have clearly indicated that the operational situation has to a great extent developed to a point where the human operator cannot consistently and successfully avoid mid-air collisions without additional aid. The need for an anti-collision device which will indicate to the pilot positively when he is on a collision course and the action to take for avoidance of a collision is acute.

One other problem poses itself in the landing phase and this is the problem of landing short. Although progress has been made in reducing these landing short accidents, they still occur in relatively large numbers. Such simple measures as restricting the initial portion of the runway and requiring the pilot to land at some predetermined spot farther down the runway are extremely beneficial and have contributed to the decrease in undershoot accidents. If continuing progress is to be made in this accident area, the pilot must be given additional information which will assist him in transitioning from three-dimensional to two-dimensional operation in aircraft with high sink rates, high angles-of-attack, and critical flare characteristics. An angle-of-attack indicator or a comparable instrument which gives the pilot essential information required for a consistently successful touchdown is indicated as highly desirable.

In the race for air superiority, more and more emphasis is being placed upon higher performance for aircraft in every category. The success of this understaking is demonstrated by the current altitude, speed, and endurance capability of modern military and commercial aircraft. As long as the pilot remains in the cockpit, however, he remains the deciding link in determining whether or not this performance can be optimally utilized. The instruments and controls which serve to give him information and turn his decisions into action assume, therefore, greater and greater importance. Unfortunately, progress in the development of these instruments and controls has not kept pace with the development of the aircraft performance. It is time for comparable effort to be directed toward the development of the cockpit environment as is exerted by the engineer in the development of the airframe, power plant, and other critical components. Unless consideration is given to getting the most out of the man, the man cannot get the most out of the machine.