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PREFACE

The Society of Air Safety Investigators is organized exclusive to promote the development of improved accident investigation procedures through lectures, displays and presentations and by the exchange of information. In furtherance of this objective, it is intended to exchange ideas, experiences and information regarding the art of aircraft accident investigation and disseminate findings to the public, in order to increase the safety of flight.

The PROCEEDINGS of the Society include a compilation of the papers presented at the Annual Seminar and are intended solely for the purpose of aircraft accident prevention. The views and opinions expressed in the PROCEEDINGS are those of the authors and do not necessarily reflect the views of the Society.

PROTECTION OF AIRLINE FLIGHT ATTENDANTS IN A DECOMPRESSION

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I. INTRODUCTION

The official report[1] of the DC-10 aircraft decompression over New Mexico in 1973 noted that physical activity shortens the time of useful consciousness (TUC)* and, so, the time to effectively obtain supplemental oxygen in a decompression. After a futile search for TUC data that would apply particularly to the flight attendants who would have been engaged in physical work at the moment of this decompression, we initiated a research program to obtain this data, simulating the conditions of this decompression.

II. RESEARCH PROGRAM

In two studies, male and female subjects representative of the flight attendant population were exposed to the decompression profile, shown in Fig. 1, which closely approximated that reconstructed for the DC-10 decompression, referenced above. Decompression from 6,500 to 34,000 ft (2,000 to 10,400 m) in 26 s was followed by descent at 5,000 ft/min (1,500 m/min).

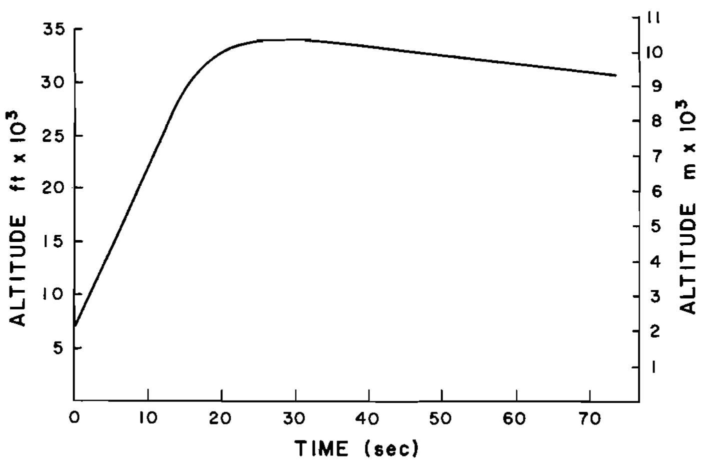

Fig. 1. Decompression profile

In the first study, reported in detail elsewhere,[2] we determined the effect of physical work at a light-to-moderate level on TUC. Ten males and ten females underwent the decompression exposure once at rest and once while performing work on a Godart bicycle ergometer at either 50 W (males) or 40 W (females). These workloads, begun 3 min before decompression and continued until loss of useful consciousness, were selected on the basis of commensurate heart rate data obtained on working flight attendants by Åstrand and Kilbom.[3] Heart rates after 3 min of work at ground level reached steady state values, averaging 106 (S.D. 8.3) for the males and 116 (S.D. 10.1) for the females. The TUC was determined with a disjunctive reaction time test, which required cancellation of one of two randomly presented lights by pushing corresponding buttons with one index finger.

As shown in Table I, the light-to-moderate workload performed in this study markedly reduced the tolerance of all subjects to hypoxia. The average TUC for the males decreased from 54 s (S.D. 7.1) at rest to 34 s (S.D. 4.4) and for the females from 54 s (S.D. 8.1) to 32 s (S.D. 4.0). There was no difference between males and females in their tolerance to hypoxia.

* Broadly defined as the period from onset of decompression to failure to perform a purposeful act (i.e., obtaining and effectively utilizing supplemental oxygen).

TABLE I. TIME OF USEFUL CONSCIOUSNESS (TUC).

	Subject	TUC - Rest (seconds)	TUC - Work (seconds)
Males	1	54	38
	2	59	25
	3	48	29
	4	71	34
	5	50	37
	6	45	34
	7	55	34
	8	54	32
	9	53	33
	10	54	40
	Range	45-71	25-40
	$\bar{X}$	54	34
	S.D.	7.1	4.4
Females	1	54	38
	2	40	26
	3	61	33
	4	52	32
	5	46	34
	6	68	35
	7	50	32
	8	61	28
	9	57	34
	10	51	26
	Range	40-68	26-38
	$\bar{X}$	54	32
	S.D.	8.1	4.0

In the second study, reported in detail elsewhere,[4] we determined the maximum time for a flight attendant performing these workloads to effectively initiate donning of an airline passenger mask after onset of decompression. In two series of tests, five males and five females were given a signal to stop work and don an airline passenger oxygen mask (Sierra, TSO-C64) at 10, 15, 20, and 25 s after onset of decompression. In one series, supplemental oxygen came from a compressed oxygen source at a flow of 14.2 l/min BTPS (2.5 l/min NTPD) immediately after lanyard detachment. In the other series, supplemental oxygen came from a chemical oxygen generator (Scott Aviox), its flow starting about 3.5 s after lanyard detachment and reaching an average level of 18.1 l/min BTPS (3.2 l/min NTPD) in another 3.0 s.

The results of this study are summarized in Tables II and III.

TABLE II. HYPOXIC EFFECTS FROM DELAYS IN MASK DONNING—COMPRESSED OXYGEN SOURCE.

SUBJECT		AGE (yr)	HEART RATE (bpm)		Time from Onset of Decompression to Mask Donning Signal (s)				TUC* (s)
					10	15	20	25	
MALES	U. R.	25	after 3 min at 50 W (ground level)	102					32
	R. L.	22		98					38
	J. W.	25		102					34
	W. S.	24		100					40
	R.W.	22		100	NO TEST				34
FEMALES	A.B.	30	after 3 min at 40 W (ground level)	108					34
	C. G.	33		112				MASK NOT DONNED	28
	S. H.	35		108	NO TEST				35
	R.C.	34		114					34
	P. G.	27		120					38

* Time of useful consciousness from previous study, determined under identical experimental conditions. (1)

NO HYPOXIA / TEMPORARY HYPOXIA / LOSS OF USEFUL CONSCIOUSNESS

TABLE III. HYPOXIC EFFECTS FROM DELAYS IN MASK DONNING—CHEMICAL OXYGEN GENERATOR SOURCE.

SUBJECT		AGE (yr)	HEART RATE (bpm)		Time from Onset of Decompression to Mask Donning Signal (s)				TUC* (s)
					10	15	20	25	
MALES	U. R.	25	after 3 min at 50 W (ground level)	104				MASK NOT DONNED	32
	R. L.	22		106					38
	J. W.	25		116					34
	W. S.	24		106					40
	R.W.	22		112					34
FEMALES	A.B.	30	after 3 min at 40 W (ground level)	118					34
	C. G.	33		106				MASK NOT DONNED	28
	S. H.	35		112				MASK NOT DONNED	35
	R.C.	34		108					34
	M. A.**	25		118					32

* Time of useful consciousness from previous study, determined under identical experimental conditions. (1)

** Different subject than in Table I.

NO HYPOXIA / TEMPORARY HYPOXIA / LOSS OF USEFUL CONSCIOUSNESS

Delays of 10 and 15 s led to no problems in mask donning in either series. However, delays of 20 and 25 s led to many instances of deterioration and loss of consciousness before and just after mask donning; these events were similar in frequency in both series. Also, some technical problems in mask donning contributed to losses of consciousness with these delays.

From this research we have concluded that to maintain full consciousness in a rapid, severe decompression, flight attendants engaged in light-to-moderate physical activity may have only a few seconds in which to effectively obtain supplemental oxygen after a decompression event is recognized. Furthermore, the great difference between TUC at work and the time for donning a continuous-flow, mask-reservoir oxygen system emphasizes the importance of minimizing the body's oxygen requirements by stopping work and maximizing the body's oxygen intake by correctly donning the mask, assuring good mask fit, and breathing normally.

III. CURRENT FLIGHT ATTENDANT PROCEDURES IN A DECOMPRESSION

Our research, and the fact that the severity of a decompression is usually not recognizable without reference to an altimeter, justified our stating flight attendant procedures to be followed in a decompression as:

> In *any* decompression, airline flight attendants should immediately don the nearest available oxygen mask and sit down or hold on until given clearance to move about the cabin by a flight deck crewmember.

We compared this statement with flight attendant procedures for a decompression given in manuals from 19 airlines. All manuals tell flight attendants to don the nearest oxygen mask; however, only five stress the immediacy of this action. Of the 19 manuals, 11 give directions to sit down or hold on; several other manuals advise moving from mask to mask while assisting passengers. Only seven manuals direct the flight attendants to remain seated or hold on until given clearance to move about the cabin by a flight deck crewmember. Notably, just one manual gives all procedures as described in this statement.

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INVESTIGATION PROCEDURES

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Eleven years ago two United States Air Force officers, each intimately concerned with Flight Safety, asked me for my ideas about accident investigation procedures. One specific question was directed to how much I used the various "handbooks for investigators" that are currently available. The answer to that question developed into a story telling session which culminated in their request that I "put some of it in writing." Hence the following which was written in 1965:

I think the investigator's handbooks are fine tools and desirable guides, especially for those who have not had years of investigation experience. I have found, however, that these documents are not by themselves always enough and that careful thinking and extreme curiosity and imagination frequently are important additional factors leading to the determination of true cause.

Generally speaking, careful thinking is usually thought of as being slow or time consuming. However, careful thinking must sometimes be rapid. Careful thinking should start immediately after the accident to determine, first of all, if you should take a rapid or slow route. The right decision here can lead to success instead of failure. For example, we had a specially instrumented, twin-engine test aircraft fail to recover from a high-Mach dive. Remembering that the aircraft was specially instrumented prompted a decision to man-sweep immediately the wreckage area for the undeveloped film records before the sunlight ruined the film in case the film magazines were broken. Sure enough, the records were found, although one would hardly recognize that the broken and mutilated remains were once film in film magazines--and sunlight already had been beating on the torn and loosened film. Once the film remains were stowed in black bags in a dark room, the investigation process was changed intentionally to a slow pace. Days were spent in consultations with the best film developing experts in the country as to how to develop the already exposed records with maximum chance of success. Success finally was achieved and the results led directly to valuable information on some high-Mach aerodynamic characteristics and the need for changes to the aircraft longitudinal control system.

As another example of the occasional need for rapid action, I know of more than one case where ice caused an accident or an incident, such as ice in the fuel system, the airspeed system, or the aircraft control system. If your initial information coupled with your imagination does not cause you to think of these possibilities, it's a matter of time until the ice melts, and the water subsequently drains away or evaporates (unless the water is trapped). Then your direct evidence is gone. I remember a case of simultaneous loss of engine thrust on a prototype twin-engine jet, with the result that the aircraft had to be landed in a field (not to be confused with an airport). The fact that ample fuel was aboard the aircraft, yet both jets lost power at the same time, made fuel system icing a suspect item. Therefore, fuel samples were taken immediately from strategic points, and various fuel line sections were capped to trap all fluid before the aircraft was disassembled and moved to a building for further investigation. This capture of fuel and water by location led to a most interesting and time-consuming solution of the accident cause, even though the content of dissolved water in the fuel was within normal limits each time the aircraft was fueled. Laboratory tests confirmed fuel system icing as cause of the accident.

On the matter of moving too fast, I have a strong emotional feeling about those early bird characters who arrive at the wreckage scene and turn parts upside down, move parts, move the wing flap control handle, move the fuel shut-off valve switch, rotate the radio frequency selector, and pull one or more circuit breakers. Some of these individuals have in one second set an investigation back a month, or forever. Actually, this is not so much a matter of moving too fast as it is ignorance and/or lack of security and investigation controls.

Now that I've mentioned fuel shut-off valves, if you want a real puzzler take a circuit malfunction that runs the valve closed, then back to the open position, prior to aircraft impact. This is a situation wherein you must have the imagination to think, "Could this happen?" Then you work on that challenge and finally show that, under certain conditions, it could happen--or it could not. The point is, if you don't "worry and fret" and ask yourself these hypothetical questions, you will miss arriving at the probable cause factors for certain accidents.

A casual, less than careful, evaluation of certain available evidence can easily throw you off completely in certain accidents. I recall a downward ejection from one of our test birds at 15,000 feet. Observation of the ground location of the bottom hatch, seat and pilot-landing-point were all about as to be expected. However, rough calculations of the separation distances indicated that the hatch location was a little bit wrong for a trajectory from 15,000 feet. Flight drop-tests of the hatch and seat from a cargo aircraft confirmed the discrepancy. Taking into account that the trouble started initially while firing the aircraft gun at 47,000 feet, and that high winds at that altitude were such that the hatch could have drifted from 47,000 feet to its location as found, this possibility was explored. Sure enough, chemical analysis of the pilot's boots revealed gunpowder residue on the boots proving that the gun was still firing after the hatch had left the aircraft. Therefore, the hatch left the bird at 47,000 feet and not at 15,000 feet. Careful developing of approximately 500 bits and pieces of 16 mm film from a test camera, which was aimed at the bottom of the bird, then further proved loss of the hatch at that altitude and time (one tiny 16 mm x 10 mm scrap of film provided the clincher). Even so, the pilot honestly couldn't believe the hatch had left while at high altitude, so he requested to relive the entire flight by the sodium pentothal procedure. You have never heard a pilot complain about severe cold temperature like this one did while lying on a couch at plus 72°F. Establishing that the hatch came off at 47,000 feet led to a complete explanation of the accident.

Failure to use and fit certain available evidence also can throw you a curve. Some investigators are prone to say "I can't explain that item, but I don't need it for my theory." This was the case when a single engine fighter took off, flew low for about 9 miles from the airport boundary, and crashed. A ground sweep of the flight path by more than 100 troops turned up a small part from the fuselage fuel-cell area on a hill quite some distance upstream from the point of impact. This brought about an interesting theory of an inflight explosion which was pursued for many days. This theory, however, didn't account for the unusual high-pitch whining noise made by the engine during and after take-off, nor the excessive take-off ground roll. Subsequently, a psychologist met with the troop who had found the part on the hill and determined, during the course of his interview, that the part actually was picked up at the impact site. The entire investigation immediately changed course--and subsequent tests showed what made the unusual noise and caused the excessive take-off run and the eventual crash. Determination of the true cause factor brought about corrective action as in the previous cases.

Many times I ask myself, "What is it that I would like to know about this accident?" Then I try to find some way to get it. For example, one test bird on final approach for no apparent reason landed short of the runway. We had our routine ways of telling that engine RPM was relatively high, but we couldn't tell if it was high enough to sustain flight. Although we were receiving telemetered data at the time, the data did not include thrust or engine speed. One of our technicians suggested that a special analysis of the telemetering records for first order engine unbalance, first order alternator frequencies and harmonics of both, might permit determination of engine speed. As it turned out, the determination of engine speed was not successful because the filtering in the telemetry system for the removal of spurious noise was too good. The point, however, is that the idea of trying was good. Other investigation efforts brought about a solution to this accident and corrective action.

When do you believe or not believe a pilot's story? I am not going into this, but it reminds me of a single-engine, two-seater which lost all engine thrust on final approach. Both of these gents soon found themselves parked in somebody's bedroom-- and quite okay. One of the most thorough investigations followed because the engine and its fuel system were, fortunately, undamaged. After many days we were stumped because we had been through every inch of fuel system, fuel controls, and the engine, and had conducted a great number of test runs with the engine installed in another aircraft. No trouble could be found, and I think each pilot wondered if the other had accidentally actuated the fuel shut-off valve switch and subsequently returned it to normal. Because we had run out of ideas to investigate, I had a mechanic-supervisor make a pickling run for temporary storage of the engine. Guess what happened? After several minutes of running, the engine suddenly quit cold, with the mechanic's feet flat on the floor and his hands on the canopy sills. Further investigation defied a repeat or explanation. I have my own idea of the cause, but the probability of occurrence is so low that I would never be able to prove it.

More than once a remark is overheard, and subsequently mentioned, with the result that it leads to, or supports, the solution of accident cause. One pilot made a comment to a non-technical friend during a dinner party about what he was going to try with the bird the next day. Too bad his dinner friend wasn't an aeronautical engineer because the tail parted company with the airplane. In another case, the two pilots of a multi-engine job had been overheard to say that they would change seats prior to landing. This comment, together with other evidence, supported inadvertent actuation of a specially installed test system switch as the cause of the accident.

Witness information can be good or bad but it always pays to weigh it and consider it carefully. Once we allow ourselves to develop pre-conceived notions, we tend to hear and put weight on only those parts that fit our theory. As a rule, I value witness information more than many investigators. It has been my experience that much can be learned if the investigator is careful to avoid leading the witness into stating what the investigator wants to hear. If the investigator is experienced, he usually can tell which witnesses are providing valid information. However, except for triangulation, witness estimates of distance and time frequently are off quite a bit. As an example, I had a problem develop after becoming airborne following take-off, and I had to chop the power. The terrain ahead was rough and I ended up inverted with a broken seat belt and sore skull. Of approximately twenty witnesses, all familiar with observing aircraft take off and land, some estimated my maximum altitude at fifty feet and some said I never got off the ground. I figured I reached a maximum altitude of approximately ten feet. As another example, we made two overhead test passes with a transport one night. The group of people on the ground consisted of laymen and accident investigators. No one in the group was aware that the two passes were at different altitudes--one being at 9,500 feet and the other at 15,000 feet. A point related to a particular accident was proved.

Supervisory error can take many forms, including aircraft maintenance, the on-the-job boss and the wife. Take the young pilot who was tagged with pilot error and pleaded for supervisory error on the basis that he never should have been graduated from flying school. Maybe he was right. Emotional stresses also have caused many accidents. I personally know of an excellent pilot who spun out on base-to-final because of an unjustified chewing-out he had received an hour before. Yet the report probably reads pilot error. Never forget the amazing things that can be determined by the aeromedical profession. They usually can tell after a fatality the presence before death of certain drugs, carbon monoxide, smoke from fire, the bends, heart condition, etc.

Hazards of the language can cause some real dillies. Most everyone knows the story of the pilot's command to the co-pilot on a slow final - "Take off power!" The co-pilot took off power. In another one the pilot wanted to ground-loop a four-engine job to avoid going down the side of a hill at the end of his landing roll. He called "Full power on four!" He got full power on all four. Then there was the case during take-off when the pilot said to his down-in-the-dumps co-pilot, "Cheer up." The gear came up, all too soon. Voice recorders in the cockpit will help investigators a great deal in many accidents. Finally, I like the story about the Captain who had just completed a difficult instrument approach and said to his co-pilot, "What I wouldn't give right now for a cold beer and a hot woman." One alert hostess quickly realized that the Captain was unaware he was connected to the cabin P.A. and took off, full speed, for the cockpit--when a passenger hollered, "Don't forget the beer!"

In conclusion, I think the Investigator Handbooks are fine--but also I think the investigator should add a lot of good thinking and ingenuity, and beware of becoming too mechanical. Another very important quality is to be objective and without prejudice. If the investigator is prejudiced, knowingly or unknowingly, another accident may occur before the next investigation is conducted in a completely objective manner.

As a final comment today, in 1976, investigation procedures and techniques over the years no doubt have improved. However, management of the investigation still is quite the same if we mean that the leader must do a good job for his part to assure the best opportunity for adequate success from the total investigation.

INVESTIGATION OF ACCIDENT IN A SMALL COUNTRY (SWITZERLAND)

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1. Introduction

As Switzerland is a small country, I would like to refer first of all briefly to the geography and aviation of this country.

Switzerland is an inland country, situated in the heart of Europe. It covers a mere 16'000 sq. mi., something between the States of Massachusetts and West Virginia in size. The number of inhabitants amounts to 6 millions.

The topography is diverse and difficult for flying. The majority of the population lives in the central part of the country (1300-2000 ft/MSL). In the south, this is bounded by the Alps, many of whose peaks reach a height of 15'000 ft/MSL and in the north, by the jura chain. Within this changeable region, the meteorological conditions vary to a degree which make forecasts especially difficult for VFR flights.

Now just a little bit about Swiss aviation:
Switzerland has 3 international airports at its disposal, namely Zurich, Geneva and Basle, the latter is actually situated on French territory and is operated by the two countries jointly. Only these 3 airports are equipped with ILS. Berne, the capital of Switzerland, has a smaller airport (1300 m runway) with NDB approach. Moreover, there are 5 VFR only aerodromes and there are 38 small airfields spread over the entire country; and there are also a large number of mountain landing places on glaciers in the Alps. Additionally, there are some military airfields where at times, civil flying activities also take place, sometimes in the evenings and at weekends As you will see, the distribution of airfields is quite large. The density of airfields too, is quite considerable. At the moment, the civil airfleet register consists of 1300 aeroplanes, 50 helicopters, 600 gliders, 30 motor gliders and 33 free balloons. There are approximately 13000 Swiss licences of which 2000 are student licences and 5000 privat pilots. Switzerland has one large airline, Swissair. This is a private joint stock company where approximately 25 % of the shares are publicly owned. Swissair has a fleet of 44 aircraft comprising Boeing 747, DC-10, DC-8 and DC-9. In addition there are three charter operators, mainly equipped with DC-9, DC-8 and Caravelle planes.

On account of its central geographical position, Switzerland enjoys large international air traffic. 52 foreign scheduled operators from all over the world fly principally to Zurich and Geneva. Moreover, there are numerous non-scheduled flights from all over the world and innumerable planes of General Aviation whose weakest representatives - I am thinking of single engines with inexperienced pilots - who, on their flights to the warm south or back get stuck in our mountains. And with this, I am at last coming to my subject.

2. Organisation of Investigation in Switzerland

The Federal Council consists of 7 members. Each heads a department. Aviation affairs come within the sphere of this with transport and power under his administration. The duties of the Federal Air Office correspond to those assigned to the FAA in the United States and to the CAA in the United Kingdom. Since 1960, the Federal Air Office no longer has anything to do with aircraft accident investigation. This is a matter for the Aircraft Accident Investigation Bureau under the administration of the General Secretariat of the Transport Department and of the Commission of Inquiry, situated outside the administration. In the USA, the Bureau and Commission correspond to the NTSB and in the UK to the AIB. The Swiss federal law of air navigation accordingly provides for the independence of the investigation from the controlling aviation authorities. Another principle governs our legal regulations: the two-stage procedure. The procedure is divided into a preliminary investigation and a procedure before the Commission.

The preliminary investigation falls under the responsability of the Aircraft Accident Investigation Bureau and its investigators. This deals with the on-scene investigation, inspection in the aeroplane concerned and documents relating to the crew, the examination of the witnesses and informants, work in laboratories, eventual reconstruction flights, evaluation of flight recorders and ATC-tapes etc. The investigator-in-charge concludes his work with an investigation report in which are included a first analysis, conclusions and the probable cause. This report is passed to the above-named Commission and also to the Federal Air Office, to all interested authorities, organisations and other interested parties, i.e. to the operator concerned, crew, owner, airport, ATC etc. Within a time limit fixed by the Federal Aircraft Accident Investigation Bureau all such parties may express their views on the substance of the report and request that the file be supplemented, or submit further evidence.

The second stage consists of the procedure before the Commission. This is almost exclusively a desk-investigation. Every month, the Commission holds a 2-day meeting in which a serie of accidents are dealt with. It is the task of the Commission to ensure that the reports of the Investigation Bureau are complete and conclusive and to draw up the final report. Of course, the Commission examines the representations of the interested parties and, in certain circumstances, undertakes supplementary investigations. A further task of the Commission consists in the formation of recommendations. The final reports of the Commission are published, whereby less important cases naturally appear only in an annual summary. It should be noted that interested parties may be present at the meetings of the Commission (not, of course, the editorial meeting covering the final report) and that in serious accidents of commercial aviation there is a Hearing which is open to the public. These public Hearings can be very interesting for journalists and TV people, but for the investigators and interested parties, however it is just a tiresome occasion where new aspects rarely come to light.

On the whole, the statutary requirement which has been in force since 1960, has proved itself well. Currently, we are in process of altering certain points.

3. Some special management problems

But also a new legal settlement does not, fortunately, deprive the responsible person of his responsability of thinking over the management of an investigation again and again. In the following, I would like to indicate a few problems which may confront a small European country with considerable air traffic.

3.1 Staff problems

a) General Aviation

Every year, between 60-90 accidents of General Aviation occur on Swiss territory, involving 30-50 deaths, 2-5 smaller accidents with larger aircraft occur annually on the airports. As figures vary, for reasons of expense, the Swiss management cannot afford a large professional team of investigators. The Bureau for Aircraft Accident Investigation consists of only 5 professionals full-time investigators stationed in Berne. There are however 14 part-time investigators living in various parts of Switzerland who can be called upon to work for us in addition to their customary occupations. The Commission of Inquiry previously mentioned consists of 5 members, chosen direct by the Government who also perform their task as a secondary duty.

Owing to the small size of our country, there is really no special problem in the control of such investigators as regards instruction and administration. Nevertheless, the daily personal contact with colleagues and chief is lacking. The telephone can certainly not replace this personal contact. It is my task, and one of which I must continually remind myself, to get into touch with these people again and again and not leave them to do their job in complete isolation. But as the investigator doing his job as a secondary one, as an emergency solution, he will only be called upon today for smaller General Aviation accidents.

As far as the professional capabilities of the investigators are concerned, it is important that they have a sound knowledge of aviation and are themselves in possession of an advanced flying certificate. All our investigators for General Aviation accidents are professional pilots (airline or commercial pilots) and flight instructors. The professional investigators are in constant flying practice and some specialise in helicopters, IFR-operation and gliding. For investigators doing the work in addition to their own job, only those are considered who are in active flight training, either with an airline company or privately. As representative of our country, I participated occasionally in investigations abroad of accidents in Swiss registered aircraft (Europe and Africa). In this respect, I discovered that there are investigators who have never sat behind a control column in their lives. It is my view that it would perhaps be useful if every investigator had been employed at some time as a flight instructor. The imagination of a student pilot knows no limits and our clients, when flying, are fully of phantasy even if they are no longer students but fully-fledged pilots. Judging by some of the accidents to private pilots the investigator should not necessarily assume normal behaviour of a pilot, but must frequently consider what is abnormal in order to understand the course of the accident.

b) Air carrier accidents

In the last 10 years there were 3 catastrophic carrier accidents in Switzerland. In the case of major air carrier accidents in Switzerland, since 1960, as in the USA, the preliminary investigation is not carried out by an individual but by a team. Up to now, this team has been in action 3 times:

1970 Crash of a Swissair Convair 990 "Coronado", in which a bomb exploded

1971 Crash of a Bulgarian Il-18 during approach at Zurich (undershoot)

1973 Crash of a Vanguard (British non-scheduled operator) near Basle.

The Swiss team is a permanent team. It is led by the Chief of the Accident Investigation Bureau as investigator-in-charge and consists of the following specialist groups: Operations,Air Traffic Control, Witness, Weather, Structures, Powerplants, Systems, Flight Recorder and Human Factors. The following are attached to the investigator-in-charge as advisers: Liaison Officer to the Federal Air Office, Press Officer and the Scientific Service of the Police. Apart from the investigator-in-charge and the Chairman of the Operations Group, all other participants are part-time. They are however specialists, selceted from industry, the Air Force and from Swissair, from the Federal Air Office and pilots of the Swiss Airline Pilots Association. Here perhaps the principle of total independence may be at risk, but in a small country the number of personnel available and the financial resources do not permit another solution. It is a matter for the investigator-in-charge to ensure that the members of the team forget their origins and utilise their technical knowledge objectively.

Let me know refer specially to the following specific points.
Members of the Scientific Service of the Police are incorporated in the team as advisors. This has proved to be of great advantage. They are specially trained police who occupy themselves with macro-micro traces, thus relieving the local police of this work. The members of the Scientific Service are also demolition specialists. On the occasion of the Swissair Coronado accident on 21.2.1970, when a bomb exploded in the aft cargo compartment, their cooperation in the investigation was decisive.

Just a few brief words about this accident. It was a scheduled flight from Zurich to Tel Aviv (Israel). 6 minutes after take-off, the crew reported cabin pressure trouble. The flight was instructed to make a right turn for an approach. The crew requested that the police were to be available after landing. Then the pilot reported fire on board. The aeroplane was IMC. Then the crew reported that they could not see anything at all in the cockpit on account of smoke. The aeroplane crashed in a ballistic trajectory at high speed into a wood and was completely disintegrated. Obviously, all occupants were killed. Half an hour earlier, an explosion occurred in a Caravelle, owned by Austrian Airlines after the take-off from Frankfort (Germany). This plane, however, was able to land with a hole in the fuselage. After the cras of the Swissair plane, a Palestine squad accepted responsability for the attempt in an announcement to the Press. Later, however, this announcement was revoked. We had therefore sufficient indications of criminal act but no proof. Let us look for a moment at the site of the accident. Only small parts were to be found. We decided to look for the needle in the haystack, in order to find some part of the bomb and to reconstruct the procedure of the destruction. All parts of the wreckage were collected. As thousands of the most minute parts were to be found on the trees or had crashed into the earth, 340 trees were felled and enormous quantities dug up from the earth and carefully examined elsewhere. All the thousands of particles were transported to a hangar where a lay-out was made on a silhouette of the plane. The most minute parts were examined on a conveyor belt not without success. A piece was discovered and identified as a face plate of an altimeter not belonging to an aeroplane. It is an altimeter which can be purchased everywhere.

On this steel disc numerous corrosion spots up to approx. 1 mm diameter were observed. Furthermore the aluminium face plate showed clear cut slots in the steel plate underneath. The corrosion spots of the nature found, are typical for close exposure to an explosion. The deformations suffered by the face plate are also typical for a high pressure gradient as obtained near an explosion center, considering the small mass of the instrument. This device has served as pressure sensitive firing mechanism for the bomb. This, together with the findings of the structural investigators gave us the clear evidence of sabotage.

But inother instances we have found police personnel as part of the investigating team render good service. Especially since they are acquainted with all local police bodies and are able to make contact with them.

The Press Officer is a further important advisor who must be on the site of the accident from the very beginning. He keeps the Press away from the investigation and supplies them with information without disturbing our work too much. A word of advice based on our own experience might be appropriate: in the first days of the investigation, do not read the newspapers, do not listen to the radio nor, in the evening, never look at the television. That is harmful for your health! For even the best Press Officer can't make the journalists any better than they are. If any journalists are here, please don't be angry and just regard yourselves as exceptions.

In addition to other specialists there is a pathologist in the Human Factors Group who is competent to carry out the autopsy of the crew. If there are many dead, the members of the cockpit crew, after being photographed in-situ are required to be transferred immediately to a judicial medical institute for a full autopsy which can be undertaken separately from the often difficult and distressing task of identifying the passengers.

3.2 Language problems

Now another problem which is unknown to you people here in the United States. The language. There are four languages in Switzerland, three of which are official, German, French, Italian. Not of course, that it is like the Tower of Babel when our investigations take place ! All investigators speak German and French. It is a bit more difficult with Italian. Experience shows, however, that questioning witnesses by means of an interpreter is difficult and frequently lead to misunderstandings. Of course, it is much more difficult when a foreign plane is involved. The following amusing incident occured 3 years ago. The pilot of a Swedish registered aircraft (American Trainer) became disorientated, was short of fuel and had to make an emergency landing in the Jura mountains. After landing, the machine collided with a cow, which was injured. As the accident occured in the French part of Switzerland, I instructed a part-time investigator living in the vicinity to proceed to the accident site. The pilot, a young Swede, and his girl friend spoke Swedish only, plus a little English. The investigator spoke only French and German whilst the local police spoke French only. The young Swedes, who were unharmed, did the only possible thing. They erected their tent on the accident site, fixed themselves up comfortably for a few days and wrote their report in Swedish. I don't know whether, in the meantime, they consumed the cow, which had of necessity been slaughtered.

Of course, in major accidents, the language problem is much more serious. In such cases, the state of registration and possibly the state where the plane was manufactured, send an accredited representative according to Annex 13 of the Convention of Chicago. He, of course, is entitled to all rights according to Annex 13 and can be present at all meetings of the team. But... he must realise that our people must conduct their discussions, which are often difficult, in their mother tongue. Naturally, the results of the discussions will always be translated for the accredited representative.

According to Annex 13 , the accredited representative has the right to liste to witnesses. Our witnesses - except for ATC people - don't often speak English and often only their own native tongue. Especially when there is a number of witnesses, questions by means of translation are tedious and time-consuming. Therefore, it is important that the members of the Witness statement group record the statements conscientiously and have them duly signed by witnesses. These statements can then be translated to the foreign representative. He can, if necessary, always put supplementary questions.

Now, just a word for the accredited representative. He should, especially if he comes from the registration country or manufacture, be accomodated by the investigator, for at least the first few days, at the accident site. The investigator should place an office at his disposal, in the immediate vicinity of his own. It is only as a result of continual and uninterrupted contact that misunderstandings can be avoided. In 1971, a Bulgarian aeroplane, Type Il-18, undershot at Zurich. About 40 people were killed. The next day , a Bulgarian delegation of more than 20 men appeared. They spoke only Bulgarian and Russian which, naturally, we did not speak either. The interpreters who came with them were only acquainted with aviation from the commercial aspect. In spite of goodwill on both sides, there was en enormous loss of time through misunderstandings. I can tell you, it was a nightmare! We investigating people cannot, what about international accidents, organise ourselves and become familiar with everything in advance and prepare ourselves for cooperation, as the US astronauts and the Russian cosmonauts did in the joint space flight. An accident is an unforeseen event and its subsequent investigation has, to a certain extent to be improvised. So, as regards cooperation with the accredited representative of another country, the investigator just cannot take Annex 13 as a gospel. The cooperation is much more a question of technical knowledge, of language and the ability to adapt one's self to the mentality and the will to cooperate with the foreigr colleague. Here too, and I speak form experience - good old Europe distinguishes itself in this respect by an alarming diversity. The accredited representative should not only speak one of the ICAO-languages (i.e. Englisk French, Spanish, Russian), but much more ICAO-languages which are spoken by his colleagues in the country of the accident. If he is unable to do this, then he must definiteyl take 1-3 interpreters with him who are familiar witk aviation (operation and technique).

3.3 Cooperation with police

As a contrast there is cooperation with police. They are in their own country and cooperation with them can be prepared. As far as the police are concerned, conditions are similar to those in the States. Switzerland is a confederation consisting of 25 cantons, each having their own police force. It is the duty of the police to guard accident sites. According to our regulations, they must ensure that, apart from the necessary rescue and recovery work, no changes are made at the accident site, to ensure that at the accident site there is no such disturbance of evidence which would hamper the course of the inquiry. Prior to the arrival of the investigator, the dead should only be recovered to the extent necessary for finding eventually still living injured persons. There will always be discussions about rescuing the dead. I myself hold the following opinion and I have been able to enforce this with our police. In General Aviation accidents, the police are to limit themselves to guarding the accident site until the arrival of the investigator. The bodies, especially those of the crew, should be photographed and in-situ examined by the investigation. The following example illustrates the importance of this principle. A few years ago, a 2-seater Aerobatic aeroplane (Type Zlin 326) crashed by low aerobatic flight. Both pilots were killed on the spot. As a young investigator, I had to take over the case. As night was coming on and the weather bad, I had to proceed by car to the accident site, a small airfield 200 miles away. In the telephone conversation, the police pressed to be allowed to remove the corpses from the wreckage on account of the spectators. I gave way, but ordered that the bodies should be photographed in-situ. This was done but on the photographs, it could not be seen whether the pilots had had their feet in the straps on the rudder pedals. As confirmed later, in the reconstruction flights, a slip sideways of one foot from the pedal, and jamming between pedal and the side wall, could have led to the blocking of the rudder and to the movement confirmed by the witness. I think I myself would have looked at the feet automatically. Since then, corpses remain where they are until the arrival of our investigators. In major accidents of Air Carriers, the matter is more difficult. After the accident, first of all the neighbours, then the fire brigade, ambulance teams and many voluntary helpers arrive on the site. Only at a later phase are the police able to get hold of the security. And only after many hours (about half a day) after the accident, the investigator-in-charge and his team arrive. It is important here that immediately following the notification of the accident, the local police are reminded by telephone of their duty to guard the site. My small experience with 3 catstrophic accidents in our country showed the following: the police are able to disperse the spectators quickly, who are only there out of curiosity. The police rapidly cordon off the accident site. Nevertheless, on arrival, we always find a quantity of people on the site, once 600! All were wearing some kind of uniform or a more or less official badge. All these fire brigade personnel, ambulance teams, civil defence helpers and police had an immediate function on arrival. However, after there was no longer any fire to extinguish or anything to be saved, they just remained there, looking closely at the site, moving switches or levers from here and there, bringing about small changes under the eye of the police and so destroying much evidence!

Lesson: The police must be instructed to ensure that the fire brigade, ambulance personnel etc., leave the accident site immediately their task is accomplished. After the arrival on the site, the investigator-in-charge must coordinate at once with the police. He, and not the police superintendent, nor even a local public prosecutor or other authority, now has to say what is to be done and what not done. Above all - guarding the site, which also includes regulation of traffic, must continue during the on-side investigation.

We have found that it is a great advantage if the headquarters of the police and those of the investigator-in-charge are at the same place, i.e., in the same building. At the beginning a police representative should be present at the meetings of the investigating team which occur daily. In the case of major accidents, measurements and photography are made by the police thanks to their larger material resources. Close up photographs however, if they are to be used as evidence, must be taken under the direct instructions of the investigation team or made directly by the team itself.

As regards the interviewing of witnesses and informers,i.e., persons who are directly concerned with the accident, i.e., the crew of the crashed plane, on principle this should be conducted by the investigation officials. The police are not in the position to put the technically correct questions. They are, however, most useful in finding witnesses.

For me, close cooperation with the police on the scene is most important. It does, though, require a good deal of tact on the part of the investigator-in-charge and his specialists. For the police superintendents are in command of numerous uniformed personnel and their team is an effective heterogenous whole, similar to an army battalion or regiment. Moreover, they are entirely familiar with the accident site. The investigator-in-charge, always a civilian, has a small team of specialists around him, all civilians. As they are highly-qualified people they are also individualists and frequently, do not know the neighbourhood at all. I am sure you will understand what I mean. Liaison with the superintendents of the police forces should therefore be made before an accident and be maintained.

3.4 Cooperation with courts

Not only the police, however, but also the local judicial organs are on the scene of the accident. On account of the law, they must ascertain whether criminal offences have been committed in connection with the accident. According to our regulations, such procedure is separate from our investigation. That is, of course, a far-reaching theory. The Criminal Authorities in a small country hardly have the possibility of engaging their own experts; the examining magistrates and public prosecutors are themselves lawyers but have no knowledge of aviation. In my activity in the field of accident investigation, now for nearly 10 years, I have had no experience of judicial authorities who could have conducted an investigation on their own account parallel to ours. The activity of the litigation investigator is unknown in Switzerland. Persons who would be suitable for this work would hardly be available in our country. Amongs the specialists coming into consideration, all are already incorporated in our organisation. The Civil and Criminal Courts await our reports to a greater extent and accept these as a factual basis for their judgement. This compels us to exercise the utmost exactitude and a certain formalism. The judicial authorities therefore await the result of our investigation. The investigation reports and the investigation records are, according to our law, available to all legal authorities (judicial and civil authorities) other authorities, interested parties including the insurance companies concerned. The Courts of Justice are naturally not bound to our statements and in particular, not to our analyses and probable causes. This ruling is contrary to that in this country. According to the US-Federal Aviation Act (section 701 e) the investigation reports may not be used in judicial proceedings. These different legal interpretations are based on the difference between the Anglo-Saxon common law system and the civil system which is valid on the West European continent. In the new Annex 13 of the ICAO, a recommendation under 5.12, appears, according to which the records should have a privileged status. Switzerland and, as I have heard, also other countries, had to inform the ICAO of their difference to this recommendation. When our records, however, are available in entirety, then certain guarantees must be embodied in our investigation procedure. Interrogations of witnesses and informers must be conducted formally. And the chief guarantee is the one referred to at the beginning, a somewhat complicated and, in most other countries unknown 2-stage procedure.

AIRCRAFT ACCIDENT INVESTIGATION AND AIR SAFETY IN A SMALL COUNTRY

Captain Oded Abarbanell, Manager, Research and Development Department,"El Al" Israel Airlines

The State of Israel was founded on May 15, 1948, following a decision taken by the General Council of the United Nations on November 29, 1947, for the partition of the British Mandate of Palestine.

The area of the State of Israel at the time of writing this paper is 33,000 square miles, which is smaller than the area of the State of Indiana but larger than the State of Maine. Within this area live 5 million people.

The history of aviation in Israel is as old as this century. For it is at the turn of this century that (so the chronicles of those times recount) a couple of strange German gentlemen disembarked from a boat in the ancient port of Jaffa, bringing with them an inflatable hydrogen balloon, basket, and some hydrogen cylinders and, inflating their balloon somewhere on the outskirts of town, floated up and away in the westerly sea-breeze, landing several hours later some 20 miles to the southeast, at the foot of the Judean hills, on the way to Jerusalem. It seems that their ascent, flight and landing passed without mishap and there is no further mention of any additional balloon flights in this country ever after.

Not so lucky was the first airplane flight which occurred some time during the late spring of 1911. A reliable witness tells me that the first airplane to appear in Israeli skies was a Henry Farman III which flew in from Beirut, with a technical stop at Haifa, and was landed by its Turkish Army pilot on the beach at Jaffa. So significant was this event that the Kaimakam (Governor) of Jaffa threw a feast for the flying hero, which lasted well into the early hours of next morning. When the pilot came back to his airplane on the beach (guarded by a squad of barefoot Turkish soldiers), accompanied by all the VIP's in the land, he looked quite groggy and unsteady on his feet. Onto the pilot's seat he went to the cheers of everybody around, the engine spluttered and caught, the airplane started its take-off run, made a beautiful "cavalier start" up to 400 feet, hesitated for a moment at the top of its steep climb, then plummeted at almost 90 degrees into the Mediterranean Sea, some 3000 feet from the shore. By the time swimmers reached the wreck the pilot had drowned. "Had there been an investigation?" I asked my witness. "No", he replied, "but there had been a splendid funeral and 7 days of official mourning".

The First World War saw much aerial activity over Israel with British, French and Italian military airplanes engaging those of the Germans, Austro-Hungarians and Turks in almost every type of aerial warfare. This activity endowed Israel with its first airfields.

Between the Wars aerial activity was small. However, civil aviation activity started with the flying boats of British Imperial Airways using first the Dead Sea and quickly changing over to the Lake of Galilee, as a stop on their England to India route.

Small domestic airline companies emerged and vanished. The Aero Club of Palestine was founded, then the "Aviron" Company, and the number of civil Israeli pilots rose steadily from year to year. Lod Airport was built, and a few large European airlines flew in and out of it linking it with European capitals. In 1936, the country had a glimpse at the "Graf Zeppelin" which flew over Tel-Aviv on route from Germany to the Far East. The Second World War brought almost to a complete halt the development of civil aviation but military aviation increased and Israel got its first large military airfields, accommodating the largest 4-engined bombers of the R.A.F. and U.S.A.F. which carried out their bombing raids over the oil-fields of Rumania.

The end of the Second World War saw the revival of civil aviation in Israel, and civil air operations haven't stopped since, despite the local wars of Independence (1948-1949); Suez (1956); Six Days (1967) and October (1973).

The inventory, more or less accurate, as at the day of writing this paper, is as follows: 170 civil aircraft are registered in Israel. Their classification is as follows:

"El Al" Israel Airlines, formed in 1949, operates 4 Boeing 747 - 200 Cs and Bs and 10 Boeing 707 - 320 Cs and Bs, 707 - 400s and 720B airplanes. It flies non-stop between Tel-Aviv and New-York City, as well as to all of Europe (including Rumania and Turkey), East to Teheran and South to Johannesburg in South Africa and Nairobi in Kenya. In 1975, "El Al", with 13 airplanes, flew 800,000 passengers and 34,000 tons of cargo in 40,000 flying hours. It operates from its home base at Ben Gurion International Airport near Tel-Aviv.

"Arkia" Inland Airlines, formed in 1950, operates 6 Vickers "Viscount" and 4 Handly-Page "Herald" airplanes on domestic flights between Jerusalem, Tel-Aviv, Haifa and Eilat. In 1975, "Arkia" carried 700,000 passengers within 16,000 flying hours.

"Kanaf", a subsidiary of "Arkia", formed in 1968, operates 9 B.N. "Islanders"; 2 Piper-"Chieftains"; 1 Aero Commander 680; 2 Cessna 337C and 1 Piper "Cherokee". It links the smaller airfields of Israel such as Mahanayim, in the Upper Galilee, Beer-Sheba in the Negev, Masada near Sodom on the Dead Sea, Santa-Catarina in the Sinai Desert and Ophir at the entrance to the Gulf of Eilat with the larger airports served by "Arkia".

"Chimavir", the largest crop dusting company, operates 15 Aero Commander S-2R; 3 Piper PA 25-235; 1 Piper PA 36 - 285. Its subsidiary, "Masok", operates 6 Bell 47G and 2 Jet Ranger Helicopters on crop dusting operations.

"Marom", a smaller crop-dusting company, operates 11 Aero-Commander 600 - 52 D; 6 Aero-Commander 52R; 2 Piper PA 25; 1 Piper PA 18 - 150; 1 Cessna 180 and 1 North-American AT-6.

Various other small air-taxi companies, charter companies and flying schools operate a total of 25 single and twin-engined airplanes, all in the Category A (less than 12,500 lbs. gross weight).

The Aero Club of Israel operates 25 gliders and sailplanes and 2 piper PA 18A - 150 airplanes.

Israel Aviation Industries operate 4 Boeing 707s; 2 Cessna 150Ls; 1 Cessna 172; 1 IAI "Westwind"; 1 IAI "Arava" and 1 Douglas DC-3C.

Private owners operate 20 light single & twin-engined airplanes in the Category A (less than 12,500 lbs. gross weight).

The total number of pilots currently holding Israeli flying-licences is 1305: 305 Airline Transport Pilot licences; 500 Commercial Pilot licences; 400 Private Pilot licences; 100 Student Pilot licences. In addition to the Airline Transport Pilot licences 250 Commercial pilots and 5 Private pilots hold current Instrument Ratings.

Israel's civil aviation activities are, as you might have already noticed, proportionately large for the small size of the country and its population.

However, the number of accidents to Israeli aircraft is small, especially in the airline category.

The national carrier, "El Al", has experienced 4 accidents throughout its 27 years of operation only 2 of which were fatal, ending in a total hull loss. In 1950 a Douglas DC-4 "Skymaster" cargo airplane crashed into a hill while on a QDM approach to Kloten Airport near Zurich, Switzerland, in heavy fog. One crew member survived, 4 killed, total hull loss. In 1951 a Douglas DC-4 "Skymaster" crashed on take-off from Lod Airport, near Tel-Aviv, Israel. Cause of accident: Airplane was not de-iced and took off laden with frozen snow which had been falling for 4 solid hours during that night - a very rare occurrence at Lod Airport, where snow had never been known to fall and deicing equipment does not exist to this very day. No fatalities, airplane repaired. In 1955 a Lockheed 049 "Constellation" was shot down over Bulgarian Territory by Mig-15 fighter aircraft of the Bulgarian Air Force. Airplane crashed 4 nautical miles from Yugoslav border. Cause of accident: Airplane drifted off airways to the east and across Bulgarian border whilst navigating between waypoints serviced by NDBs. All passengers and crew on board were killed, total hull loss. In 1972, after 17 accident-free years, a Boeing 707 made a night-landing at Lod Airport, near Tel-Aviv, Israel, using main-gear only. Cause of accident: Nose-gear extended but was not locked down properly. No fatalities. No injuries. Slight damage to airplane repaired.

"Arkia's" accident record since its founding in 1950 is as follows:

180,000 hours were flown. One Vickers "Viscount" had a total brake failure after landing during a training flight. There were no fatalities and no injuries but the airplane was a total hull loss. Four Handley-Page "Heralds" had accidents during taxy or after normal landings when in all four cases the main gear collapsed due to material failure (metal-fatigue) although the gear had been properly maintained and serviced and properly operated. There were no fatalities and no injuries on any of these accidents and, although damage was severe, all airplanes were repaired. One "Viscount" had a main-landing wheel shear after landing due to bearing-seizure - no fatalities, injuries or additional damage to airplane were caused. Several tyre bursts occurred to both "Viscount" and "Herald" aircraft. One was caused due to heavy braking after the aborted take-off of a "Herald", the others due to foreign objects. No fatalities or injuries were caused. Two fatalities occurred when unskilled personnel, on two separate occasions, walked into active propellers.

The record of accidents in agricultural aviation, where flight safety does not look as good, reads as follows:

During the 5 years for which statistics are available (1972-1976), 90,000 hours were flown on agricultural aviation operations. 30 accidents occurred during this time. 20 of these accidents may be classified as mechanical (such as engine loss due various causes); 5 accidents occurred in the take-off or landing phase and were caused by human error; significant are the 5 remaining accidents which were caused due to fuel depletion; hence human error again. None of these 30 accidents were fatal. However, in 20 of these accidents the pilot was injured and 10 out of those were total hull losses.

General aviation, in which I have included the small domestic subsidiary of "Arkia", "Kanaf" and all other operators and private aircraft owners and pilots have a slightly better record:

145,000 hours of flying were flown during the 5 years 1972-1976. 20 accidents occurred during this period; 10 accidents can be classified as mechanical (such as loss of engine); 5 occurred during the take-off or landing phase due to human error; 1 occurred due to fuel depletion - human error. Only 1 accident, to a Piper Twin-Comanche, was fatal - the pilot was killed. In another 9 accidents there were injuries but no fatalities. 5 of these accidents terminated in total hull loss.

Reasons attributed to the low accident rate, in particular as regards the Israeli Airline Industry are as follows:

1) Alcoholism is practically non-existent among the Israeli population.

2) The weather is particularly clement in Israel: no Israeli airport or air field can boast about more than 5 days per year during which fog or low cloud has closed the airport due to weather being below state minima. Similarly, none of these airports and airfields require an IFR approach and landing more than 65 days in the year - the other 300 days allowing VFR approaches and landings in fine weather. Due to this blessing only Ben-Gurion International Airport is equipped with an ILS, and that only on one runway.

3) The national airline, "El Al", is mainly a long-range airline. The number of landings per number of flying hours, or miles flown, or passenger/miles or ton/miles is low, thus turning it into a rare customer in the major sector of accidents: The approach and landing phase.

Israeli Air Law is based on British Air Law, which dates back to the year 1920 and has since evolved into a series of laws pertaining to Air Navigation. However, Flight Safety is dealt with in a series of Regulations which first came out in 1961. As for Aircraft Accident Investigation - the regulations governing this subject were only formulated in 1969. In other words - until 1969 the investigation of aircraft accidents was not covered by Government regulations; furthermore - until 1961 no government regulations existed as to flight-safety standards, procedures and requirements. It may be gratifying to know that until 1971 no litigation concerning aircraft accidents or air safety took place in Israeli courts - lawyers just did not have the confidence that the existing Air Law, prior to 1971, would provide their cases with enough legal backing.

Although prior to 1961 interest in Flight Safety and Aircraft Accident Investigation as a separate subject and entity did not exist - pilots were very much aware that they were responsible for the safe conduct of their flights and Chief Pilots were held informally responsible for the safety of flight operations under their management. However, in 1961, the safety-bug bit its first victim, who started a program of self-study on the specific subject of flight-safety and in 1963 passed the Aircraft Accident Investigation course at the University of Southern California.

The following year, in 1964, "El Al" Israel Airlines organised a Flight Safety Group and appointed the man as Chairman. This was the first formal Flight Safety body in the country and it went on operating until 1971 when "El Al" disbanded it and appointed a Safety Officer for the Operations Division, promoting the subject in 1972 to a Manager of Flight Safety for the whole Airline. 1972 saw also the appointment of a Safety Officer in "Arkia" and the formation of a Flight Safety Department within the Civil Aviation Administration, which is part of the Ministry of Transport. Today every organization operating aircraft has its own Flight Safety Officer.

There exist in Israel today 10 Aircraft Accident Investigators, 5 of which have had one kind of formal training or another. Training sources are: The University of Southern California, Los-Angeles; the University of Stockholm, Sweden; the NTSB school in Washington D.C. and the Department of Transport school in Oklahoma City, Oklahoma. Only 3 investigators have been actively employed in aircraft accident investigation and have logged experience of 10 investigations or more. Only 1 has been actively employed in the investigation of accidents to aircraft of both less than 12,500 lbs. gross weight and those of larger size, including wide-bodied jets such as the 747s.

The machinery of the investigation in Israel normally operates as follows: - As soon as notification of an accident reaches the Department of Flight Safety in the Civil Aviation Administration, an Investigator is sent to the scene for the technical, on-the-spot investigation. This investigator will normally be a member of the CAA (Department of Flight Safety or any other Department) but may also be an investigator outside the CAA such as one belonging to any of the two major airlines ("El Al" or "Arkia") especially if the aircraft involved is over 12,500 lbs. Immediately following the technical investigation a Board of Investigation including at least 3 members, one of whom will act as Chairman, will be appointed by the Minister of Transport. Some Boards include 5 members or more according to necessity. At least one of the members, usually the Chairman, will be a professional investigator. The other members will usually be specialists required for the case, such as pilots or other aircrew with considerable experience on the type of aircraft involved; aeronautical engineers or maintenance specialists or technicians; pathologists or legal experts. The investigation is conducted according to ICAO recommendations in Annex 13 and the Manual of Accident Investigation and is compatible with investigations of the NTSB in the U.S.A. and the Board of Trade in the U.K.

In order to illustrate the problem - areas in aircraft accident investigation in Israel I shall produce 4 cases: 3 of them are accidents, the fourth is an investigation of a long series of serious incidents of identical nature. I have investigated all those cases either as investigator or as Chairman of the Investigation Board.

The first case is an accident to a Cessna 150G which took off in daylight and weather conditions of no relevance, piloted by a 25 year old Student-Pilot who had a total of 11 hours to his credit. After lift-off the airplane assumed a very steep climb-angle and at approximately 400 feet AGL stalled and entered a spin, hitting the ground at the side of the runway, halfway between runway and control tower, having completed 1/4 turn of a left spin, facing 90^{o} left of runway (towards the tower) and at an impact angle of 60^{o}. The student-pilot was killed immediately. The airplane was a total hull loss. Investigation discovered that the engine was operating normally and at full power at time of impact. All primary and secondary flight controls were operating normally. Normal take-off flaps were used as required by the operations manual of the flying-school. Elevator trim was set correctly. The investigation also revealed that on the eve of the accident which occured on the Israeli Day of Independence - a party took place at the house of the student-pilot.

Witnesses testified that the deceased had no more than the equivalent of 2-3 ounces of alcohol and that the party was all over more than 12 hours before the accident. On the morning of the accident the deceased attended a flight-show by some IAF airplanes and expressed admiration for the steep angle of climb of some F-4s. At lunch, the deceased had some beer which contained the equivalent of 1-2 ounces of alcohol. This meal (including the beer) ended 90 minutes prior to his accident He then drove to the airfield where he had an appointment with his flight-instructor. His instructor didn't show up but his wife called and said his instructor called home one hour previously and asked her to tell him to go ahead and go on a solo-flight, including short field take-offs and landings. (The instructor testified to the Board that this was true.) The student-pilot, who had a total of 1 hr dual on the Piper PA-18A-150 and 8 hrs dual as well as 2 hrs solo on the Cessna 150G then took the airplane for a solo flight which ended in the crash. According to the autopsy report the deceased showed insignificant "traces" of alcohol in the blood. This was contrary to testimony about the beer he drank shortly before.

The Chief Pathologist of the Central Government Pathological Institute, who performed the autopsy was surprised to hear from the Chairman of the Board that the alcohol tests had to be conducted by taking 10cm^3 of blood, bladder and stomach contents. His test was carried out on a much smaller amount of blood only, as was his practice during autopsies of road accidents. Thus the possibility that the pilot was intoxicated to a certain degree could not be substantiated and the reputation of Israeli pilots as non-inebriates remained unblemished. The investigation concluded that the cause of the accident was due to the student-pilot pulling on the stick at the end of a "maximum performance" or short take-off roll thus bringing the airplane to a climbing angle or pitch of about 20^o, stalling at 400' AGL and entering a spin without recovery before impact. Since CAA regulations stipulate that the student-pilot receive dual flight training before everyone of his first 3 solo flights and that his instructor be present at the airfield during all solo flights thereafter, until the student passes his Private Pilot Licence check, the Board recommended that the flight-instructor-rating be suspended perpetually from his Commercial Pilot's Licence. The Board also recommended that shor take-offs and landings not be taught or practiced until after a pilot obtains his PPL. The Board also commented on the lack of supervision at this particular flying school. (This led to an investigation of the school which led to cancellation of their operator's licence and closure of the school). Proper toxicological tests were recommended by the Board and passed to the Government Pathological Institute. The Government legal adviser had decided to prosecute the flight instructor. The case dragged through court for 5 years and was handled by 3 judges in turn (one of them has died during this period). The DA failed to prove his case and the flight instructor got his rating back - after 5 years suspension. As you may see, the Investigation Board in Israel often acts in an advisory capacity and is required to make recommendations to the Ministry of Transport and CAA. Unfortunately, some of its recommendations are treated with too much zeal and so backfire.

The second case is an accident to a Boeing 707 - 320BC airplane and reads as follows:

After departure from Fiumicino Airport, Rome, whilst climbing through 6000' the No.2 utility hydraulic pump warning light illuminated and the hydraulic fluid quantity shown on the hydraulic quantity gauge dropped to zero. The F/O deactivated the pump. The F/E shut the SOV. The Captain decided to continue to destination and advised Rome, Tel-Aviv and Company of his malfunction and decision.

The flight arrived overhead Lod VOR with 12000 kgs. of fuel. Flaps were extended electrically, landing-gear was extended manually. The main gear extended and locked showing "GREEN" position lights. The nose-gear green position light remained OFF. When retarding the throttle the "GEAR" position light illuminated "RED" and the gear-unsafe warning-horn sounded.

The Captain sent the F/E to check the gear visually to confirm position. The F/E went back and checked the main gear through the viewing-window in the cabin floor, then went down into the Lower 41 and checked the nose-gear visually. The F/E reported back to the Captain that the main gear was down and locked and that the nose-gear was down and locked as well with the indicator arrows lined up and the locking-pin in position (in the "locked-down" hole).

The Captain expressed doubts due to the "red" (unsafe) nose-gear and gear position lights and warning horn and requested that the engineer check the nose-gear again. The F/E reported back that he rechecked the manual-winding receptacle in the cockpit floor as well as the nose-gear alignment arrows and locking-pin in the Lower 41 and found all indications to show nose-gear down and locked.

The Captain decided to come in for a landing. The Lod weather at 2000 GMT was: Wind calm; CAVOK; Temp.: + 24^{o}C. Dew Point: +19^{o}C; QNH 1004 mbs. The landing was carried out on Runway 08. The runway was not foamed. Fire-engines and ambulances were standing-by in emergency positions along runway.

Touchdown was normal, however, 2000' from threshold. When nose of aircraft settled down to normal attitude for nose-gear-ground contact Captain realized that nose-gear was not down. F/E called out for a go-around but Captain elected to terminate landing, lowered the nose down to the runway gently using reverse thrust but no brakes. Aircraft stopped 4000' from touch-down (6000' from threshold, with 6000' for runway remaining) dead on centerline. Fire-engines sprayed radome and nose-section of aircraft and runway underneath them, with foam, while a few sparks issued from them on contact. Examination of runway shows the nose to have been in contact with the runway during the last 1000 feet only, when airspeed was 100 kts, diminishing to zero due the augmented deceleration of reverse thrust cum skin friction. No fire broke out. As soon as aircraft came to rest, order was given for an emergency evacuation. All 4 escape slides were operated. Only 3 inflated. The left-front slide (forward main entry door) did not deploy. One hostess and one passenger evacuated by the rear slides and declared them to be too steep and not fully reaching the ground since aircraft was resting on its nose with tail high in the air. The rest of the 83 passengers and 9 crew evacuated via the right-front slide (forward galley). No injuries were incurred by passengers or crew during the landing or evacuation.

Investigation concluded that the loss of all hydraulic fluid during climb-out through 6000' after departure from Fiumicino was due to the dislocation of a pressure-line from the pressure-relief-valve of the right-wing leading-edge flaps system, the No.2 utility hydraulic pump warning light was illuminated due to loss of the hydraulic fluid.

The landing-gear manual (emergency) extension was not carried out according to the correct sequence, as laid down in the procedure for manual gear-extension appearing in the emergency check list as well as the Pilot's Handling Handbook.

Due to the wrong sequence of operation the nose-gear doors opened but the nose-gear never came out of the uplock position whilst the tip of the locking-pin was forced into the down-lock hole, from which position it jumped back out and into its normal (UNLOCKED) position when nose of aircraft came in contact with runway. Both the pin and the hole-rim showed clear signs of this forcing of the pin into the hole. This abnormality was facilitated by the malfunction of the nose-gear sequencing pawl.

The F/E failed to recognize the position of the steering cylinders. Had he done so he would have found out that the nose-gear was up and not down.

The Captain chose to believe his F/E rather than his warning lights and horn. The Captain made his landing with unbased confidence that the nose-gear was down and locked, thus being caught unprepared for a go-around when realizing that the nose-gear was missing.

The following care and maintenance was given the landing-gear of the aircraft ivolved: 1. Lubrication and thorough check every 1300 hours. 2. General check every 350 hours. 3. Functioning check once every year. 4. Dismantling, check and thorough lubrication once every year. 5. The locking mechanism was last replaced on the aircraft 3 months prior to the accident and the landing gear extension and retraction was checked both in normal (hydraulic) and emergency (manual) modes at the same time. However, the nose-gear sequencing pawl had never received any care or inspection since the aircraft came out of production six years previously.

The following recommendations were made: The Captain was passed for requalification. The F/E was passed for requalification. The necessary servicing and inspection recommendations were made to the maintenance division. Proper "UP" decals are to be fixed to the steering cylinders so as to give a clear indication of the nose-gear when in the up position since the arrow alignment in itself may be ambiguous.

The difference between UP and DOWN position, as seen through the mirror and lens in the Lower 41, will be explained more explicitly in the relevant manuals.

The third case is an accident to a Piper PA-31-350 "Chieftain". The airplane took off from an airfield 910 feet ASL situated in extremely variegated terrain ranging from mountains 3000 feet ASL to a lake 750 feet BSL, all within 10 miles of the airfield. The airplane carried 1 pilot who happened to be the Chief Pilot of the commuter airline to which the airplane belonged and 8 passengers, the passenger seat next to the pilot remaining vacant. The fuel tanks were only half full and the airplane weighed less than its permissible 7000 lbs. AUW and was properly balanced. Take-off flaps were selected prior to T.O. and checked by indicator and visually to be in position. T.O. was normal. After end of runway was passed landing gear was retracted. At 200 feet above field elevation the pilot who normally retracts flaps in two stages gave the flap selector its first blip "up" and noticed an immediate tendency for the airplane to roll to the left. Suspecting flap assymetry he selected flaps "UP" once more but with no positive results: The flap indicator showed "Flaps Up" but the tendency to roll to the left was still there. The pilot then tried to even out the assymetry by selecting flaps down. The indicator continued showing "Flaps Up" but the tendency to roll to the left became much stronger. To stop the airplane from rolling the pilot had to apply full right aileron and considerable right rudder. In this condition the airplane would fly straight and level but would not climb up from its altitude of 1200 feet ASL which meant the pilot could not clear all obstacles and maneouver the airplane back to the field for a landing.

Flying south, towards the lowest ground, which meant flying over the Lake of Galilee, 750 feet BSL, the pilot throttled back the right engine throttle to a point about half way between fully open and fully closed. In this position, with the aileron fully to the right and considerable rudder the airplane went into a 15^{0} right bank and could be turned to the right but lost height at a rate of about 500 feet per minute. The pilot then decided to carry out a forced landing in a green-lucern field which lay along the north shore of the lake. The entire flight was carried out at a speed of between 120 and 145 m.p.h. The pilot carried out the proper forced landing check-list and lowered the landing gear. The gear came down but had not locked when the pilot, coming in over the threshold of the field at 120 m.p.h., touched down smoothly, with the unlocked gear retracting. A series of 9 aluminum water pipes which lay across the field, hidden in the lucern growth, one foot above ground at 100 foot intervals, were hit by the airplane and slowed it up. The pipes being of aluminum actually absorbed a great deal of the impact. After 100 feet the airplane slided over a 200 foot wide ditch filled with water, then over a 1 foot cement embankment and came to rest on a narrow, 10-foot-wide road, breaking into two between the second and third row of seats. Although there was leakage of gasoline from the left wing tank no fire broke out. The pilot jumped out through his left emergency window and helped the 8 passengers out through the rear emergency exit to a safe point 100 yards away. 2 passengers were seriously injured. 2 were moderately injured and 2 more were injured lightly. The other 2 passengers (sitting in the second row of seats) and the pilot were not injured. The airplane came to rest over the road 4 minutes after it took off. Throughout the flight the pilot was in contact with another company pilot who took off 30 seconds behind him in a company B.N. Islander. The Islander continued flying 1000 feet behind and 100 feet above the Chieftain throughout the latter's flight. When the departure airport could not be alerted by the Islander pilot on VHF he alerted the area control center. 25 minutes after the crash one SAR helicopter and 2 ambulances arrived. The helicopter evacuated the 2 seriously injured pax. The ambulances each took 2 of the 4 other injured pax. The investigation revealed the following:

The accident was caused by a failure of the worm drive- in transmission assembly of the left flap after take-off, thus resulting in an assymetric flap condition. The pilot was unaware of the exact condition and, believing that the right flap had been jammed in a 15^{o} setting with the left flap retracted to 0^{o}, attempted to regain symmetry by lowering flaps, hoping the left flap would attain the same angle as the right. However, the left flap stayed up and the right flap descended further and reached a setting of 25o before the time-delay unit in the flap system stopped the operation of the flap motor. In this assymetrical condition the airplane could not be controlled properly and flown safely.

The Board of Investigation has sent the defective worm drive-in transmission which had only 200 hrs flying as had the airplane on which it was installed - to the FAA for metalurgical tests. Other transmissions on other airplanes of the same type were found worn-out. All airplanes of this type were recommended a thorough flap-transmission check by the Board after every 25 hours of flying. The NTSB was advised by the Board.

The fourth case deals with the investigation of a long series of incidents of identical nature:

"El Al" operates a daily non-stop flight between Tel-Aviv and New York using Boeing 747 - 258B & C airplanes. The route is 5100 nautical miles long. All flights depart at maximum take-off weight, that is, 357,000 kilograms. The T.O. runway is 12000 feet long, 130 feet ASL.

During the 6 months of summer (April to September) the ambient temperature at Ben-Gurion Airport at 0830 Local Time often reads between 86^{o} and 104^{o} Fahrenheit. The temperature of the ten foot layer directly above the bitumen runway is usually 5^{o}F warmer than the ambient air (the wind is usually calm to a Westerly of up to 5 kts.). The black runway surface itself is usually 10^{o}F warmer than the ambient air. The airplanes used 30-ply nylon thread tyres. After 4 years of operation between 10 to all of the 18 tyres on every airplane were recapped tyres. During the summer of 1975 (April-September 1975) 18 incidents occurred, involving at least 1 tyre. In 10 incidents at least 1 tyre peeled off. In 8 incidents at least 1 tyre burst. 3 out of the 18 incidents occurred during taxy between the gate and the T.O. runway. 15 incidents occurred during the take-off roll. In 10 out of the 15 T.O. roll incidents the T.O. had to be aborted. In 8 out of these 10 aborts at least 1 more tyre peeled or burst. In 7 cases this occurred during the deceleration stop. In 1 case it occurred during taxy back to the gate.

An investigation team set out to determine the cause of tyre bursts and peel-offs and recommend remedial action. The investigation lasted one month and the cause was found to be a complex of the following factors:

1. Maximum (high) taxy and take-off weights.
2. Lack of load-evener system (discontinued on all 747 aircraft by manufacturer and certified by FAA).
3. As a result of 2 above: High stress loads on tyres during turns.
4. Long taxy distance to runway 26 at LLBG.
5. High taxy and runway surface temperature.
6. High ambient temperature.
7. As a result of all 6 above: Inability to keep pressures in tyres and shock struts within a one half p.s.i. tolerance.

All the above factors result in energy-absorption by the tyre from without (runway and taxy surfaces; ambient air), the energy being dissipated by means of extremely fast temperature rise which temperature reaches extremely high values. These temperatures having the usual physical bearing on the tyre pressure, coupled with pressure-stress during sharp turns on taxy and directional corrections on the take-off roll, result in burst tyres (especially when the tyre is new) or peeling-off tyres (especially when the tyre is recapped). The fusible plugs, which were designed to absorb heat-energy from within (from the brake assembly) do not fulfil their fail-safe design function on these cases of heat energy absorption from without as they would have (and indeed have in the past) had the heat-energy resulted from within as in the case of heavy-braking or prolonged use of brakes during taxy ("riding the brakes").

It is important to note that in numerous tyre bursts or peel-offs the tyre fragments were found to be hot while the brake assemblies were found to be cool to the point where a flat hand could be rested on the brake assembly, without discomfort. Hence no prolonged or heavy braking was involved in these tyre failures.

The investigating team added:

It is also our belief that recapped tyres do not take the pressure-stress during turns as well as new tyres.

In conclusion, we would like to recommend:

1. Immediate discontinuation of recapping by Pneumeader, who, as is shown in Chapter 2, paragraph 2.8, has been the supplier of most failed tyres.
2. Conversion from 30 ply-rating tyres to 32 ply-rating tyres.
3. Evaluation of the Firestone "Mach 1" tyre.
4. Molecular tests of new and recapped tyres of all makes (since we harbour a strong suspicion that original molecular composition of the tyre material is lost during the recapping vulcanisation.
5. Spraying of all tyres with water mist by fire-fighter based at side of runway whenever aborted take-off occurs (recommended by Boeing, practiced by other airlines, e.g. Braniff). Then check drum and brake assemblies as per maintenance manual.

At a later date molecular tests to recapped tyre material were carried out and the investigation team's suspicions were confirmed.

As a result, policy had been changed to use only new tyres on max. weight departures during the summer months. The number of T.O.'s and Ldg's for each new tyre had been limited. Recapped tyres allowed for use on departures with airplane weight not in excess of 330,000 kgs. or during the 6 autumn and winter months were limited to 2 recappings instead of the former limit of 5. Change-over from 20 ply-rating tyres to 32 ply-rating tyres.

During the 6 months of this summer not one tyre incident occurred. The cost of the new tyre policy amounted to 50% of the cost of damage and delays caused during the 6 summer months of the previous year due to tyre incidents.

To conclude this paper I wish to note the following difficulties in the efficient management of aircraft accident investigation in Israel:

1. Lack of professional investigators with formal training and sufficient experience.
2. Lack of regulations and procedures governing accident investigation, e.g. total lack of procedure as to who is responsible for guarding the wreck, as a result of which it often happens that unauthorized persons, often the operator or maintenance agency, have access to the wreck prior to arrival of the Investigator.
3. Lack of equipment for retrieval of wrecks from the sea or deep waters, as well as lack of equipment for the retrieval of heavy, wide-bodied jets which might crash over land.
4. Lack of a central laboratory, belonging to the Department of Flight Safety of the CAA.
5. Poor supervision by the CAA of execution of Accident Investigation Board recommendations especially after accidents involving General Aviation and the minor companies operating aircraft in the Category A.

THE INVESTIGATION OF THREE ACCIDENTS IN THE REPUBLIC OF BOLIVIA

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19 de octubre de 1975: Avión Curtiss-Wright C-46, matrícula CP-992 de Aerovías Las Minas que sufrió accidente en las cercanías del Aeropuerto de Trinidad.

I. INVESTIGACION

1.1 Reseña del vuelo

La aeronave del servicio nacional de transporte no regular de carga, despegó del Aeropuerto Internacional "Jorge Wilsterman" de Cochabamba, a horas 18:12 GMT con destino a la pista denominada El Desengaño (Lat. 14º23'S - Long. 65º25'W), donde estimaba llegar a horas 19:35).

A horas 19:00 la tripulación había informado formación de hielo y severa turbulencia siendo éste el último contacto de radio mantenido con la aeronave.

Posteriormente y ante aviso de pobladores de la zona que indicaban haber visto un avión precipitarse a tierra fragmentado, la Torre de Control de Trinidad solicitó la identificación de las aeronaves en vuelo en ese sector; no habiendose logrado establecer comunicación con el avión CP-992, ante lo cual se declararon las correspondientes fases de emergencia.

El día 20 de octubre a horas 10:40 se encontraron los restos de la aeronave, aproximadamente a 10 km. de Trinidad, entre las Lagunas Mamoré Viejo y Chachary, zona situada entre las coordenadas geográficas de latitud sud 14º44' y longitud oeste 64º51'. Por la investigación realizada se establece que el accidente ocurrió a horas 15:35.

1.2 Lesiones a personas

LESIONES	TRIPULANTES	PASAJEROS	OTROS
Mortales	3		
No mortales			
Ilesos			

1.3 Daños sufridos por la aeronave

Como consecuencia del accidente la aeronave se fragmentó con destrucción

1.4 Otros daños

No se constataron daños a objetos que no sean la aeronave, ni daños a terceros.

1.5 Información sobre la tripulación

Piloto:

Fecha de nacimiento:	6 de julio de 1945
Nacionalidad:	Boliviano
Clase de licencia:	Comercial Primera-Avión
Fecha de otorgación:	2 de mayo de 1975
Habilitaciones:	Multimotores terrestres más de 5.700 kgs. PBMD/C-46
Fecha último exámen psicofísico:	5 de septiembre de 1975
Vigencia del Certificado Médico:	5 de marzo de 1976
Experiencia:	Total Gral. horas de vuelo: 2.282:42 Total horas de vuelo al mando 126:53

Copiloto:

Fecha de nacimiento:	2 de mayo de 1953
Nacionalidad:	Boliviano
Clase de licencia:	Comercial - Avión
Fecha de otorgación:	14 de mayo de 1973
Habilitaciones:	Limitación copiloto C-46
Fecha último exámen psicofísico:	3 de junio de 1975
Vigencia del Certificado Médico:	3 de junio de 1976
Experiencia:	Total Gral. horas de vuelo: 1.500:00

Mecánico a bordo:

Fecha de nacimiento:	11 de enero de 1958
Nacionalidad:	Boliviano

1.6 Información sobre la aeronave

La aeronave Curtiss-Wright C-46 estabada debidamente inscrita, con Certificado de Aeronavegabilidad vigente hasta el 29 de octubre de 1975.

La aeronave había sido sometida a Peso y Balance en fecha 28 de abril de 1975 habiendose consignado un peso vacio neto de 13.102 kgs.

Nave:

Modelo	Nº Serie	Tiempo Total	Tiempo U.R.M.
C-46A	41-12306	11.103:54	3.877:57

Motores:

Num.	Marca	Modelo	Nº Serie	Tiempo U.R.M.
1	Pratt & Whitney	R-2800-51M1	FP-42505	403:51
2	Pratt & Whitney	R-2800-51M1	FP-090734	315:26

Hélices:

Num.	Marca	Modelo	Nº Serie	Tiempo U.R.M.
1	Hamilton Standard	23E50-505	RRD-9270	664:13
2	Hamilton Standard	23E50-505	RRC-7177	593:53

1.7 Información meteorológica

Transcripción de la información meteorológica ordinaria correspondiente al día 19 de octubre de 1975 emitida para las estaciones de Cochabamba y Trinidad y la situación sinóptica para el mismo día.

Horas: 14:00

Cochabamba - Viento 200/10 ILIMITADO 4/8 Cu 1400 2/8 As 2700 1/8 Ci 6000 Temp. 24ºC Punto Rocío 02ºC QNH 1024.
Trinidad - Viento 330/10 ILIMITADO 4/8 Cu 600 1/8 Cb 900 1/8 Ci 6000 Temp. 24ºC Punto Rocío 23ºC QNH 1010 PCPN AL S/SE.

Horas 15:00

Cochabamba - Viento Calma 3/8 Cu 1500 1/8 Ac 3000 1/8 Ci 6000 Temp. 25ºC Punto Rocío 03ºC QNH 1020.
Trinidad - Viento 300/12 ILIMITADO 1/8 CuSc 600 1/8 Cb 900 1/8 Ci 6000 Temp. 36ºC Punto Rocío 23ºC QNH 1010 PCPN AL S/SE.

Horas 16:00

Cochabamba - Viento Calma ILIMITADO 2/8 CuCs 1500 2/8 Ci 6000 Temp. 25ºC Punto Rocío 3ºC QNH 1020
Trinidad - Viento 120/30 ILIMITADO 4/8 St 120 2/8 Sc 210 1/8 As 2100 Temp. 22ºC Punto Rocío 21ºC QNH 1021 PCPNS AL S/SE.

Situación sinóptica: cabeza de frente frio débil a moderado llegará día domingo 19 de octubre en las primeras horas a Yacuiba.

1.8 Ayudas a la navegación

Los equipos de radioayudas en tierra funcionaban normalmente.

1.9 Equipos de comunicaciones

Las comunicaciones aire/tierra y tierra/aire funcionaron normalmente en todo momento en que hubo contacto de radio entre las estaciones y la aeronave.

1.10 Aeródromos e instalaciones terrestres

No corresponde a la investigación

1.11 Registradores de vuelo

No existían instalados a bordo

1.12 Restos de la aeronave

Se ubicaron e identificaron los restos correspondientes a los componentes del avión, dispersos en el terreno a lo largo de una trayectoria casi restilínea en una distancia de aproximadamente 10 - km. en el siguiente orden:

a) Fragmentos de la parte superior del fuselaje y fragmentos de alas.
b) Empenaje.
c) Motor izquierdo y pala de hélice.
d) Conjunto formado por la parte inferior del fuselaje, plano central con motor derecho, tren de aterrizaje principal, partes de panel de instrumentos.

Se comprobó que el tren de aterrizaje se encontraba desplegado y asegurado. No existían evidencias de que alguna hélice haya sido perfilada. Los flaps de ala en posición arriba. Se ubicó el reloj del avión que indicaba las 15:35 horas y un tacómetro señalando para el motor izquierdo 3.500 RPM.

1.13 Información médica y patológica

Se identificaron positivamente los cuerpos del piloto y copiloto que fueron ubicados sobre el terreno apartados de los restos del avión, en las cercanías en que fue localizado el motor izquierdo. El impacto del cuerpo del piloto contra el terreno dejó en éste una clara huella de la figura del mismo, en posición de cúbito - dorsal. Del cuerpo del tercer tripulante solo se pudo recuperar un miembro inferior dado que este cayó en una laguna de difícil rastreo e infestada de pirañas.

El exámen médico de los cuerpos de piloto y copiloto revela que se encontraban politraumatizados y completos, únicamente con lesiones sufridas por el impacto contra el terreno, no existiendo en ellos incrustaciones o heridas debidas a fragmentos de avión ú otras materias extrañas.

1.14 Incendio

La investigación de campo realizada evidencia que la aeronave tuvo fuego a bordo en el motor derecho, parte trasera, sección accesorios. No hubo incendio en cualquier otro componente del avión ni antes ni después del accidente.

1.15 Sobrevivencia

Las características del accidente no daba lugar a sobrevivencia.

II. ANALISIS Y CONCLUSIONES

La aeronave se encontraba debidamente inscrita y con Certificado de Aeronavegabilidad vigente.

Realizó despegue del Aeropuerto de Cochabamba con un Peso Bruto Máximo de Despegue muy por debajo del autorizado.

El piloto del avión tuvo anteriormente dos accidentes que fueron debidamente investigados, estableciendose en sus conclusiones como probables causas las debidas a factor humano en cuento se refiere a la operación de las aeronaves, por lo cual se determinó que debia recibir entrenamiento y re-examinación de vuelo en material Curtiss=Wright C-46 habiendo sido habilitado por un piloto autorizado, sin haberse dado parte a la autoridad competente.

Las condiciones meteorológicas en el momento del vuelo (IMC) no daban lugar a efectuar un vuelo VFR. El día del accidente existia en el país una condición frontal que fue pronosticada.

La disposición en que quedaron los restos de la aeronave y la inspección del lugar revelan el haberse producido una falla estructural del avión en vuelo, excluyendose una posible colisión en el aire y descartándose la posibilidad de una explosión a bordo, dada la verificación efectuada de los diversos componentes del avión y fragmentos, que no revelan huellas o daños típicos causados por la detonación de algún artefacto explosivo a bordo o la explosión de algún componente o sistema del avión, sino más bien los debidos a sobrecarga ejercida por fuerzas aerodinámicas que determinaron la desintegración del avión en vuelo.

En un principio las declaraciones de los testigos aparentaban el haberse producido una explosión en vuelo pero por el análisis exhaustivo efectuado y la evaluación técnica de las declaraciones se demuestra lo aqui establecido.

La investigación revela que cuando la aeronave emergió a vuelo visual, dada la posible falta de control, se encontraba descendiendo con un ángulo pronunciado y con sobrevelocidad, para disminuir la cual probablemente se desplegó el tren de aterrizaje y se trató de recuperar la aeronave en forma inadecuada lo que ocasionó una distribución de presiones asimétricas dando lugar a una gradiente de presiones desfavorables en el exterior del fuselaje lo que creó una fuerza de succión hacia el exterior, que contribuyó a que a partir del parabrisas de la cabina de pilotaje se desprendiera la parte superior del fuselaje seccionandose éste el plano vertical de dirección para iniciar una gradual desintegración del avión como consecuencia de las maniobras erráticas realizadas a gran velocidad con el consiguiente desprendimiento del empenaje, puntas de ala, fragmentación de alas, desprendimiento del motor izquierdo, para finalmente hacer impacto contra el terreno el conjunto formado por la parte inferior del fuselaje, plano central y motor derecho.

Luego del detenido análisis de las circunstancias y acontecimientos se establecen los factores que determinan la probable causa del accidente como los debidos a:

1. Falla de pilotaje por la falta de adecuado control del avión, desconocimiento y falta de entrenamiento para vuelo por instrumentos.

2. Falla o mal funcionamiento del motor derecho con presencia de fuego.

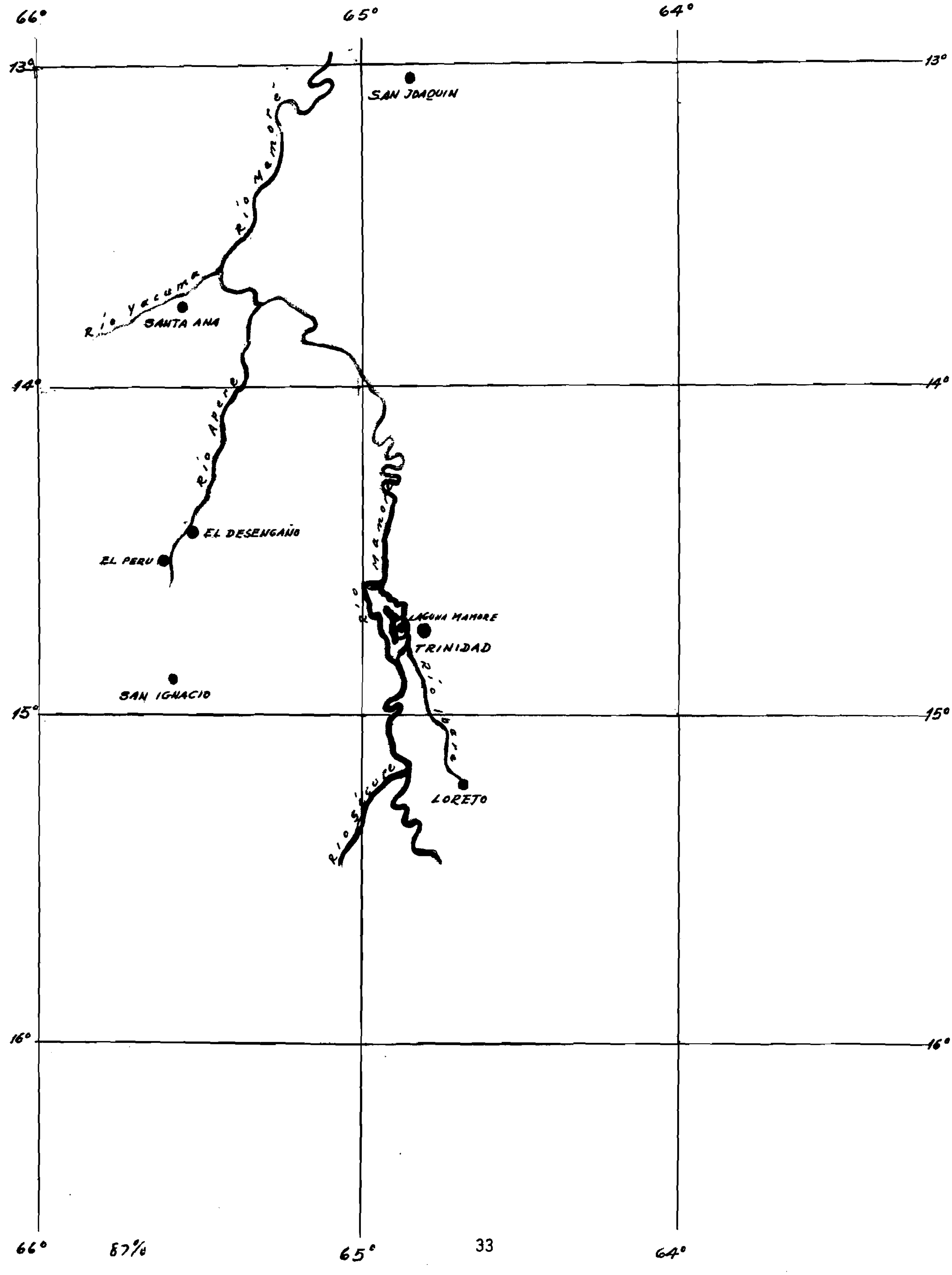
3. Las condiciones meteorológicas prevalecientes.

III. RECOMENDACIONES

1. Se logre por todos los medios aconsejables a que el personal de vuelo ejercite la conveniencia de estudiar con mayor detenimiento las condiciones meteorológicas de vuelo prevalecientes efectuando una evaluación adecuada, previo al vuelo.

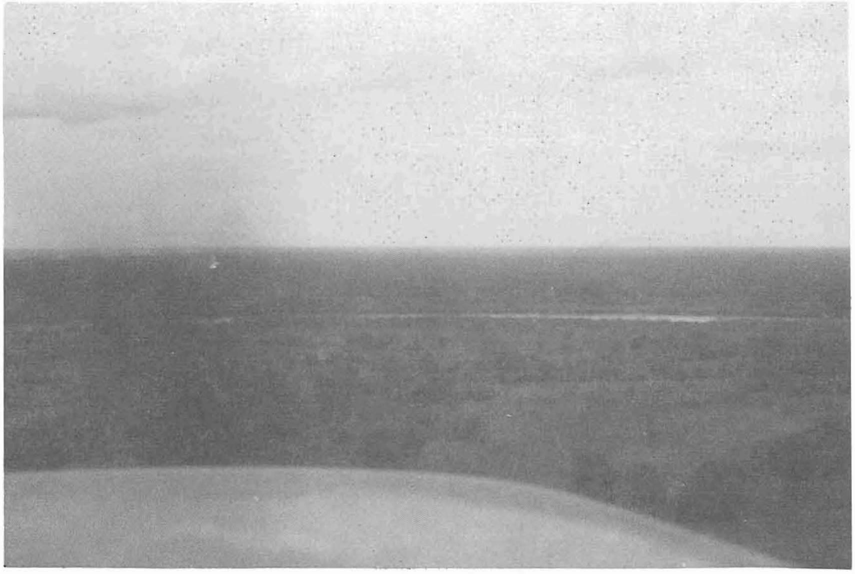
2. Incidir en forma especial para lograr un mayor entrenamiento de las tripulaciones en Simuladores de Vuelo y en los procedimientos de emergencia de las aeronaves ya que el accidente expuesto demuestra que el factor humano tiene importancia decisiva en la forma en que se desarrollaron los acontecimientos.

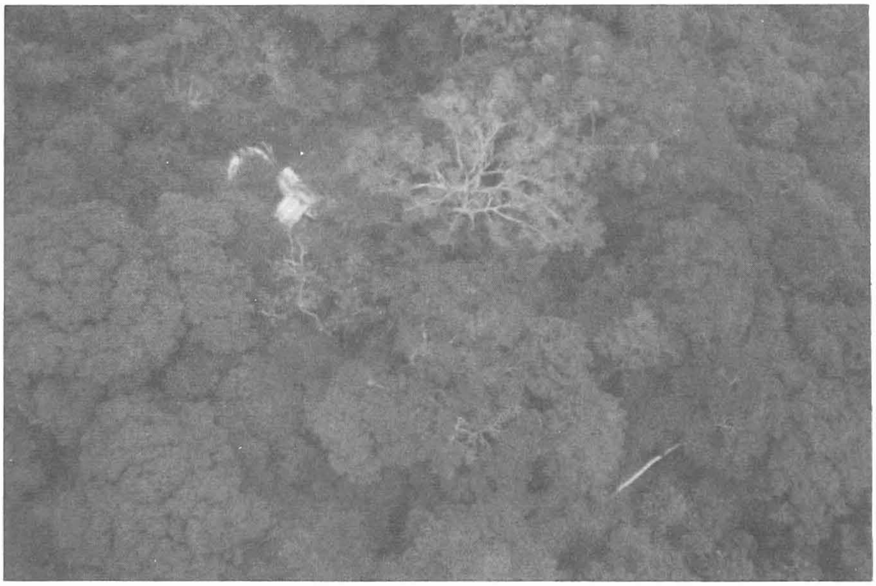
3. Que instalen a bordo de todas las aeronaves de más de 5.700 ks. de PBMD registradores de datos de vuelo y de Voz en el puesto de pilotaje.



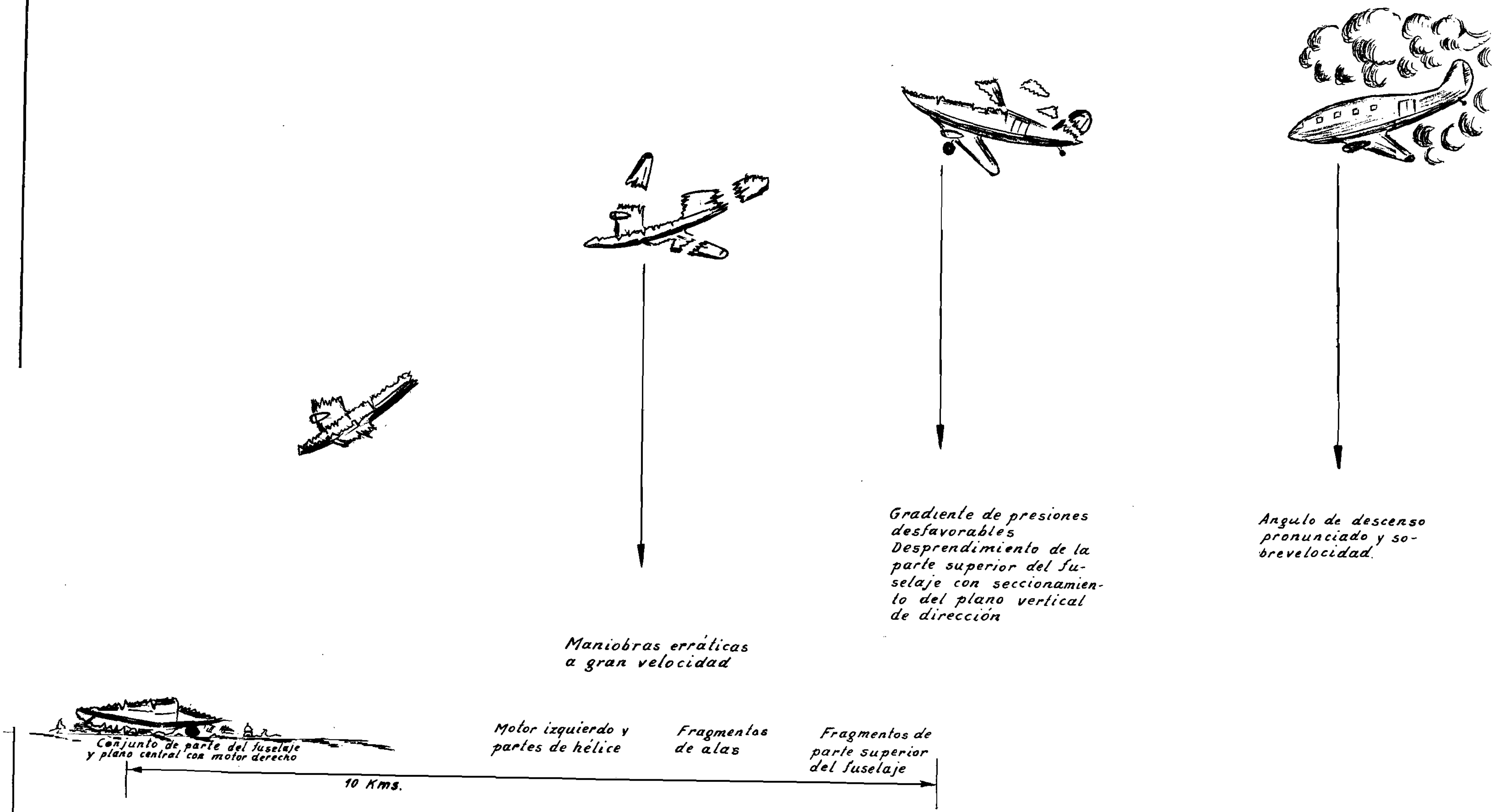
66°
65°
64°
13°
14°
15°
16°
SAN JOAQUIN
Rio Mamore
Rio Yacuma
SANTA ANA
Rio Apere
EL DESENGAÑO
EL PERU
SAN IGNACIO
Rio Mamore
LAGUNA MAMORE
TRINIDAD
Rio Ibare
LORETO
Rio Securé

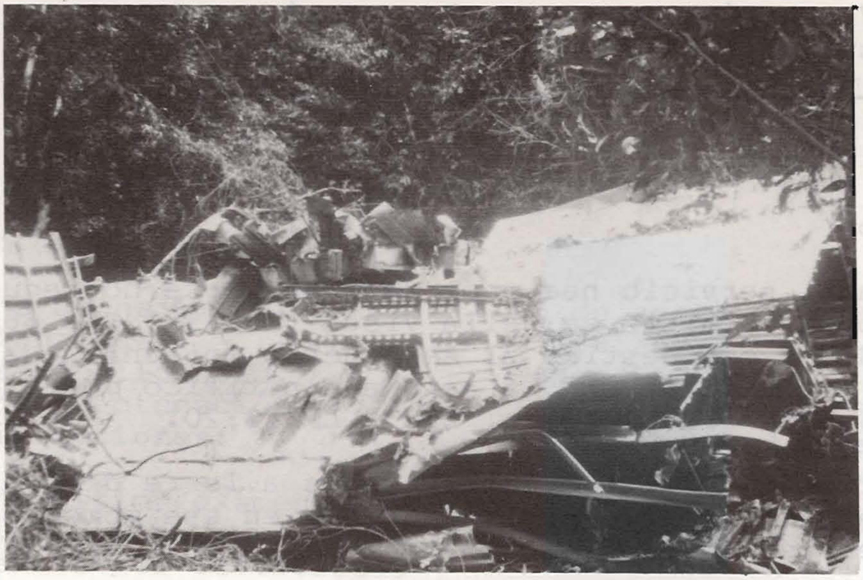
87/6





CROQUIS DEL ACCIDENTE DE LA AERONAVE CURTISS C-46 - MATRICULA CP-992 DE AEROVIAS "LAS MINAS"





22 de octubre de 1975: Avión Douglas C-47D, Matrícula CP-735 de Vibas Ltda. que sufrió accidente en las cercanías de "La Joya".

I. INVESTIGACION

1.1 Reseña del vuelo

La aeronave afectada al servicio nacional de transporte no regular de carga despegó de la pista de Bella Vista (13º 55' S - 66º 28' W) a horas 11:58 GMT con destino al Aeropuerto Internacional El Alto de La Paz a horas 13:04 GMT. La aeronave notificó posición Coroico, IMC, FL 185, 220 grados rumbo, ETA SLLP 13:20.

A horas 13:22 la aeronave solicitó instrucciones a Torre de Control para aterrizaje. La aeronave fue notificada que en ese momento La Paz se encontraba cerrada para operación VFR.

A horas 13:24 Torre de Control sugirió proseguir al aeródromo alterno, respondiendo la aeronave encontrarse escasa de combustible.

A horas 13:24 la aeronave informó desviando a Oruro dadas las condiciones meteorológicas en La Paz.

A horas 13:56 la aeronave informó nuevamente que por condiciones meteorológicas en Oruro desviaba a Cochabamba, no dando su ETA.

Luego no se volvió a establecer comunicación con la aeronave, hasta horas 14:35 cuando la misma informó haber efectuado aterrizaje de emergencia - a las 14:29 con el tren de aterrizaje plegado, indicando luego el lugar que fue situado entre las coordenadas geográficas 17º 47' de latitud Sur y 76º 26' de longitud oeste.

1.2 Lesiones a personas

Lesiones	Tripulación	Pasajeros	Otros
Mortales			
No mortales			
Ilesos	3	2	

1.3 Daños sufridos por la aeronave

Como consecuencia del aterrizaje con el tren plegado la aeronave sufrió daños substanciales.

1.4 Otros daños

No se constataron daños a objetos que no sean la aeronave, ni daños a terceros.

1.5 Información sobre la tripulación

Piloto:

Fecha de nacimiento:	16 de enero de 1934
Nacionalidad:	Boliviano
Clase de licencia:	Comercial Primera - Avión
Fecha de otorgación:	13 de agosto de 1975
Habilitaciones:	Multimotores terrestres DC-3/C-47 Instrumentos
Fecha último exámen psicofísico:	23 de julio de 1975
Vigencia del Certificado Médico:	23 de enero de 1976
Experiencia:	Total horas de vuelo General: 5.745:22 Total horas de vuelo al mando 81:05

Copiloto:

Fecha de nacimiento:	25 de noviembre de 1948
Nacionalidad:	Boliviano
Clase de licencia:	Comercial de avión
Fecha de otorgación:	3 de septiembre de 1975
Habilitaciones:	Limitación copiloto DC-3/C-47
Fecha último exámen psicofísico:	19 de septiembre de 1975
Vigencia del Certificado Médico:	19 de septiembre de 1976
Experiencia:	Total horas de vuelo General: 271:22

Mecánico a bordo

Fecha de nacimiento:	12 de julio de 1938
Nacionalidad:	Boliviano
Clase de licencia:	Nave y motores tipo "B" - vigente

1.6 Información sobre la aeronave

La aeronave Douglas C-47D estaba debidamente inscrita, con Certificado de Aeronavegabilidad vigente hasta el 16 de enero de 1976 determinándose por el exámen de la bitácora de nave, motores y hélices que no había anormalidad en ninguno de dichos componentes.

1.7 Información meteorológica ordinaria correspondiente al día 22 de octubre de 1975, emitida para la estación La Paz:

Hora 11:00 Z

Viento 060/06 - VISIBILIDAD MAS 10 KM - BANCOS NIEBLA - 2/ST 90 S/Sc 400 3/as 2100 - Temp. 1ºC Punto de Rocío MENOS 1ºC.

Hora 12:00 Z

Viento 060/06 - VISIBILIDAD MAS 10 KM - BANCO NIEBLA - 2/ST 90 4/Sc 450 2/Ac 2100 - Temp. 2ºC Punto de Rocío MENOS 1ºC - BANCOS NIEBLA N/NE.

Hora 13:00Z

Viento 070/06 - VISIBILIDAD MAS 10 KM - 1/ST 4/Sc 450 3/As 2100 - Temp. 2ºC Punto de Rocío MENOS 1ºC.

Hora 13:10 Z

SPEL - 070/06 - VISIBILIDAD 800 MTS NEVADA LIG - 2/ST 90 3/Sc 360 3/AsNs 2000.

Hora 14:00 Z
Viento 250/06 - VISIBILIDAD 1000 MTS AGUANIEVES - 4/St 30 2/StSc 360 5/AsNs 1500 .

Información meteorológica ordinaria correspondiente al día 22 de octubre de 1975 emitida para la estación Oruro:

Hora 13:00 Z

Viento calma - VISIBILIDAD MAS 10 Km - 3/St 300 3/Sc 500 2/Sc 600 - Temp. 6ºC Punto de Rocío 2ºC PCPN N/E/S/SE.

Hora 14:00 Z

SPEL - VIENTO CALMA - VISIBILIDAD 8 Km 4/St 300 4/Sc 450 - Temp. 4ºC Punto de Rocío 3ºC - DF MAL.

Hora 14:30 Z

SPEL - VIENTO CALMA - VISIBILIDAD 8 KM 4/St 300 4/Sc 450 - TEMP. 4ºC Punto de Rocío 3ºC - PCPN TODAS DIRECCIONES

1.8 Ayudas a la navegación

Los equipos de radioayudas en tierra funcionaban normalmente excepto la radioayuda NDB de Oruro que se consideró fuera de servicio.

1.9 Equipos de comunicaciones

Las comunicaciones aire/tierra y tierra/aire funcionaron formalmente en todo momento en que hubo contacto de radio entre las estaciones y la aeronave.

a) Información del Registro de Control de Tránsito Aéreo:

09:04/39 - CP-735 - Notifica posición coroico IMC, FL 185, 220 grados rumbo, ETA SLLP 09:20

09:06 - CP-1019 Solicita radiofaro Oruro.

Oruro - Radiofaro en el aire, posiblemente este movida la frecuencia.

09:13 - Cochabamba	-	Metar 2/Sc 600 1/Cu 1300 5/As 3000 Temp. 14/07 ALT 1030 PSOS ORURO Y LA PAZ INVISIBLES Sc BAJOS RESTO OPERABLES.
09:14/29 La Paz	-	Nieve ligera visibilidad reducida bancos de niebla.
CP-735	-	Recibido
09:15/46 CP-735	-	Informe visibilidad hacia viacha
09:16/41 La Paz	-	Visibilidad 200 metros nieve ligera continuas
CP-735	-	Recibido
09:18/44 CP-1243	-	Weather La Paz
La Paz	-	Bajo mínimo, estable
CP-1243	-	Favor, viento
La Paz	-	Setenta grados con seis nudos
09:20 - CP-1243	-	Notifico QRF San Borja
CP-607	-	Notifico QRF San Borja estimando Coroico 09:40
CP-1243	-	Llama a CP-735 indicando regrese a San Borja
09:26/10 - Uncía	-	Solicita Metar Oruro para despegue CP-925 Plan Cerdas a Cochabamba
Oruro	-	Calma ilimitado 3/St 300 3/Sc 500 2/Sc 600 Temp/06/M02 PCPN N/NE/SE/S
09:27 - La Paz	-	TAM 43 La Paz bajo mínimo aterrice en Reyes orden Operaciones TAM

b) Información del Registro de Torre de Control La Paz:

09:22 - CP-735	-	Solicita QAM La Paz e instrucciones
Torre	-	Plafond 50 metros visibilidad 100 metros
09:23/20 - Torre	-	CP-735 su información CP-607 QRF San Borja FL180 ETA Coroico 40
09:24/30 - Torre	-	CP-735 sugiero alternativa
09:24/37 - CP-735	-	No tengo alternativa estamos escasos combustible
Torre	-	Plafond 100 metros visibilidad 100 metros
09:33/12 - CP-735	-	Desviando Oruro estimado 05 solicita DF Oruro

1.10 Aeródromos e instalaciones terrestres

No corresponde a la investigación

1.11 Registradores de vuelo

No existían instalados a bordo

1.12 Restos de la aeronave

Se separaron de la nave

1.13 Información médica y patológica

No se llevó a cabo

1.14 Incendio

No hubo incendio

1.15 Sobrevivencia

La aeronave fue ubicada inmediatamente, habiendo los tripulantes y pasajeros abandonado la misma por sus propios medios utilizando la puerta principal. No se constató falla de asientos o cinturones de seguridad.

II. ANALISIS Y CONCLUSIONES

La aeronave se encontraba debidamente inscrita y con Certificado de Aeronavegabilidad vigente.

La tripulación se encontraba debidamente calificada y habilitada. Se ha efectuado la comprobación del Peso Bruto Máximo de Despegue estableciendose que estaba dentro del límite máximo autorizado. La aeronave realizaba un vuelo en condiciones meteorológicas por instrumentos (IMC).

Las condiciones meteorológicas prevalecientes no daban lugar a realizar un vuelo VFR.

La aeronave no contaba con el equipo adecuado VOR para efectuar - aproximación instrumental.

La cantidad de gasolina a bordo no era la suficiente para efectuar vuelo en condiciones meteorológicas por instrumentos. No se hizo un plan de navegación adecuado.

El Servicio de Tránsito Aéreo no dió aviso oportuno a la aeronave del rápido empeoramiento de las condiciones meteorológicas en el aeródromo de destino y su alterno.

La aeronave no realizó QRF al aeródromo más cercano en el Beni dado que la tripulación consideró no contar con el suficiente combustible a bordo.

Por lo cual se establecen como factores que determinan la probable causa del accidente, los siguientes:

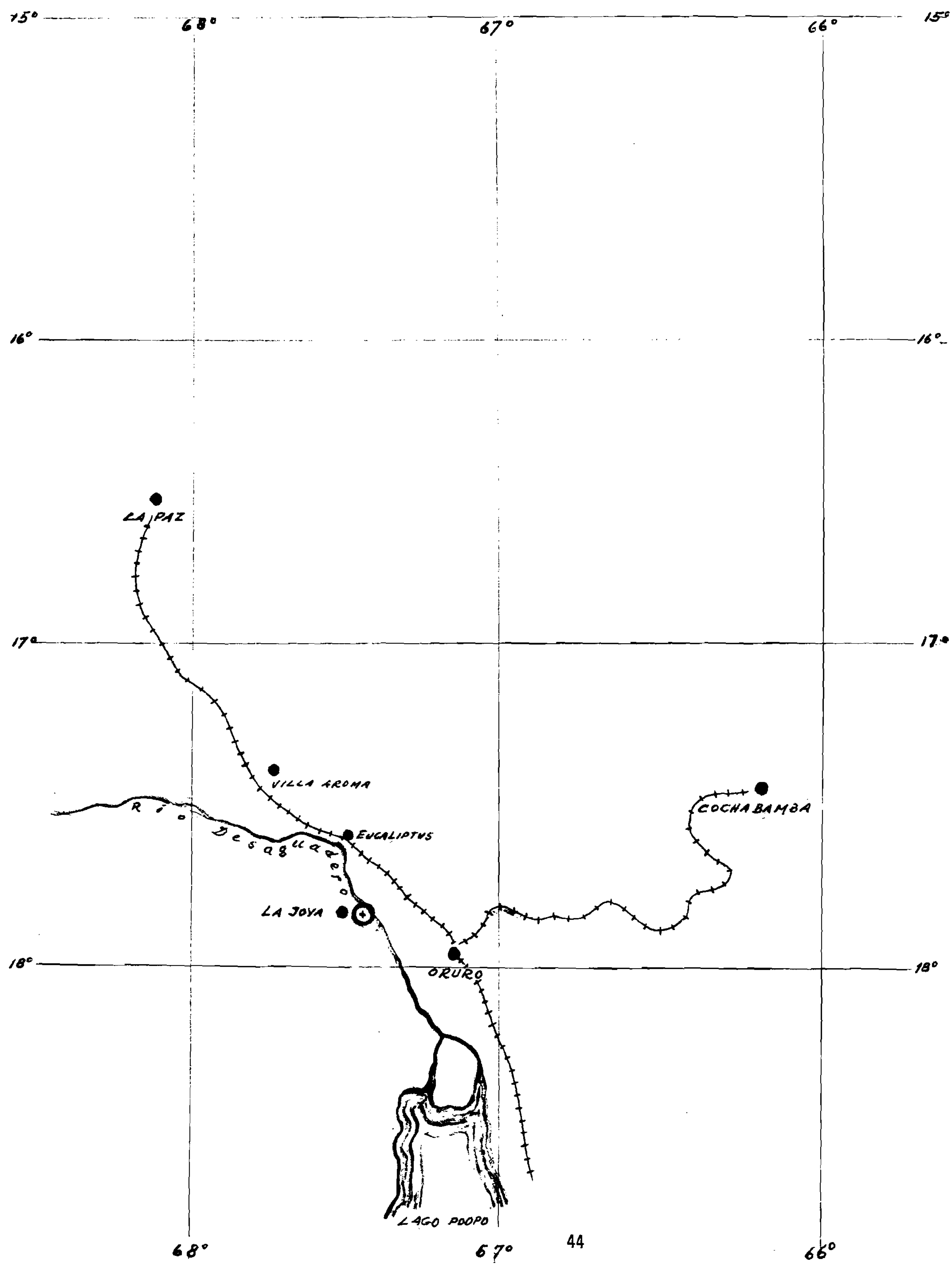
1. La tripulación consideró no contar con suficiente combustible a bordo para continuar vuelo a un aeródromo alterno.

2. El Servicio de Tránsito Aéreo de La Paz no dió aviso oportuno a la aeronave acerca del rápido empeoramiento de las condiciones meteorológicas en el aeródromo de destino.

3. El piloto no hizo una evaluación cabal de las condiciones meteorológicas prevalecientes.

III. RECOMENDACIONES

Emisión de boletínes pertinentes incidiendo en la necesidad de dar cumplimiento a disposiciones sobre vuelos en condiciones meteorológicas por instrumentos.


15°
68°
67°
66°
15°
16°
16°
LA PAZ
17°
17°
VILLA AROMA
COCHABAMBA
Rio Desaguadero
EUCALIPTUS
LA JOYA
ORURO
18°
18°
LAGO POOPO
68°
67°
66°


P-735

16 de febrero de 1975: Helicóptero Bell 47G4A, matrícula N1446. De Petroleum Helicopters Inc. que sufrió accidente en el Rio Enajegua (Beni).

I. INVESTIGACION

1.1 Reseña del vuelo

El helicóptero realizaba un vuelo VFR a lo largo del Río Enagegua (Lat. 13º35'S - Long. 68º53'W) en misión de búsqueda de dos trabajadores los cuales se suponía que el Río había arrastrado.

La empresa propietaria y operadora del helicóptero realizaba trabajo aéreo especializado en prospección de hidrocarburos, teniéndo como base de operaciones Ixiamas (Lat. 13º45'S - Long. 68º09'W), lugar de donde despegó el helicóptero.

El cause del Río tiene entre 40 à 50 metros de ancho poseyendo orillas que se elevan sobre el cause a aproximadamente dos metros de altura, con árboles que sobrepasan los 30 metros de altura, - muchos de ellos con parte de las raices a la vista.

El helicóptero volaba con una velocidad aproximada de 5 nudos a una altura de 5 a 10 metros sobre el río, siguiendo su curso.
El río, en el momento del accidente, se encontraba con las aguas crecidas debido a lluvias recientes, que aumentaron su caudal en forma considerable por sobre el nivel normal.

Un árbol de la orilla cayó sobre el helicóptero en el momento en que éste volaba a lo largo del río, aproximadamente a las 12:25 GMT.

1.2 Lesiones a personas

Lesiones	Tripulantes	Pasajeros	Otros
Mortales	1		
No mortales			
Ilesos			

1.3 Daños sufridos por la aeronave

Como consecuencia del accidente el helicóptero sufrió daños mayores.

1.4 Otros daños

No se constataron daños a objetos que no sean la aeronave, ni daños a terceros.

1.5 Información sobre el piloto

Fecha de nacimiento:	7 de septiembre de 1944
Nacionalidad:	Norteamericano
Clase de licencia:	Comercial Helicóptero - Aviones
Fecha de otorgación:	19 de agosto de 1970
Habilitaciones:	Monomotores terrestres - Helicópteros - Instrumentos.
Fecha último exámen psicofísico:	28 de agosto de 1974
Vigencia del Certificado Médico:	28 de agosto de 1975
Experiencia:	Total horas de vuelo en ala fija: 1.409:00 Total horas de vuelo en Helicóptero: 4.723:05 Total horas de vuelo últimos 90 días: 111:05 Total horas de vuelo últimos 30 días: 48:50 Total horas de vuelo últimas 24 horas: 01:45

1.6 Información sobre la aeronave

El helicóptero fabricado por Bell Helicopters Inc. modelo 47G4A, matrícula N1446W, tenía un total de 5.934:50 horas de vuelo habiéndose efectuado la última inspección de mantenimiento el día 10 de febrero de 1975.

1.7 Información meteorológica

Las condiciones meteorológicas prevalecientes en el momento del accidente no fueron posible factor causal.

1.8 Ayudas a la Navegación

No corresponde a la investigación.

1.9 Equipos de comunicaciones

Las comunicaciones aire/tierra y tierra/aire funcionaron normalmente en todo momento en que hubo contacto de radio entre la aeronave y su base de operaciones.

1.10 Aeródromos e instalaciones terrestres

No corresponde a la investigacion.

1.11 Registradores de vuelo

No existían instalados a bordo.

1.12 Restos de la aeronave

Como consecuencia del accidente no se separaron las partes del helicóptero quedando este en el lecho del río, habiendose roto el conjunto de núcleo del rotor principal y toda la aeronave. Una de las palas del rotor principal seccionó el mando ciclíco en su parte superior.

1.13 Información médica y patológica

Se realizó el reconocimiento médico del piloto únicamente para fines legales de inhumación.

1.14 Incendio

No hubo incendio

1.15 Sobrevivencia

El piloto recibió heridas graves en la cabeza que no daban lugar a sobrevivir.

II. ANALISIS Y CONCLUSIONES

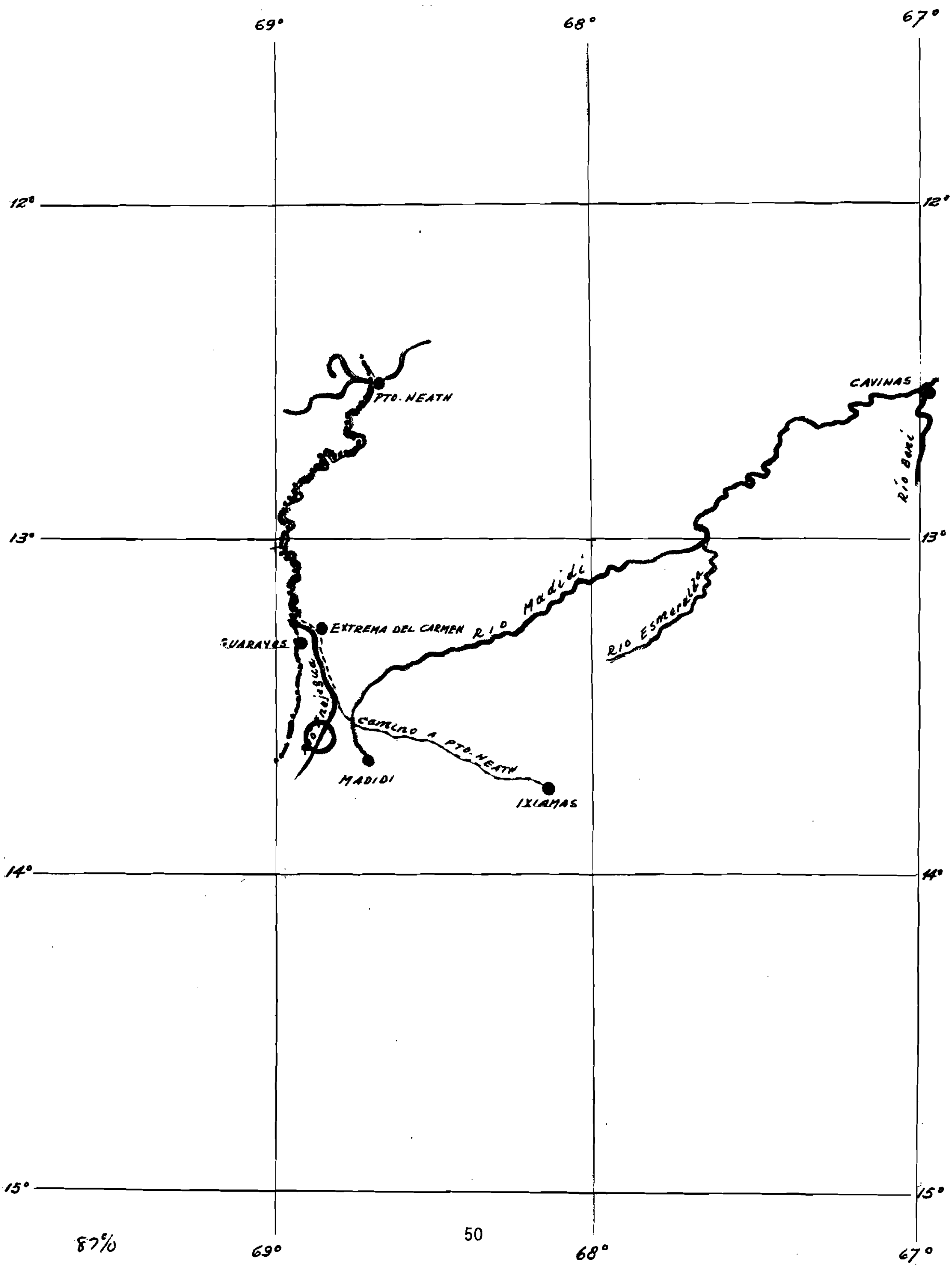
El helicóptero realizaba un vuelo a baja altura siguiendo el curso del río.

Debido a la época en que ríos y arroyos crecen en caudal por las intensas lluvias, lo que ocasiona que se erosione el terreno de las riberas dejando portanto las raices de los árboles prácticamente al aire. El helicóptero volando a poca altura sobre el río, probablemente generó con el torbellino del rotor principal un batimiento de las aguas que golpearon la ribera contribuyendo asi a acelerar la caída de un árbol a la derecha del helicóptero en el momento en que este pasaba. Prácticamente cayó sobre el helicóptero la copa del árbol aplastandolo contra el río al mismo tiempo que las ramas eran destrozadas por una de las palas del rotor principal cuyo nucleo se rompió dando como resultado que las palas rotaran en posición de aproximadamente 60 grados de su posiciónn normal, las que destrozaron la cabina y lesionaron gravemente al piloto. Por la posición del helicóptero en el río se puede establecer que probablemente el piloto trató de esquivar el árbol desviándose hacia la izquierda no lográndolo.

Lo expuesto anteriormente establece como probable causa que motivara el accidente.

III. RECOMENDACIONES

1. Dado el tipo de operación que se debe efectuar en estos casos que se haga conocer los posibles riesgos que puedan afrontar los pilotos.


69°
68°
67°
12°
13°
14°
15°
PTO. HEATH
CAVINAS
Río Beni
Río Madidi
Río Esmeralda
EXTREMA DEL CARMEN
GUARAYOS
Camino a Pto. Heath
MADIDI
IXIAMAS

El cause del río Enaguegua tiene un ancho de 40 a 50 metros y cuyas orillas se elevan sobre el cause aproximadamente dos metros de altura, con árboles que sobrepasan los 30 metros de altura. (En la foto se aprecia la posición final de los restos del helicóptero)

Al caer el árbol a través del río, prácticamente la copa aplastó el helicóptero contra el río.

El núcleo del rotor principal se rompió dando como resultado que las palas rotaran en posición de aproximadamente 60 grados de su posición normal, las que destrozaron las ramas del árboly la cabina del helicóptero, lesionando mortalmente al piloto.

MANAGING THE AIRPORT PHASE OF THE INVESTIGATION

John C. Self, Facilities Risk Management

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I. INTRODUCTION

Airports are of significant and growing concern to air safety investigators. Consider the following set of facts: A wide-bodied aircraft taxies for takeoff. The surface winds are gusting to 50 KTS and warming temperatures have turned the pavement at this far-north airport dangerously slick with ice. During the taxi sequence, the right wing gear reaches the edge of the taxiway pavement. The nose wheel lifts off the taxiway and wind pressure against the vertical fin rotates the aircraft perpendicular to the taxiway. The aircraft slides backwards down the 65 foot embankment and comes to rest across a service road. There is no fire and all occupants are evacuated successfully but the aircraft sustains many million dollars worth of damage.

Consider another set of facts: Deteriorating weather has forced the closure of several hub airports in the Northeast United States. The resulting congestion at alternates has led officials at one alternate airport to park a number of large aircraft on one of its runways. Later that evening a twin turbojet aircraft, mistaking this still lighted runway for another runway, attempts a takeoff. After colliding with several unlighted airliners, the smaller jet comes to rest. There are no injuries, but substantial damage has been done to several aircraft in addition to the twin turbojet.

In the accidents just described and in many others, certain elements of the airport environment counted heavily in the investigation of the accident. The purpose of this paper is to describe the tools that an air safety investigator may use in analyzing the airport environment and its elements. These elements are then considered as they might be encountered by an aircraft involved in an accident.

Inasmuch as air safety investigators are seeking causal factors in accidents, we will examine the duties of airport operators as they relate to accident prevention and accident response. We will examine further how these duties arise from Federal Aviation Regulations, other laws and regulations and an airport's general and contractual obligations.

This paper is intended for use as a reference for documenting airport factors in accident investigations. To this end, a large number of factual references have been included. While it will be seen that this approach yields a somewhat labored narrative style, we feel the reader will be rewarded for his patience. The references cited are current as of August 1, 1976.

II. SOURCES OF AIRPORT INFORMATION

Operational data concerning airports is published in the Airman's Information Manual (AIM) parts two and three. Additional data is maintained by the FAA in the Airport Master Record (FAA Form 5010). In addition to a large volume of physical description, this record includes a plan view drawing of the airport. The sources mentioned above are public information and available in the case of the AIM by subscription through the Government Printing Office. FAA 5010's are available at FAA regional offices.

Airports served by air carrier aircraft are required to publish an "operations manual" for the approval of the FAA. These manuals contain a large amount of very detailed operational information. When approved by the FAA and published, these manuals become contracts between the airport, its air carrier users and the FAA. Requirements for operations manuals are contained in Federal Aviation Regulation 139.31 and 139.33. A detailed description of how to produce an operations manual is contained in FAA advisory circular 150/5280-1. While usually not considered public records, operations manuals are disseminated to a wide variety of airport users and can be made available to the investigator by the airport manager or FAA regional office. Other more specific records and publications will be referenced in the sections following.

III. DUTIES OF AIRPORT OPERATORS IN ACCIDENT PREVENTION & ACCIDENT RESPONSE

The airport operator has a considerable measure of control over the facility. He establishes the terms and conditions for airport users and may provide a variety of basic services, such as fire protection, security, field and building maintenance, aviation fuels, electric power, sewage treatment and parking. The list may be even more extensive at larger airports.

Out of the control and authority of the airport and the services it provides and often charges for, a host of responsibilities emerge. Seen from the operator's viewpoint, these responsibilities can be organized as those arising from laws and regulations and those arising from his general prudential responsibilities as a landlord.

A. Laws and Regulations--Aviation

The greater share of an airport's responsibilities will be seen to arise from specialized regulations. While these are mandatory for airports in certain categories, air safety investigators are not concerned with enforcement but rather with accident prevention. In this light, the regulations can be viewed as a guide to safe and efficient operations and separately from whether they create a legal obligation for a particular airport.

The following regulations are discussed in the paragraphs below:

FAR 139	Airport Certification
FAR 107	Airport Security
FAR 77	Objects Affecting Navigable Airspace
FAR 151	Federal Aid to Airports

FAA advisory circulars

Federal Aviation Regulation 139--Airport Certification

FAR 139 is the basic and most far-reaching regulation pertaining to airport safety for air carrier airports. It includes standards for both accident prevention and accident response. These standards require that each air carrier airport publish an operations manual. Operations manuals must describe the way in which an individual airport will comply with the specific standards of FAR 139. There are a large number of specific standards promulgated under this regulation.

The following list summarizes the areas in which specific standards are promulgated:

Eligibility Standards

139.43	Pavement areas.
139.45	Safety areas.
139.47	Marking and lighting runways, thresholds and taxiways.
139.49	Airport fire fighting and rescue, equipment and service.
139.51	Handling and storing hazardous articles and materials.
139.53	Traffic and wind direction indicators.
139.55	Emergency plans.
139.57	Self-inspection program.
139.59	Ground vehicles (in operational area).
139.61	Obstructions
139.63	Protection of NAVAIDS

139.65 Public protection (from inadvertent entry into operational area).
139.67 Bird hazard reduction.
139.69 Airport conditions, assessment and reporting (by NOTAM/AIRAD to air carrier users).
139.71 Identifying, marking and reporting construction and other unserviceable areas.

Operational Standards

This section establishes continuing operating standards for application after eligibility is established. Examples are specific standards for snow removal (139.85), pavement repair (139.83) and lighting replacement (139.87).

Federal Air Regulation 107--Airport Security

FAR 107 requires airport operators to publish a master security plan for the approval of the FAA. In its plan, the airport identifies the air operational area and is committed to a time phased improvement of its protection from unauthorized entry (by fences, gates, guards, etc.) to an extent and at a rate satisfactory to the FAA. In addition, immediately upon approval of the plan, the airport must implement the following programs:

1. Provide a uniformed, armed and deputized peace officer at final pre-boarding passenger screening. The officer is to be on station prior to and during the screening until all aircraft doors are closed and the aircraft taxies away. "Sterile concourse" concepts have been accepted as meeting these criteria.

2. Provide for, control and enforce the visual identification of persons and vehicles entering and within the air operations area. (Except where an entry point is under the exclusive control of an operator required to have an approved security plan of his own.)

Federal Air Regulation 77--Objects Affecting Navigable Airspace

FAR 77 contains a description in words of the imaginary surfaces surrounding an airport through which solid objects should not protrude except under conditions described in the regulation. Airport operators are required by FAR 139.61 and 139.93 to maintain all areas under their control to the clearances actually existing where the airport was certificated and to mark and light all objects defined as obstructions under FAR 77 except where relieved of this responsibility by an FAA aeronautical study.

Federal Air Regulation 151--Federal Aid to Airports

This part describes the standards for construction and improvements on airports which are aided by federal grant participation (usually referred to as ADAP grants). Significantly, this section makes mandatory, the federal advisory standards in effect at the time the grant was approved. The regulation permits exceptions to this general rule, but the reasons for such exceptions should be documented.

FAA Advisory Circulars

These publications contain the "nuts and bolts" of equipments and practices recommended by the FAA. Included here are such essential items as the exact method for marking and lighting a runway, the recommended placement of wind socks and so on. There are over 150 separate circulars pertaining to airports. These circulars range from book size manuals such as "Planning the State Airport System" (AC 150/5050-3A) to a few well focused pages such as "Specifications for L-828 Constant Current Regulators" (AC 150/5345-10C) and literally every level of specificity in between. The titles of those advisory circulars currently effective can be determined by reference to "Advisory Circulars and Status of the Federal Aviation Regulations" (AC 00-2) which is available by subscription from the Government Printing Office or from most local FAA offices.

B. Laws and Regulations--Non-Aviation

Aircraft, when present on an airport, are in contact with a significant industrial and service operation to which certain non-aviation regulations apply.

National Fire Protection Association (NFPA) Fire Codes and Recommended Practices

NFPA publishes a multi-volume set of fire prevention codes and recommended practices. NFPA codes are not of themselves mandatory, however, many local communities have incorporated NFPA codes by ordinance making them mandatory in these communities. Even in the absence of an ordinance, the codes are a "national concensus" standard and may be taken as a guide to safe operations. NFPA codes of interest to air safety investigators are summarized as follows:

Emergency Services

Code Number	Subject
4,4a	Fire department organization
9	Fire department training, reports and records
1001	Fire fighter qualification
27	Private fire brigades
402	Aircraft rescue standard operating procedures
403	Aircraft rescue and fire fighting services at airports
406M	Handling crash fires, using structural fire fighting equipment
412	Aircraft foam fire fighting vehicles
414	Aircraft rescue fire fighting vehicles
422M	Aircraft fire investigator's manual

Design and Protection Standards

Code Number	Subject
408	Aircraft fire extinguishers
415	Aircraft fueling ramp drainage
416	Airport terminal buildings
417	Aircraft loading walkways
418	Rooftop heliports (protection standards)
419	Airport water supply systems
421	Aircraft interiors
101	Life safety (occupancy) code

Aircraft Ground Servicing

Safety precautions associated with ground servicing may be of interest to air safety investigators in a situation where persons have already boarded the aircraft with the intention of flight.

Code Number	Subject
407	Aircraft fuel servicing
410A through 410F	Aircraft ground servicing (various)

NFPA codes specify maximum room capacities and minimum egress standards for public buildings including terminals holding rooms and aircraft boarding areas. There is a potential conflict between these requirements and the security requirements of FAR 107. FAR 107 requires ramp access doors to be locked from the inside whereas NFPA codes (or a local ordinance) may specify that a minimum number of exits be provided or that all exits be unobstructed unless the space is continuously attended. Such potential conflicts can of course be resolved. The adequate resolution may be an issue in an accident such as a fire at the gate, where passengers have boarded the aircraft through jetways.

Occupational Safety and Health Standards (Federal OSHA and Approved State Plans)

"OSHA" requirements are the principal source of workplace standards in the United States. Understanding OSHA is a specialty unto itself. Federal OSHA standards are over 1,000 pages in length. OSHA standards have not been extended to aircraft in operational phases such as taxiing, or in-flight. OSHA does extend to the ground servicing of aircraft, and in general to airport ramps. Of interest to the air safety investigators, are areas where OSHA standards include topics either not addressed in the aviation regulations, or where the OSHA standards are more strict or definite. Examples are the OSHA standard for the barricading and marking of construction areas and the standards for limits of noise exposure for employees.

General and Contractual Obligations

The standards of prudent conduct apply equally to airport operators as to others. The duty to provide reasonable care arises out of the many services the airport operator provides and often charges for. If an airport provides chocks and tie-downs as a courtesy to transient aircraft, they should be the appropriate size, weight, strength, etc. for the use intended and be in good condition. The fact that an airport engages in contracts, concessions, leases, space permits and rents parking space, implies certain obligations to provide reasonable controls and precautions with respect to the activities of the tenants, concessionaires and others and provide a reasonable measure of enforcement of its regulations.

IV. INVESTIGATOR'S EXAMINATION OF AIRPORT ELEMENTS--NORMAL CONDITIONS

Inasmuch as there are many factors to be evaluated in an airport accident, it is unrealistic to expect the investigator to be familiar with all the material in advance, We would like to present a method of evaluating airport elements based on the order they might be encountered by an arriving aircraft. The elements are summarized as follows:

A. Imaginary Surfaces, the Obstruction Clearance of Glide Slopes
B. Electronic Navigation Aids
C. Visual Alignment and Guidance Aids
D. Environmental Hazards
E. The Physical Condition of Operational Surfaces and Their Associated Safety Areas
F. Taxi Guidance and Markings
G. Aircraft Parking Aprons
H. Aircraft Servicing

Except for sudden events such as power failure, the airport environment can be viewed as stable during the period of minutes where an aircraft is actively encountering it. The airport does, however, change or evolve in longer time frames, as in response to maintenance activities. It is important, therefore, that elements of the airport environment be evaluated as of the time of the accident and in the order they were encountered in the accident sequence.

A. Imaginary Surfaces, the Obstruction Clearance of Glide Slopes

An aircraft's first encounter with the airport environment is with the "clear airspace" around it. This airspace is limited by the "imaginary surfaces" as described in FAR 77. This clear airspace was defined for the purpose of protecting aircraft operating around an airport. As a practical matter, objects frequently penetrate this airspace. Examples are tall buildings, radio towers, power transmission lines, terrain features and the tails of parked aircraft.

No regulation requires an airport operator to remove existing obstructions. He must, however, maintain the same obstruction clearances as when the airport was certificated (FAR 139.61) and mark and light the obstruction (FAR 139.93) if it is in an area under his control. Advisory circular AC 70/7460-1D discusses the approved method of marking and lighting obstructions. The clearing or trimming of tall trees falls under this obligation as does the establishment of parking areas that will not allow aircraft, especially tall tailed aircraft, to penetrate the imaginary surfaces.

Not all penetrations of protected airspace are deemed hazardous to air navigation. The FAA has an administrative procedure under which "obstruction evaluations" are performed to determine whether a particular object constitutes an air navigation hazard.

In these evaluations, the FAA considers what effect the proposed construction would have on the reception of NAVAIDS, visibility minimums and the clearance of glide slopes and runway thresholds. "Obstruction evaluations" are public documents. They are filed by areas and maintained at FAA regional offices.

Even if it is determined that a proposed construction project would constitute a hazard to air navigation, the FAA cannot prevent the construction if local zoning authorities decide to let it proceed. The recent bicentennial flagpole project near the Atlanta Airport is an example. The proposed flagpole would have topped out at 150 feet AGL, at a location just 2,500 feet east of Runway 26. If the construction had proceeded, it would have required the displacement of the Runway 26 threshold by 2,300 feet, the changing of marking and lighting and the relocation of NAVAIDS. In addition to the physical work, a substantial increase in IFR minimums would have been required. This construction was not stopped by the FAA but by a suit in federal court by the Atlanta City attorney.

Airport managers should promote compatible land use around their airports and be alert for proposed projects that would infringe on the airspace. The airport operator is often in the best position to represent aviation interests to local zoning authorities and land use commissions.

B. Electronic Navigation Aids

Most electronic navigation aids are operated by the FAA. Some VOR's and NDB's are, however, operated by state aeronautics commissions and individual airport operators. The ownership and maintenance responsibility of a navigation aid should not be assumed. Federally owned aids sometimes depend on airport supplied normal and emergency electric power. If the service interruption of a navigational aid appears to be a factor in an accident, the arrangements for the provision of electric power should be reviewed. If an emergency generator is provided, its suitability, automatic features and periodic testing may become issues. Advisory circular AC 150/5340-17A (Standby Power for Non-FAA Airport Lighting Systems) applies.

C. Visual Alignment and Guidance Aids

This category includes every type of visual clue generated within the airport environment for an arriving aircraft. Examples of such clues are airport beacons, runway installations, wind socks, wind tees and upslope or downslope illusion.

Detailed information as to the recommended marking and lighting of the air operations area is contained in the AC 150/5340 (series) advisory circulars. These standards may be mandatory if projects involving their installation were built with ADAP funds.

For air carrier airports FAR 139.47 requires that all marking and lighting equipment be maintained in operable condition and FAR 139.87 requires the prompt cleaning and replacement of lighting fixtures as found necessary on self-inspection.

FAR 139.71 requires special marking and lighting for construction and other unserviceable pavement areas. FAR 139.53 requires segmented circles at air carrier airports without full time control towers and lighted wind direction indicators at all airports. Provisions for normal and emergency electrical power for lighted aids is subject to the references cited under Section B above.

Upslope and downslope illusions at airports have proven to be significant accident factors at night, or in poor visibility. While such illusions are difficult to counteract, airport operators have at least the following options available:

--Installation of VASI at thresholds impacted by upslope or downslope illusion. These installations provide reliable glide slope clues which may help to overcome the illusion.

--The Airport Master Record (FAA Form 5010) and Airman's Information Manual contain operational data for airport users. Airport operators may publish notices of any upslope or downslope illusion as a warning to users.

D. Environmental Hazards

In this section, we are referring to recognizable hazards which may arise in the airport environment and nearby areas and affect aviation safety. Examples are bird hazards, slippery conditions due to water or ice, lights from nearby shopping centers or stadiums and smoke from the burning of rubbish. Other examples in your area may come to mind. FAR 139.57 and 139.91 detail airport self-inspection requirements for the documentation and correction of on-airport hazards. Advisory circular AC 150/5200-18 provides detailed guidance and recommended techniques. In practice, not every hazard can be immediately corrected. Accordingly, FAR 139.69 provides for the issuance of timely warnings to users through the NOTAM/AIRAD system (described in AC 210-1A, AC 210-3 and the Airman's Information Manual). FAR 139.67 describes the requirements for reducing bird hazards at airports. Advisory circulars AC 150/5200-3A, AC 150/5200-8 and AC 150/5200-9 discuss recommended techniques for dealing with the problem. Some helpful material on "bird management" is also being published by private sources. The Flight Safety Foundation Airport Safety Bulletin of March/April 1976 reviews this subject thoughtfully.

Airport operators are expected to show an interest in all environmental hazards even though a particular hazard may be outside their direct control. For example when stadium lights interfere with night approaches, the airport manager may be in the best position to lead the affected aviation interests in seeking a solution. Because most airports are operated by governmental entities, the airport manager may be able to influence the zoning and permit policies of local government as they apply to operations which may constitute a hazard to his airport users. Advisory circular AC 150/5320-11 emphasizes the need for airport operators to keep airport information current so that the FAA can apply appropriate FAR 77 criteria to proposed construction projects.

E. The Physical Condition of Operational Surfaces and Their Associated Safety Areas

The standard dimensions for runways and taxiways are contained in advisory circulars AC 150/5330-2A and AC 150/5335-1A. With respect to dimensions, FAR 139 deals only with runway safety areas and extended runway safety areas which must conform dimensionally to "FAA criteria in effect at the time of construction" (FAR 139.45). FAR 139 is considerably more explicit, however, in terms of the conditions which must prevail within the pavement and safety areas (FAR 139.43, 139.45, 139.83 and 139.85). The criteria can be summarized as follows:

--Pavement areas; eligibility

° Show that no pavement lip exceeds three inches between weight bearing pavement and associated pavement shoulder.

--Pavement areas; operations

°Issue timely warnings (NOTAMS) when unable to correct a hazardous condition at once.

°Prompt repair of any crack, hole, etc. on a runway that is more than three inches deep or across.

°Prompt removal of snow, slush, standing water, rubber deposits, as required by operational considerations.

°Prompt cleaning of any solvent used to remove rubber deposits.

°For controlling icy conditions, only sand acceptable in minimizing FOD damage to aircraft may be used.

°Prevent ponding on runways.

°Prevent ponding on taxiways and aprons of an extent that would obscure markings.

°Conduct self-inspections in accordance with FAR 139.91.

--Safety areas; eligibility

°No potentially hazardous surface variations (ruts, depressions, etc.).

°No objects located in safety areas except those functionally necessary (NAVAIDS, approach lights, anemometers, etc.) or those mounted on frangible supports of minimum height.

°Adequate drainage by storm sewer or natural topography.

--Safety areas; operations

°Conduct self-inspection in accordance with FAR 139.91.

°Issue timely warnings (NOTAMS) where unable to correct a hazardous condition at once.

Advisory circulars in the AC 150/5380 series present recommended techniques for pavement maintenance. AC 150/5320-12 discusses the skid resistance of airport pavements.

Foreign object damage to aircraft may be an accident factor. Airport responsibility for cleanliness arises from its activity of sweeping runways, taxiways and aprons, its obligation to conduct self-inspection (FAR 139.91) and its obligation to promptly remove "containments" from runways (FAR 139.83B). AC 150/5380-5 presents recommended techniques for controlling debris at airports.

F. Taxi Guidance and Markings

The next element of the airport environment encountered by an arriving aircraft would be taxiway guidance and marking. The remarks and references presented under Section C above (Visual Alignment and Guidance Aids) apply to this element. The general rule for air carrier airports is that taxi guidance, including signs installed on the airport be maintained in an operational status. Any dangerous, or unserviceable pavement areas are to be specially marked and lighted in accordance with FAR 139.71.

G. Aircraft Parking Aprons

This element includes the conditions of the parking area, the obstruction clearance of aircraft parked in designated locations, control of vehicular traffic, ramp lighting, tie-downs and the security of the parking apron.

On the parking apron, aircraft transition between the operational and non-operational condition. After this transition aircraft merit consideration as "obstructions", under FAR 77 and become subject to, or at least in contact with regulatory regimes for industrial safety, vehicular traffic, workplace safety and fire prevention. Aircraft accident investigators must still be concerned with aircraft in the non-operational condition for two reasons: First, persons will be in fact aboard the aircraft for the purpose of flight during loading and unloading; secondly, because potential conflicts between aviation regulations and other regulatory regimes may affect operational aircraft. An example of the second type of difficulty is that whereas OSHA standards prescribe minimum illumination for a workplace, FAR 139.47(c) provides that ramp and building lights shall not interfere with aircraft or air traffic control. While such interfaces can be and are reconciled, it may be necessary to examine the practical result closely in the event of an accident.

The physical condition of aircraft parking aprons is covered under the FAR 139 criteria noted in Section E above. Advisory circular AC 150/5335-2 provides detailed guidance on apron design. Jet blast and methods of dealing with it are detailed in AC 150/5325-6A.

FAR 139.59 requires airport operators to provide safe and orderly arrangements for the operation of ground vehicles in the air operations area. Vehicles operating on runways and taxiways are required to have two-way radio contact with the tower while those on the apron need not be so equipped. FAA inspectors have interpreted the regulation to imply that the airport operate a ramp driver testing and license program, promulgate speed limits, driving lanes, roads, etc. and provide a reasonable measure of enforcement for its regulations.

Security of the air operations area is virtually the exclusive responsibility of the airport operator at air carrier airports, mandated both by FAR 107 and 139.65. The only exception is for entry points under the exclusive control of an organization required to have its own approved security plan.

Airport operators who elect to provide tie-down facilities, chocks, etc. as a courtesy to transient aircraft must ensure that such material is appropriate for the use provided and is in satisfactory condition.

H. Aircraft Servicing

The majority of aircraft servicing is performed by the airlines or aircraft operators themselves, or by service organizations under contract to the airlines. In some instances an airport's responsibility will arise from its ownership of facilities such as an underground fuel system or tank farm. Additional responsibility for aircraft servicing arises out of FAR 139.51. In this regulation, airport operators are required to monitor their tenant organizations in both aircraft fueling and the handling of hazardous materials. Aircraft ground servicing is subject to NFPA codes 407 and 410A through 410F.

V. INVESTIGATOR'S EXAMINATION OF AIRPORT ELEMENTS--POST-CRASH CONDITIONS

We have now followed the path of an arriving aircraft from its first encounter with the airport environment until all persons boarded with the intention of flight have departed. We have in moving from one element to another examined the responsibilities of the airport operation as they arise from the customary duties of landlords and from specialized laws and regulations. The approximate reverse order of encounter may be used for departing aircraft.

As air safety investigators, we would not expect to deal with a smooth progression in encountering the airport environment. At some point, there is an accident. The occurrence of a crash brings into focus a further set of airport responsibilities which may be characterized as emergency planning and disaster response. For air carrier airports, these responsibilities are detailed of FAR 139.49, 139.55 and 139.89 and may be supported by mutual aid pacts, community disaster plans or a civil defense organization. Detailed information on accident response equipment and recommended practices is contained in advisory circulars AC 150/5200 (series) and the NFPA codes referenced under "emergency services" above.

A. Emergency Plans

FAR 139 requires airport operators to publish an emergency plan as part of its operations manual. The following contingencies are required to be covered in the plan:

--Aircraft accidents and incidents.
--Bomb threats and incidents.
--Structural fires.
--Natural disasters.
--Sabotage and other unlawful interference with operations.
--Radiological incidents and nuclear attack.

The plan must show how the response elements listed below are coordinated into this plan:

--Medical services.
--Crowd control.
--Removal of disabled aircraft.
--Emergency alarms and systems.
--Mutual assistance with local safety and security agencies.
--A description of control tower functions relating to emergency actions.

The airport operator must show that he has coordinated his plan with law enforcement agencies, rescue agencies, medical resources, the principal tenants at the airport and any other interested persons.

The airport operator must also show that all airport personnel having duties under the plan are properly trained and familiar with the plan.

A recent FAA notice of proposed rulemaking will, if adopted, require the extension of emergency planning to encompass the method of providing transportation and medical services to the largest number of persons that could be expected to be involved in an air disaster. The airport operator would be required to identify hospital facilities, ambulance and paramedic facilities and law enforcement agencies that have agreed to carry out crowd control, transportation and medical care. In addition, the airport operator would have to specify buildings which can be used to shelter the injured persons until they can be transported to medical facilities and buildings that can be used as temporary morgue facilities.

One could expect good emergency plans to be tested and updated periodically even though the present regulations do not require full scale disaster drills.

B. Disaster Response

By regulation, the responsibility of an airport operator to respond to accidents extends to the crash fire fighting capability appropriate to the flying activity at the airport as described in FAR 139.49. In practice, airports may elect to provide rescue elements beyond fire suppression such as evacuation assistance, initial medical evaluation, crowd control and so forth, even though according to the regulations, the airport need only plan for the community to provide elements beyond fire suppression.

VI. SUMMARY

This discussion has included a wide range of material covering in fact several occupational specialties among FAA and airport executives. Using the material as a guide, air safety investigators can "dig deeper" into airport elements which may be causally related to an accident.

We have dwelt at length with the FAR's and other regulations because compliance is expected to enhance aviation safety. It clearly does, but the regulations themselves cannot be considered the last word in aviation safety. The very complexity of the regulations indicates a need for simplifying and rationalizing airport safety.

The entire purpose of these regulations is to save the lives that might be lost and avoid the injuries suffered in accidents. We submit that there is a challenge here for those persons with the most complete understanding of aircraft accidents, the air safety investigators. That challenge is to examine thoroughly the airport environment at an accident site and to work with airport managers to improve conditions of safety. Unsafe conditions or practices may be discovered that are unrelated to the present accident but which could under different circumstances be a factor in a later accident. By taking this initiative, air safety investigators can have a direct impact on the prevention of future accidents.

MANAGING THE INVESTIGATION OF INFORMATION RETREIVAL FROM AIRBORN CRASH RECORDERS

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I. INTRODUCTION

Airborne crash recorders include Flight Data Recorders (FDR's), Cockpit Voice Recorders (CVR's) or Audio Recorder and Digital Flight Data Recorders (DFDR's).

Their function is, of course, to continuously record circumstances and conditions in flight.

Civil Aviation Authorties (CAA's) around the world require carrying these recorders aboard various transport category aircraft. The use and variety of recorders to meet these regulations has greatly increased in the recent years.

The information retrieved from these recorders has repeatedly proven to be an important tool to an accident investigator in his efforts to manage the investigation.

A recently published NTSB * study, evolving from reviews of 509 accident and incident flight recorder readouts over the period from 1960 to 1973, helps to emphasize the value of recorded data to an investigator.

These tapes contain tremendous amounts of vital information, but they are not worth anything unless the information can be retrieved from them for proper investigation management.

II SUMMARY

Following are some of the assorted data readout objectives -

1. To recover the maximum amount of the accident or incident related information from good tapes as well as damaged tapes or tapes with a poor signal.
2. To protect the original recording medium from further damage.
3. To present the recorded information as quickly as possible in a consistant and accurate format.

The playback system should be designed to be easily reconfigured to handle tapes from various recorders whether they are damaged or not.

Operator skill, experience and thorough knowledge of the readout equipment are also essential to obtain maximum information from the tapes and to protect them further damage.

The Sundstrand Data Control new Incident Analysis Equipment was specifically designed for analysis of damaged tapes and to handle tapes from many, if not all, the recorder types. Of equal and perhaps more important are:

1. Retrieving information
2. The establishment of standardized procedures to be followed when someone other than regulatory agencies need to read the tapes.

These are the two major parts which I wish to cover in this presentation.

III FDR MEDIUM READOUT

Before I discuss more advanced retrieval requirements and Incident Analysis Equipment (IAE) developed by SDC, I would first like to suggest some feasible standards to be followed in reading out of FDR medium.

The FDR has been in use some 16 years and we, at SDC, have done many readouts during this time. Quite often we receive recorded medium to read, but very minimal, if any instructions as to what is needed to be read. So here are some suggestions

* REF: Special Study-Flight Data Recorder Readout Experience in Aircraft Accident Investigations 1960-1973. NTSB Report No. NTSB-AAS-75-1

as to how we would like to handle the medium and what instructions we would like to receive with it.

Assume you have a full spool of FDR recorded medium (200'). Total 800 hours recording time. How to proceed?

1. Handle the tape carefully to avoid damage.
2. Find the incident location on the medium.
3. Clearly mark the beginning and end of the area to be read using a felt tip pen.
4. Do not deform the tape or mark in the area to be read.

Unrecorded tape may be cut off to save time in handling during the readout. Generally it is not a good idea to remove the previously recorded part of the tape from the incident area. Often it is necessary to review several flights previous to an incident to establish the condition and calibration of the recorder. Once cut off, the tape may be lost. The best practice is to leave the recorded tape on a spool with the incident area furthest out and a few wraps of unrecorded tape covering it.

The recording may be on both sides, THEREFORE, care should be exercised before any tape is cut off. DO NOT fold the tape in the incident area.

Information required by the person doing the readout.

1. Name, tel. no. & organization of investigator.
2. Brief description of incident/accident
3. Parameters to be read.
4. Length of time prior to incident to be read.
5. Which parameters are most critical.
6. How to present the data.
   - Raw data only
   - Converted to engineering units
   - Corrected for - barometric pressure
     - calibration error

   (Barometric pressure for location and time of incident is required and last calibration data.)
   - Graphs - raw data
     - corrected data
   - Photographs of traces

Following is a general procedure followed in medium readout. Before starting the actual readout the following checks should be made:

1. General condition of the tape should be examined and noted whether all the parameters were recorded in the normal manner. The tape should be cleaned if necessary.
2. The "offset" or transverse alignment of traces should be noted.
3. If the altitude is to be read it is a good idea to check the altitude recordings against 2 or 3 previous runway elevations.

After accurately aligning the reference line with the movement of the readout device, it is a good idea to zero the "X" axis (time) on the very beginning of the flight such as recorder "POWER-ON" condition. The readout may consist of the last few minutes before the incident. However, often it is necessary to go back and examine some prior event. This way the time scale will be in proper sequence. The readout of each parameter can be started after setting the zero scale of the "Y" axis of the readout device. The "Y" axis zero must be rechecked or reset as required to obtain maximum accuracy.

For the most efficient readout it is recommended that one parameter be completed and then a return to the starting point for the next parameter, rather than reading all the parameters at one setting of time. One parameter may not have changed or the rate of change may be linear requiring very few readings whereas, the next parameter may require very frequent readings.

After all required parameters have been read all the data points are converted to engineering units for further processing.

IV. MAGNETIC RECORDERS

The more advanced magnetic recorders have created a whole new set of problems in the data retrieval, analysis, equipment requirements and operator skills.

The recording mediums in these are Mylar, Kapton (polyimid) and Vicalloy (metal). Their thickness varies from 1/2mil to about 1 1/4mils and widths vary from 1/4" to 1/2". The base material may be coated with iron oxide or no coating at all as in the case of Vicalloy and they may or may not be back lubricated.

The recording speeds vary from about 0.4ips to close to 3.0ips. The signal formats contain variables such as - number of tracks, their location on the tape, direction of signal, signal density, signal context (audio or digital) and some recordings are serial while others are time correlated parallel track recordings. The recorded data may be within design specifications or it may be well out of specs. with gaps in the signal of the tape itself. The signal to noise ratio may be very poor. The recording medium may be in very bad condition after exposure to extreme heat, salt water or other fluids present in an air disaster. We have also seen an increase of black boxes to extract and condition signals from these tapes which has added to the confusion. The operator must have complete knowledge of these systems in order to obtain all of the vital information accurately and in a correct format.

Playback System Requirements:

1. The playback equipment should be easy to reconfigure to playback tapes from any one of several recorders.
2. It should be designed to handle and process signals from damaged tapes with poor signals.
3. The system should be able to handle anomolies which may or may not be related to the incident such as signal transients, signal interruptions, sudden increase in flutter levels, etc.

With a properly designed flexible playback device, experiments may be performed in an attempt to recover more data. One segment may be recovered while another segment is temporarily lost, but thru repeated playback and analysis under different conditions the results may be pieced together for more accurate final data.

Playback Operation and Operator Skill:

A good playback system is essential. However, the operators skill and experience is necessary for maximum data recovery. The original recording medium and its contents must be protected during any playback operation and handling. It is the ultimate for available data.

1. Thorough knowledge of playback equipment and recording system is required to be able to detect and evaluate any anomolies.
2. The tape and playback signal should be closely scrutinized in the area of incident for any tears, marks or damage and evaluated for their effect on on the signal. It may be necessary to make a hard copy of these regions to assist in evaluation.
3. If the operator plays back tapes from many manufacturers recorders, he must be thoroughly familiar with all their playback systems.

Approaches to Assembling Playback Systems:

Commercial Tape Recorder - For playback of audio (CVR) tapes. The equipment available contains very few playback requirements outlined earlier. They are designed as recorders and if the operator is not very careful and knows the equipment well, he may either erase the signal or record over it, thereby destroying the only record of the accident. They are not designed to handle damaged tapes, etc.

One may obtain from each manufacturer a specialized playback device for each type of recorder being produced.

Disadvantages:

1. It is not an effective overall system.
2. It can handle only tapes from one recorder on each device.
3. It may utilize the recorder transport as a playback device with minimum playback electronics.
4. It is often designed as test equipment with very limited capabilities.
5. It does not contain sophisticated mechanisms and electronics required for handling damaged tapes.
6. The operator has to learn many systems.

Yet another method would be to obtain from each manufacturer, for each of his recorders, a device specially designed for this purpose.

The best overall solution to an effective system would be to build or purchase a transport and playback electronics specifically designed for analysis of damaged tapes and capable of playback of tapes from several, if not all, recorder types.

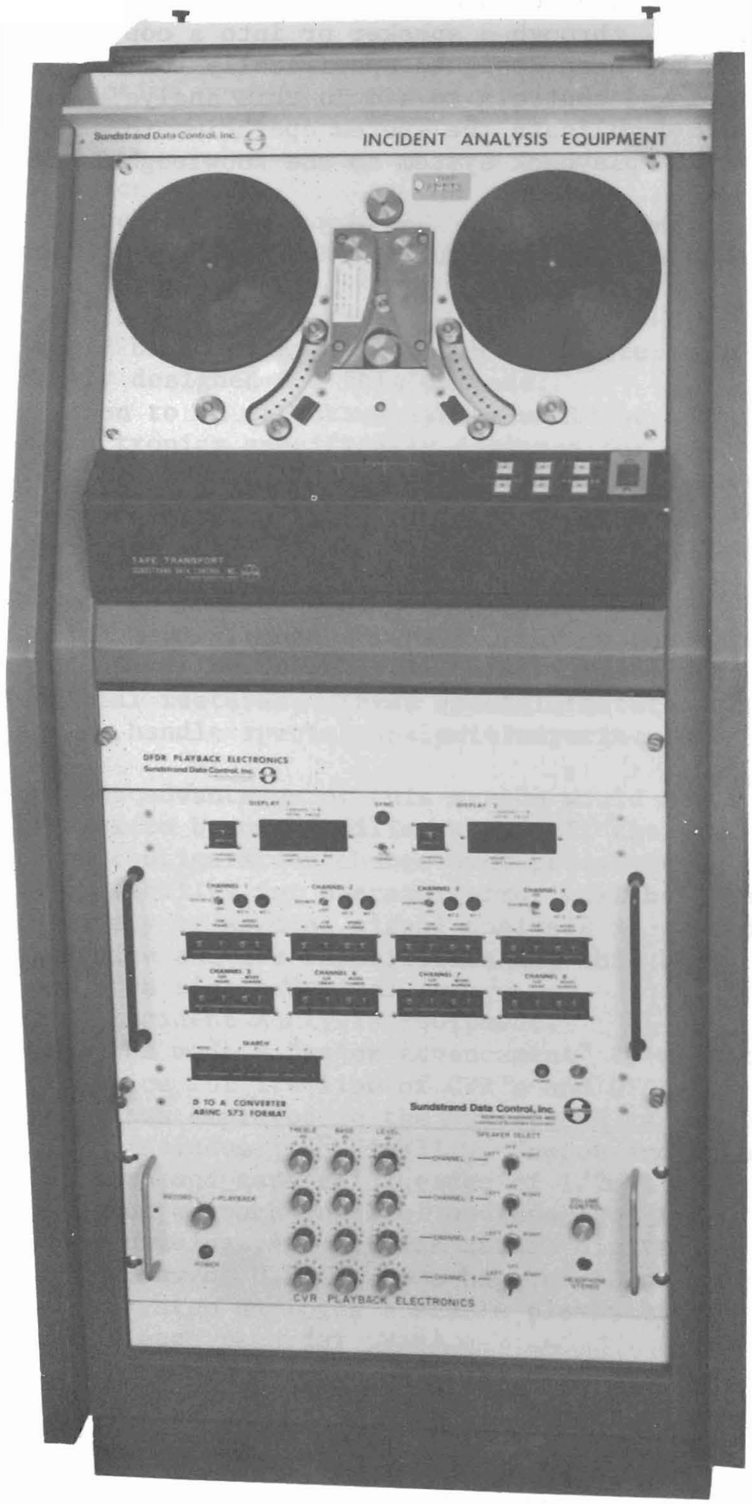
There are many advantages in this approach. From the design standpoint the playback equipment will become much more cost effective and valuable because of the elimination of redundant transports, playback amplifiers, control circuits, power supplies, cabinets, etc., not to mention the cost to design and maintenance. Because of the reqirement of handling several recorder types, the system becomes inherently more flexible in design and operation, thereby allowing for the economical inclusion of less frequently used special features. These special features then expand the capability of the playback to handle special analysis experiments aside from the normal operation.

One of the most important advantages of this system would be user familiarization. The user has only one playback to become familiar with. If the equipment is properly designed with no complicated configuration change-over procedures, set up and operation time as well as the possibility for operator error will be greatly reduced. The experimentation in data recovery or special signal analysis is gained thru thorough knowledge of the playback device and its capabilities and this knowledge and confidence is gained thru repeated use of a single device.

Sundstrand Data Control Incident Analysis Equipment:

Sundstrand Data Control has made a "major advancement" to meet this problem by developing such a playback device for its line of CVR's and DFDR's. This playback device handles all types of tapes employed in the Sundstrand random bin and reel to reel, CVR's and DFDR's. This includes 1/4" Vicalloy, Kapton and Mylar tapes in their lubricated and unlubricated form and tape thicknesses of 1/2mil or greater. The recorded signal formats range from 4 track parallel endless loop to 4 track parallel bi-directional (8 track) audio recordings, to 4 track serial digital recordings. The tape speeds on playback vary from a low of 0.82ips to a high of 30ips. The tape tension can be varied from 0 to 8oz. The system employes a single playback transport with interchangeable head assemblies for each recorder type.

A change in playback configuration for a specific recorder involves only installation of the head assembly onto the transport. The head assembly programs the playback for the proper speed, number of tracks, number of tape passes and proper tape tension. The head assembly also provides the precision tape guiding and head poitioning required for proper alignment of the tracks and, where required, time correlated playback of parallel recorded signals. This approach also minimizes cross contamination of lubricants, etc., between types of medium by minimal use of common components where the build up occurs. Playback signals are preamplified by a high performance preamplifier located in the transport and then provided to one of two signal conditioning modules located elsewhere in the equipment rack. One of these modules is designed specifically for conditioning of the digital playback signal into a computer compatable format. The other is designed for conditioning audio signals for playback signal into a computer compatable format. The other is designed for conditioning audio signals for playback through a speaker or into a copy recorder or other analysis equipment. The system has been designed specifically for analysis of damaged tape and has many added features and controls to aid in this analysis. These have been employed in such a way as to not complicate the system operation for the casual user, but to provide a highly flexible playback system to the knowledgable operator.


Sundstrand Data Control, Inc.
INCIDENT ANALYSIS EQUIPMENT
TAPE TRANSPORT
DFDR PLAYBACK ELECTRONICS
Sundstrand Data Control, Inc.
D TO A CONVERTER
ARINC 573 FORMAT
Sundstrand Data Control, Inc.
CVR PLAYBACK ELECTRONICS

AN ACOUSTIC WIND SHEAR DETECTION SYSTEM AT DULLES INTERNATIONAL AIRPORT

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I. INTRODUCTION

An acoustic Doppler wind-shear detection system was installed at Dulles International Airport during the summer of 1976. This is the first operational test system that has been developed under a joint FAA-NOAA program. Design and development work on acoustic wind sensing devices has been going on at the NOAA Wave Propagation Laboratory during the past four years and culminated in the Dulles system installation.

The paper describes the work leading to the Dulles installation, and offers a description of the various system components. Results based on tests of a prototype system at Table Mountain are presented to show the system's capability to measure wind shear. A brief discussion of potential second-generation systems is also included.

II. HISTORY

Wind shear, a sudden change in the direction or velocity of the relative wind flowing across the wings of an aircraft, is suspected of being the primary cause of a number of recent air accidents. The effect of a sudden shear encounter on an aircraft is an abrupt increase (or decrease) in the indicated airspeed. If the pitch angle remains constant, the airspeed change causes a change in the total lift developed by the wing. During landing, when an aircraft is operating in a high drag configuration, the change in descent rate resulting from a decreased lift can be severe enough so as to require immediate corrective action from the pilot to prevent landing short of the runway.

Wind shear occurs at the interface between separate air masses, such as along a synoptic-scale frontal boundary, or across an intense inversion. Cold air outflow from thunderstorms also produces wind shear. The acoustic Doppler system at Dulles was designed to detect the synoptic-scale shears, which at the inception of the program were perceived to be the most dangerous. The detection of gust fronts was then thought to be less of a problem since the generating thunderstorm is highly visible, and would alert pilots to be cautious. Recent experience has indicated that gust fronts were underrated as a hazard to aircraft.

The role of the Wave Propagation Laboratory in the aviation wind-shear problem began in 1971 with the demonstration that Doppler techniques could be used to extract wind information from an atmospherically scattered acoustic signal (Beran et al., 1971; Beran and Clifford, 1971; Beran 1971). This achievement coincided with the growing awareness of low-level wind shear as a danger to aircraft. The FAA, recognizing the potential of acoustic Doppler for detecting wind shear, initiated an interagency agreement with WPL specifying as a goal the development of an acoustic system to its full capability and the establishment of its limitations.

Phase I of the agreement was concluded in 1973. Studies were carried out during this period on the structure and climatology of wind shear, optimum sensor locations, and alternate detection systems. The results of these studies emphasized the need for more data and supported the acoustic Doppler as the most feasible sensor to develop at that time.

Work under the second phase of the agreement began with studies to determine the preferable system configuration, Doppler extraction technique and type of antenna. Following these studies and a subsequent period of development, an experimental model was constructed at Denver Stapleton International Airport in December 1973. The system was operated for three months. Results from these tests indicated that an acoustic system could operate successfully in a noisy airport environment. (Beran, et al., 1974). The test also identified some problems which had to be corrected prior to installation of an operational system. The necessary design changes were made and tested on a prototype unit at NOAA's field site at Table Mountain, Colorado. The test unit consists of one leg of a complete system and is capable of measuring only one component of the horizontal wind. The Table Mountain system is used to test concepts and design changes prior to their being incorporated at Dulles.

III. GENERAL PRINCIPLES

The Dulles system makes use of the fact that a sound wave scattered from a moving medium will be Doppler shifted in frequency relative to the original transmitted wave. This change is proportional to the component of the velocity of the moving medium in the direction of the bisector of the angle formed by the incident and scattered ray paths. The translation from frequency shift to horizontal wind can be explained by referring to Figure 1, which shows the scattering geometry for a bistatic configuration. Sound is transmitted at T with wave vector $\vec{K}_o$ and scatters off a volume 0 moving with velocity $\vec{V}$. The scattered sound is received at R. The magnitude of the wind, V, in this plane is found to be

$$V = \frac{\lambda_o \ \Delta f}{2 \sin(\theta/2) \cos \beta} \tag{1}$$

where λ_o is the wavelength of the transmitted sound, Δf is the Doppler frequency shift, θ is the angle between $\vec{K}_s$ and $\vec{K}_o$, and β is the angle in the plane of the transmitted and received beams between V and $(\vec{K}_s - \vec{K}_o)$. Equation (1) is applied by assuming that $\vec{V}$ is horizontal, i.e., there is no vertical wind component. This is obviously not the case over the short term, since thermal plumes can cause vertical velocities of 1-2 m/s. However, by averaging the calculated winds over longer intervals (5 minutes or longer) the vertical component is removed from the wind estimate. For a fixed transmit frequency and system configuration, the horizontal wind in volume i reduces to

$$V_i = K_i \ \Delta f \tag{2}$$

where K_i becomes a predetermined constant. Note that equation (2) only gives the component of the horizontal wind in one direction. To calculate the total horizontal wind vector, at least one other component must be measured.

IV. SYSTEM DESCRIPTION

The Dulles installation is actually a dual sensor system. Acoustic methods are used to measure winds and detect shears in clear air. However, during periods of precipitation the effectiveness of the acoustic system can be seriously limited. A radar system at the site is then used as the wind sensor. A brief description of the radar system is included later in this section. The acoustic system at Dulles measures three components of the wind simultaneously. It does this by utilizing a single vertically pointing transmitter and three receivers (see Figure 2). The receivers are spaced 290 m from the transmitter and separated by approximately 120° in azimuth. A smaller satellite transmitter is situated near each receiver on a line between the receiver and the main transmitter. To obtain a measurement of the wind, a short burst of high-power, single-frequency acoustic energy is transmitted vertically. As the pulse travels upward, a small percentage of its energy is scattered by temperature and wind velocity fluctuations in the atmosphere. The scattered sound is shifted in frequency as a function of the wind speed. Each receiver "tracks" the pulse upward and measures the frequency shift of the scattered signal. The volume above the main transmitter is divided into 17 smaller volumes, each 30 meters high, beginning at 120 meters (Figure 3). Scattering volumes for the lower 120 meters are located above the satellite transmitters. The receivers collect the acoustic energy scattered from within each volume. The returned energy is analyzed to determine the Doppler shift. Wind along each of the three directions and total wind is then calculated. The calculations are repeated for each small volume, resulting in a wind profile reaching to 600 meters in height.

The acoustic system can be divided by function into the following subsystems: main transmitter, receiver, satellite transmitter, data processor, and display. The main transmitter (Figure 4) is an off-axis parabolic horn driven by 12 transducers (high-powered acoustic drivers). The transducers are connected to a manifold (Figure 5) which enables the sound generated by each transducer to be summed, producing a high-powered tone burst. The level of sound pressure generated above the mouth of the transmitter is approximately 125 dB (re 20 $\mu N/m^2$) which is comparable in intensity to the sound generated by a jet take-off 100 ft away.

Only a very small fraction of this energy is scattered back to the receivers. The received signal is approximately 120 dB below the level of the transmitted pulse and is of the same order of loudness as the threshold of human hearing. Because of the weakness of the scattered signal, external acoustic noise can make the extraction of the signal extremely difficult. To reduce external noise as much as possible, the receivers are mounted in sunken, fiberglass bunkers. The bunkers are installed so as to minimize wind noise by making a smooth transition with the surrounding terrain (Figure 6). An acoustically transparent cover completes the streamlining. In addition, to reduce reflections the interior of the bunker is lined with sound absorbing material. After being scattered, the Doppler-shifted acoustic signal enters through the cover, is reflected by the parabolic surface, and is collected by an array of transducers. The array is arranged such that each transducer beam intersects a segment of the main transmitter beam between 120 and 600 meters (Figure 3). The transducers are mounted in 3 columns, with each transducer in a given column looking at a succeeding higher volume. The center column of transducers scans the volume directly above the main transmitter. The two side columns steer the receiver beams ± 10° to each side. These side columns of transducers enable the receiver to pick up the transmitted pulse during strong cross winds that may blow the pulse out of the center beam. By switching the receiver input to the appropriate transducer, the transmitted sound pulse is tracked as it propagates upward.

Because of both reduced scattering at angles approaching 90° and system geometry constraints, the receiver cannot be used to sense scattered signals from the main transmitter below 120 meters. A smaller, low-powered satellite transmitter 50 meters in front of each receiver bunker provides the source for scattered signal at the lower heights. These transmitters are pulsed after the main transmitter burst has propagated up beyond the highest beam of the receiver array. The receiver transducers track the satellite pulse up to a height of 120 meters.

All system control and data analysis tasks are carried out by a Data General Eclipse minicomputer. During one measurement cycle system, centered about the minicomputer, performs the following:

- pulses the transmitters
- steers the receiver beams
- samples the returned signals
- analyzes the data to produce wind profiles
- sends wind information to the airport control tower
- archives all important information on magnetic tape

The received signal is sampled and digitized during periods when the scattered signal is present at the receiver. It is then fast Fourier transformed to produce a power spectrum. The spectrum created at each height gate for each leg of the system is then averaged in time with the spectrum calculated during previous measurement cycles. The averaging algorithm weights the more recent spectra, heavier than old spectra. The weighting is a decaying exponential with a preset decay time constant. Following this exponential averaging, the mean frequency of the average spectrum is used to calculate the Doppler frequency shift and wind for each height and leg. These winds are combined to form the wind profile.

One serious limitation of acoustic systems is their susceptibility to down time resulting from rain noise. The sound generated by raindrops falling on the receivers, if severe enough, can completely obscure the scattered signal. To counter this problem, the low-power pulsed electromagnetic Doppler radar has been incorporated into the system. The radar is turned on whenever rain is sensed at the computer site. Since the radar operates most effectively when tracers such as water droplets are present, it complements the acoustic system to provide continuous operation. The radar uses a Velocity Azimuth Display (VAD) scan to measure wind speed and direction. A separate minicomputer is utilized to calculate the Doppler frequency shift of the radar returns and to generate wind profiles. During transitional periods when both acoustic and radar systems are operating, the results from the two are compared and the best measurement is used to produce the wind profile. Even though both the radar and acoustic subsystems have been tested independently, Dulles marks the first attempt to integrate them into a single system.

Following the system test period, a display will be installed in the tower at Dulles to warn the controllers of hazardous shear conditions. A criterion to judge from the measured wind profiles when shears become hazardous is still lacking at this time. During the Stapleton tests, a simple vector subtraction of winds at successive heights was performed. If the difference exceeded a pre-determined threshold, a hazardous shear was indicated. Under operational conditions a more comprehensive test is needed, since some very hazardous conditions can be produced by gradual wind changes between corresponding heights. The problem is further complicated by visibility variations. What is considered to be a hazardous shear in a heavy overcast may be easily handled by a pilot on a clear day. Simulator studies at NASA-Marshall have been addressing this problem, and as new information becomes available on this subject the shear detection criteria will be updated. Once a critical shear condition is known to exist, the relevant information must ultimately be channeled to the pilot. The initial procedure at Dulles will be to alert the local controller and have the information relayed verbally. The tower display will sound an alarm, then display the height of the shear layer and the changes in headwind and crosswind which a pilot is expected to encounter at that height. In addition the total wind change from 1500 feet to the surface will be displayed to give notice of large but gradual wind shear. The tower display will be connected to the wind-shear detection system site by leased commercial phone line.

The acoustic system repeats a complete measurement cycle every 15 seconds. During precipitation periods when the radar is providing wind data, the cycle time for new information increases to 45 seconds. To facilitate later analysis of system performance, all spectra, wind estimates, data test results, and system reliability indicators are stored on magnetic tape at 5 minute intervals. Data from an array of meteorological sensors located at the site are also archived. The data tapes will provide a complete time history of system operation for later analysis, testing, and comparison with other sources.

V. SITE SELECTION

The wind-shear detection system is situated on a 65 acre site 1.1 miles southwest of the west end of runway 12-30 (Figure 7). A number of factors were considered in the selection of this site. Meteorological records at Dulles indicated that weather fronts consistently approach the airport from the west. Since frontal passage is a primary cause of synoptic-scale wind shears, it was desirable to locate the system at a point where it will detect such shears before they reach the airport and the low-level approach paths.

A second important aspect of the siting problem is the desirability to minimize background noise. Noise surveys were performed at three potential sites around the airport. The site chosen was found to have a relatively low background noise level. Analysis of air traffic patterns also indicated that jet activity in the proximity of the site is usually relatively light. The closest runway, 12-30, is only used by approximately 15% of the total traffic during normal operations.

Availability of land, future airport expansion and the effect on airport operations were also considered. The wind-shear sensor site utilizes commercial power and telephone lines. The connections to these lines were obtained without having to encroach on runways or approach paths.

VI. SYSTEM PERFORMANCE

Only limited data are available at this time on the Dulles system operation. However, tests at Table Mountain, Colorado where a one-leg prototype of the Dulles system was installed, have provided sufficient data to make some estimate of system performance. Figure 8 shows a comparison between acoustic Doppler wind estimates and those measured by a balloon-borne anemometer. Such tests have generally shown excellent agreement for wind speed up to 10 m/s, the operating limit of the balloon. Comparison data for higher wind speeds are presently unattainable because of the lack of an acceptable standard sensor. The design goal of wind measurement with an accuracy of ± 1 m/s in speed and ± 10° in direction appears to be met. The ability of the system to measure winds during shear conditions has also been demonstrated. Figure 9 shows a series of wind profiles measured during the passage of a thunderstorm gust front.

The Dulles system will undergo extensive tests for the next six to nine months. During this period, efforts will be made to determine the accuracy and limitations of the system. Comparisons with a balloon-borne anemometer, radiosonde, airborne instruments and pilot reports are scheduled for this period. If, at the end of this period, the system is judged to be an acceptable wind-shear sensor, it will become part of the Dulles operational network.

VII. ALTERNATE WIND-SHEAR DETECTION SYSTEM

During the past four years, the thunderstorm gust front has been increasingly recognized as a source of wind shears which are hazardous to aircraft. Gust fronts tend to be localized rather than synoptic in scale, and thus can escape detection by the acoustic Doppler system. It has been observed, however, that the passage of a gust front produces a sharp increase in the barometric pressure measured at the ground. As a result of extensive work with microbarographs (Bedard 1966, Bedard and Meade, 1976; Bedard 1976) a system was developed at WPL using an array of inexpensive surface-based pressure jump detectors. By monitoring the entire array, a gust front can be tracked as it travels across the airport. This system is also being tested at Dulles airport (Figure 10). At present the pressure-jump gust-front detection system and acoustic system are tested independently. They could eventually be combined, in a total system concept, as a single, comprehensive source of shear information.

Experimental work at WPL has been proceeding on second-generation wind-shear detection systems in parallel with the Dulles installation. Rapid advances in both radar processing techniques and laser technology have made these sensors attractive as future detectors. Both radar and the CO_2 pulsed lidar appear to have the potential to scan the entire airport region out to about 20 km radius, with emphasis along approach and departure paths, under all weather conditions. Basic development and testing of these sensors are still required.

VIII. CONCLUSIONS

Although the Dulles system is still being tested, results from the Table Mountain prototype indicate that an accurate profile of winds aloft can be obtained for wind speeds up to 10 m/s. Better comparison sensors are needed to accurately evaluate system performance for higher winds. Tests with instrumented aircraft at Dulles could provide additional comparison data. However, the horizontal separation between the sensors along with the relatively brief comparison times may make a valid evolution difficult to obtain.

Because the acoustic system measures the wind directly above the sensor, it is not effective for detecting all of the shear conditions which may occur. Thunderstorm gust fronts may be localized and consequently may not pass directly over the sensor. An array of pressure jump detectors will be included in the present Dulles system to detect the presence of gust fronts in the airport vicinity. Such a total system should provide comprehensive wind-shear detection under all weather conditions.

Second-generation systems using lidar and radar techniques may eventually provide a more cost-effective solution to the wind-shear problem. These systems have the capability of measuring winds over the entire airport region, including directly along the approach and departure paths. These systems are at least two years away from prototype installation at airports.

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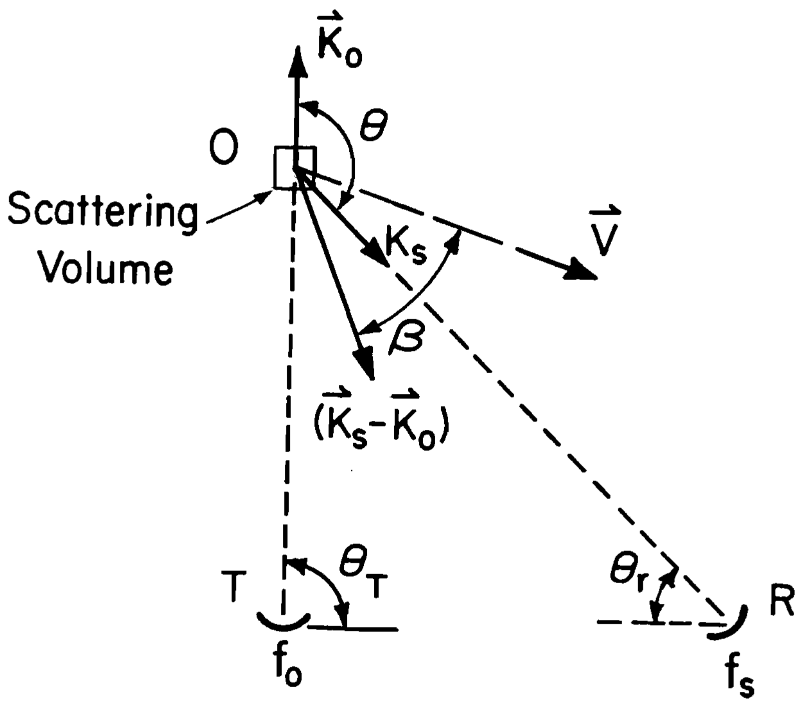

FIGURE 1. Wave Vector Diagram Showing the Component of the Wind Measured by a Doppler Shift

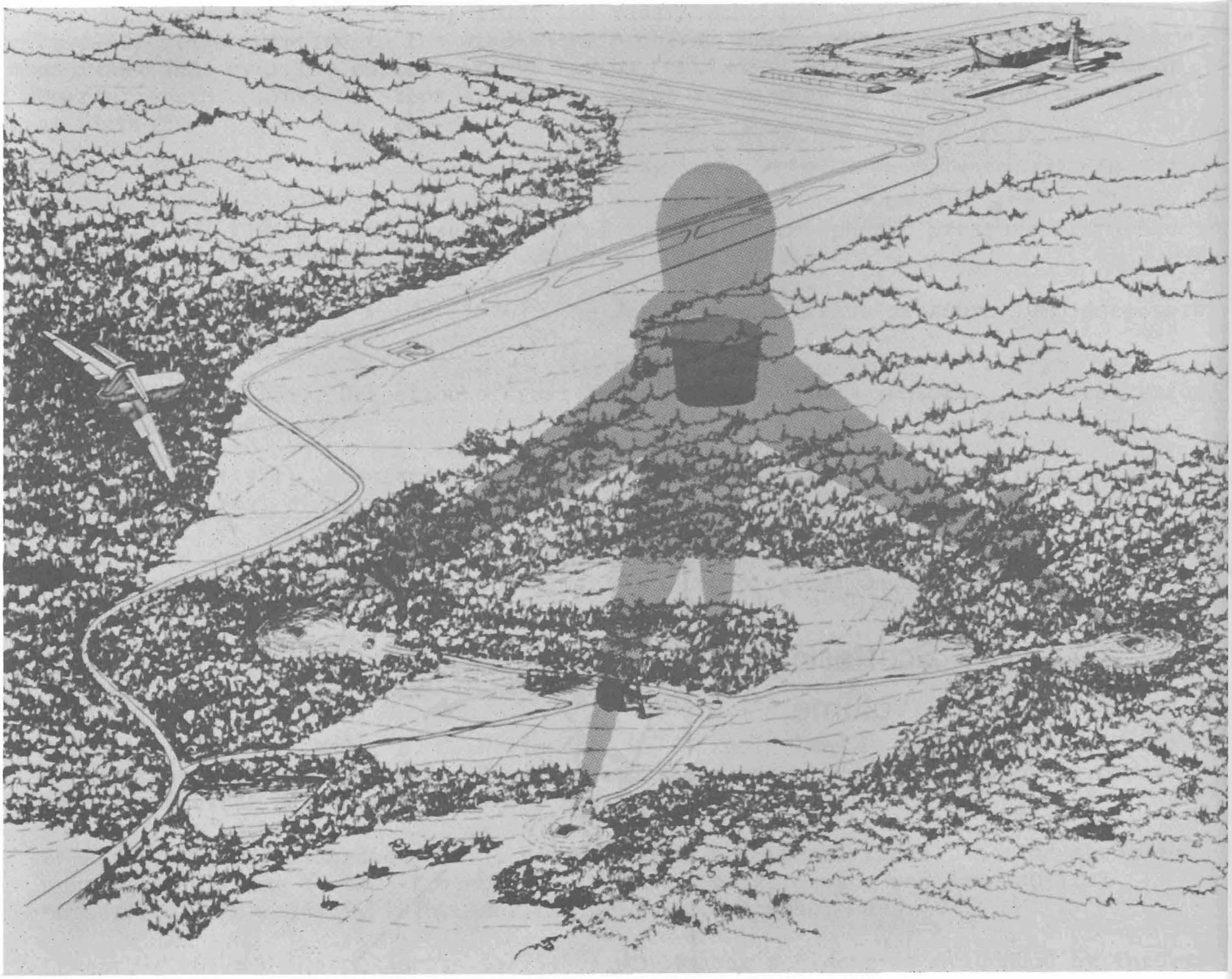

FIGURE 2. Artists Concept of Acoustic Doppler Installation at Dulles International Airport

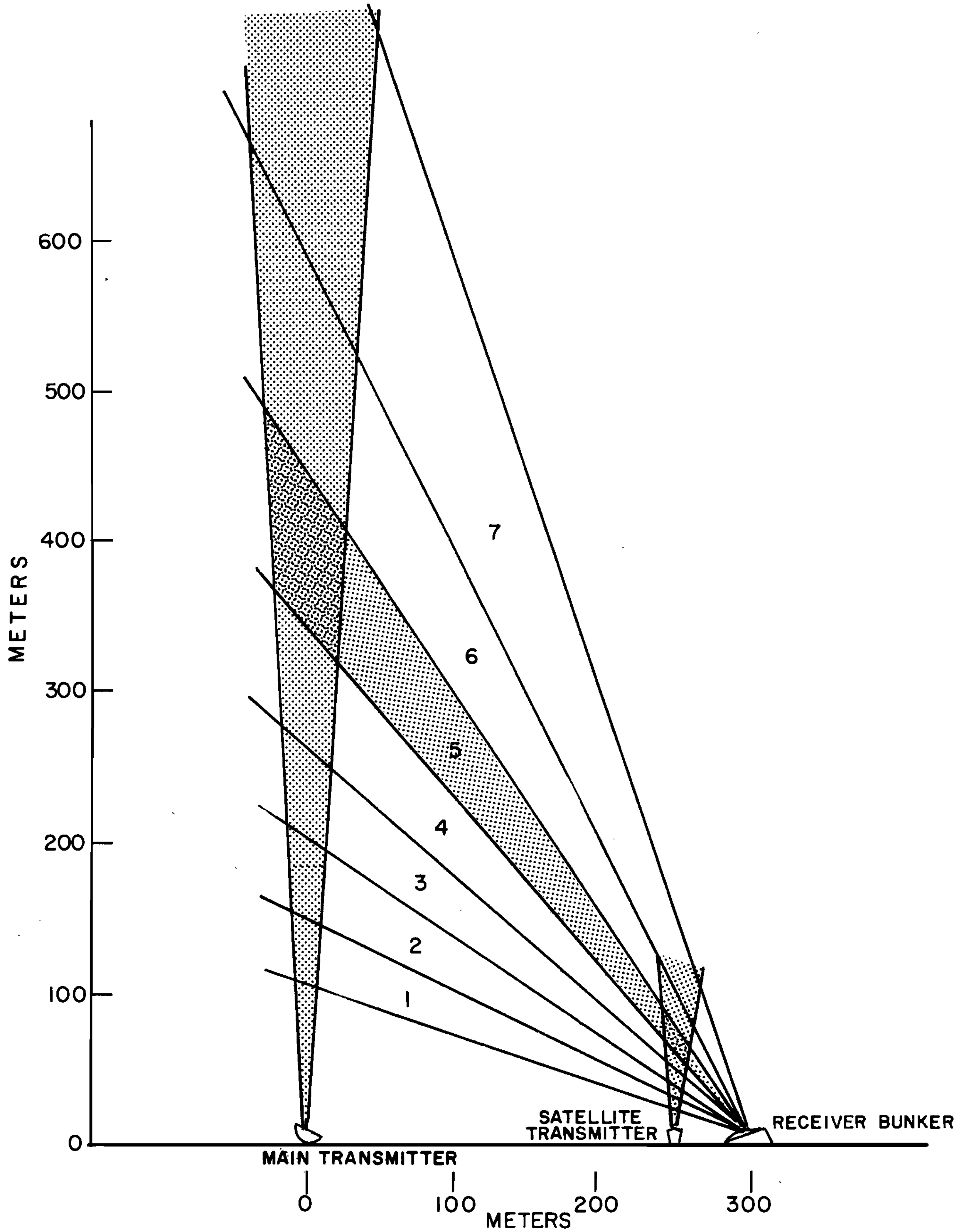

FIGURE 3. Two Dimensional Diagram Showing Intersection of 7 Receiver Beams With Main Satellite Transmitter Beams. Pulses are tracked by switching receiver beams as the transmitted pulse propagates up.

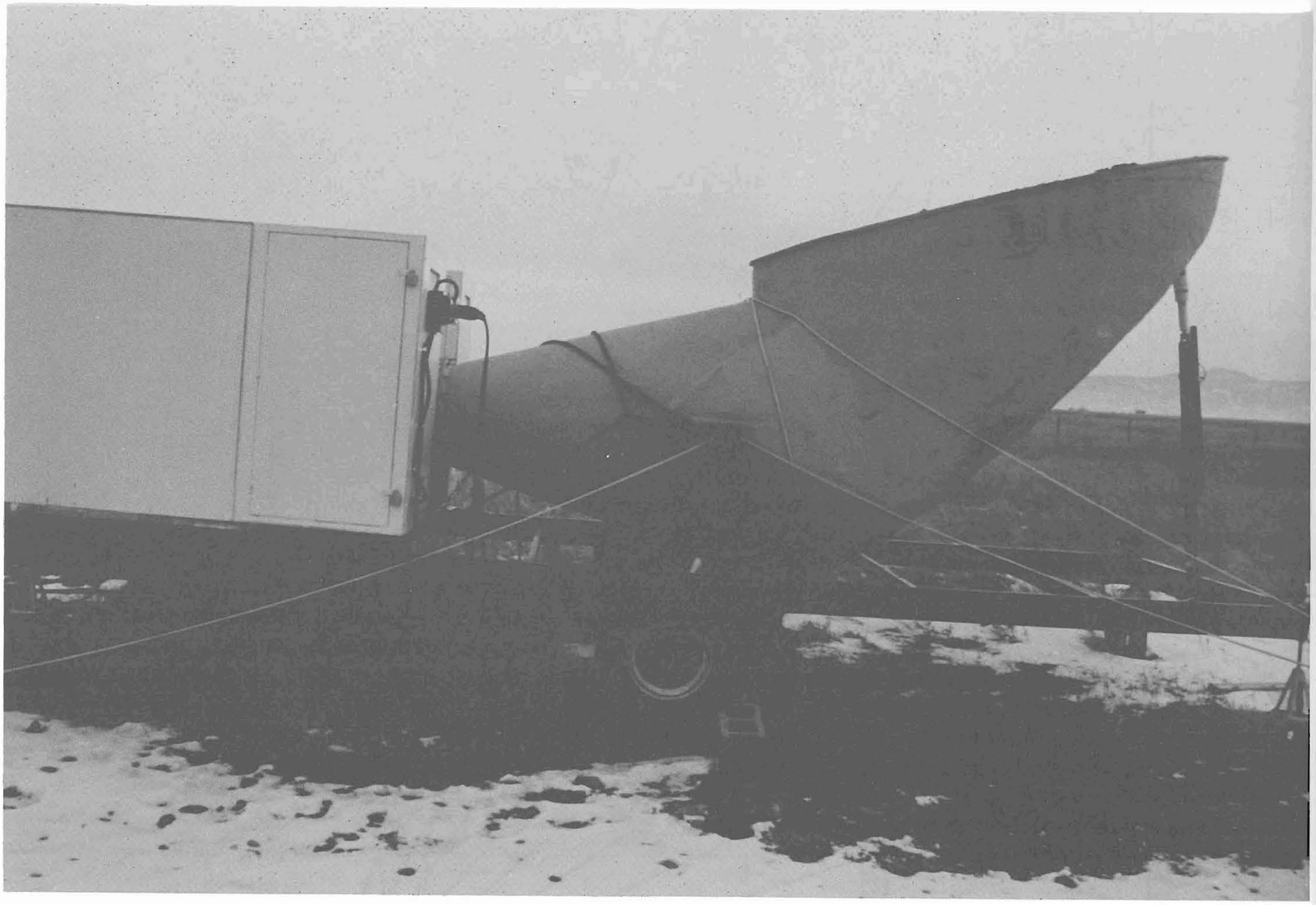

FIGURE 4. Prototype Main Transmitter Mounted on Movable Platform. The diameter of the exit portion of horn is approximately 2 meters.

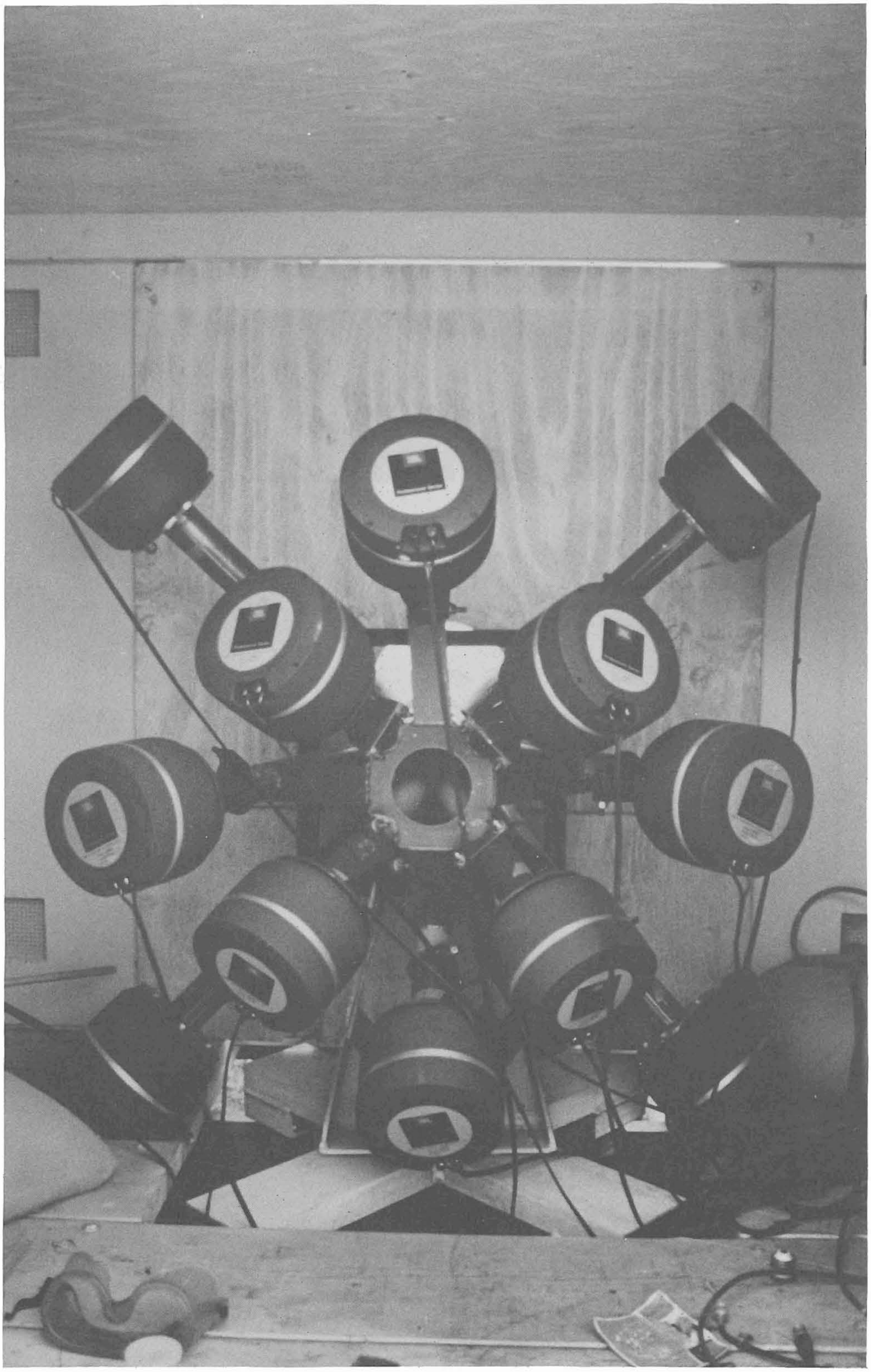

FIGURE 5. Dulles Main Transmitter Manifold Showing 12 Transducers. The manifold is attached to the entry cone of the horn reflector antenna.

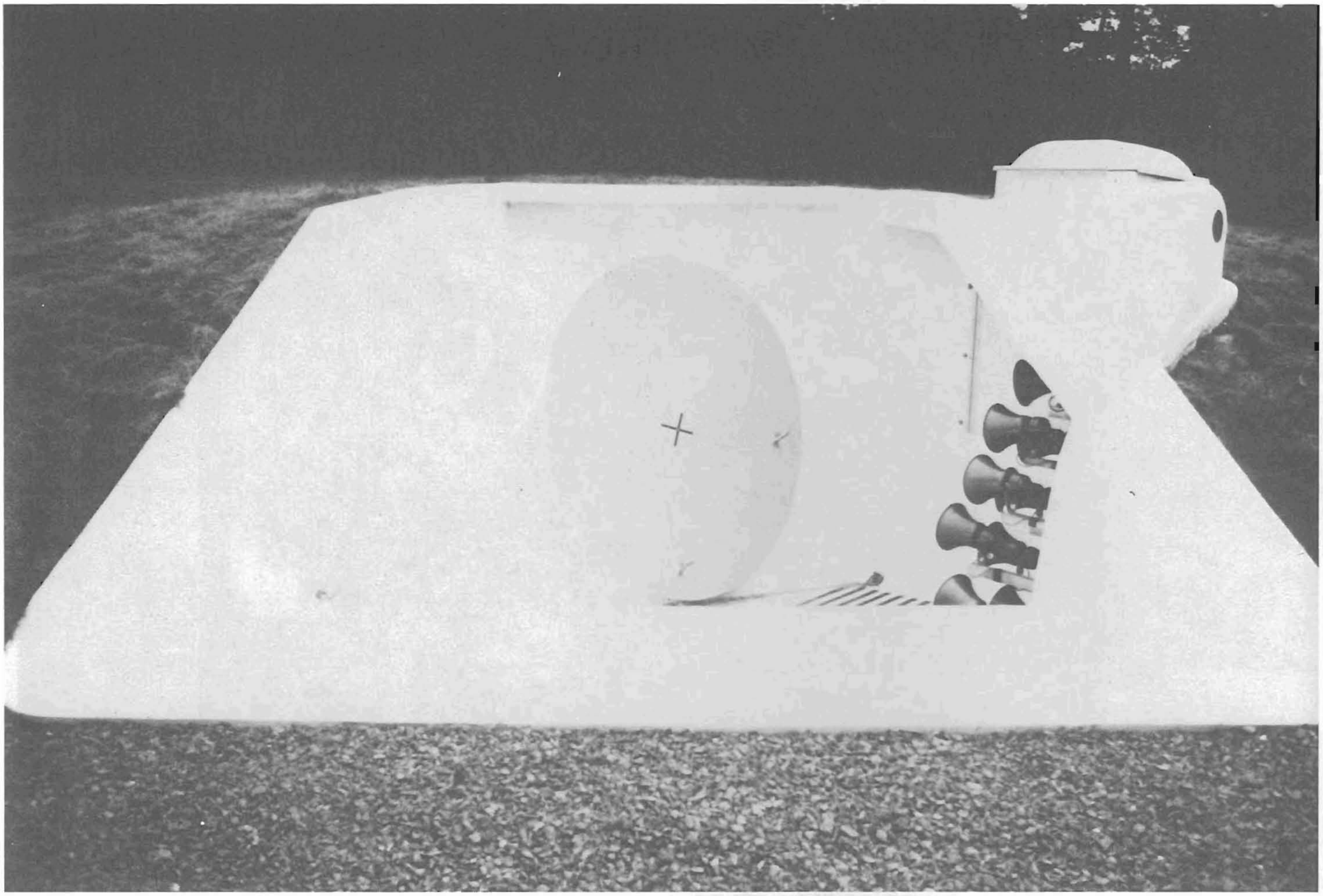

FIGURE 6. Dulles Receiver Bunker Without Cover Showing Acoustic Reflector and Receiver Transducer Array.

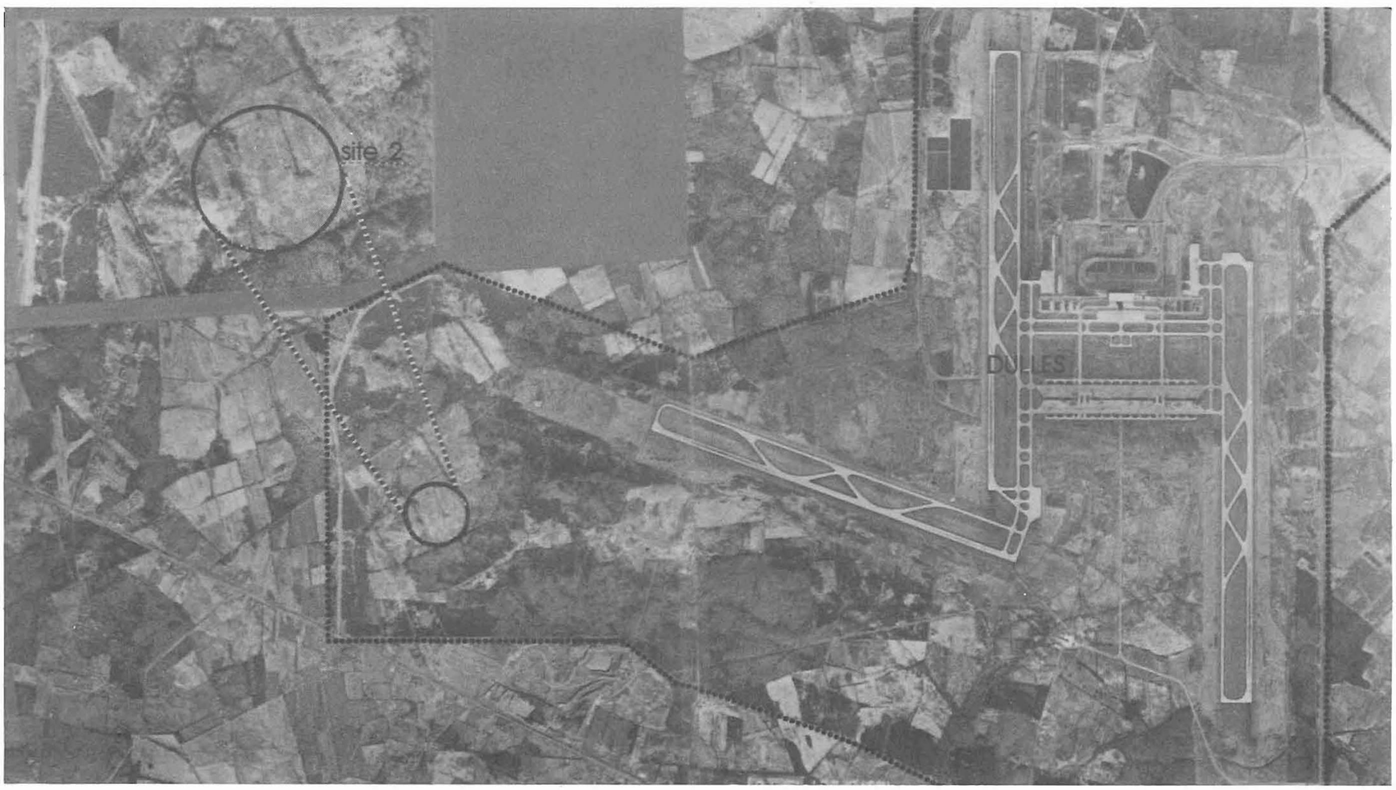

FIGURE 7. Site of Acoustic Doppler and EM Radar Installation at Dulles. (The location is labelled "Site 2" in the photo)

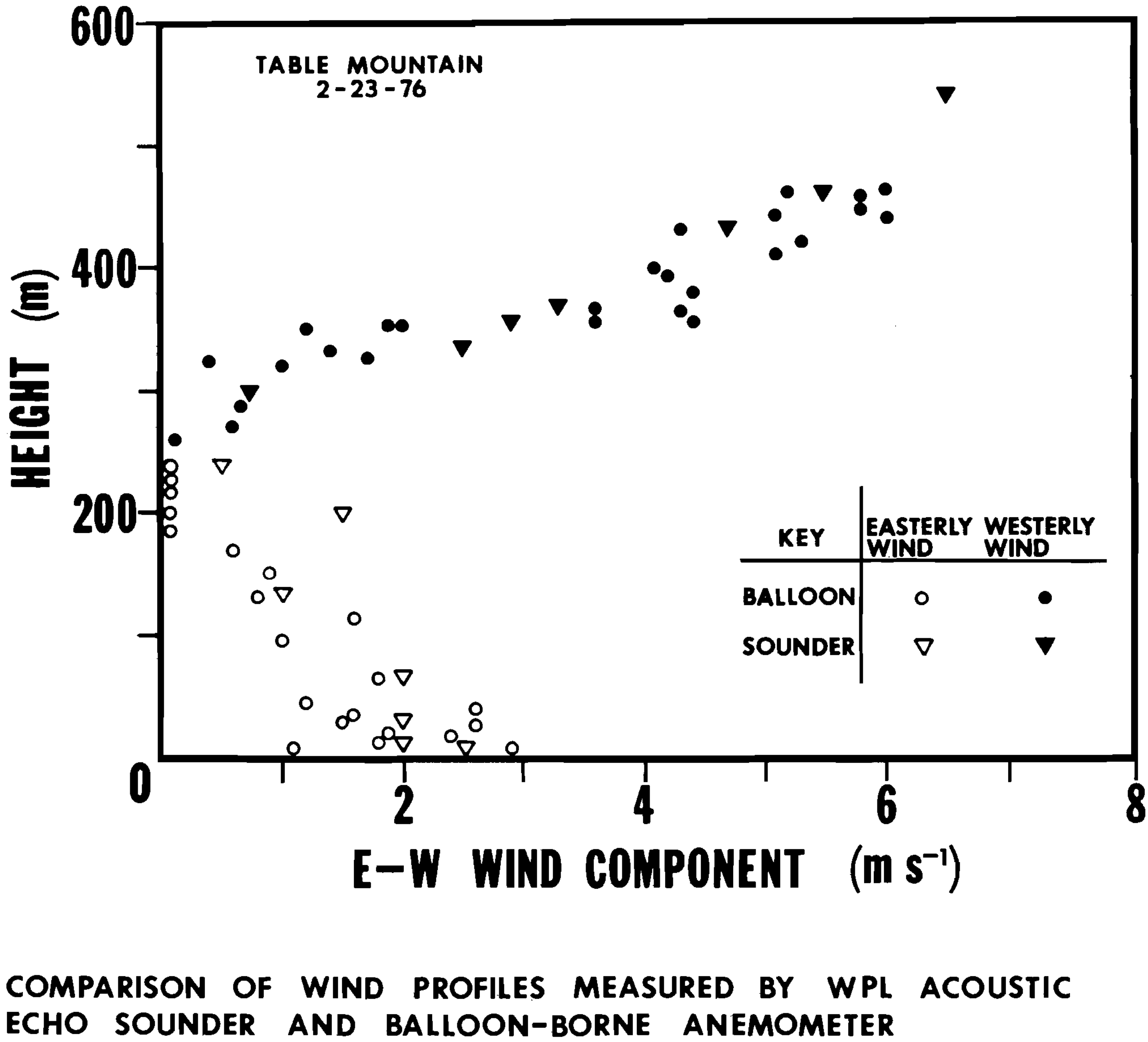

FIGURE 8. Comparison of Wind Profiles Measured by Prototype Acoustic Echo Sounder and Balloon-Borne Anemometer.

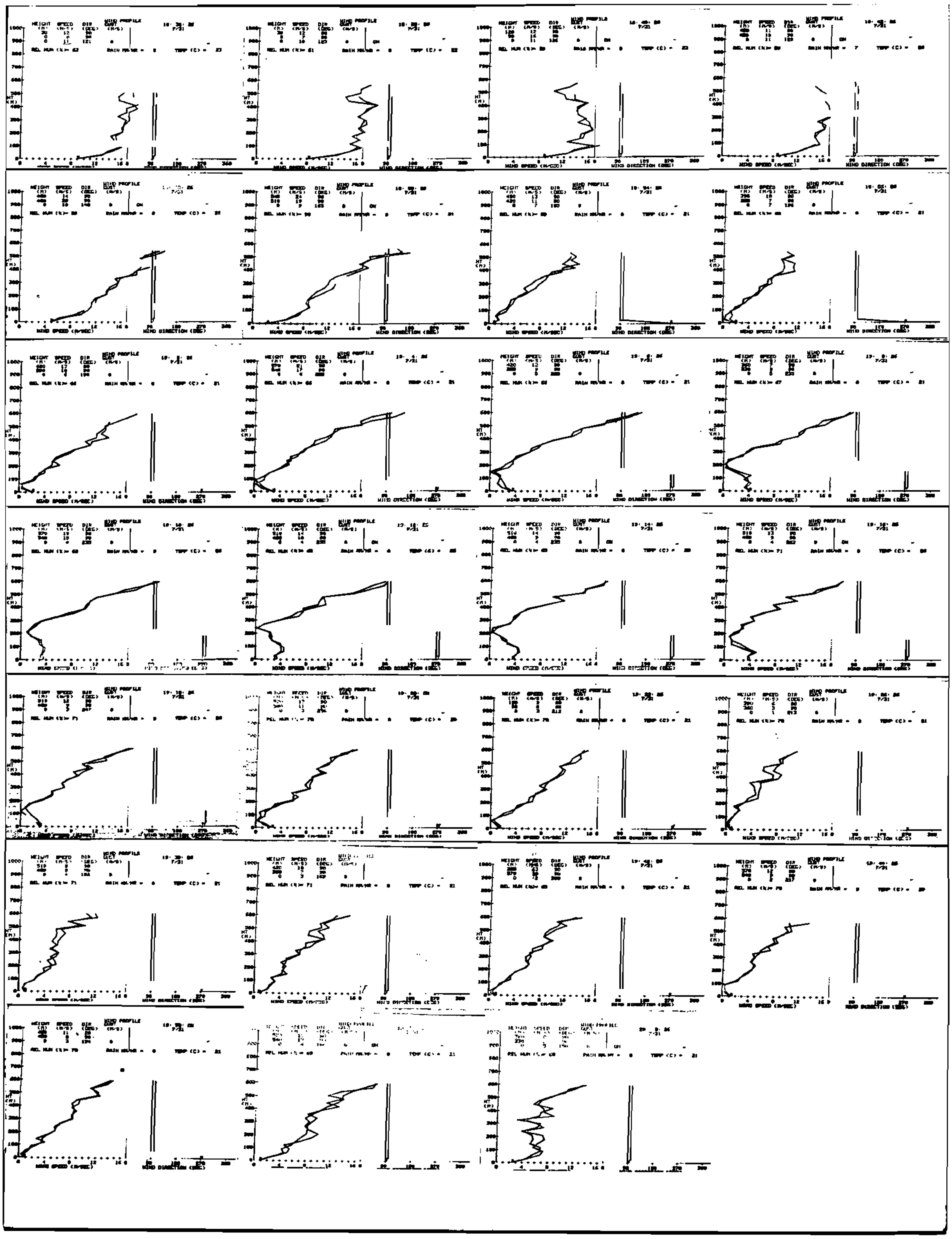

FIGURE 9. Time Sequence of Prototype Acoustic Doppler Wind Measurement Showing Gust Front Passage. Only the E-W component of wind speed is measured. Double profiles on each time frame represent comparison of Doppler extraction methods.

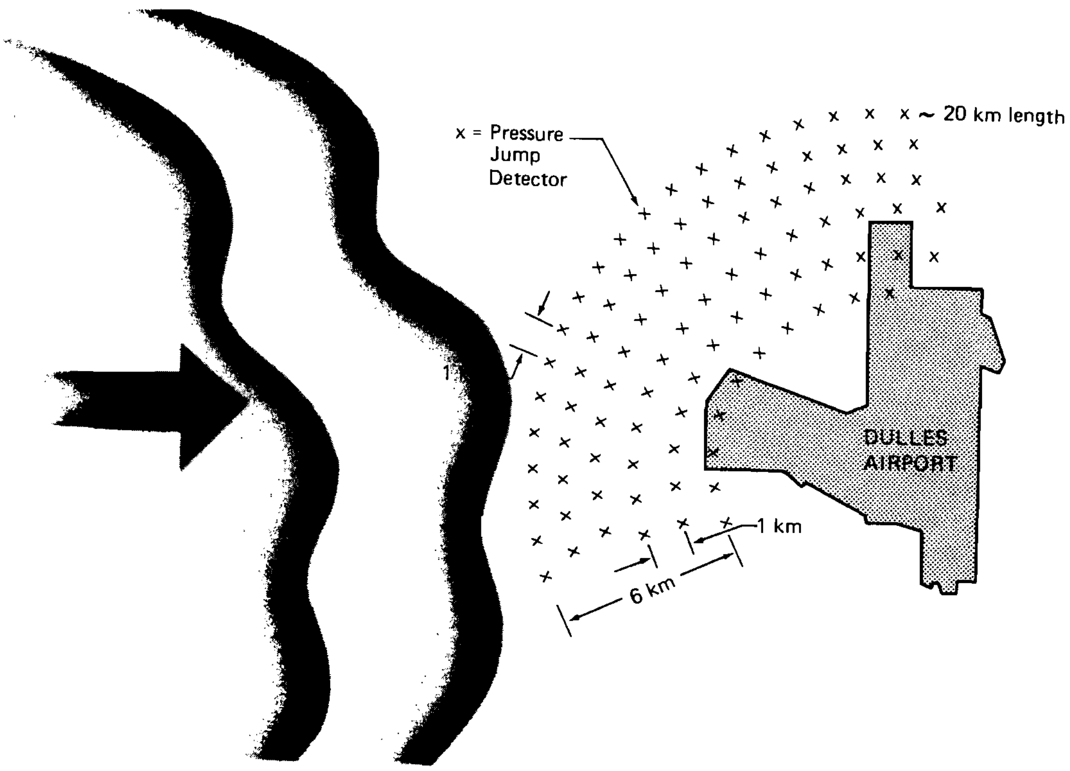

FIGURE 10. LOCATION OF PRESSURE JUMP DETECTORS AROUND DULLES

DYNAMIC LOADS - THEIR INFLUENCE ON AIRPLANE DESIGN AND SAFETY

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The development of airplanes with increased structural efficiency, defined loosely as the relationship of structural weight to takeoff weight, has brought into prominence the dynamic loads specialist. Major portions of current airplanes are designed to the strength requirements dictated by dynamic response. For example, the Lockheed L-1011 Tristar reflects dynamic loads requirements in design of the following components.

a) Fuselage forebody and aftbody
b) Vertical tail
c) Engines, including the supporting structure
d) Landing gear and supporting structure
e) Middle portion of the wing
f) Inner wing, inboard of the main gear

The calculation of dynamic loads acting on an airplane requires at least a working knowledge of most of the aeronautical engineering disciplines. The dynamicist must be conversant with aerodynamics, structures, propulsion, control system analysis and design, hydraulics, and, above all, mathematics. He interfaces with wind tunnel, flight test and ground test personnel within his own company, and with vendors and subcontractors to insure the adequacy and safety of his design.

Although the calculation of dynamic loads requires extensive use of mathematics, I'll avoid insofar as possible the use of differential equations, Laplace transforms, and other useful mathematical tools of the trade. I'll attempt to describe what dynamic loads are, how they act, and how they are reflected into airplane design.

Let's begin with a definition or two so we'll both know what I'm going to talk about. What do I mean when I use the term, "loads"? That term is a synonym for forces, the forces acting on the airplane, or parts of the airplane, in flight or on the ground. The forces are of two general types, namely the aerodynamic forces due to flow of the air over and around the various surfaces - these keep the airplane in the air - and the reacting gravity or inertia forces - these try to put the airplane back on the ground. Loads engineers deal with the distribution of these forces, their interaction and the balance between them. Results of their analyses are transmitted to design and stress engineers for conversion to drawings, and thence to the shop where the drawings are transformed to hardware.

Loads themselves are of two general classes, depending on the rate of change of the forces acting on the airplane, with a grey area between the classes. Static loads result from phenomena that act relatively slowly on the airplane, such as steady maneuvers - turning, high-g pull-outs, steady rolls, certain types of braking, and the like. Dynamic loads are produced by phenomena that act quickly on the airplane, such as wake turbulence penetration, taxiing over bumps, landing impact, rough air (turbulence), catapult launch and arrested landing. The rate of loading is obviously a relative matter. A preferred distinction between static and dynamic loads is whether or not the elastic modes of the airplane become excited due to the rate and distribution of loading. These elastic modes are readily observable when an airplane taxis over rough taxiways or lands firmly, by watching the wing tip motion. They are calculated for use in loads analyses and verified in ground and flight vibration testing.

The terms I've mentioned under the subject of dynamic loads relate generally to the entire airframe. The dynamicist is also concerned with subelements such as landing gear, brakes, anti-shimmy systems, propulsion systems, control systems, and arresting gear. He also has responsibility for fatigue loads on the airframe and landing gear. Ride comfort and crashworthiness are subjects he addresses also during the design of an airplane.

Obviously, a lifetime of engineering is required for an individual to be totally experienced in all the fields I've mentioned, such that he can exercise judgment in the evaluation of loads, or even the specification of critical loading conditions. He has criteria guides available to him in the Federal Aviation Regulations, military specifications, and other sources issued by various licensing agencies, but he is on his own with respect to the technique to be used in his analyses, subject to licensing agency approval.

The analyst is reasonably free to use all the tools at his disposal, including sophisticated mathematical modeling, wind tunnel testing, ground and flight testing. He tries to improve continuously his methods of analysis through research and education to provide the customer a safe, airworthy vehicle. The state of the art advances daily with the introduction of new theories and techniques, some proven in testing and others purely hypothetical; and the requirement for lighter weight, more efficient structures.

One subelement of the dynamicist's responsibility was specified as landing gear. Landing gear are designed to absorb or dissipate by some means the energy associated with the rate of descent during landing. Some gears use oleo shock struts, forcing oil through an orifice into an air chamber, generating heat to dissipate the energy. The dynamicists aid the gear designer in specifying the volume of oil, the volume of air into which the oil is ejected, the size of the orifice through which the oil flows, and the desired rate of closure of the strut, or the load/deflection curve of the shock strut. A metering pin may be used to vary the size of the orifice during the stroke to control further the rate of oil flow. This type of gear acts very much like an automotive shock absorber. The system consisting of tires and oleo strut is highly nonlinear, complicating the analysts job.

A second type of gear is used very successfully on Cessna light airplanes. This is a spring-steel strut that dissipates the energy by means of a scrubbing action of the tires on the runway. The dynamicist helps specify the tire footprint area and strut spring rates. You wouldn't want your airplane to have a bounce-off problem due to too stiff a spring, nor would you want the gear to be so soft as to deform excessively in landing, maybe catching the propeller or overloading the nose wheel.

It's one thing to specify on paper what the gear characteristics should be, and quite another to be certain the gear on the airplane responds as you'd like. The verification is usually found in drop tests, and occasionally in flight demonstration tests. The top of the gear mounted in a drop test tower has a fixture built in such that weight can be applied equal to the static weight on the gear on the ground. The gear assembly is then raised to a height such that a free fall will produce the desired vertical velocity at impact. The wheels are spun up to the landing speed, say 100 miles an hour or so. The assembly is then released to fall freely, impacting on a grating simulating a runway.

Forces and deflections are measured at a number of places and in different directions on the gear as a function of time, with test results compared to analysis. Some alterations are usually required to the orifice or metering pin to achieve the desired load/deflection or load/time characteristics. Revisions may also be necessary to the theoretical analysis to provide a better correlation of test and theory. The dynamic loads man, then, works very closely with the test crew to insure a match to the desired gear characteristics. His role in this instance is supportive, looking over the test crews' shoulders and making recommendations.

Sometimes a problem arises in flight testing that requires action relative to the gear characteristics. Problems may result from a peculiarity of the interaction of gear and airframe. The L-1011 showed a tendency to bounce off during low-sinking-speed landings in the early part of the flight test program. A modification was made to the gear to control the rebound tendancy.

Most modern day large aircraft use a spoiler system on upper or upper and lower wing surfaces, deploying the spoilers at some time during the landing event to kill the lift. This increases the weight on the landing gear, making the brakes more effective. Deployment of the spoilers on the L-1011 is tied to compression of the oleo strut and the position of the main gear bogie at touchdown. Our loads analysis showed that too early deployment could cause an overload of the main gear, so we required the insertion of a time delay circuit in the spoiler deployment system. This is one instance where dynamic loads interfaced with the control system designers.

Two other gear problem areas are in the dynamicists bailiwick. One is nose wheel shimmy, a stability situation sometimes rectified by locating the nose wheel with an appropriate amount of trail behind the strut, determined by shimmy tests or on the basis of experience, or by the addition of a shimmy damper to control the tendency to shimmy. Failure of the damper can result in nose gear shimmy, introducing substantial loading into the strut and airframe at rather high frequency, possibly leading to a fatigue failure of the torque arms, the strut, or the airframe.

The second gear problem is brake chatter. A chattering brake is inefficient with respect to stopping power, and introduces relatively high frequency oscillatory loads into the structure. Neither effect is desired, so brakes are designed and tested to preclude chatter. The dynamicist works very closely with the brake manufacturer to monitor the braking characteristics as they influence the gear and airframe design. This is true even for aircraft with anti-skid systems aboard, especially when considering certain types of failures.

I noted earlier that the prime function of the landing gear was to absorb the energy associated with landing impact. A second role of the gear is to provide a reasonably soft ride during taxi over the design types of runways or taxiways, whether paved, sod or dirt. Usually, the oleo shock strut type of gear is rather stiff, such that the strut deflects only slightly under normal taxi loading. The airplane taxis mostly "on the tires," with the tires serving as springs, deflecting to soften most of the bumps. Accordingly, then, the dynamicist must reflect the deflection characteristics of the tires in his taxi loads and ride quality analyses.

Taxi loads design certain part of the airframe structures, such as the wing in down loading and the fuselage forebody due to high nose gear loads. Wing flexibility plays quite a large role in taxi loads analysis, with the wing tips experiencing load factors considerably higher than the c.g. due to flexibility. As an example, some time ago I was called on to help analyze the cause of the loss of a tip-tank from a Lockheed 1049-G Constellation in Shemya, Alaska. The airplane taxied diagonally through a rather deep drainage depression. The phasing of the main gear wheels passing through the depression excited the wing in bending, producing substantial dynamic loads in the tank. These loads resulted in the tank loss.

Lockheed's proposed SST had a rather long, slender forward fuselage, extending well forward from the nose gear to the cockpit, similar, in fact, to the Concorde. The predicted acceleration (or g) response at the cockpit while taxiing over terrain of design roughness was quite large, large enough in theory to cause the flight crew to be unable to read their instruments. The main gear was being reviewed, as the source of the excitation, to improve the pilot's ride quality and to reduce forebody loads.

Not all aircraft are blessed with smoothly paved taxiways and runways for their day-to-day operations. Sod or dirt strips are not uncommon, and may, in fact, be the more usual situation in general aviation flying. I recall participating as a navigator in a light plane rally some years ago. The destination was a small dirt strip in Bouquet Canyon, some 30 miles or so north of Los Angeles. This dirt strip was rather short, a bit rocky, and really nestled into the canyon. Landings were required to be precise and well-controlled. Several Beech Bonanza's were included in the rally. Their pilots used rather firm braking due to the short runway, and as a result of the high nose gear loads and the rocky strip, a few nose wheel tires blew out and one nose gear shock strut failed. We had a few unhappy Bonanza pilots at the picnic luncheon!

Strips as rough as the Bouquet Canyon runway are quite unusual, but ones almost as rough are accommodated in design. Soft tires and more flexible oleo struts help relieve the gear loads, and proper structural design to the high dynamic taxi loads insures a safe airframe. Of course, no one can design a gear to guarantee failure-free operation when landing or taxiing in a rockpile - we engineers do need some help from pilots in their use of good judgement and from airport operators in the judicious repair of runways and taxiways.

Some military airplanes are designed to operate from unimproved landing strips, notably the Lockheed C-5A. A multitude of wheels and tires - 24 on the main landing gear - distributes the loads so that no one tire is loaded to excess. The landing gear setup on the C-5A was a loads-man's nightmare, but it meets all requirements for use on the unimproved strips.

The airplane in flight is subjected to a number of phenomena, each of which produce either static or dynamic loading. Examples are wake turbulence, atmospheric turbulence, stall buffet, pitch maneuvers, rolling maneuvers, and steady turns. The first three produce dynamic loadings since the structure is loaded relatively quickly and is excited into its vibratory modes. The latter three are treated as static loads since the loads are applied sufficiently slowly so the vibratory modes are not excited significantly. The structure deforms under both types of loading, the nature of the deformation differentiating between static and dynamic loads.

The calculation of the airplane's response to atmospheric turbulence is an art that requires considerable time and effort on the part of the dynamicist. The gust loads criterion has evolved through the years to one currently requiring an enormous amount of analysis. Airplanes of the DC-3, DC-4 and Constellation vintage were designed to a criterion which ascribed a single particular shape to the gust. Design of later versions of the Constellation and its contemporaries required the use of the same general shape of gust, but tuned to maximize the dynamic response of the airplane. (This criterion is still required by the British CAA in certifying an airplane in the United Kingdom.) Current transport airplanes must meet the criterion that the effects of continuous turbulence be taken into account in their design. Hence the application of statistical methods in determining the gust loads, the most convenient way to accommodate the random nature of continuous turbulence.

Briefly stated, the new FAA criterion requires that a more realistic view of turbulence be taken and incorporated into design. Most experienced pilots recognize that rough air is more or less continuous, at least during flight through patches of some significant duration. Seldom does a single discrete bump occur, except, perhaps, as a part of the continuous choppiness. This is not imply that discrete bumps don't exist, but rather to indicate that their presence is accommodated as a part of the statistical data used in design, the statistical description of the atmosphere.

The calculation of dynamic gust loads is the pacing item in a design loads cycle due to the amount of effort involved. (A design loads cycle begins with the gathering of basic airplane data for use in design -- geometry, cruise speeds, payloads, design weights -- and ends with the release of loads to the Stress organization.) The gust loads are determined on a statistical basis, using techniques developed for and approved by the FAA. These statistical loads are then transformed to unique loading conditions for use by the stress engineers.

Approximately 140 gust loading conditions were specified for the basic L-1011. This rather large number has been reduced substantially for subsequent derivative versions, based on experience in determining gust-critical regions of the airplane. About 40 conditions were issued in our most recent analysis of a longer range version of the L-1011, most of these associated with the vertical tail and aft fuselage. The rest of the airplane was not ignored, but other dynamic or static loading conditions proved to be more critical.

The vertical tail of an airplane is often designed by lateral or side gusts. These side gusts excite a rigid body motion known as Dutch roll, a combination of rolling and yawing motion. This mode is frequently very lightly damped in swept-wing airplanes, and may even be unstable although controllable in certain flight conditions. Accordingly, due to side gusts, the motion of the airplane can increase in amplitude with an attendant increase in vertical tail loads. The frequency of this motion is usually low enough so that the pilot can control the motion, even without augmented control system damping.

The L-1011 and other swept-wing transports incorporate an element of the automatic control system which senses yaw rate and commands a rudder angle to oppose the motion, serving as a yaw damper. This damper also is effective as a gust loads alleviation device, reducing the vertical tail loads by about a third of the undamped values. Multiple systems are used to insure the operation of the damper and at least one of the systems must be working prior to dispatch of the airplane.

The dynamic loads engineers participated in the development of the yaw damper due to the influence of the damper on vertical tail load. The control system personnel provided us with the characteristics of the yaw damper, and after several iterations agreement was reached on its proper design.

The yaw damper performance was considered over the complete range of flight conditions, and turbulence severity levels, including those at which the control system was saturated - more rudder was needed than was available. Fortunately, this latter situation can be readily accommodated in the airplane by appropriate compromise between the system authority limits and the design gust loads.

In the interest of safety, possible modes of failure of the yaw damper system were analyzed to insure that the induced loads did not exceed the design levels. Design loads were adjusted wherever the need was noted.

The dynamicist becomes involved with the automatic control system design in another somewhat indirect manner. Any control system is subject to failures of one type or another, ranging from a failure which produces a static control surface deflection to oscillatory failures at predictable frequencies. The dynamicist analyzes the response of the airplane to these oscillatory failures and compares the resulting loads to the design level of loads.

In the event that the calculated loads exceed the design level, two courses of action are available, namely change the structure to take the loads, or revise the control system to preclude the failure or reduce its effect. The effect can often be reduced by altering the frequency of oscillation, tuning the system away from structural resonance, or by restricting the commanded control surface deflection. Both of these procedures may require some modification to the automatic control system, and probably an iterative effort on the part of the control system designers and the dynamicist to minimize the changes while insuring the safety of the vehicle. This modification is normally far less costly in terms of time and structural weight than modifying the structure.

Buffet, including that due to stall, is another phenomenon that the dynamicist investigates. This is usually the result of turbulent flow or downwash from the stalling wings impacting on the horizontal and vertical tails. The pilot feels it as a stick shake and a general shaking of the airplane. Buffet works as an effective stall warning device, but can introduce rather substantial loads on the tail, reflecting also into the aft fuselage.

Landing loads must also be considered in structural design. Surprisingly, landing loads are not generally critical on the wing because the large down inertia loads are relieved by the up air loads. The forward and aft fuselage are normally designed by landing loads. The forebody responds rather like the tip end of a fishing rod -- it gets a substantial whipping motion at impact, so the vibratory inertia loads dominate. The aft fuselage loads are produced by the big down tail load, required to balance the flaps-extended pitching moment, in combination with the vibratory inertia loads at impact.

The L-1011 contains an automatic landing system as a part of its overall automatic control system. Dynamic loads contributed to the development of this system by specifying the limits on rolled attitude, crab angle, and pitch angle that the system should not exceed. These limits were based on the strength of the landing gear and its supporting structure, and are so unrestrictive that they have yet to be approached, no less reached, in our total current service. In fact, the autoland system as design worked so well in flight test demonstrations that the oleo shock struts failed to compress enough to trigger the spoiler deployment until the airplane was well down the runway. Landings at 1/2 foot per second were common in the early test program for the autoland system. The system has been modified since such that one to two foot per second landings are common.

I also noted earlier the involvement with the automatic control system, specifically in the development of the yaw damper and automatic landing system. A research program is currently underway to use the control system for loads alleviation purposes, both static loads due to maneuver and dynamic gust loads. On a theoretical basis, loads relief in the critical conditions of about 25 percent has been achieved, where load relief may be related to structural weight saving. Airlines are interested in this concept simply because a structural weight saving implies increased payload capability - money in their pocket. We expect to enter a flight test phase of this program in early 1977. This flight test phase will be lengthy as we proceed slowly with extensive planning and analysis to insure the safety of the airplane. Additional advantages in performance and airframe capability may accrue from this research program.

Another research program in which we in dynamic loads are involved is an investigation into crashworthiness and survivability of general aviation vehicles. We are developing mathematical models of light airplanes and subjecting them to crash conditions using a sophisticated computer analysis. The analysis was verified by comparing a full scale helicopter crash test with analytical results, showing rather remarkable agreement. The rigid body motions were duplicated as well as the local deformations, including the penetration of failed structure into the passenger cabin. We are working under FAA contract in conjunction with Cessna for the good of the flying public. Since the research is incomplete I cannot report definitive results, only indicate our prior success. The FAA and the CAA, Britain's counterpart, require crashworthy design. For example we conducted failure analyses of the L-1011, landing at reduced sinking speeds with all combinations of deranged landing gear - all wheels up, one wheel up, two up, etc. We substantiated analytically the safety of the L-1011 underfloor lounge for one of our customers. Some minor structural modifications were required to insure passenger protection from a highly unlikely mode of failure. We were the first to complete this substantiation for the wide body jets, primarily since we were the first with a below floor lounge.

I mentioned in passing catapult takeoffs and arrested landings. These are very severe dynamic conditions, critical for most of the airframe, as you may well imagine. I recall witnessing arrestment tests of a Lockheed T2-V, and early jet trainer proposed for the Navy, in which the tip tanks actually contacted the ground in a combination of bending and twisting motion. The wing motion was violent, but the wing stayed in one piece -- a good illustration of design with deflection in mind.

The only military-oriented dynamic loading conditions I've mentioned are the catapult launches and arrested landings. Although these are extremely severe conditions, designing most of the structure of Navy airplanes, other types of military-peculiar loadings are considered. These include release of various wing-mounted stores such as bombs or rockets, and machine gun firing. These conditions seldom induce design levels of loading, unless taken in combination with some maneuver load, a not unlikely situation.

MANAGEMENT OF THE INVESTIGATION

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Management of the Investigation in my opinion embraces the entire processes of conducting the investigation. This will constitute on the one hand correct grouping of Investigators into workable teams and on the other logical sectionalisation of data inputs, depending on the scale and scope of the investigation, not forgetting that the orderly collection, consideration, and in some cases, discussion of these data will lead to an early determination of the cause of the accident.

Like the aircraft designers who daily inject new systems and concepts into the machine, so should the investigators ply for new techniques in order to arrest all such novelties within the investigative processes during accidents. The machines today are wholly automated, so that solving an accident no longer demands just the routine examination of Flight Path, Weather, the Aircraft, meticulous interrogation of witnesses, survived crew members, connected Aviation Personnel, Engineers, etc., but equally so, the results of Experts' investigation of component parts, units and structural sections of the aircraft, coupled with readouts of Black Boxes, Cockpit Voice and other Recorders. In short the Investigation Team now has a collection of pertinent data, some not as readily available as others, but all available to be collated and analysed for Probable, Most Probable and Cause of the accident.

I venture to mention what could be called a Management Circle (See Attached Diagram). Because Management of the Investigation should be a continuous chaim process, the outer circle has been made to comprise segments of data inputs, fed into the middle circle forming groups of the Investigation Team, which finally feed the Nucleus of the circle, the Deciding Factor Group, in which the determination of the cause of the accident is accomplished.

Sectionalising the segmental inputs is not half as difficult as grouping the Investigators, since the obvious groups cannot be made purely distinctive with relation to the input segments. It will be noted that in the main, the Human Factors Group will handle data from Segements B, C, and part of A. The Machine and Systems Group is to handle inputs from Segment C and the rest of Segment A. The Experimental Data and Units and Equipment Groups have more or less defined segmental inputs. Yet, defined as these are, it takes the same if not longer periods to obtain the inputs.

Considering in sequence the seven Segmental Inputs, we have "A" Aircraft Data. Here, both manufacturers and operators have the sacred task to be unbiased, honest, unreserved and thorough. Of course, the Machine and Systems Group which in the main has to handle this side of things should at best be comprised of, among others, Engineers and Pilots, who can go through aspects like performances and other records with a fine-toothed comb. In this regard, the Licensing Authority in the State of Registry will also have some role to play by way of verification of aircraft Certificates, Licences, Signatures and attestation of positions regarding mandatory and other modifications, Service Bulletins, etc. Performance records should be verified by the Operator's crew as well as the manufacturer's Expert, the latter could even be co-opted in the Group if the cause of the accident points to that segment.

This Group should therefore comprise an Aeronautical Engineer, an experienced

Airline Transport Pilot, a Manufacturer's Representative who could preferably be a Systems Expert or an experienced designer who knows that particular aircraft, a competent Aviation Personnel from the State of Registry and the Operator's (Airline) Representative.

If, for example, the accident is suspected to be caused by a particular inspection or mandatory modification not being done, the Group should trace back all along the maintenance line, the procedure and actual mode and method of repair work usually carried out by the contracted Repairing Organization. Their system of inspection after any such modification should be examined. Most importantly also, the method by which the Operator (Airline) keeps itself informed of all pertinent inspections, modifications and airworthiness directives for their fleet generally should be examined. The aim of these exercises will be to find the missing link so as to avoid a recurrence with any of their remaining aircraft, or to save another Operator falling a victim to similar circumstances. Here I take pride to mention an accident to a Bell 47G 4A Helicopter 9L-LAO, the first one that occurred in my country, Sierra Leone, on 8th July, 1974. I had the privilege to investigate that accident. The helicopter lost engine power due to con rod failure and crash-landed in a bad terrain area. The reason was simply that an Airworthiness Directive did not reach the Operator. Fortunately, the two persons on-board received no injuries. But, the craft was substantially damaged.

The Human Factors Group which also has a minor role in this segment should normally comprise Aviation Medicine Doctors, Psychiatrists, an Experienced Investigator and an Aviator. Their own role will be to determine the sincerety in the approach to and handling of the various contributions by the Operator's Crews and the Manufacturer's Representatives especially, since these are subject who may tend to be discreet or reserved for obvious reasons. This Group will aim at assuring the Machine and Systems Group that their man-derived inputs are genuine to the best of their determination.

In Segment "B", Crew Data, to be handled by the Human Factors Group, the composition of which has already been mentioned, the inputs are numerous and should be handled most meticulously. The Aviator and Experienced Investigator should handle the Crews' Licences and Experiences, the Aviation Medicine Doctor and Psychiatrist can take care of the Medical Records, Duty and Rest, Periods, and other connected psychological considerations. Attempts should be made where Pilot error is suspected, to determine things like activities at the last port of call, last diet and its likely effects on any recent reported or mentioned ailments.

The state of mind of the Pilot and Co-pilot before take-off, any observed change in behavioural patterns among other crew members should be investigated. When the human mind is full or troubled, much as he may try to suppress or contain his moods, he sooner or later gives vent to these feelings (repressions) by one or other outbursts which may show itself either verbally or by some unusual actions. In this connection, I would refer to the Trident Accident near Staines, United Kingdom in June, 1972, when all including the crew suffered fatal injuries, and the Boeing 747 incident near Nairobi Airport in September, 1974, which could have ended in a similar catastrophe. In the former the effects of an undetected Pilot ailment which resulted in incapacitation, and the troubled, obsessed or unsettled mind were highlighted in Chapter IV Section B (Medical). In the latter, the effect of crew fatigue among other circumstances was evident - the section headed "Environmental Factors Affecting the Crew". All these findings are within the investigative techniques of both the Psychiatrist and Aviation Medicine Doctor. As for non-adherence to correct Duty and Rest periods, simple and well established tests and questions can soon bring out, that fatigue residue of crews. In this segment, it is most important to acquire enough data to be able to rule out completely, or suspect with evidence, Flight Crew error.

In Segment "C", another fully Human Factors Group input segment, except for the weather element, the Group will again be dealing with mainly man-evolved facts. Air Traffic Controllers are trained Aviation Personnel and their evidence can be most reliable especially where recordings may exist of actual conversations between Pilot or Co-pilot and the Duty Controller before the crash, when applicable. Even in cases where only their observations are necessary; those too can be reliable. It will be fitting to mention here that if the blameworthiness is pointing in the area of Air Traffic Control, it would be desirable to co-opt an Experienced Air Traffic Control Officer in this Group. In cases where a controller might have inadvertently given the wrong clearance, advice or information, he would be aware after the crash that the finger of suspicion is pointing at him and may naturally try to be evasive. The experienced aforementioned expertise in that Group should be able to detect that typical nervousness, inconsistency in answers, and general agitative attitude. In the same way, other Aviation Personnel like the loader, the fire and rescue crew, the panic air hostess or the other selfish cabin crew who at the first sign of danger forgets completely about the passengers and places him or herself safely near an Emergency Exit, should be questioned in every detail. Cases have been known where Fire Crew placed their vehicle at the wrong position, tried to axe through the wrong section of the fuselage, etc. There have also been cases when cabin crew did not execute emergency procedures either correctly or at the right time. All these inaccuracies usually result in fatalities. In any case, these Aviation Personnel can be most helpful with the investigation, or most difficult to handle. Because, they know how to be helpfully involved or cleaverly evasive, especially when they are aware that the cause of the crash may be in their area of responsibility. A trained and experienced Human Factors Group should be able to spot red herrings or direct helpful answers.

The layman's evidence is nearly always not easy to record or unravel for the meaning he or she wants to convey. It must be realized that such evidence are flavoured with excitement. Accounts of heights and attitudes of aircraft are invariably grossly exaggerated. Descriptions of sounds of engines, crashes, etc. are seldom accurate. Also whilst the majority are anxious to swear to the authenticity of such evidence, the Group should know that many are most unreliable and can merely lead them away from the facts. In spite of this, on no account should the Group make is obvious to any volunteer of evidence, that he or she is exaggerating or talking nonsense, if such be the case. The Group may be looking for just that one relevant fact to confirm or complete a pattern which it could have derived from others, whilst the rest of that particular evidence may be completely misleading or irrelevant. Given the right type of questions, the desired answers could be obtained. Many International Aircraft Accident Investigating Organizations have Format of Questionnaires which are handed out to volunteer witnesses. This system saves time and effort, but in my opinion is not completely satisfactory. The good investigator must interview the few witnesses whose evidence he thinks reliable, for general assessment as to their sanity, consistency, general intelligence and unconnectedness with any of the involved parties in the accident. In these days when litigations most times defeat our main objective, it pays to avoid this and other such pitfalls.

I deliberately put Weather under the Human Factors Group, because in spite of the weather radars and other scientific gadgets employed to detect weather these days, the human being in nearly all cases have to interpret the indications of these gadgets on a weather map to mean anything to the Navigator, Co-pilot or Pilot. We also know that this weather element is very changeable. In many regions the half hourly TAFs. have been found inadequate. It thus seems that we ought to be aware that gadgetry without the expertise in this field can give no satisfaction. So that when reliance has to be put on the weather, the best equipment and the most experienced Meteorologist will have to rely in some measure on graphs and "weather patterns"; somehow there are no patterns anymore, since an expected pattern is never what is experienced in the area at the particular time of year. However, it is important to note here that when weather is significant in an accident, it is most desirable to get the most accurate weather for that area at the time of the accident.

Military airplanes are also required to withstand dynamic landing, gust, and taxi loads similar to those to which commercial transports are designed. The licensing agencies or customers may be different, but the loading conditions and methods of analysis are virtually the same.

In conclusion, then, a review has been presented of dynamic loading conditions and how they influence the design of today's airplanes. An indication was also given of how safety considerations are incorporated into the design. The presentation has been quite general, intended to provide the non-technical investigator some insight into aircraft design criteria and philosophy.

Moving now to Segment "D", Equipment and Electronic Systems Data, please note that the Systems is not the Systems as is understood in the Machines and Systems Group. This is Electronic Systems Group which as the drawing shows is to be handled by a Units and Equipment Group. To begin with, this Group should comprise of at least an Electronics Engineer, a Physicist, a Pilot, a Black Box Readout Expert and a Service Engineer. Inputs from this segment should include readings from checks on Auto Pilot and Corresponding Group Equipment. Where this is significant to the accident, checks should be made on control signals from the various computers, whether they are of the required magnitude. Actual measurement should be taken off control surface movements on specific signal inputs, whether these conform to designers specifications. In conjunction with such movements, observance should be made on available display panels in cockpit, whether these panels in fact register in the correct sense the exact movements of control surfaces. A voltage drop at the crucial instant due to regulator becoming faulty or a lightening storm could give severe deviations from normal in control surfaces' movements, resulting in a crash. All these and other such likelihoods should be checked in detail. Auto pilots are reliable only within certain tolerances. When the cause of the accident points to this area, all the output parameters from the Automatic Pilot should be verified. If doubts still occur, the same flight conditions should either be simulated or where possible experimented in, before making the final conclusions. This fact of simulating the same flight conditions or conducting equivalent experimentation was born out by the BEA Ambassador (Elizabethan) aircraft G-ALZU accident at Munich Riem Airport in February, 1958. A total of 21 plus 2 souls died in that accident. The German Federal Office of Aviation conducted and concluded a Commission of Inquiry in March, 1960. Over four years afterwards in July, 1964, the United Kingdom Ministry of Aviation put forward the results of experimentation on Slush Drag Tests on the Ambassador Aircraft, carried out by the Royal Aircraft Establishment at Farnborough which caused a re-opening of the Inquiry. (Quite apart from ice accretion which destroys lift, slush on runway has some decelerating effect on aircraft).

Having carefully gone through the records of all flight instruments, they should then be individually checked against tested and certified one. Anomalies like sticky needles or indicators, strained movements, defective pneumatic, hydraulic and electrical supply lines should all be explored in every detail. A faulty in-flight instrument is worse than no instrument at all. Faulty instruments have been known to cause pilots taking the wrong decisions which normally result in crashes.

Moving on to Segment "E - Readouts Data". This is the job for the experts. It will be noted that the Units and Equipment Group should handle both this and the previous segment "D". As already stated, a Black Box Readout Expert should be in this Group. Usually the Black Box or Boxes, if retrieved, will be taken in by the Expert to a specially equipped laboratory where the readout exercises are carried out. This is a tedious task, but these experts are usually dedicated to the task and would spend long pains-taking hours going through each parametric readout for any and all deviations from normal. Parameters of control surfaces are also recorded, and since the same Group handles both segments, there is the obvious advantage of cross checking most of the findings making up inputs for D and E by means of these readouts. Black Boxes in themselves are not easy to handle, but in the main they quickly pinpoint the abnormal manoeuvre or control response patterns. To the Investigation Team, a Black Box these days is a necessary tool. Phenomena like fierce cross wind components and wake turbulences which can quite easily deviate a fully loaded transport aircraft beyond its computer tolerances on finals without leaving any evidence for the Investigation Team, are easily picked up normally by the Black Box thereby saving lengthy discussions on Probable Causes.

Another important factor which will come out in this segment is Pilot and Co-pilot responses to given flight conditions. It would seem here that the Human Factors Group should have a role to play. However, since these responses are instigated by flight conditions which are also recorded by the Black Boxes, if a wrong Pilot or Co-pilot's response is brought out by the Black Box readout, or even for any other crew member, it cannot really be challenged. The Human Factors Group can then be employed to determine why the wrong manoeuvre was executed by that Pilot or Co-pilot. Indeed, when such situations are present, the Human Factors Group must have had an indicative input as to the unsettled mind or behaviour of either the pilot or co-pilot from Segment B or D, so that with the Black Box readout data, it will not merely serve to confirm that indication but will offer them, i.e., the "Human Factors Group" the opportunity to explore that condition to finality.

Playback of Cockpit Voice and other recorders is most helpful when the accident cause is in the area of Cockpit and Cabin Crew Error. Conversations between Pilot, Co-pilot, Air Traffic Control, Cabin Crews, etc., are all vital to the Investigating Team. The point at which the system breaks down can be easily determined. Cabin Crews' instructions at the crucial instant will be obtained; ATC advice, Pilot's emergency calls, instruction given to Co-pilot, last minute cockpit conversations will all be available. With something like the last instruction to the Co-pilot, the Black Box readout will indicate whether the Co-pilot responded and if he did, whether he responded correctly, etc. Similarly an ATC advice or information can be checked against what the Pilot actually did, or how the aircraft responded to some particular control by the pilot. This and many other similar functions can be obtained as inputs from this segment into the Units and Equipment bank.

Segment F, Experimental Results. This is a unique segment, in that it is the only one with its own Group, the Experimental Data Group. This is the Group which must comprise a Mettalurgist, Physicist, Engineer, Mechinist, and Chemical Engineer. In this segment, where Metal Fatigue, Corrosion, Stress Concentration, Material Unsuitability, Deficiency in Material Constituents, Uneven Spread of Constituents, Non-Uniformity of Quality due maybe to improper treatment, Coatings and Electrolytic Actions, Finishes, etc. can be of importance, such a group composition can handle these aspects quite satisfactorily. Examinations involving Non-destructive testing, Ultrasonics, X-rays, Grain analyses and Structure probing, Shock loadings, etc. can be accomplished without strain.

This Group will be able to determine whether the suspected structure failed before the crash or not, as well as the position of the on-setting corrosion, and the cause, if that is the case. Similarly, the Group can determine the load likely to have caused the break, and will be able to suggest a few remedies. If a weak structure is suspected, not only can the Group determine the weakness of the structure, but such a Group will be able to give the reasons why that structure is classified as weak, and if it should be strengthened, the magnitudes of expansion, compression and torsional stresses and strains to be considered. Also, between this Group and the Machine and Systems Group, having located and indentified structures in the area of Wreckage Distribution, suspected structures can be further investigated with a view to recommending to designers, the need for strengthening items like seat structures, seat belts, repositioning of seats, redesigning or modifying of back rest structures, seat materials, relocation of Exit Doors, strengthening of Spars, etc.

The final Segment "G" is one to be handled by the Machine and Systems Group, the composition of which has already been mentioned. The first item in the segment is Wreckage Distribution. Whenever possible the area of wreckage distribution in an air crash must be demarcated and guarded. Vital evidence can be lost or interferred with by rescuers or intruders. Each item should be marked, its position pegged before its removal from the area. Where possible the profile of how the item appeared in situ, touched the ground, or was hanging on a tree should be recorded by photography or drawing before that item is removed. If and when it becomes necessary to reconstruct the wreckage or final flight path, these little details will be most helpful in conjunction with other factors. Knowing the direction of flight and considering the wreckage distribution could give some idea about the wind in the area at that time. On the other hand, having the correct weather for the area at the time, and considering the distribution of the wreckage, even where the main structure of the aircraft is badly burnt, could determine whether or not an explosion occurred inside the aircraft before the crash. In other cases, examination of the main wreckage will soon indicate things like Cabin Decompression, etc.

In the main, examination of wreckage is usually most revealing. Again, the Human Factors Group has some contribution to make in this area since there are bound to be bodies among the wreckage. The Aviation Medicine Doctors (Pathologists) can derive many facts from observations and tests on bodies. Positions of bodies can tell a lot; coupled with the tests, these aviation pathologists can really captivate the show. They can quite easily reveal from the bodies evidence of bomb explosion, the composition of the particular explosives, the approximate area where such a bomb could have been planted in the aircraft and also the approximate time of explosion. As a matter of fact, when these pathologists fail to detect will be picked up by the Experimental Data Group from material wreckage analyses. This brings to mind the report of the Comet Series 4B G-ARCO accident which occurred in the Medditterranean near Rhodes on 12th October, 1967. Sections 1.15 Tests and research, 1.16 Consideration of salvage and 1.17 Medical aspects, bring out these facts quite conclusively. That was a long drawn-out investigation due to exploration of the possibility of salvaging bodies and debri from the sea depths. But the team was able to confirm that explosion took place on-board by April, 1968.

The next item in this segment is the Pre and Post Crash Fire consideration. An aircraft in flight can be compared to a bomb ready to be detonated. What with the large quantity of fuel, its speed, the main body being of metallic structure, it only needs an impact with or to rub against another metal or really hard surface for a spark to occur resulting in an explosion. This is really not thinking of the engines or the electrics, other active heat and fire sources. All these tend to indicate that a crashed airliner will nearly always end up in a blaze. The Group's concern under this item is to ascertain that as far as possible, all available measures were employed to either prevent the fire or put it out, whichever should have been applicable. With pre-crash fire, an engine could have started the fire, or a faulty sustem, or electrical short circuit. Did the pilot get the warning signal in the case of an engine? Did the pilot trigger the extinguisher button? In the other cases, was an alarm raised? What were the Captain's instructions (Recorder)? Did the cabin crew attend properly? Did the extinguishers fail? If so, Why? The answers to these and many other such questions should be unearthed.

The last heading in this segment is Flight Path and Wreckage Re-construction. In some cases when certain facts have to be confirmed, there is the need to either reconstruct that final Flight Path, the Wreckage or both. Reconstruction of the wreckage is a quick method of determining whether part or parts of the aircraft failed before the crash. This can also bring to light things like faulty hydraulic or pneumatic lines before the crash. In this latter case, an instrument could have been non-functional or mal-functioning before take-off without the notice of the pilot or co-pilot and so caused the crash. Control levers or cable pulleys could not have been properly locked or assembled correctly after a last major overhaul, etc. Some object, e.g., a large bird could have struck the aircraft in flight, without the notice of positive knowledge of the pilot. There will definitely be a dent at the place of impact. Depending on the attitude of the aircraft and the forces involved such an impact could cause instability or affect the lift. The Pilot would know that something has gone wrong but could not pinpoint the cause, as a result, a crash would occur. These are only a few of the suspicions which can be confirmed by the wreckage reconstruction, if necessary. The Turkish Airlines DC-10 accident in Ermenenville Forest, France in Marchm 1974, brought out a fact of not securely latching the Aft Cargo Door. This fact coupled with cabin pressurization and varying altitudes resulted in failure of two bolts, causing one of the worst air disasters in the history of the flying machine. All 12 crew and 334 passengers suffered fatal injuries.

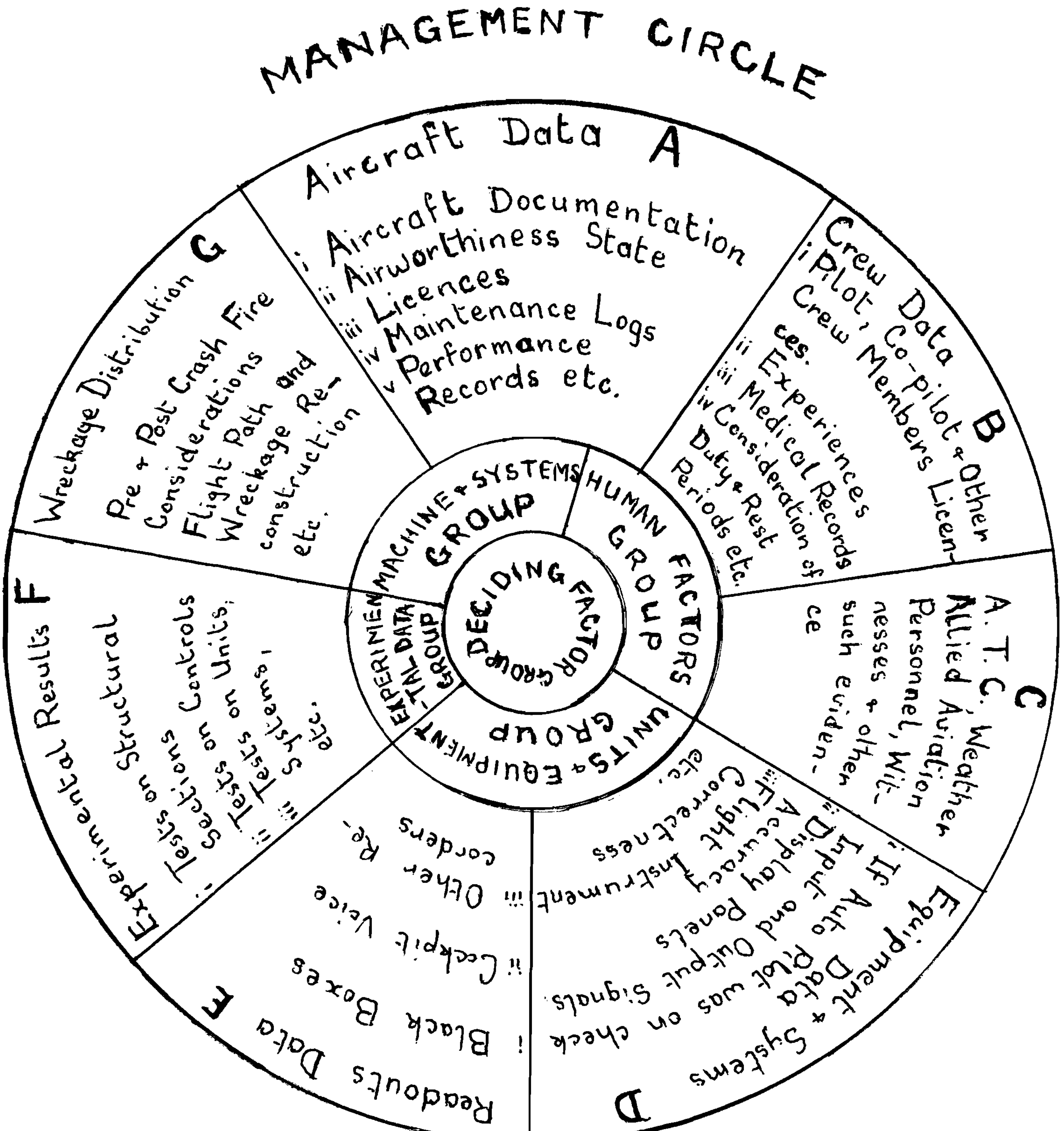
Reconstruction of the final Flight Path is nearly always desirable when the crash occurs in bad terrain area. The exact attitude of the aircraft on impact with the hill or mountain is required. This can then be compared with the instruments' recordings and the Black Box readouts. Against these can also be checked the recordings of the pilot's last declared position and heading, also the declared weather for that region. Having ascertained these, the (hows and whys) can be explored in more detail. Did an engine fail at a time when the Pilot needed maximum power to climb? How did he get the aircraft trapped in that area? Did the weather force him to that area? Those are all questions that could then be answered more fully.

The Four Groups of the Investigation Team having agreed upon when necessary, the collected huge bank of data, can individually feed their findings to the Deciding Factor Group. It should be pointed out that some of these groups may not have much to investigate, once liability has been conclusively ruled out of their segment or segments of responsibility. So the Deciding Factor Group will now be in possession of tangible facts for logical discussions. This Group should comprise the Chief Accident Investigator, an Experienced Test Pilot, an Experienced Aviation Medicine Doctor, an Engineer and if possible a State Lawyer. With the tailored facts, these experts will spend very little time deciding on the Probable, Most Probable, or Cause of the Accident. With the set-up here expounded, such a group will nearly always come up with the Exact cause or causes of the accident

To round up, I wish to state that this concept of a Management Circle is borne from the fact that an aircraft accident investigation should follow a chain pattern. Unless the Investigative circle closes, facts will remain uncovered. Such facts may well have a bearing on the subject accident. It is better to uncover the facts and rule them out than have a situation where it is not possible to bring out all the facts.

It will be noted that the Management Circle has in fact enveloped distinctive segmentations forming areas of responsibilities for the defined Groups of the Accident Investigation Team. There are instances of interrelated responsibilities, especially in areas involving Human Factors. The Human Factor involvement in Aircraft Accident and the Investigation for that matter is somehow limitless. The Aircraft is a man-made, and as at present, a man-operated machine. Take off the human involvement and it will be incomplete. So no matter how well the responsibilities are distributed, there is bound to be some overlapping of responsibilities. For this reason, when a cause is determined common among two or more Groups, cross-checking of data should be encouraged and a common decision taken before facts are fed to the Deciding Factors Group.

The write-up on this paper may not be the best method of managing an Aircraft Accident Investigation. But, it does contain quite a sizeable proportion of occurrences and circumstances within an aircraft accident investigative cycle. If adopted, findings will be full proof, accurate, unbiased and certainly unchallenged.



THE DIAGRAM

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INVESTIGATIVE OUNTERPRESSURES

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The goal of publicly supported aircraft accident investigation is to reduce the probability of recurrence of accidents. Furthermore, during the course of the investigation, facts may be surfaced which may not be related to the accident under investigation but which may prevent losses from other causes.

The fixing of blame for an accident is not a SASI objective, nor that of the National Transportation Safety Board (NTSB) nor of investigating bodies of many other nations. Nevertheless, the fear of blame inhibits an easy flow of pertinent information to the investigators. In the United States, at least, the economic, social and legal systems pose punitive threats that endanger the future of accident investigations. These threats induce understandable defensive and non-involvement attitudes by participants in the investigation who may have a vested interest in the outcome.

These punitive threats assume a variety of forms. Economic threats were the earliest and most obvious. They resulted from litigation stemming from product liability and negligence cases. Exposure to loss of livelihood by suspension or revocation of certificates and possible loss of business by the manufacturer of the aircraft or by the operator also inhibit the free flow of information. These and other restraints will be discussed in more detail later.

The vested interest is not limited to industry. It includes government organizations, unions and institutions which fear unfavorable repercussions. Their reputations, their interrelated activities, their support may be at risk.

The complex interdisciplinary and technical nature of aviation is such that it is extremely difficult from a practical standpoint to conduct an investigation without the participation of vested interests. However, years ago the overriding challenges posed by aviation safety induced most participants to volunteer information, although it might be self-damning, for the good of the industry. Even when adversary concepts crept into accident investigations, the self-protective attitudes of participants did not prevent the investigators from developing the truth. The record over the years has been exceptional.

The opinions expressed in this paper are those of the author and do not necessarily represent those of the University of Southern California.

Unfortunately, the adverse climate is expanding and becoming more intense. In addition to the threats I have mentioned, i.e., those concerning product liability, negligence, suspension or revocation of certificates, and loss of business, industry must now also face the menace of criminal prosecution of top executives for perhaps inadvertent oversights. This may also apply to line personnel. Additionally, the threat of imprisonment of airmen for human error is now a likely possibility, perhaps more so in dictatorships than in democracies. Accompanying these impediments to acquiescent response by witnesses in accident investigations are threats to national prestige, antagonistic attitudes between nations, adverse publicity, and loss of one's status among his peers. In the United States two other threats may become significant: the Freedom of Information Act and the proposed "Sunshine" Act. The first makes it difficult if not impossible to maintain proprietary information in confidence. I believe this became evident when the CAB was compelled to reveal the code of names used in the study of "Design Induced Pilot Errors". The "Sunshine" Act will expose all deliberative conferences to public gaze. This would include presently closed discussions on "probable cause" by the NTSB. In a sense this is akin to exposing the private deliberations of a jury to the public.

Public interest organizations also may create a climate of apprehension because of their possible pronouncements.

Insurance underwriters are not famous for their charitable views.

I am not proposing that these pressures are good or bad for society. I do wish to emphasize that they can interfere seriously with the investigation of accidents.

With all these uncomfortable pressures it is entirely natural and predictable that participants in accident investigation will be impelled to protect themselves, their colleagues, and their organizations, whether they be industrial, government, unions or others.

The following excerpt from a lecture on "Methodology and Patterns of Research in Aircraft Accidents" is pertinent here:

> " Through a process of elimination or synthesis of evidence in an atmosphere where each party attempts to protect itself from implications of its own deficiencies, the truth concerning the immediate cause of the accident floats to the surface in most cases, one might say almost by indirection. Extraordinary competence of the patient and thorough investigators is, therefore, required to follow the path that leads to 'probable cause'.
>
> " Intangible factors exist which are difficult, if not impossible, to put in the form of evidence. The personal worries, outside interests, working environment, management pressures on pilots, mechanics, dispatchers, air traffic controllers, can seldom be proven by public evidence as a cause of an accident.

"   Human factors such as these are more likely to be uncovered in a "privileged" form of investigation than in the open type of investigation now conducted.

"   The probable cause must be based strictly on proven evidence. Significant human factors, which may be pertinent but unproven, are therefore omitted in the probable cause."

(J. Lederer: Annals of the New York Academy of Sciences,1963)

Self-protection is a natural trait except among the most dedicated or where the facts can be yielded without harmful repercussions. An extreme example of dedication was the airline pilot, many years ago, who freely confessed to making a bad landing approach which resulted in the death of a child. He committed suicide a few days later. There was also the case of a mechanic harassed by intense personal problems and loss of sleep. He freely admitted that his negligence resulted in the crash of an air transport. (Perhaps his supervisor could have been faulted for not recognizing the problem - - management at and above the level of supervisor may become more vulnerable than they have been in the past as factors in the probable cause or underlying cause.)

But confessions are rarely volunteered. In a statement issued in 1962, General E. R. Quesada, 1st Administrator of the Federal Aviation Agency, asserted that "the very nature of the proceedings employed to inquire into the cause of an air accident is such as to make it inevitable that interested parties will engage in adversary efforts to shift blame rather than give objective assistance in tracking down the cause and cure".

The military services have long recognized the safety benefits of a procedure which enables participants in an accident willingly to discuss what happened without unfavorable repercussions. U. S. Air Force Regulation 127--4 requires that no member of the Accident Board has a personal interest in the investigation and that each one is able to act impartially (Par 10-c (2)), but also that:

(1) These reports and their attachments will not be used as evidence for disciplinary action; as evidence in determining the misconduct or line-of-duty status of any personnel; as evidence before flying avaluation boards; as evidence to determine pecuniary liability; or, except as stated in (3) below, as evidence to determine liability in claims against the US Government.

(2) These reports and their attachments are not released to the Department of Justice, any US Attorney, or any other person for litigation purposes in any legal proceeding, civil or criminal, except as stated in (3) below. These prohibitions include any action by or against the US. These reports and their attachments are used solely within the US Air Force and are not appended to nor enclosed in any report or document, including reports of claims

> investigations, unless the sole purpose of the other reports or documents is to prevent accidents. This prohibition includes crash, preliminary, supplemental, and progress reports; formal reports on AF Forms 711 series; and special mishap investigative reports prepared by the Directorate of Aerospace Safety.

Because the confidential nature of the Accident Board's findings cannot be used for punitive purposes, the military also conducts collateral investigations to resolve claims exceeding $25,000.00, or if fatal or major injury occurs. This collateral investigation is independent and apart from the other investigation. It is made for the purpose of looking after claims, litigation, disciplinary action or adverse administrative actions.

Lt. Col. Harry W. Wesley, writing in "Aerospace Safety" for December 1975, says in "Who is to Blame for this Accident?":

> " Am I saying 'find out who the guilty so-and-so is and then impartially hang him?' Absolutely not! Punitive measures taken as a result of an accident investigation are definitely detrimental to the interests of free and open disclosure of essential information in future investigations. Any personal or pecuniary liability arising from an accident should come about only as the result of a collateral investigation which is wholly separate and apart from the accident investigation."

On collateral investigation, A.F.R. 174-4 states:

> (b) Collateral Investigation. The commander who assumes investigative responsibility will, at the time he or she appoints the aircraft or missile accident investigation board, direct a collateral investigation under AFR 110-14, if claim(s) against the Government for property damage exceeds $25,000.00, or if fatal or major injury (see atch 1) occurs to any person as a result of the accident, or if the possibility of litigation against the Government or a Government contractor may arise from the accident. The collateral investigation is conducted independently and apart from any portion of the accident investigation, and is used to obtain and preserve all available evidence for use in litigation, claims, disciplinary action, or adverse administrative actions. (See AFR 110-14 for factual information that must be released to a collateral board as well as nonfactual material that is not furnished to a collateral board.)

During this corollary investigation, the adversary climate may at times reveal pertinent information that was not produced before the investigation board. (I suspect in civil aviation this is also true of closed hearings conducted within the confines of company offices.) Civilian trials with their adversary court proceedings may at times also produce testimony not presented to the official investigating body. Lawyers who read this could probably produce many such incidents. Nevertheless, on balance, the confidential protective type hearings work well. They must, at the least, expedite the flow of information and reveal information not readily obtained in a court, or at open investigations.

The confidential, non-punitive type of frank disclosure, however desirable, is not likely to be adopted in this country or by nations with similar mores, short of a dictatorship.

It is true that Public Law 93-633 prohibits the use of NTSB accident reports as evidence or use in any suit or action for damages. This official prohibition is delusive. The declared climate in which the evidence is presented is supposed to be non-adversary but few have faith in this because the investigation provides the ammunition for the facts to become available for use in lawsuits and other punitive actions.

Most organizations probably issue instructions to their personnel describing how to restrain themselves in accident investigations in order to minimize harm to the organization or to themselves. Valuable clues may thus be obscured. In the case of line personnel, these restraints may be suggested by both the organizations for which they work and by the Unions to which they belong. This is in sad contract to the freedom of expression that prevailed in years long gone by.

I have always fought restraints in accident investigations, but in view of current trends with their threats of punitive measures, I feel now that such restraints are justified, as I shall explain.

SPECIFICS

Product Liability

Congressman Dale Milford, of Texas, has clearly stated the problems posed by product liability litigation. His thoughts are contained in an article "A No-Fault Aviation Insurance Plan", published by the Southern Methodist University School of Law. This subject is important enough in my opinion to provide extensive excerpts from his article, which follow:

"The purposes of this paper are to:

(1) outline certain serious problems which are threatening public safety and the Aviation Industry;

(2) outline one possible solution;

(3) solicit your criticisms, advice, suggestions and assistance in improving this plan or substituting another plan.

"In this paper, an attempt will be made to define these problems and then to explain a possible solution. I do not suggest that the solution herein is the answer. I do contend that it is an answer. My goal is to find the best solution to the stated problems."

I. IDENTIFICATION OF PROBLEMS

The public safety and national welfare are being seriously threatened by the following aviation-related problems:

1. Inadequate safeguards to assure complete, accurate and comprehensive investigations of aviation accidents; hence, the possibility that unsafe aircraft may be in operation now or at a later date.

2. Excessive consumer costs, passed through by the aviation industry, attributable to liability insurance premiums paid by aircraft manufacturers and air carriers.

3. A threat of business termination of major segments in the aviation industry due to single catastrophic aircraft accidents.

4. Retardation of technological advancements and improvements within the aviation manufacturing industry resulting in a threat to this nation's position as the world's leading aircraft manufacturer.

A. AIRCRAFT ACCIDENT INVESTIGATION DEFECTS

The complex technology involved in the manufacturing of today's aircraft presents a monumental task for accident investigators. The National Transportation Safety Board (NTSB) is responsible for investigating all major aviation accidents in this country.

Recently, accidents have been investigated by technical teams provided by the federal government and the aviation industry. In effect, manufacturers of airframes, engines and the various aircraft operational systems are appointed literally to investigate their own products. This situation is necessary because no other person or agency possesses the necessary technological expertise. Government members primarily administer major aviation accident investigations.

In years past, under the old Civil Aeronautics Board's (CAB) investigations, the accident board and individual team member investigations were confidential. Their work products, notes, reports, etc. could not be used in civil litigation. The original purpose of the accident board was to find causative factors, with no regard for liability or fault.

In recent years, Congress passed the Tort Claims Act and the Freedom of Information Act. These acts now permit the work products of accident investigation boards to be subpoenaed in civil liability litigation. Unfortunately, these acts have brought an end to effective investigations of major aircraft accidents.

The government alone does not have personnel with the necessary technological expertise to conduct investigations of major aviation accidents. Furthermore, under present laws, both industrial and governmental members of accident investigating boards have a definite conflict of interest. Their own survival or welfare may hinge on the results of the investigation.

An example of this conflict would be as follows. Assume that a Boeing 747 is involved in a major accident. Only Boeing has the necessary expertise to examine the ruins of the crash and determime whether or not a defect was present in the air-frame. Yet, if the Boeing accident investigators admit the presence of a defect, the company will be found liable and must pay all damages and related costs of the accident. This situation creates a potential hazard to the public. As these airplanes become older, that potential hazard increases.

It is virtually impossible to eliminate positively and completely all potential defects or "bugs" prior to placing the airplanes into operation because of the complexities of modern day aircraft. Furthermore, "bugs" may not show up until after millions of flying hours. These defects are potential killers.

It is vitally important for public safety that bugs or aircraft defects be discovered and eliminated immediately. In the past, all segments of the aviation industry were eager to find any possible defect and to correct it. Now the situation is different.

The cost of a Boeing 747 accident (total settlement) can be as high as $100,000,000. Such a figure can virtually wipe out an airline company or aircraft component manufacturer.

It is unreasonable to believe that any industry investigator would voluntarily admit to a defect which would put his company out of business. Therefore, present NTSB investigations are not working in a manner which will assure public protection. The individual accident investigating team members certainly could be motivated or concerned with "being sure that their own company's skirts are clean", rather than determining the cause of the accident.

Aircraft technology and product improvements are being seriously hampered as a result of civil liability lawsuits. Aviation, being a new technology, has a past history of constant and immediate improvements of its products. The practice has been slowed considerably.

The production of a new high-technology aircraft can amount to a risk which could bankrupt the manufacturer. Therefore, rather than take the chance, he will stay with his "safe" older model, even though the newer one is really the safer one. The manufacturer is fully aware of the extremely difficult task of trying to explain a complicated technology to a lay jury during a liability lawsuit, with the bereaved widow and her children sitting in the court room.

Manufacturers are also reluctant to make product improvements or modifications lest the change amount to an admission that the older version was deficient, thereby breeding a rash of lawsuits.

Even the smallest aircraft will be assembled from the parts of a hundred or more manufacturers. Any one of these parts could be the cause of an accident. According to the complaints we are receiving, some attorneys simply file lawsuits against all of the component manufacturers. This forces each manufacturer to wage a costly defense. The plaintiff then begins a round of negotiations with each defendant with offers to settle for a sum below the defense cost. With several defendants being involved, the collective settlement amount can be substantial.

Under this plan, a death caused by an aircraft accident would warrant immediate payment of the maximum recovery. Injuries would be treated in the present manner of personal injury practice up to the maximum allowable. Damaged parties would have no other recourse. Federal law would mandate that all operators of aircraft would be required to carry sufficient insurance to satisfy any passenger or crew claims under the provisions of the absolute liability law. Air carriers would be required to offer or make available the sale of additional trip life insurance for any passenger who deemed his estate to be of greater value than the absolute limits provided by the carrier.

The entire intent of this paper is to identify certain problems which threaten the safety and welfare of the public.

It is proposed herein to remove aviation from the provisions of common law recovery based on negligence, and to replace it with strict liability, with recovery based on provable damage up to a set amount.

If anyone has a better plan to provide solutions to these problems, it will be most welcome.

It is only fair to admit that product liability lawsuits have become very effective in arousing further concern of top managements with improving the integrity of their products. In recognition of this, the literature now available to advise industry on how to protect itself against product liability suits by specific technical methodology has become very extensive (such as fault-tree analysis, careful documentation, failure-mode-and-effect analysis, design reviews and other components of system safety). Much of it stems from the Department of Defense and NASA space projects where project assurance is vital also.

As a result of very large financial verdicts in product liability cases, industry is becoming extremely cautious in protecting itself against potential lawsuits. Its files can be subpoened for information that might harm the organization in areas not contemplated in past years. As Mr. Milford says - "This creates a technical climate which is likely to inhibit innovative design." .

However, one manufacturer has taken an enlightened attitude towards this problem. It advises its technical staff as follows:

> " Whenever one of our aircraft has been involved in an accident, lawsuits against the company have invariably followed, frequently despite the fact that the accident was attributable to operational causes and nothing about the aircraft contributed to it. Employees have been required to give testimony, in depositions or in court, and have been required to turn over their files for examination by plaintiffs' attorneys. And those attorneys often try to use statements from records to suggest that there are design or manufacturing defects in our aircraft.
>
> " Despite this situation we must preserve the free flow of information within the company. That is, we should take care not to let the prospect of litigation prevent us from communicating with one another - - in writing where necessary - - about improvements, safety considerations, problems, design changes and changes in the state of the art.

" In these areas we often do receive suggestions and inquiries that are understandably based on incomplete or inadequate information. And the history of change and development in aviation does reflect many false starts and impractical suggestions that were eventually discarded. Thus, the evaluation of a new idea often requires open discussion and critical inputs from many disciplines before it is clear whether the idea is acceptable. The threat of present or future litigation should not prevent this dialogue from taking place. Do keep in mind, however, that we may later on have to defend the company against an attorney who may go so far as to suggest that an idea -- which we had the courage and energy to discuss and the broad experience and good judgment to discard -- "should have been adopted".

" Therefore, it is important that we always complete the record to show the final resolution of internal discussion of suggestions for change and improvement. We can't rely on memory, so document just why we did or did not adopt a particular course of action. Our own written words won't be used against us unfairly if we "close the loop" by creating a contemporaneous record reflecting the reasons for rejection or other disposition of a suggestion.

" Of course, you should remain fully aware that in litigation an attempt may be made to take what you put forward as an untested suggestion and turn it into "gospel". Yet, we should not fear written communication.

" We have to respect the practicalities of this environment, but let's not be afraid to communicate.

" Note: This "close-the-loop" guideline is an appropriate matter for you to discuss at your group meetings."

Unfortunately, the liability threat now may go beyond the organization and on down to the individual.

In SAE Paper 760494 "Aircraft Crashworthiness: A Blight or Panacea: and Mr. Engineer, Are you Responsible?", Mr. D. C. Johnston, a lawyer, has this to say:

" Generally speaking, mere nonfeasance or failure to perform a duty owed to the employer by the employee does not render the employee liable to third persons for injuries occasioned because of such nonfeasance or omission, the employee having a duty to his employer rather than to the injured third party. The basic test of liability on the part of an employee to a third person is, as in all cases of actionable negligence, whether the plaintiff has alleged ultimate facts which demonstrate that the defendant employee breached a legal duty which he personally owed to the plaintiff, as distinguished from the breach of a duty owed by the employee to the employer. In other words, it must be a positive or active wrong, or act of negligence, and not the mere failure to perform a duty. Caveat: recent cases indicate a trend in the opposite direction to the effect that an employee may also be answerable to an injured third party for acts of nonfeasance or omission.

" This is not to say that the employer is not responsible for nonfeasance of an employee, or the failure to perform a duty, since, under the generally accepted rule of "respondeat superior", the employer is legally responsible to an injured third party for any act or omission of an employee who was acting within the scope of his employment.

" From time to time, the question is asked as to whether or not an employee is entitled to indemnification from his employer for harm or loss suffered by reason of a third party claim, whether well-founded or not. This question cannot be answered with any degree of particularity since the laws of the several States in this regard are grounded upon judicial propouncements or statutes. However, generally speaking, and in the absence of an express or written contract to the contrary, an employee is not entitled to indemnification from his employer for damages which may be awarded to an injured third party by reason of any negligent act of commission or omission by the employee."

This threat was recognized 25 years ago in my paper, "Infusion of Safety in Aeronautical Engineering Curricula" at a joint meeting of the Royal Aeronautical Society and the Institute of the Aeronautical Sciences in Brighton, England. The pertinent statements are:

" He (the engineer) must protect himself against a legal system which, in the event of an accident, will spare no effort to destroy his reputation," even though "no expert or group of experts, however wise and qualified, is omniscient enough to foresee all possibilities of trouble, of malfunctioning and of accidents that may result from a new design or rearrangement of an old one."

I'm afraid this fell on deaf ears.

In brief, at the elbow of every engineer and in the cockpit of every transport lurks the spectre of a potential adversary: the threat of legal liability if an accident should occur. Naturally, extreme caution and reluctance can be expected in giving testimony.

Threat of Imprisonment and Criminal Prosecution

The threats of arrest or criminal prosecution of airmen and executives following an accident have been practically non-existent until recently. In a world of great social unrest and political turbulence, coupled to the proliferation of rules by various regulatory agencies with punitive powers, one can never be certain that inadvertent or perhaps innocent or inescapable human error or management oversight will be treated with compassion. Threats and actual arrests have already been made. The Captain of an American air transport was arrested by police in 1964, following an accident at the Rome (Italy) airport. He was released but there were some uncomfortable moments. The four-man crew of an Interflug TU--134 has been sentenced to prison for allegedly contributing to the death of 24 people when the plane crashed in East Germany in 1975. An airplane crew and a weather forecaster in Taiwan were threatened with jail following an accident.

The concerted pressure of IFALPA was effective in releasing a crew from jail in an African nation a few years ago. There may be other cases. I regret I did not have time accurately to document those that I cited. These are taken from memory.

Top executives as well as airmen are becoming subject to the threat of imprisonment. In my opinion, a great blow to accident investigation was struck when the Department of Justice of the USA invoked criminal sanctions against an air carrier for the unlawful transportation of hazardous materials. True, a fatal accident occurred. The action by the Department of Justice was perhaps legally correct but the danger was initiated so remote from the air carrier's operations that it seems unreasonable to call for criminal prosecution. Undoubtedly, this carrier and others will try to tighten control of hazardous cargo, but in a large organization it is virtually impossible totally to prevent inadvertent violations even with the best of management, especially when they originate outside Company control. It will happen again. It is probably occurring right now.

This new threat of criminal prosecution and the numerous rules, sometimes conflicting, issued by a variety of government agencies with punitive powers, pose baffling and uncomfortable threats to top executives.

Business Week for May 10, 1976, carried an article - "The Law Closes In On Managers". It quotes Mr. William B. Johnson, Chairman of IC Industries:

> " You shudder at the risk of innocent violations. No question that deliberate violations as opposed to inadvertent violations of the law should be prosecuted. It would be impossible to live in a society in which every inadvertent mistake or human error were punished. We are approaching a situation in which we may not be aware of a violation because the regulations are becoming so numerous and often difficult to interpret."

The article suggests that every organizational chart have a slot for " a Vice President in Charge of Going to Jail!".

The American Express Company, in its July 1976 News Letter calls attention to the increasing threats of adversary action by government agencies:

> EXECUTIVE LIABILITY
>
> Old government regulatory agencies are getting tougher, and new ones crop up almost every day. That poses a new and bewildering threat to corporate managers: increased personal liability for corporate acts of negligence and lawlessness.
>
> In the most significant case to date, the Supreme Court upheld a fine levied personally against the president of a supermarket chain for unsanitary conditions in one of the chain's warehouses. And the manager of a food processing plant in California recently received a suspended jail term after being cited by state officials for health code violations.
>
> Executives have never been entirely free of legal liability growing out of their corporate duties. But their obligations had become pretty well defined through the years. Now there are new regulations from such traditional agencies as the Justice Dept., the Securities & Exchange Commission, and the Food & Drug Administration.
>
> More important, there are so many new agencies with tough enforcement powers: the Environmental Protection Agency (EPA), the Consumer Product Safety Commission (CPSC), and the Equal Employment Opportunity Commission (EEOC). And there

> are tough new laws on the books, including the Employee Retirement Income Security Act (ERISA) and the Occupational Safety & Health Act (OSHA).
>
> Just keeping up with the paperwork now required is a chore. Further, the new agencies are still developing and testing their enforcement powers. How tough they will actually be will depend on test cases just being launched.
>
> One clear result: Corporations are beefing up their legal staffs to deal with compliance problems. Meanwhile, directors' and officers' liability insurance is becoming harder to buy as the growing number of suits against corporate managers turns insurance companies edgy.

Testimony could become innocent self-entrapment in an investigation.

The article in Business Week also says:

> Moreover, even the most conscientious manager can fall into the trap of conflicting rules enforced by different agencies. Heinz U.S.A. cites one instance when the company followed an FPC order to "turn down the lights, you're using too much power", only to be told by OSHA, "Turn up the lights, you are creating a safety hazard".

<u>Suspension and Revocation</u>

The science of human factors and its corollary human error abounds with uncertainties. Except for deliberate acts of commission or omission, should human error call for the suspension or revocation of an airman's certificate? Discipline is essential but for further study of the pros and cons of punishment, I recommend the 1952 lecture on Crime and Punishment by Prof. Kenneth Andrews of the Harvard Graduate School of Business Administration given at the Flight Safety Foundation's Seminar that year. In view of the lack of sure knowledge about human error, the ALPA seems justified in advising its members to adopt the following procedures in the event of an accident. It may at times interfere with the free flow of information to the investigators:

1. If any crew member requires hospitalization, the ALPA representative should insure that representatives of the FAA will not have access to the crew member(s) while they are in the hospital. In addition to the fact that the crew members need not talk to the FAA, the probability exists that the pilots will be on some form of medication. There should be no discussions with representatives of either the FAA or the NTSB while the pilots are on medication that might interfere with their ability to function properly.

2. Although the crew is obligated to aid the NTSB in its investigation of the accident/incident, the investigation must be conducted in a reasonable manner to insure that the pilots' rights are protected. This would include at least waiting a reasonable period of time until the pilots have had an opportunity to discuss and review the accident/incident with their representatives and amongst themselves and after it is determined that they are physically and mentally competent to answer questions in an intelligent manner.

3. The ALPA accident representative should advise the crew that they are <u>under no obligation</u> to discuss the accident/incident with representatives of the FAA. Further, the crew <u>should not</u> discuss the accident/incident with representatives of the FAA in any manner, casually or formally, until a decision has been made to do so by the crew's representatives - - including its legal representatives.

4. The FAA can require the crew to give their names, addresses, and <u>show</u> their certificate to FAA representatives. A crew member should never relinquish his certificate to a FAA investigator, or any other investigator.

5. In the event an informal inquiry is conducted while the on-site investigation is continuing, the pilots should secure the agreement of the FAA representatives that nothing which the pilots say during the inquiry will be used against them in a certificate action or a civil penalty proceeding. In the event the FAA representative does not give this agreement a crew member may request that the FAA representative be excluded from the informal inquiry of the crew.

6. If the news media contact the crew, they should make no statements and answer no questions.

7. The ALPA Coordinator will contact the Deputy Director-Accident Investigation to determine if on-site legal assistance is needed.

The Association of Flight Attendants is more explicit in advising members. The following is taken from the AFA Flight Log of March 11, 1976:

" Someday you may be involved in an aircraft accident, a hijacking, or an emergency evaction . . . .

DO YOU KNOW WHAT TO DO AFTERWARDS?

DO NOT make any statements to the press.

DO NOT make statements to the National Transportation Safety Board, the Company, or any group or individual until:

you have reached your Union representative;

you have received medical attention.

DO NOT allow any statement to be taped.

DO NOT make any statements while under sedation.

DO NOT express any opinions or hearsay.

DO call your Central Safety Chairperson or your local Union representative immediately.

DO call the AFA Home Office (202-797-4184) if you can't reach your representative.

DO read the back of your membership card.

DO get rest and medical attention before you make any statements.

DO only make factual statements after you have representation.

DO carry your Union representative's number in your wallet.

If you are involved in an aircraft accident, hijacking, or emergency evacuation you will be approached by many individuals and groups who may claim to have the credentials to interrogate you about your experience. DO NOT BE INTIMIDATED BY THIS, EDUCATE YOURSELF NOW TO THE FACTS, SO THAT AFTER AN EMERGENCY, YOU WILL KNOW EXACTLY WHAT TO DO.

UNDER THE CONSTITUTION OF THE UNITED STATES, YOU ARE ENTITLED TO REPRESENTATION BEFORE MAKING ANY STATEMENTS CONCERNING AN ACCIDENT IN WHICH YOU ARE INVOLVED. Additionally, the reverse side of your Union representative card provides you with the following statement:

> ' Before making a statement or report, I wish to consult with a representative of the Association of Flight Attendants.'

You are NOT required to make any statements to your Company, to the press, or to the FAA. Doing so may in fact jeopardize the investigation of the accident/emergency by the duly official investigating body - the National Transportation Safety Board. The NTSB "owns" the aircraft accident. Neither Company nor the FAA have any claim, at this point, on the aircraft or its occupants.

" You will be required to make a statement to the NTSB concerning the emergency within a reasonable period of time. However, you are entitled under Part 831.8 of the NTSB rules of practice to representation. We encourage you to hold off making any statements until you have received adequate rest and medical attention and until you have obtained Union representation.

At a later date, the NTSB will most likely have hearings on the accident, and you may be asked to testify. Therefore, the statement you make in the days following the accident (prior to the hearing) is crucial as you will be held accountable for your statement. This is why you must be sure your thoughts are clear and that you are represented. Additionally, you must be careful not to make any non-factual statements or express opinion or hearsay. You should only make statements concerning what you actually saw, heard, or did - - in other words, what exactly happened to you.

Probably the most important thing you can do NOW is to check your Union bulletin board and copy down your representatives' phone numbers. You should carry these in your wallet along with your membership card."

As I have mentioned in the past, I opposed this attitude of restraint in accident investigation. I felt it was unbecoming, unprofessional conduct, especially because aviation needed all the help it could get to prevent accidents . . . but in the current adversary climate of investigation, I condone this position even to the extent that management and airmen might take the fifth amendment against self-incrimination when they are threatened with imprisonment or criminal prosecution. Individual rights are more important than safety.

Of course, witnesses who take the fifth amendment or similar action in defense of their organizations or of themselves impede the progress of investigation. In the case of management, the understandable reluctance of top executives to admit oversights may impel the investigating agency to employ experts on organizational management. Again reverting to Prof. Kenneth Andrews, in another Flight Safety Foundation lecture - "Morale and Safety", in 1952, he said that "every accident, no matter how minor, is a failure of organization". (I presume he would omit Acts of God.)

A curious note is that the Los Angeles Times of July 20, 1976, reports on a recently organized company whose purpose is to act as corporate watchdog to detect irregularities in administrative, managerial and operational aspects of a company for which the officers and directors may be held responsible and liable for action even though hidden from them.

Government agencies are also vulnerable. The threat of exposure of the inefficiency or oversight of government agencies has the effect of inhibiting employees of such agencies from giving evidence without advice of counsel. An altruistic stand in the public interest becomes embarrassing if the evidence may be prejudicial to the organization. The threat of litigation against the government is another consideration that may inhibit voluntary admission of a fault, even though the public may feel that fault deserves compensation if it causes harm.

The threat to organizational prestige, corporate image, national honor, personal probity and even insurance acceptance increasingly pervades all accident investigation, unfortunately. We have retrogated from the climate of the challenging past when the progress of aviation was the paramount consideration.

For example, in respect to uncovering design fault, the first Vice President of one of the world's largest aircraft manufacturers told me thirty years ago that he did not care who was at fault, including his own company, so long as safety was advanced.

In the same year, I discussed the legal and financial implications connected with uncovering operational faults with "Pat" Patterson, then President of United Air Lines. His response was that he would rather have lawsuits than have accidents. These attitudes are the lost glories of the aviation industry, for reasons I have mentioned.

Highly motivated and dedicated investigators may themselves unconsciously exert pressures that may inhibit a witness. If the investigator is biased, arrogant, contemptuous, accusative, or fails to follow the techniques of a skilled investigator, the witness is likely to be non-cooperative. It behooves a good investigator to impart an objective, non-adversary spirit to the investigation regardless of an inner conviction that the witness may be evasive. As a whole, the selection and indoctrination of investigators seems to have been very well done, but periodic reminders or critiques regarding their approach and techniques might be in order.

The results of accident investigation have become big business. They are coupled to legal, financial and societal factors that threaten the future of objective determination of facts, conditions and circumstances. Instead of a mature, dedicated attitude towards the advancement of aviation by all concerned parties, the future seems beset with frustrating threats that will probably fester for a long time before cures are found, if ever.

From the standpoint of the NTSB, this should be an additional challenge that must be overcome by appropriate practices if possible, until the Congress steps in to help. Somehow I feel confident they will overcome. The public is behind them.

In summary, vested interests are needed in aircraft accident investigation and hearings. These interests participate under pressure of threats posed by a diversity of economic considerations, by criminal prosecutions, by inadvertent violations of regulations flowing from a variety of agencies, by adverse publicity, tarnished reputations. These pressures create and intensify an adversary climate in accident investigations, sometimes subtle, but present nevertheless. The problem is to force accident investigations from this adversary climate. The solution rests with the public and the ingenuity of investigating bodies.

I apologize for the emphasis on this country's investigative practices at an International Seminar but I suspect that other nations have similar problems.

I should end by admitting I have a "vested" interest in the success of accident investigation. As the first Director of the Safety Bureau, 36 years ago, I was responsible for establishing the organization, adopting the procedures and approving the techniques which underlie the fine efforts of the NTSB.

I wish to retain pride in its accomplishments.

ACCIDENT INVESTIGATORS - COLLEAGUES OR ADVERSARIES

Joseph D. Caldara Major General USAF (Ret.)

The first "official" aircraft accident investigation was conducted in 1908 right here in the Washington area. Of course, it followed the first "official" aircraft accident. All the records of those years are not readily available for ready reference, but the record of the first official investigation had as a primary cause, "Aircraft collided with the ground!" And that is about as good a cause as any I have seen in the last 3 decades of involvement in Flying Safety and Aircraft Accident Investigations. The pilot, who was killed was a second lieutenant, named Tom Selfridge. Selfridge Air Force Base was named for him. The instructor was one of the better known aviators of the time, one named Wright. After all, he and his brother had built the aireoplane, as they were called then, for the Army and who else could instruct? As fate would have it, he lived to instruct more military pilots.

From what records are available, the accident investigation board consisted of qualified investigators from the infantry and cavalry. And the investigation compared very favorably with one conducted of the loss of a Quartermaster Corps wagon over a bluff on the Potomac River. In those days a Quartermaster Corps wagon was capable of carrying some twelve to fifteen hundred pounds of cargo. And believe it or not, according to the accident investigation, the load of government property that was lost in the river totalled some 14 tons! We can be fairly sure of several things though. In the aircraft accident investigation, there is no record of an adversary relationship between the Wright Brothers Aeroplane Company and the U. S. Government; or the instructor and the student-pilot; or the Army and the survivors. Also there is no record of a follow-on law-suit. But that investigation, and the thousands that followed helped define the concept that a good, sound accident investigation could only be conducted by the partnership of the manufacturer's representatives and those of the using agency, be it military or civilian. When the government, in the form of the civilian aviation agency of the time became a part of the accident investigation, it was supposedly going to be the "father-figure". monitoring the objective activities of the other interested parties. Ah, the joys of being naive!

Please bear in mind that the eventual concept of using information from an aircraft accident investigation to prevent a reoccurrence of the same kind of accident was a very long time in developing. The old Army Air Corps had a theory that went something like this, "If you fly you crash, if you crash you die, ergo, if you fly-you die!" In fact there are times when I wonder if the same thought pattern doesn't still prevail. But this sort of thinking could lend itself to the continued use of the probable cause for a crash, "the airplane collided with the ground." It wasn't until long after World War I that anyone even thought of trying to find out what happened to the machine, or the pilot, BEFORE it collided with the ground.

With the passing of the years, and the continued development and increased sophistication of aircraft, the very economics of flying mandated a better investigation than had been accomplished in the past. Each new model, be it military or civilian, or even military converted to civilian as was the case in the early '20s, cost more than its predecessor. And as the cost continued to rise, the realization dawned that aircraft accidents were an expensive luxury that need not be suffered - if action could be taken to derive a lesson from the investigation and get the message to the rest of the operators and pilots involved.

As airlines were formed and grew, and as manufacturers developed bigger and faster, and hopefully better aircraft, there was more meaning to the individual's pursuit of the investigation. It was only logical, since the operator bought the aircraft on a warranty that he would want the cause of the accident to be determined as material failure. This vested interest in protecting his own investment was not only human, it was a logical extension of the capitalist way of life. On the other hand, it was just as logical for the manufacturer to want to see the cause of the accident to be determined as operator error because then he was not liable for replacing the equipment. And believe me, in the early days of accident investigation, vested personal interest amounted to just that. It was to be many years before the aviation version of an ambulance chaser would appear on the scene and eventually warp many an accident investigation completely out of focus. Of course there was always that good old philosophy, "There's nothing fairer than pilot error" to absolve both the operator and the manufacturer from any causal responsibility.

This same philosophy gradually expanded to include those government agencies which would become more and more involved with aviation over the years. And in recent years, subordinate organizations within the government agencies have become more and more involved.

Given this interest in, and perhaps even devotion to the protection of individual vested interests, you may better understand why the title, Accident Investigators- Colleagues or Adversaries? According to the way the various regulations, and charters, and whatever documents are written, all accident investigators are colleagues. According to the way accident investigations have gone over the past two decades they seem to have become adversaries. When that word is used repeatedly in the transcript of an investigation hearing, there are more people than I who think the same way.

With this background, is there a possible way that an accident investigation can be managed so that it will come up with an objective finding? From my own personal experience, I can honestly say, "Yes!". Because I inherited much of the foregoing philosophy and saw it change for the better. In the middle 50's, the Air Force had two front line aircraft, the F-100 in fighters and the B-52 in bombers. Both were new, although not really beyond the then existing state of the art. And both were in trouble. To save time I must ask you to accept my word for that.

Although I had long been involved in accident investigations, it wasn't until I was the Director, Flight Safety Research that I really found out just what was involved in trying to determine the primary cause, as we said then, of an accident. The staff at the Safety Directorate was fairly large, and very competent. But I learned very rapidly that we did not have the depth in engineering or operating or maintaining that the manufacturers had. It occurred to me that since they were as anxious as I to find out why a crash had really occurred, we should make it a team affair- the Air Force people and the Industry people. It sounded simple to me, and also seemed to have some appeal for the civilian side. Ah- yes.

I broached the idea to several of my friends, Presidents in the aviation industry, and after I explained what I was after, they agreed in general and so I was off to the Air Staff to get its approval. Ah-yes!

The first reaction was quick and somewhat violent. In no uncertain terms I was told that <u>for years</u> the toughest job about aircraft accident investigations was <u>to</u> keep the manufacturers from whitewashing the whole thing- to protect themselves! It was for this very reason that manufacturers' participation was minimized as much as possible. I'll skip the many discussions, and the weeks it took to get the concept approved, but I still thank God for a Chief of Staff who was as keenly interested in solving the problem as I was. And after continued negotiations with various industry representatives, we finally formed an Air Force-Industry AccidentInvestigation Team. Letter agreements spelled out the rationale and also designated those industry representatives by discipline who would participate for the company in the accident investigations. You understand, of course, that each company team investigated only those accidents involving their own aircraft. Early on in the program we learned that where some major sub-components were concerned, other than engines as the engine manufacturers were included on the teams, the prime manufacturer would be responsible for the technical participation by the component manufacturer or provide it himself. For your information every major airframe manufacturer participated in the program. And so the problem of an objective accident investigation was solved- well not quite.

As luck would have it, the first accident the team would function in was the third of a series on one of the new aircraft. And also as luck would have it, we were carrying the two prior crashes as Cause Unknown because we had not been able to determine any other cause, other than "colliding with the ground". If the concept was to be tested there could not be a more rigorous or demanding test. You are all familiar with the functional groups that investigate a crash, so there is no need to belabor that point. But the management of the various groups became a matter of evolvement and development over the days that ensued. It only took until the first general review meeting that evening of the second day to disclose that in fact there were two separate teams investigating the accident, the Air Force group and the manufacturer's group. Again, as luck would have it, the chief of that particular team was not only a friend of long standing but he was just as interested as I was to get a really objective answer. Had he lost his vested interest? Far from it! At this point, if we didn't come up with something real the Air Force would lose one of its newest and best aircraft, and the manufacturer would lose the on-going contract. So we both could take a pragmatic approach to the organization/management problem. The very next morning, each group functioned on a real partnership basis. In cases of disagreement, either the company Chief or I, or both of us would resolve any differences in opinion. The rough spots that one would expect were exascerbated because of the difficulty in trying to find out why an apparently fine machine and expert crew could fall out of the sky- with no warning or communication from the crew to any ground station. There were also rough spots in the clash of strong personalities who were convinced of their own expertise and were not a bit bashful about standing up for their opinions. I have said for years that all pilots were prima donnas, they <u>HAD</u> to be if they were to be good pilots. But that prima donna personality extended right down through every level of the accident investigation team. And of course, that also complicated the management job. But by the end of that first accident investigation, the team was functioning as a real team, and the answers that came out were objective. I can't say that every team functioned as well, or I was happy with every investigation's results. But I can say that the cooperation, coordination and results achieved were far better than anything experienced in the past.

It stands to reason that in many of the aircraft crashes that are investigated today, there is no requirement for a team of highly qualified experts. Many crash investigations are a 1 man affair, and rightly so. But all of the major crashes do require teams of many experts, and these are the units wherein management is at such a premium. And this applies to the military just as much as it does to civilian crashes. What are some of the requirements for an accident investigation team to be objective and effective? And be reminded that if the team is not objective, it is not truly effective. First, each member of the team must not only be highly qualified in his particular area of responsibility, he must have the vision and judgment to recognize the validity of his colleagues' judgments as well as his own. This sounds simple, but believe me, it isn't. Some of the best qualified engineers I know cannot argue a position- they make a pronunciation and that is that. And that just will never work. Recognizing the validity of his colleagues' judgments is just another way of saying that the individual is objective. Only a fool would not be loyal to his service or to his company. But that kind of loyalty should never compromise the professional judgment of an accident investigator! Second; each investigator must be willing and able to undergo whatever rigors the investigation provides in order to do a full and complete study of his area of responsibility. Does that sound unnecessary to you? Well, in an investigation in the Arctic of a very complicated accident, the team spent less than one day at the scene of the crash and the balance of a fortnight in the warmth of the hotel rooms. O yes, the investigation reflected it, quite clearly. Third; the government, manufacturers' and operators' chiefs must be as dedicated as every investigator to the principle of a truly objective finding. If any one of them isn't, then the senior government representative, if there is one present should establish that fact for the record. Fourth; a daily investigation review meeting must include every agency or organization involved in the investigation and attempt to resolve any outstanding differences of position each day. Note- that says difference of position, not difference of opinion. Fifth; every investigator, and the Chiefs must be able to recognize and admit to fault on behalf of his sponsor if it be discovered.

These are not the only factors involved in managing an objective investigation, but if they are included along with the others the results will be as good as possible. There has been a decided change in the climate of accident investigations over the past 10-20 years. It is probably in accord with the change in the attitude and mores of the people as a whole. When the Air Force-Industry Accident Investigation team was first formed, all accident investigation reports were privileged documents, and I mean just what that said, privileged documents. O sure, every now and then in the Air Force some hard-nosed commander would get into one to courtmartial some one, but inevitably, that mistake was corrected- and fast. As a result of this status-accident prevention efforts were far more meaningful than they are today.

I am the first to recognize that to some people, an objective accident investigation is not one that provides the best case for litigation. However, in my opinion there is only one justification for an accident investigation- to find out what went wrong, so that a reoccurrence can be prevented. If that is not the end objective of the investigation, the entire action is an exercise in futility.

AIR SAFETY AND LITIGATION IN CONFLICT

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My comments are directed towards the American system of jurisprudence and the performance of an aircrash investigation by the National Transportation Safety Board, assisted by the various operators, manufacturers and Federal Aviation Administration.

The investigation's main objective is to determine the probable cause of the crash, the methods used and the logistics required in reaching this goal may be titled management.

While an investigator's goal may be directed toward solving the question of probable cause of a particular crash with the hope of preventing future deaths, he may feel he should proceed on this task unobstructed by pressures and unrelated matters as potential litigation by the injured parties, for his task is of a higher order. It is becoming increasingly difficult for the investigator to manage his mission in an ideal vacuum with the news of the crash broadcasted from coast to coast and demands of the press and relatives for a quick answer as to the existing tragedy. As more law firms become involved in this specialized area of negligence, attorneys with their photographers and investigators, are appearing on the crash scene.

One main criticism of attorneys held by investigators is that the interest of the attorney is different than the investigator; the attorneys tend to distort, misunderstand and ignore what the investigator considers the facts of the crash in the attorney's attempt to represent

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his client. Basically, this may be summarized by stating the attorney is interested not in safety but solely in money. While this criticism may not be totally untrue, it ignores the substantial benefits derived toward safety in aviation arising out of the financial and political pressures which are brought to bear on the manufacturers, operators and regulatory agencies.

The investigator's criticism may be based on his personal experience in depositions or on learning the outcome of a case which resulted in a verdict totally contrary to the probable cause found by the investigator. Attorneys and investigators both lose sight of one basic fact; we are dealing with people, with all the emotions and factors which make up individual personalities. The attorney may be faced with a difficult task in defending a particular case or presenting a claim. The investigator, having reached his decision as to the probable cause and having adopted it as another step in a completion of his life's work does not want to be challenged subsequently in his analysis, particularly on collateral matters.

Previously an investigator's opinions were held to be confidential and only shared among his colleagues. With the changes in litigation pretrial discovery techniques, more investigators will be challenged regarding their opinions as to the probable cause of a crash and how they were reached. Only where an attorney knows the opinion of the investigator as to the probable cause of the crash may he effectively probe the reasoning that resulted in the opinion; the factors which were considered and more importantly the factors which were disregarded in reaching that opinion.

It is necessary for the investigator to understand the difference between the functions and methods of the defense attorney as opposed to a claimant's attorney to appreciate why he is often the target of both. The role of the defense attorney may be stated as an attempt to shift the liability for the crash either to the claimant or some other person. Failing in that, he must then reduce the financial exposure of his client by minimizing the damages claimed. The claimant's attorney's role is to fix the cause of the crash on a solvent defendant. Failing in that, his claim becomes worthless. Where the cause of the injury or damage can be fixed on a solvent defendant, his next step is to recover the highest possible settlement or award for his client should the matter proceed to trial.

With these basic objectives in mind, we must note that there is a clear difference between the handling of an air crash involving an airline as opposed to a general aviation crash. This difference is clearly related to the training, experience and ability of the investigator. In major crashes, the logistics and available management expertise far exceed that available to the sole investigator involved with a general aviation crash.

Where a major airliner crashes, the claimant's attorney is assured of a recovery for his client. The standard of care imposed upon the air carrier as a matter of law, the knowledge of the solvency of the carrier and the existence of liability insurance provide a financial security blanket. In fact, some insurance groups have taken the position that a major air crash is indefensible, the amount of damages being the sole question. Some London underwriters have turned to evaluating risk and losses in terms of increased premiums based on past damage awards. These underwriters are not interested in saving a million dollars through negotiations on a major crash which results in a loss of 50 million dollars. Instead, they look to an increased premium to cover their losses. Perhaps it is only where one air carrier suffers repeated losses that the insurance companies take a clear look at the safety aspects of their risk where before they abrogated their financial exposure to the regulatory agencies and the internal checks conducted by the airline.

Conflict and criticism in the main body of litigation between the passenger and the air carrier seldom occurs. Only when the air carrier is attempting to spread its own liability to another solvent defendant does a conflict arise with the air safety investigator as the target. On the other hand, where one investigator in a local field office is required to investigate three separate crashes, a helicopter, a balloon and twin engine Beachcraft, all in one month, the demands upon him become excessive. He may not have experience in any of these categories or types of aircraft. Errors and the pressures to submit a probable cause during the early part of the litigation often leads to subsequent harassment and unnecessary litigation against potential defendants.

The following examples illustrate conflicts caused by investigators:

On a hazy evening a helicopter was proceeding back to its base. While in transit, it collided with an unlighted construction crane at the 75 foot level. The accident report concluded the crane did not have to be lighted to conform with the Federal Aviation Regulations. The pilot's widow, and owner of the helicopter filed suit. After the claimant's attorney investigated the application of the appropriate regulations and internal FAA Handbooks, it was concluded that the crane, in fact, should have been lighted. The appropriate internal documents were provided to the defense attorney, and the case was settled for its full value. In this case, the investigator failed to obtain all the relevant information and improperly included his conclusion in the factual portion of the report. This error initially caused the defense attorney to resist settlement, resulting in additional cost to all parties.

During an instrument approach to an uncontrolled field, the pilot incurred reverse sensing and impacted with a mountain. While the facts of the accident were quite clear, during the investigator's explanation on deposition of the crash he also experienced reverse sensing by improperly explaining the procedure for VOR approach. This questionable testimony resulted in protracted, unnecessary litigation. While some investigators do not make good witnesses, they shoud be good investigators.

A midair collision occurred between a single engine training aircraft and a transport category aircraft. The accident report indicated that the transport was below its assigned altitude. A subsequent investigation by the defense attorney resulted in an amendment to the report showing the transport was at the assigned altitude and the flight recorder readout had been incorrect. Defense costs to the transport carrier were substantial.

A transport on approach to a major airport crashed short of the runway. One contributing factor was alleged to be the air traffic controller's failure to provide appropriate weather information to comply with the "Look See" Requirements of the Handbook. While the government was successful in avoiding liability, the entire facts were never divulged. There was a clear area of liability relating to the use and coordination of the fire fighting equipment. The widows and children received nothing because of the failure of the claimant's attorney to develop the facts which were sequestered in the investigative analysis section of the report unavailable to the claimant's attorney.

While an investigator may feel he is not involved in the safety aspect of the investigation to prepare the case for the claimant's attorney, that is exactly what is taking place as a result of our investigative system. Whether there is a better method remains to be seen. Each investigator cannot be unmindful of the fact that he, because of his position, is at the crash scene with access to the evidence, the only evidence which the claimant needs to prove his case and the only evidence which the defense attorney has to defend his. Whatever unanswered questions or additional use of the evidence could be had, they generally remain unanswered as the evidence will probably be destroyed before the attorney with the time and resources available to cover every aspect of the particular crash even where the main cause of the crash was obvious. Again, an understanding of the attempt to shift some of the liability to another solvent defendant is the explanation for this probe by the attorney into other apparently minor non-causal areas.

Changes in the law as shown by recent cases involving financial recovery by pilots who actually caused a crash but sustained additional injuries as a result of the design of the aircraft have caused manufacturers to take a second look at crashworthiness data. Most of this data has been available for years to the industry but real interest was not aroused until the financial aspects appeared. These changed in the law will cause the investigator of the future to place additional emphasis to this area of investigation.

It should be obvious, in a society which is so business and financially oriented that the financial losses associated with a crash are motivating factors in improving the operation and design of aircraft. While the motivating forces of the claimant's attorney may be dollars, the collateral benefits should not be ignored. The better facilities, the additional care taken by investigators in covering all aspects of a crash, the realization of the dual importance of his work and findings and an understanding of the framework within which attorneys must operate will result in less conflict between attorneys and investigators. Only where there are differences of opinion can there be conflict. It is more desirable to resolve these differences by improving the scope and facilities of the investigator than to expect attorneys to change. Contrary to Shakespeare's advice, it is both illegal and unlikely that we can "first kill all the lawyers". Rather, we must seek to understand them, as best we can.

A BOTCHED INVESTIGATION--ARE THERE ANY LEGAL RAMIFICATIONS

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It wasn't very many years ago that it was almost impossible to successfully sue a doctor for his mistakes. Today, a patient who has been wronged at the hands of a negligent surgeon can recover a money sum to help rectify the incompetent mistake. In actions where the mistake is obviously the fault of the doctor's negligence (such as amputating the wrong leg or operating on the wrong ear), it is clearly, morally, as well as legally correct that the injured party may have a cause of action. But, the malpractice field has burgeoned and grown logarythmically over the very recent past until now the physician may be sued for a failure to recognize the true problem. A doctor who fails to properly diagnose an illness may be found negligent and damages may be had. The doctor then is held up to a standard of care at least as high as should be expected from today's medical profession. Today, the ability to properly diagnose illnesses is aided dramatically by the scientific method, exotic x-ray, isotope scanning equipment, and blood analysis equipment, as well as access to diagnostic clinics in most areas. Thus, a California doctor who gave thirty-three cortisone shots, combined with treatments over a year's time to a man complaining of worsening spinal pains finds himself the Defendant in a lawsuit in which the patient Plaintiff is now dying of inoperable spinal cancer.

Medical malpractice may be in the form of the failure of one doctor to disclose pertinent medical information to a referral doctor about the allergies of a patient to certain medicines. Thus, when the patient dies at the operating table due to an allergic reaction to an anesthesia, the surgeon, the anesthesiologist and the referring general practitioner who was knowledgeable of the patient's allergy may perhaps all share part of the legal liability of the patient's wrongful death. In each case of medical malpractice, we find that the doctor has breached a duty of care prescribed by law, and this duty was in most cases arrived at consensually and contractually in the normal manner a patient seeks out and hires a doctor.

Even less talked about than medical malpractice is the burgeoning area of legal malpractice. A lawyer who suggests to a client that he has no case of malpractice against the City Hospital even though the City Hospital amputated the wrong leg, if the client, because of his faith in the lawyer's reputation, believes the lawyer and statute of limitations runs with respect to the hospital, then the lawyer may find that he will pay the Plaintiff that amount that the hospital should have had to pay.

Thus, a lawyer's miscalculating the law, or failing to act to the benefit of this client, and if the failure to do so harms the client, then the client has a cause of action against his own attorney.

Often times, a man has actions in trespass against another for disturbing property belonging to him or trespass on the person when he is unlawfully touched. Actions are possible in defamation and these may be defined as the publication to one or more persons by a writing, by spoken word or by actions that belittle or lessen the person's stature in his community, thereby damaging him.

How does this effect the Air Safety Investigator? Up to date, probably not at all, but there is a possibility that the law could expand to its fringes to include the malfeasance of an Air Safety Investigatior who botches an investigation so badly, or who destroys the evidence, or whose findings are obviously negligently mistaken so as to change the legal liabilities then perhaps there may be a springing legal liability of the investigator or the investigating agency.

The Air Safety Investigator already admits to a moral obligation to the public with respect to his professional aeronautical endeavor. Is it possible that there may be a legal obligation to the public as well?

It has been well-stated at law that the United States Government and its agents and agencies through the Tort Claim Act may, even though they had no duty to act, that when they did act they had the duty not to act negligently. A general rule of tort law is that the negligence of the party involved had to be the proximate cause of the damage to the party complaining. You then correctly ask how can an investigator or agency who botches an investigation ever be considered the cause of the accident? He obviously can't. What he can be blamed for is the negligent destruction or conduct or mismanagement of an investigation that loses the evidence of the obvious and true cause of an accident, thereby destroying the remedy for a hurt party or Plaintiff.

This then equates the investigator to a doctor or a lawyer sued in malpractice for the failure to properly diagnose the patient or properly analyze the respective legal problem. Here when the lawyer fails to correctly advise his client of his legal remedies and causes of action, the client may claim damages that he could have received from the original Defendant against his own lawyer. Is it any different for the Air Safety Investigator and should it be different?

Certainly the first agencies and investigators to the scene of a small aircraft accident are usually the local police, and then the local F.A.A., and finally, the NTSB investigator who then orders the crash sight secured and roped off while the investigation proceeds. At times, these investigators have been known to not allow other bona-fide investigators to the scene. By bona-fide, I mean qualified investigators with a vested interest in the accident in that they represent one of the deceased, or one of the claimants under an insurance agreement. NTSB regulations 831.16 and 831.17 delineates who may and who may not be part of an investigation. Basically, the NTSB does not allow a legal representative of a claimant or the insured to be part of an accident investigating team while in fine sounding language it specifies that persons, Government agencies, activities or products involved in the accident and who can supply suitably qualified personnel may assist in the investigation. Further then access to the wreckage may be controlled by the investigator in charge limited solely to the persons as qualified above. Thus, in a general aviation accident the airframe manufacturer, the engine manufacturer and hull insurance investigator are allowed to the scene while the widow's investigator is statutorally barred. In fact, the opening statement read to an air carrier accident go team by the NTSB investigator asks if there are any lawyers present and if there are the NTSB investigator disqualifies them summarily.

Obviously, allowing all persons to the scene of an accident creates a problem of management to the NTSB investigator, but exclusion of such persons states categorically to all concerned that the NTSB and FAA have taken the responsibility to perform the investigation in a professional and non-negligent manner. Can a contractual duty be implied to the FAA and NTSB to a Plaintiff such as a widow if the widow hires a bona-fide qualified investigator who demands immediate access to wreckage, and is denied access until the wreckage is released subsequent to the investigation? It appears possible that the denial of access of an agent of a legitimate Plaintiff might then in effect force the limiting authority to impliedly become the de facto agent of that Plaintiff so denied. Thus, if we can establish a duty to act on behalf of the Plaintiff, we can also establish a duty of the investigator to not act negligently. Can these federal statutes and codes that empower these investigators to conduct an investigation and these same coes that empower the investigator to restrict access to the wreck scene of other qualified investigators be construed as a duty to conduct the aviation investigation accident investigation in a non-negligent manner for which a cause of action can arise if it is shown that the investigation itself was botched to the extent that the true cause of the accident is lost forever, and evidence destroyed before the release to the public. Certainly a private aircraft accident investigator contracted to do a professional job may be held liable for his malpractice just as any professional man for hire. The sole issue is whether or not a legal duty can be imposed on an investigator that can require him to do a non-negligent job or be liable for his mistakes.

If by virtue of the NTSB's excluding a bona-fide investigator from access to the wreckage at the scene then we can imply that the government has undertaken the duty to conduct the investigation in a non-negligent manner for the benefit of all parties. Even if we can establish a duty of the FAA/NTSB, is a breach of that duty actionable? It can never be said that a breach of the duty caused the accident, thus, we have a hard time arriving at damages.

It can be agreed however that the widow who had a cause of action at law but for the intervening negligence of the Investigator has been denied a cause of action. Denial of the cause of action may have a determinable value, say the reasonable settlement value of a similar lawsuit.

In Texas, an employee may not recover from his employer for damages for wrongful death money exceeding the existing amount specified for under the Workmen's Compensation Law. The employee is not, however, barred from suing a responsible third party for his wrongful death. The facts of the case are that the deceased fell from a structure on which he was working. He was seen to be wearing a safety belt as supplied by his employer and purchased from another company. After the accident his employer immediately destroyed the safety belt so as to preclude it ever being used again (Needless to say they destroyed evidence that the belt was faulty and had in fact failed). By destroying the evidence the employer ruined any chance that the widow had against the belt manufacturer. If this lawsuit is successful, it could have far reaching repercussions.

It is most obvious that if it can be shown that an investigator is accepting money or presents of any kind so as to change his determination of fact that this is both criminally actionable as well as actionable in civil court with respect to the payor, the payee and their companies.

The current Federal Statute that makes an investigator criminally liable is found in the Federal Aviation Act 1958. In paraphrase it says "any person who knowingly and without authority removes, conceals, or withholds any part of a civil aircraft involved in an accident or any property aboard such aircraft at the time of the accident shall be subject to a fine of $100 to $5,000 or to imprisonment for up to one year or both.

You argue that the reason to investigate an aircraft accident is to promote safety by labeling the cause and seeking ways to prevent follow on accidents. Further, you say perhaps that the law and certain lawyers have no interest in aviation safety and are only interested in collecting exhorbitant fees in often spurious law suits.

I submit that the accident prevention policies of the NTSB and FAA are not mutually exclusive from the results obtained by litigation lawyers trying aviation lawsuits. Do you believe for an instant that an A.D. requiring installation of shoulder harnesses was more instrumental in their intallation than the fact that manufacturers were being successfully litigated against in the area of survivability and crash-worthiness. I submit that current accident investigations tend to characterize each accident by giving it a label and then pigeon-holing it into a computer. After time we arrive at statistical trends that are meaningful and action can be taken. Often a major lawsuit gets faster results.

As early as 1961, it was noted that gust locks on certain commuter airplanes were being mutilated and only parts of them were being utilized. In January, 1969, John Reed, the Chairman of the NTSB, issued a strong letter urging the FAA take action against commuters who were using partial gust lock pins. The letter quotes a survey showing that improper gust pins were utilized by a majority of the commuters flying out of Washington National Airport and O'Hare Airport. Nothing was done and in 1972, there was a fiery crash at Scholes Field, Galveston, Texas, in which an improper gust lock was still in use by a commuter airline. Under Part 135, the FAA had the duty to inspect commuter airlines daily operations.

In another instance, a FAA flight surgeon ordered blood drawn from a dying pilot. Without consent of the wife, the unconscious pilot, or any attending physician, he ordered blood drawn wrongly relying on supposed authority that cannot be found in U.S. Codes. He did not ascertain what treatments had been accomplished before he arrived in the emergency room, and he himself did not obtain the blood. Instead, he ordered a nurse to take the blood. She utilized a swabe of 70% isopropyl alchohol to swab the skin previous to inserting the needle.

Immediately previous to the insertion of this needle, a blood technician had taken other blood and had swabbed the arm liberally with 70% isopropyl alcohol. Then the FAA doctor turned the blood sample over to a police lab that utilized a crude Di Chromate precipitation test that could not differentiate between Methyl or Isopropyl alcohol. The original NTSB report reflected a blood alcohol reading in the final report.

This reading presumes the consumption of alcohol before flying and could have effected the widow's recovery as well as any lawsuit levied against her husband's estate as well as any insurance claims.

The FAA doctor (investigator) certainly botched the investigation. He committed among other things trespass on the person. While the NTSB has statutory ability to conduct autopsy and toxicological examinations on the deceased there is <u>no</u> legal provision or authorizing statute for violation of the living to draw blood. He had the blood drawn in a negligent manner, had it tested in a negligent manner and when he published the erroneous findings he defamed the pilot. In the case at hand he also as a doctor may have committed malpractice.

The point is in this instance a botched investigation could have had major legal implications. In the case at hand, a recovery could have been prejudiced and in fact, perhaps a pilot was defamed, by an investigator that apparently didn't know that you use soap and water or phisohex as a preparation when you correctly draw a blood alcohol sample.

In another investigation, an investigator states probable cause pilot error in the crash of a fuel injected light aircraft into a large field. The pilot, a CFI, had a student who required High Altitude Simulated Emergency work and the airplane was found in a configuration that in an expert's opinion would be that the airplane was in fact conducting just such a practice. The report goes on to state that the investigator removed the cover to the injector and moved the diagphram and in so doing, fuel squirted out. This apparently meant to the investigator that there was no problem with the fuel to the injector. In talking with a civilian engineering representative to VT-1, a squadron of Navy fuel injected training aircraft he mentioned that one problem area was in simulated High Altitude emergencies that the diagphram closes allowing only metered idle fuel through an orifice. That the diagphram and associated valve sticks shut, and upon application of go around power, the engine remains at idle or fails due to lean mixture.

Thus, usually ground impact frees the stuck valve. Occasionally, the Navy has found them stuck. Thus, by moving the diagphram to see if there was fuel, the investigator did precisely the wrong thing. He may have moved the position of the diagphram and associated valve and forever destroyed the evidence of the real cause of the accident. Notably, there is no pigeon-hole in any FAA computer for this failure/malfunction as it is extremely hard to catch.

In another case, an NTSB report shows cause unknown - probable pilot disorientation/error when an airplane knocks down a hundred yards of scrub oak while wings level at high speed while crashing into a very inaccessible swamp. The investigator photographed the altimeter and states it said 2500 feet while it actually reads 11,650 feet perfectly on all three pointers and the 18,000 feet altitude flag marker. The glass is intact except for a small area in the bottom right hand side that is missing. Moreover, the photo shows a chip of glass imbedded under the glass at the 6:00 o'clock position. Logically, this precludes the big hand from making one revolution since the glass was imbedded there. The investigator took no stock in the stuck reading. The investigator, after photographing the aircraft, left the altimeter in the swamp. It has not been recovered. Since that time, the FAA has issued an A.D. covering altimeters utilized in many General Aviation airplanes that have a teflon bearing that can clog the gear train of the altimeter causing it to stick at altitude. I am not saying that this was the case at hand. What I am saying is that the evidence was left in the swamp, and the pigeon-hole that was chosen was probable cause pilot error.

We, as accident investigators, owe the public more than veracity, integrity, inquisitiveness, and the promotion of aviation safety. We owe them the highest standard of care commensurate with the title air safety investigator not to make mistakes, not to expedite an investigation into its convenient cubby hole, not to make snap judgments and to preserve those parts that form up the relevant evidence upon which your conclusions of fact are formed.

Had the medical profession cleaned its own house years ago, by enforcing the standards and policing itself of its incompetence, rather than stonewalling behind a conspiracy of silence, there probably would be no great malpractice problem in medicine today. Note that the problem had to be of such magnitude that doctors finally sick of the AMA and the conspiracy of silence were finally willing to speak out and testify against their own incompetence.

I hope that the standards within the air safety investigators of the world remains so high, and that in the search for truth, inquisitiveness, veracity, and persistence are rewarded, so that no client and attorney feel compelled to run a lawsuit against an air safety investigator up the proverbial flagpole in hopes some Federal Judge will salute.

A NEW DENTAL IDENTIFICATION DEVICE

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High priority is given to identification and preservation of human remains following fatal aircraft disasters. Good management for successful and thorough investigation stresses organization, careful procedures, rapid action and experienced identification experts, including dentists. Appendix 9 of the I.C.A.O. Manual of Aircraft Accident Investigation contains a Summary of Identification Methods based on visual, circumstantial and specific evidence. The role of dental evidence in resolving identifications is illustrated in Table I, where almost half of the difficult identifications were resolved by dental evidence.

The method of dental identification used in all cases is the only one[1] in use today -- the AM-PM Record Comparison method. It is a successful method but it has many limitations or drawbacks as shown in Table II.

Most of the limitations arise in assembling, comparing and confirming the assorted components of dental evidence. A system of identification based on a ceramic personal identifier, recoverable as prima facie evidence of a victim's identity appears near and could make most other forms of evidence secondary in importance but still very necessary.

A new dental identification device which is radiographically detectable, relatively indestructible, and which can easily be placed in selected teeth incidental to regular restorative treatment may simplify and speed the identification of mutilated humans who cannot be identified by any other means.

The widespread utilization of this identification device would simplify identification procedures and provide a useful adjunct to the existing AM-PM Record Comparison method. The device is relatively low cost; requires virtually no new training for the dentist, no new dental materials or manufacturing technology; and is readily adaptable to rapid, widespread application. It has been referred to as a "breakthrough",[5] a "fresh idea",[6] and "a useful adjunct to forensic odontology".[7]

The device (Figure I) consists of a ceramic personal identifier that can be easily placed sub-restorative, incidental to regular dental restorative procedures with the inclusion of a specially-characterized .027, 18-8 stainless steel or silver-plated brass pin, termed a Radiographic Disclosure Pin, which when viewed in an X-ray would signify the presence of an identifier in that tooth. The pin is a necessary component of the system as the identifier, in most instances, would be obscured by the metallic restoration. The pin must necessarily be placed and checked with X-ray following insertion to establish that it will be visible in subsequent dental X-rays; perhaps years later if needed.

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* Philip Samis is in private dental practice and is the inventor of the identification device described in this paper.

The identifier is composed of alumina substrate carrying intelligence recorded in a microminiature mode and is relatively indestructible in relation to teeth, which are incinerated at 1,000°F - 1,100°F. The identifier has survived repeated test firing to 1,650°F.

The dental technique is simple. No new expensive equipment or training is required of the general dentist. The pins and identifier can be mass-produced and are inexpensive. The device appreas to eliminate or minimize many of the limitations of the AM-PM Record Comparison method. This new device for dental identification appears to combine steps 2 and 3 into one simple step and is void of any major limitations (Figure II). The identifier is, in fact, a combined AM-PM record located in the most sheltered area of the least destructible of human tissue; namely teeth.

The Dentify* device as the basis for a new system of dental identification, whem compared to the AM-PM Record Comparison method, appears to have the following favourable advantages:

1. inexpensive,
2. minimal labour content,
3. combines steps 2 and 3 at PM and eliminates step 4 at PM,
4. no central repository of records necessary,
5. no updating of records,
6. no need to locate the victim's dentist,
7. no new major expense for immediate application and expansion on a National or International basis.

At postmortem with this device, assuming adequate preparation of the jaws, radiographs would be taken and processed immediately. If an R.D.P. was viewed in any of the radiographs, recovery of the identifier by one of the following methods would begin immediately:

1. Excavate indicated tooth with dental drill and locate identifier. Read under magnification and corpse is identified.
2. Remove tooth and incinerate; recover identifier from ashes; read under magnification giving corpse identity.
3. Remove tooth and crush; identifier readily found and readable under magnification.

The durability and integrity of the restoration would be the main limiting factor in the usefulness and undisrupted retention of the dental identifier in the selected teeth in the antemortem context. Amalgams and crowns have a usefulness of several years. Postmortem limitations would result and the identifier lost in cases of virtually complete incineration or loss of the teeth from the sockets of certain victims.

High-heat laboratory tests have proved the relative indestructibility of the ceramic identifier to 980°C (1,650°F) when placed under amalgam or other fillings in extracted human teeth. Amalgam restorations are recovered and useful in identification after temperatures of 1,024°C.[8] The clinical application of the device to humans is simply and quickly done. A clinical study with a group of 50 volunteers observed the following criteria:

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* Dentify is a registered tradename in Canada and the United States with patents pending world-wide.

1. Identifiers were placed incidental to regular treatment. That is, the teeth had to be filled or restored because of decay and the identifier and pin were included. The teeth were not cut just to accept a chip and pin.

2. Only posterior upper and lower teeth were utilized as these are the teeth most often preserved in high-heat or high-impact accidents.

3. One-tooth placement in two quadrants was accepted as an economic and adequate application to assure identification with one-tooth placement either bi-maxillary or one-tooth placement in the maxilla contralateral to mandibular one-tooth placement.

Figure III depicts the various combinations depending on the presence of utilizable teeth. A, B, and C are considered most suitable in terms of time, cost and long-term retention in the mouth. A1 and A2 would provide very little advantage over A in that the mandible is often lost in skeletonizing situations. D is a one-tooth, four-quadrant placement and might be applicable to combat troops, certain flight personnel or persons in hazardous industries.

Recovery of the identifier at an accident would require only slight changes in present procedures. Unidentified victims would be dentally X-rayed as a first procedure in the dental examination. If a Radiographic Disclosure Pin were visible in X-ray, that would signal the presence of a ceramic identifier and identity could be resolved by recovery of the chips and reading the data under 10 x 20x magnification. Light, readily-portable, conventional X-ray units are available for field work. Pen-sized devices with I^{125} or Thulium as a source of radiation have been used for dental radiography[9, 10] and might be readily adaptable to this purpose and incorporated as another component of an identification system based on a series of devices instead of record comparison.

The current AM-PM Record Comparison system is being improved by planned use of the computer for storage of AM data and later recall and comparison in the PM situation. Figure IV depicts the AM-PM Record Comparison system with a computer data base.

Where a centralized system of record storage exists (FAA), or if it is considered necessary, placement of an alpha-numeric code on the identifier (see Figure I) to serve as a designate or computer retrieval code would be advantageous (Figure V). A suitable designation system would have the following benefits:

1. Identify the chip manufacturer.

2. Provide for third party information (who ordered or requested identity chip: military, insurance company, airline, etc.).

3. The full designate can retrieve from a computer all personal information for verification of the identification of the victim.

4. The designate would help to prevent fraud and counterfeiting of the identity chips for illegal or criminal purposes.

5. The code is designed in such a way as to permit coverage of a vast number of people.

A sample code system might consist of a one-line alpha-numeric arrangement in addition to the uncoded name, social security number and citizenship, as well as the data base location and year of manufacture. The coded line could be an 8 or 9 digit computer retrieval key used as in Figure V to obtain a readout or printout for confirmation of identification already obtained in the field.

The placement of ceramic identifiers under dental restorations as a routine measure would greatly simplify identification in severe mutilating accidents. The placement of uncoded information which is readable under 10 x 20x magnification enables immediate identification when the chip is recovered. Addition of a designate code with a computer retrieval code or key adapts the device to a centralized computer record system. The possible use of light, portable, X-radiation sources in the field suggests the eventual development of an identification system with considerable advantages over the presently-used AM-PM Record Comparison method.

The identifying device has been laboratory-tested for destructibility under high heat. The recovery methods have resulted in all chips being recovered in fully-readable condition. The clinical problems are minute. The placement of a pin in a tooth concerns some dentists but, generally, is of no concern to most dentists in that it is a simple procedure repeated many times per week as part of routine dental restoration of damaged teeth. Pins are widely used in dentistry as is 18-8 stainless steel. The ceramic substrate material, Al_2O_3, is a commercial material widely used in electronics and is superior to certain dental materials, particularly in regard to thermal expansion (Table III) which was the physical property of major concern because of the internal placement of the chip.

Other research studies of the Dentify device are being encouraged. Certification of the device under new Federal regulations concerning sale of medical or dental devices which became effective April 1, 1976 in Canada has been initiated.

Widespread application would certainly simplify identification by providing rapid, time-saving and relatively easy prospective identification with beneficial accident investigation and management aspects in all severe, mutilating, mass disasters.

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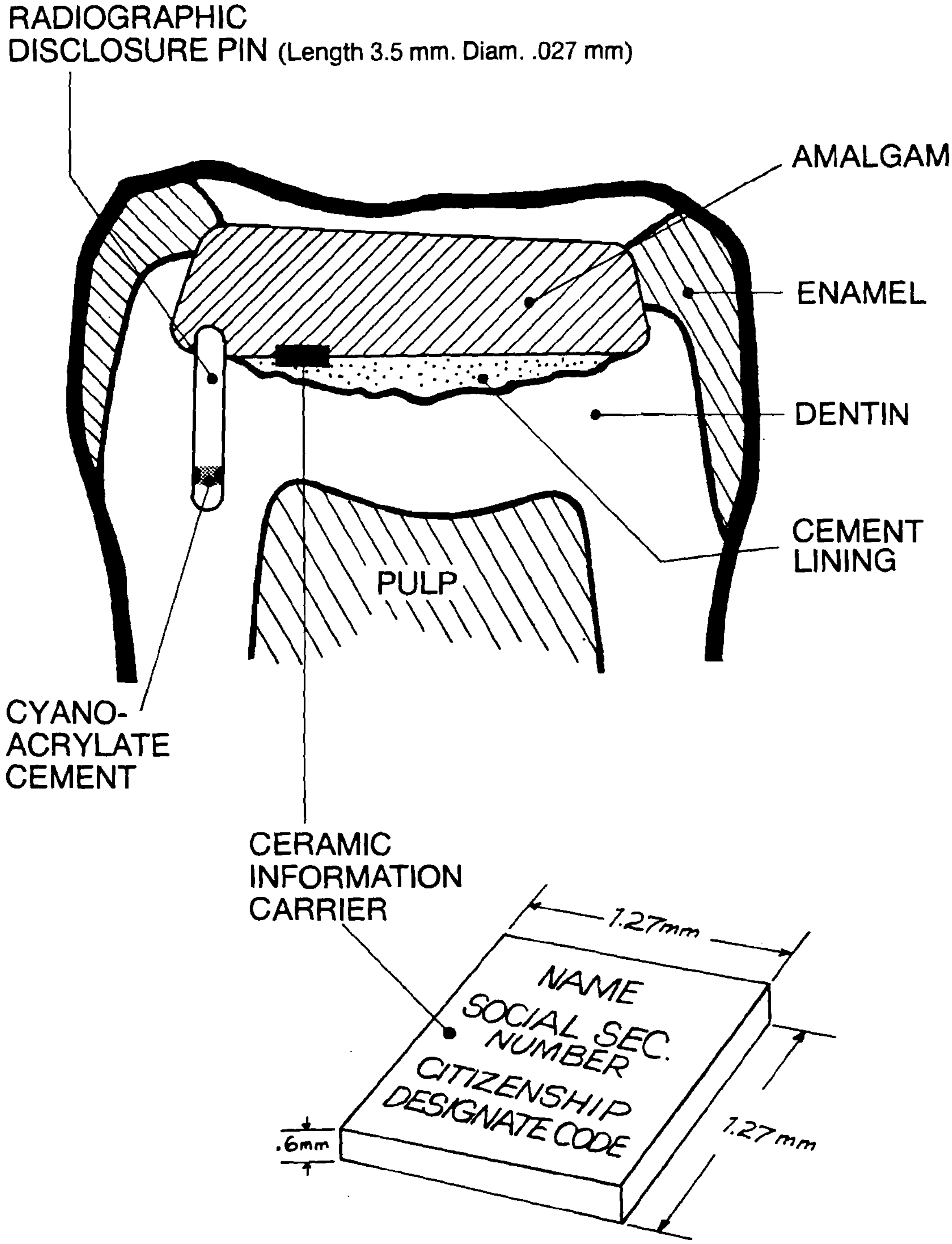
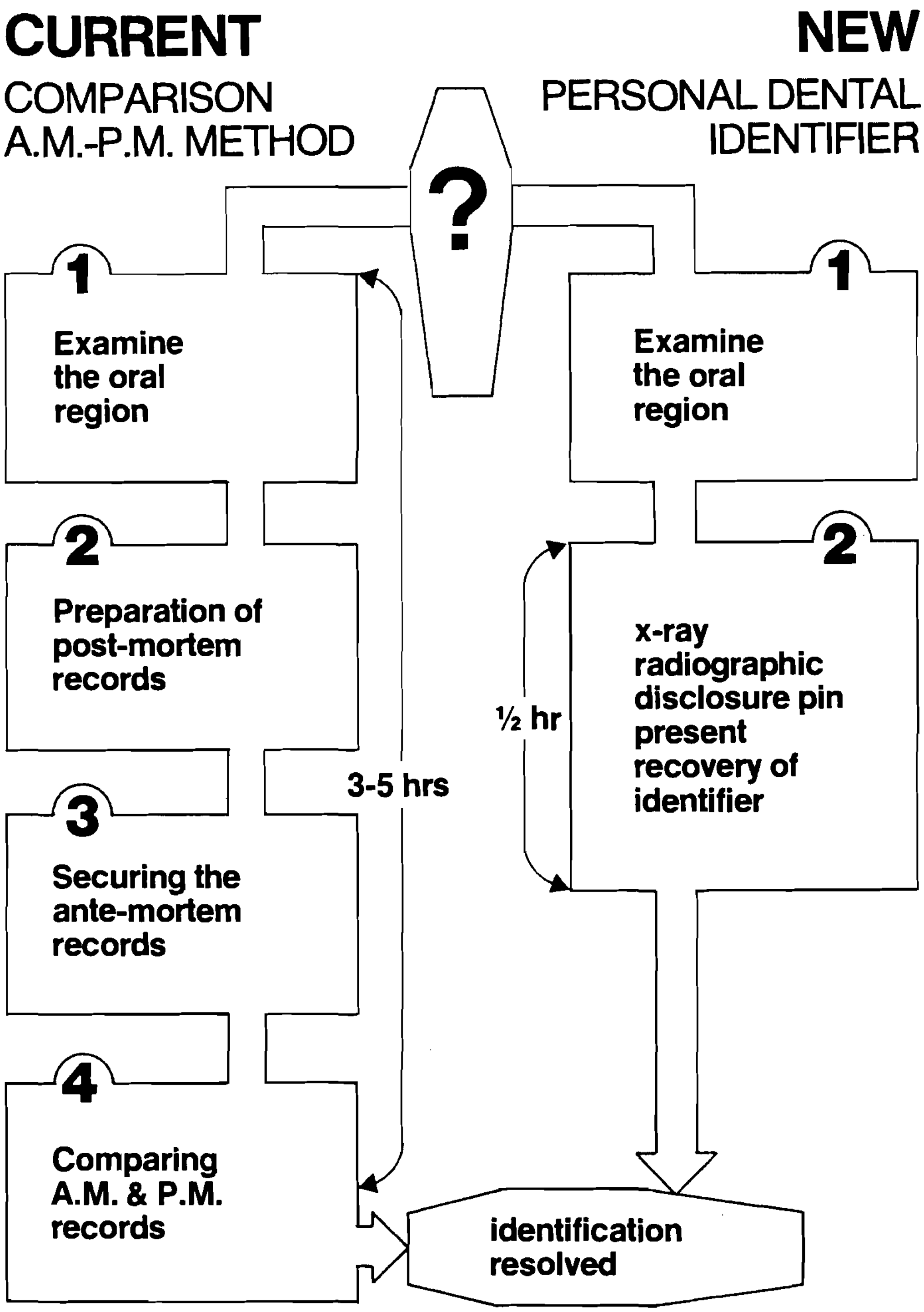


RADIOGRAPHIC
DISCLOSURE PIN (Length 3.5 mm. Diam. .027 mm)
AMALGAM
ENAMEL
DENTIN
CEMENT
LINING
PULP
CYANO-
ACRYLATE
CEMENT
CERAMIC
INFORMATION
CARRIER
1.27mm
NAME
SOCIAL SEC.
NUMBER
CITIZENSHIP
DESIGNATE CODE
.6mm
1.27mm

FIGURE ONE



The time estimate given to the AM-PM comparison system is based on . . . five man hours per body . . . not including time required for forwarding of AM records. In certain situations it is probably much more than five hours. In the article by Kogan, Petersen, Locke, Petersen, & Ball, concerning the Woodbridge disaster, seventy-nine identifications were performed in 492 hours for an average of 6.22 man hours per identification.

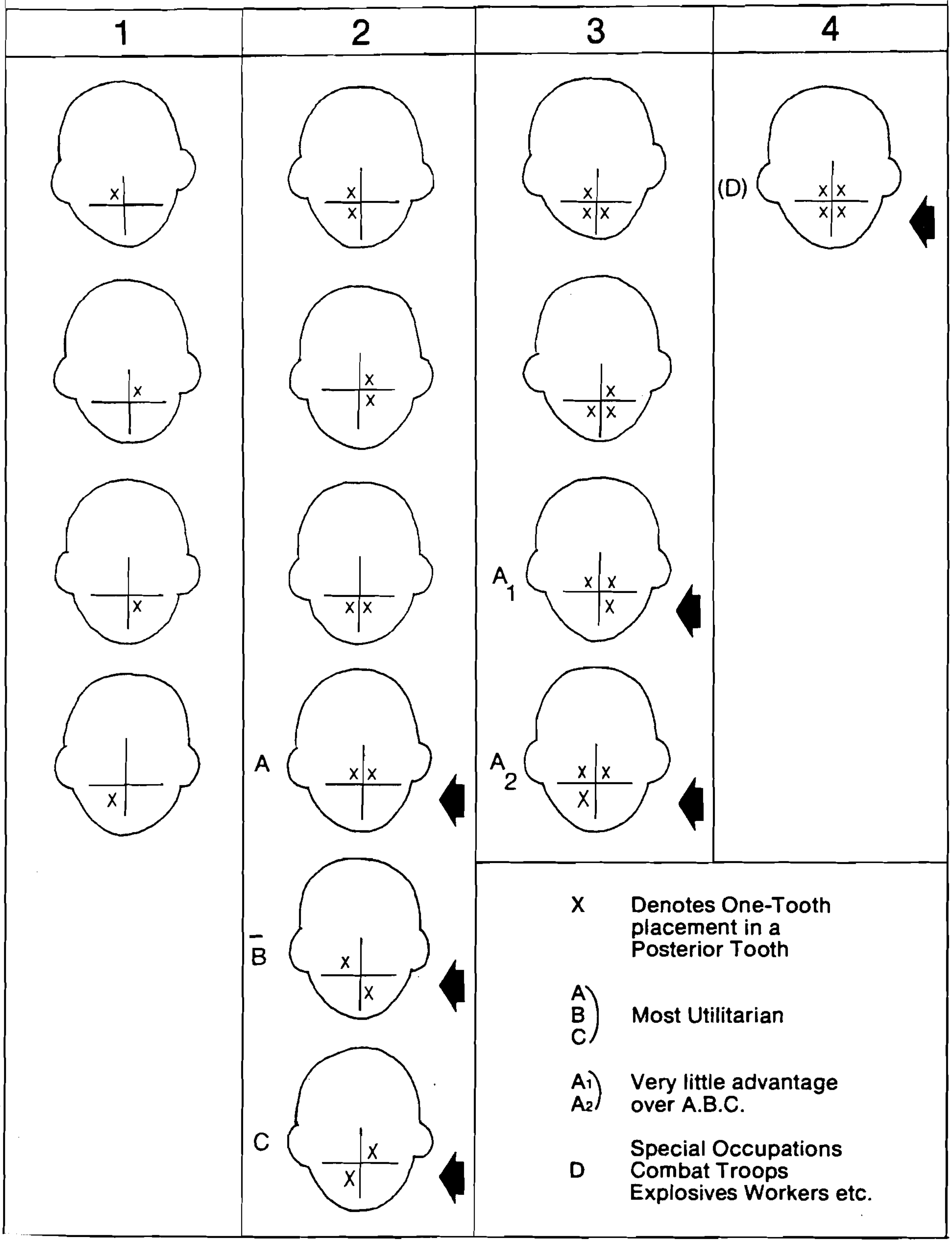
The time estimate given to step 2 of the new system is based on laboratory tests using high-speed x-rays with fixer and developer attached, and incinerating extracted human teeth to recover and read the identifier.

(1975 Year Book of Dentistry, Hotel Fire, Dental Identification Aspects; pg. 521-2.)

FIGURE TWO

POSSIBLE COMBINATIONS DEPENDING ON PRESENCE OF UTILIZABLE TEETH

Number of Quadrants



THE COMPUTER IN THE AM-PM RECORD COMPARISON SYSTEM

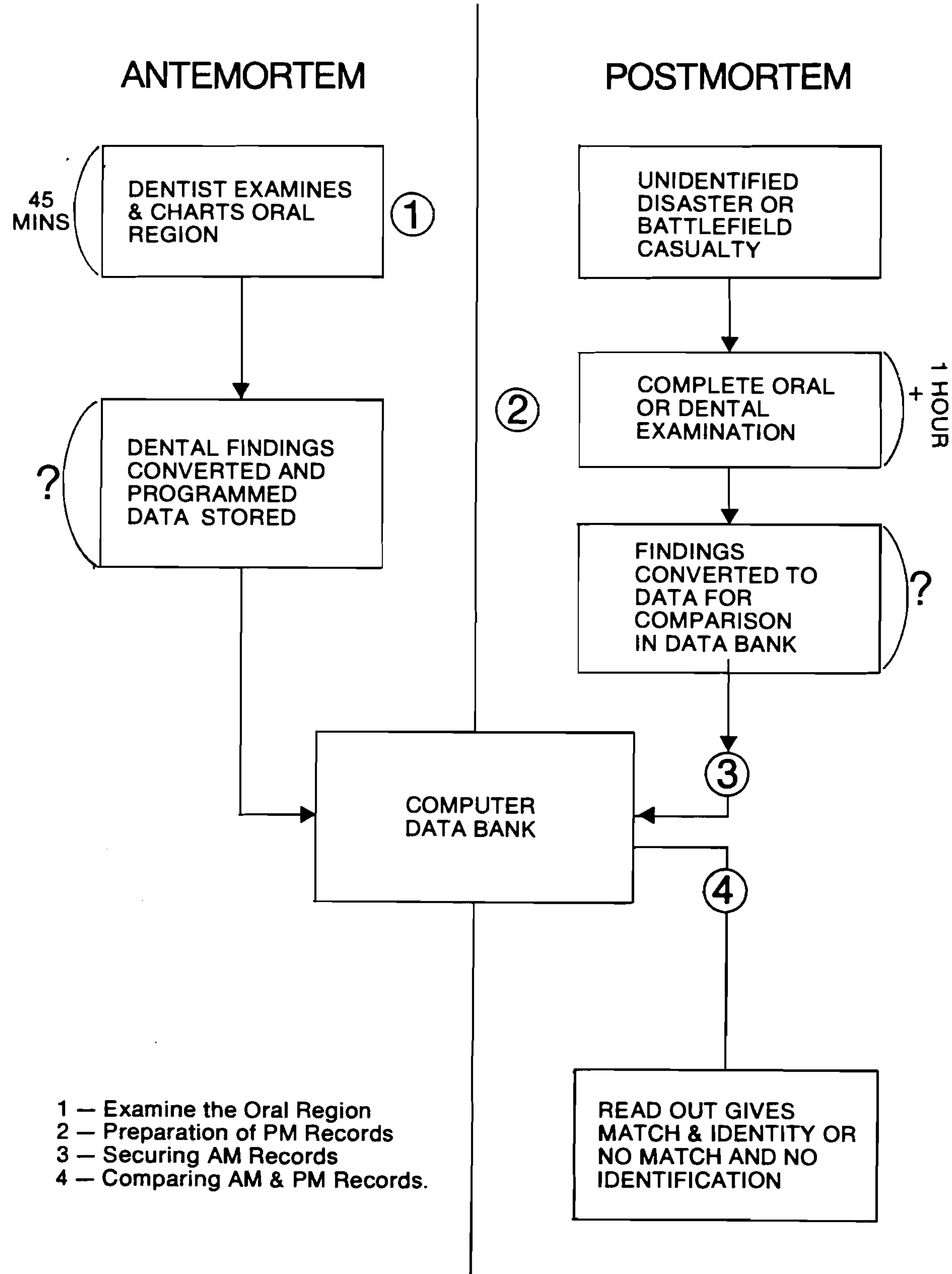


FIG. FOUR

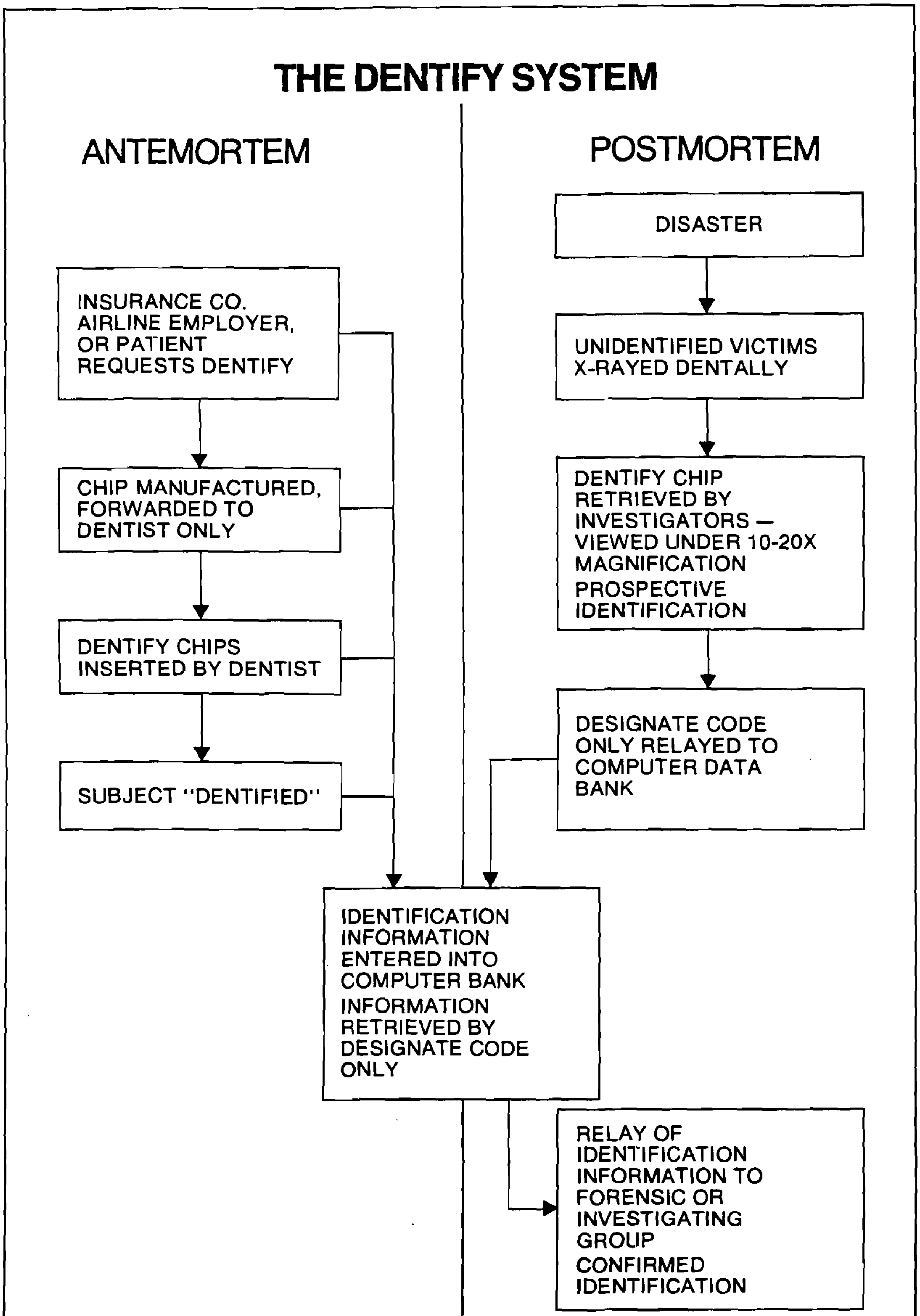

THE DENTIFY SYSTEM
ANTEMORTEM
POSTMORTEM
INSURANCE CO. AIRLINE EMPLOYER, OR PATIENT REQUESTS DENTIFY
CHIP MANUFACTURED, FORWARDED TO DENTIST ONLY
DENTIFY CHIPS INSERTED BY DENTIST
SUBJECT "DENTIFIED"
DISASTER
UNIDENTIFIED VICTIMS X-RAYED DENTALLY
DENTIFY CHIP RETRIEVED BY INVESTIGATORS — VIEWED UNDER 10-20X MAGNIFICATION
PROSPECTIVE IDENTIFICATION
DESIGNATE CODE ONLY RELAYED TO COMPUTER DATA BANK
IDENTIFICATION INFORMATION ENTERED INTO COMPUTER BANK
INFORMATION RETRIEVED BY DESIGNATE CODE ONLY
RELAY OF IDENTIFICATION INFORMATION TO FORENSIC OR INVESTIGATING GROUP
CONFIRMED IDENTIFICATION

FIG. FIVE

MEANS OF IDENTIFICATION IN

THIRTEEN FATAL PUBLIC TRANSPORT ACCIDENTS

JOURNAL OF THE IRISH DENTAL ASSOCIATION

MARCH-APRIL 1974; VOL. 20, NO. 2, M. MIDDA

Victims Identified 577

Unidentified 28

Total 605

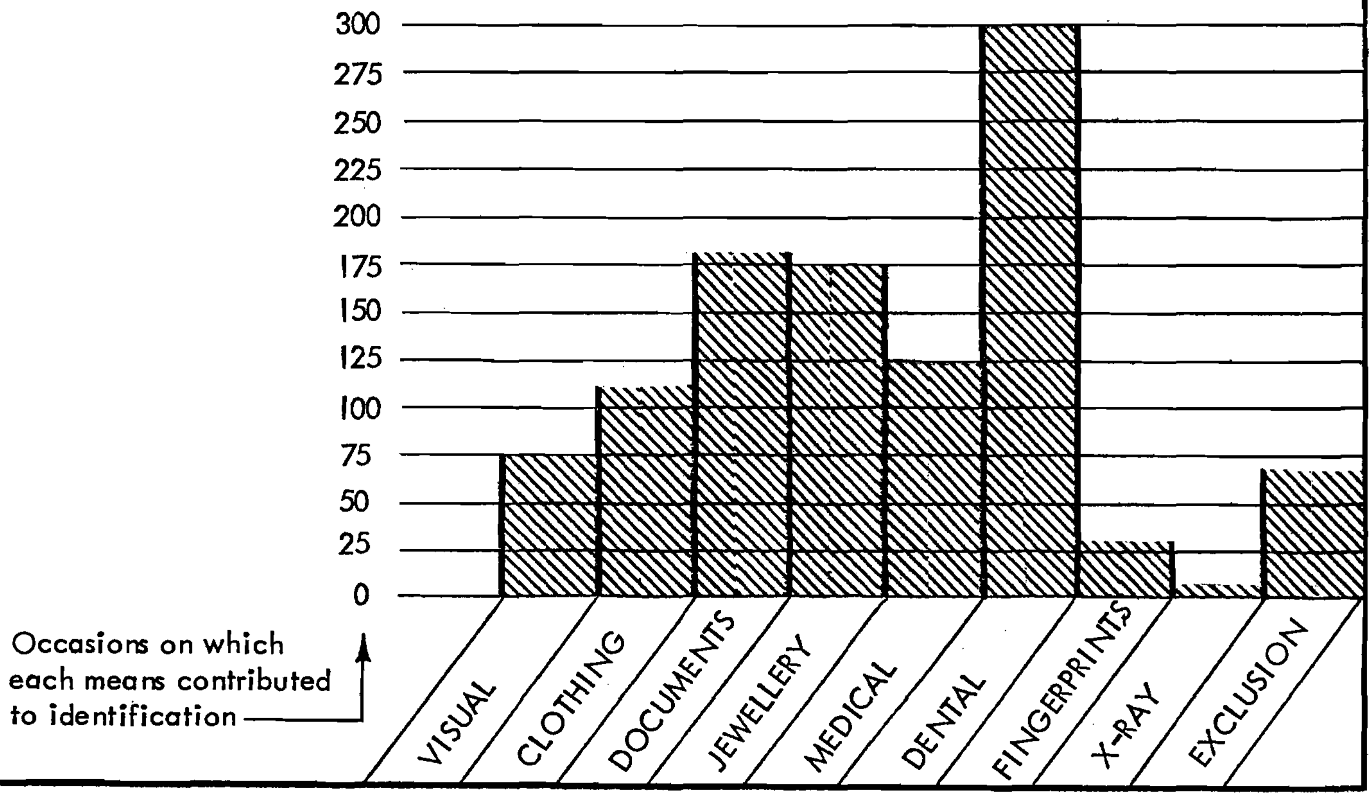


TABLE I

THE AM-PM RECORD COMPARISON SYSTEM - LIMITATIONS

1. EXAMINING THE ORAL REGION:	a) it is time consuming or labour intensive. b) the forensic dentist is often not utilized quickly enough to prevent loss or damage of useful evidence. c) there is a shortage of dentists trained in forensic attitudes and disciplines. d) there is a shortage of training courses. e) often a grisly, nauseating, possibly dangerous task. f) special kits and portable equipment may not be readily available.
2. PREPARING POSTMORTEM RECORDS:	a) a lengthy, and often difficult procedure or, b) only minor fragments may be available.
3. SECURING ANTEMORTEM RECORDS: This step appears to be the major bottleneck in the AM-PM comparison system for the following major reasons:	a) there is a multiplicity of charting systems, and adoption of a universal system appears to be well in the future. b) locating AM records may be difficult or impossible (patients move, dentists die). c) AM records are often incomplete. The average dentist does not record restorations in situ on new patients. d) dental records may not be up to date, and are often inaccurate. e) transmission of the AM data may be time consuming, costly, and require a skilled person or operator.[2] f) mobility of people in Western World generally, frequent change of jobs, residence, and even citizenship, consequently adds to the difficulty of having an up to date, locatable AM dental record.
4. COMPARING AM-PM RECORDS:	This step appears to have the fewest drawbacks, as new tools, particularly computers, have been studied in this application and found to be promising.[3,4] The computer as a tool would appear to be an expensive and labour-intensive item in that additional skilled personnel are required to make it a workable feature.

TABLE TWO

PROPERTIES & COMPOSITION OF CERAMIC SUBSTRATE

PROPERTY	UNIT	A dense 96% Al_2O_3	A dense 99.5% Al_2O_3
Water Absorption	%	0	0
Specific Gravity		3.70	3.89
Hardness	Rockwell 45N	78	80
Flexural Strength**	lbs. per sq. in.	50,000	60,000
Thermal Expansion Linear Coefficient Per °C	25—300°C. 25—700°C. 25—900°C.	6.4×10^{-6} 7.5×10^{-6} 7.9×10^{-6}	6.0×10^{-6} 7.5×10^{-6} 8.3×10^{-6}

	MATERIAL	LINEAR COEFFICIENT OF EXPANSION (mm mm °C.$\times 10^{-6}$)
Linear Coefficients of Thermal Expansion of Some Important Dental Materials*	Tooth (across crown)	11.4
	Silicate cement	7.6
	Dental amalgam	25.0
	Porcelain	4.1
	Dental resin [poly(methyl methacrylate)]	81.0

*From Souder and Paffenbarger, *Physical Properties of Dental Materials.* National Bureau of Standards Circular C433.

TABLE THREE

INTER-MODAL ACCIDENT INVESTIGATION MANAGEMENT AND TECHNIQUES

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INTRODUCTION

Members of the Society of Air Safety Investigators might seem to have cornered the aircraft accident investigation expertise, or have we? Examination shows us to be weak in these areas:

1. We have not shared our expertise among ourselves very well.
2. We have not taken advantage of the expertise possessed by specialists in other types of investigations, and
3. We have not done a very good job of sharing our expertise with those outside of aviation.

Our book shelves at home and office have the same standard references or texts on aircraft accident investigation. One cannot help but be aware that they are somewhat limited in number, content, and scope.

When all is said and done, we end up with the ICAO Manual and a government publication or two. Now and then we run across something like General Electric's "Jet Engine Accident Investigation" or Harry Hurt's "Aircraft and Missile Structures." When people like Carol Roberts, Jerry Bruggink and Ludwig Benner, all of NTSB, W. J. Quinlivan of Lockheed, Dave Holiday of Los Angeles, Jerry Lederer, and a few others come up with some original thinking or innovative approaches, the best we can usually hope for is a paper or maybe a journal article. The chances of it becoming part of the widely recognized and readily available literature is slight. We don't make good use of the knowledge we already have.

There is another problem. As prima-donnas of the investigation world we sometimes tend to view other accident investigators from a lofty perch, casually appraising their activities, not seeing the connection with aviation and seldom taking them seriously. I bring you news from down there where the routine day-to-day investigation of accidents is taking place. They are doing great. They have sound ideas and could tell us a lot about accident investigation. Their innovative successes could often be directly applied to aviation. The fact is we could learn a lot about aircraft accident investigation from people who don't know anything about airplanes. We could significantly improve our sophisticated aircraft accident investigative skills through knowing the techniques of other specialized investigation areas.

MATERIAL CONTRIBUTIONS

Some of the in-depth motor vehicle accident investigations offer possibilities. Last year at our Ottawa meeting we had two presentations by non-aviation types who specialized in vehicle accidents.

One presentation had to do with light bulb analysis. Although I heard several remarks concerning the fact that nothing new was presented, yet we cannot find in a single guide to aircraft accident investigation, the in-depth techniques and answers to light bulb analysis as complete as that presented from outside our field. That research and technique is now documented and in our seminar proceedings for last year.

Another item from the outside which received the old "not invented here" reception was the presentation designed to show who was at the controls of a vehicle when the crash occurred. How many times have we wondered who was actually flying? In some cases we have been at a loss to know who was in which seat in the cockpit. The technique presented last year, also from the outside, would often settle that question.

The skill of those who specialize in other types of accidents is often directly transferable to aircraft accidents. Several examples can be cited.

The investigation techniques of the skilled railroad accident investigator can have a direct application to aircraft accident investigation. Some of the better aerial photographs seen of accident sites concern railroad accidents. Could it be that we in aviation can learn from the railroad people about aerial photos? We could learn something.

The techniques of the marine, the pipeline, the consumer product, and the mining accident investigator can also be applied to aviation. Take the case of the fire investigator for example:

I have yet to see an aircraft accident investigation manual which tells us how to go through the various levels of fire debris and make determinations. Yet this is an elementary step for the fire investigator. The expert fire investigator's arson probing techniques not only provide us with the knowledge seldom used in aircraft fire investigation, but with organized systematic approaches for doing so.

Detailed investigation of underground fuel and natural gas line accidents have brought environmental deterioration factors to light that we do not ordinarily deal with, but never-the-less can be applied to our kind of accident investigation.

Understanding how a marine accident investigator finds the facts on ships collisions or running aground can be applied directly to aircraft collisions and control system deficiencies. Most of us can see that the techniques of the marine accident investigator dealing with turbine failures can present us with ideas for dealing with aircraft turbine failures.

For years at my university, we have used films developed by the Bureau of Mines to teach the nature of fires and explosions for aircraft accident investigation. The techniques of tracing fire and explosion accidents through a mile deep shaft, 15 level mine can be of considerable value in working on a fire-explosion involved aircraft accident.

Incidentally, the next time you find yourself freezing at a mountainside accident site, you might consider yourself lucky compared to the mine accident investigator. He is likely to be as far underground as you are above sea level. In addition, with a dim head-lamp, he will probably have crawled on his hands and knees for ½ mile through water and debris to investigate a 3' high mine face, all of this while wearing a mask and with a tank on his back so he can breathe safely (I'll take the aircraft accident).

Thorough investigation of a motorcycle accident or even a bicycle accident will bring into play tire characteristics, center of gravity elements, and tire-surface interfaces that can far exceed our usual involvement with hydroplaning and skid coefficients.

Even the everyday industrial accident with its common grinding wheel disintegrations and lifting accidents gives knowledge directly transferable to the aircraft engine and cockpit.

We are an organization devoted to improvement of aircraft accident investigation through the exchange of information. It would appear that not only do we need to make available and exchange our own knowledge, but need a concentrated effort to bring in investigative knowledge from other fields.

ENVIRONMENTAL ASPECTS

So far, mostly the technological areas of investigation have been discussed. Similar remarks could be made about human factors and environmental aspects.

A couple of years ago while compiling an aircraft accident investigation bibliography, we found that 60% of the information researched in the area had been done by medical people. It would seem to point out that 60% of our problems are medical, or, that as investigators we do a poor job of researching and documentation. We could probably name, with difficulty, on our 10 fingers, the people in this room, in this group of experts, who have made significant contributions to accident investigation and then seen it validated and used by the profession. Often times our jobs, our situations, or our limitations, do not permit us to make these contributions. That may be, and it is all the more reason to look at the research and techniques that have developed in other investigative areas.

With our elaborate pre-accident planning, crash rescue plans, investigator kits and check lists on actions at the accident scene, there are still many things to be gained from investigation specialists outside of aviation.

Particularly in need of reinforcement and new knowledge is our ability to methodically examine all aspects of an accident. Perhaps the most organized technique for doing this is contained in the Accident/Incident Investigation Manual based on MORT (M-O-R-T). Yet, I dare say that with the exception of NTSB personnel, not more than 1 out of 10 people in this room can explain what MORT means. It stands for Management Oversight and Risk Tree, and has been in proven use as an investigation tool for 7 years. In modified form it is in everyday use by some of the National Transportation Safety Board Investigators. It came from outside of aviation.

We are proud of pointing out our multi-disciplinary approach to aircraft accident investigation in which we bring in specialists from different fields. Great, but in our zeal to be multi-disciplinary we sometimes forget to be, or are unable to be, interdisciplinary, that is to point out how the disciplines work with and interface with each other. For example most of us do not get very far into the management aspects of an accident, where a spade is really called a spade.

I refer you to the Energy Resources Development Administration where the requirement exists to have a committee or accident investigation board member with management expertise to actually determine how this area interplays with the other causes. Where else is it mandatory that not only do the management aspects of an accident get investigated, but where it is also mandatory for a management expert to participate in the investigation?

Just finding out about accidents, injuries and incidents can sometimes be a problem. Are you aware that our U. S. Consumer Product Safety Commission has a very special way of getting accident information? They use information sources you might expect, but in addition they operate the National Electronic Injury Surveillance System (NEISS) which monitors 119 hospital emergency rooms, nation-wide, for injuries associated with consumer products. Using this, and other information sources they operate an Injury Information Clearinghouse to decide which accidents they will investigate with a nation wide network of trained investigators. Incidentally, the public has guaranteed access to information collected by the clearinghouse and the research they carry out. We might not have much enthusiasm for investigating accidents involving toys and kitchen appliances, but the Commission did have the advantage of organizing their investigative effort without prior experience. As a result they have developed several innovative techniques.

Vehicle accidents are documented a million times a year all over

America, ten million times around the world. To assist the novice investigator, some simple techniques have been developed to assure clarity and accurateness of accident diagrams. Some of the ideas such as standard symbols and diagram sheets deserve consideration in helping the aircraft accident investigator present a clear concise diagram, that can be readily interpreted by any reviewer.

For many of us there comes a time when we must make recommendations for prevention of further similar accidents. Dr. Haddon, of the Insurance Institute for Highway Safety, years ago, gave us an item called Countermeasure Strategies, that has a practical application in making corrective recommendations. Once again, I would question that 1 out of 10 of us are familiar with the Haddon's ten strategies for reducing accidental loss.

CONCLUSIONS

I am not suggesting that the SASI ranks be opened to include investigators in other fields. However, we should not feel that we cannot significantly improve aircraft accident by learning from the other investigators who outnumber us 1000 to 1. They have knowledge and expertise that we may never acquire unless it is sought out and used.

We would be remiss in looking at what other investigators can do for us, without touching on what we can do for others. Not only do we have a responsibility to make use of the expertise of others in our field, but we have an obligation to make our knowledge available to them. Our proven techniques need to be documented and made available to others. How many of our experts, and most of us are experts, have dealt with, or written for automotive investigators, exchanged knowledge with marine or pipeline investigators, or met with local chapters of the Society of Safety Engineers? It is a two way street with benefits for all.

Let us upgrade aircraft accident investigation by absorbing the techniques of other investigators. Let us pass on our extensive know-how to other investigators by better exchange of information among ourselves.

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THE EPIDEMIOLOGY OF MILITARY AIR DISPLAY ACCIDENTS

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INTRODUCTION

Air displays have been popular throughout the world since the inception of aviation seventy years ago. The first Canadian military airshow accident occurred at what is now Canadian Forces Base Petawawa in August, 1909 when J.A.D. McCurdy and F.W. (Casey) Baldwin demolished the "Silver Dart" while conducting demonstration flights for the Department of the Militia "under most unfavourable conditions of terrain and wind".([9]) Since the late 1950s most Canadians have had the opportunity to see one or more of the three official aerobatic teams which performed for a total of nine years between 1959 and 1974. In addition to this, a solo aerobatic performance known as the Red Knight Programme was conducted from 1960 to 1969 inclusive.

Pilots involved in fatal accidents have been compared with a control group consisting of pilots who flew with and survived one or more years as an officially designated aerobatic pilot. This comparison is based on the assumption that aerobatic pilots have been selected from a common stock of available fighter pilots and that the selection criteria were the same both for fatally injured and survivor pilots.

In this paper the twenty fatal military airshow accidents occurring in the eighteen year period between 1 March, 1956 and 1 March, 1974, have been analyzed to identify epidemiological factors. The information is presented as a contribution to the continuance of effective and safer airshows.

MATERIALS AND METHODS

The proceedings of Boards of Inquiry into the twenty fatal accidents involving aircraft performing in an airshow or conducting authorized training for an airshow were reviewed. The twenty pilots sustaining fatal injuries were compared with a control group consisting of the thirty-six survivor pilots who flew for 55 man years with official Canadian military aerobatic teams during the period 1 January, 1959, to 31 December, 1973. Available data have been reviewed and subjected to statistical analysis.([7]) Characteristics of fatally injured and control pilots were compared using the Chi square test.

The underlying premise throughout the study has been that accidents are caused by human beings and not machines. Human failure in aircraft accidents can usually be assigned to one or more of the operations, maintenance or design phases([11]). This is an important distinction for it is only by the modification of human behaviour in whichever phase it occurs that future accidents can be prevented. The fatally injured pilots have been divided into "Designated" and "Non-Designated" aerobatic pilots where a "Designated" aerobatic pilot has been defined as:

> "A pilot who has been posted or attached to a unit for the primary and continuing purpose of conducting flying displays".

This differentiates designated pilots from those who were given special authorization to conduct one or more air displays or fly pasts in which the type and number of maneuver were normally specifically restricted.

RESULTS

Time of year

Figure 1 illustrates that May and June have the highest overall frequency of airshow accidents. There are, however, important differences between the distribution of accidents involving designated and non-designated aerobatic pilots. Eighteen per cent of fatal accidents involving designated pilots occurred in each of February, March and May but only nine per cent occurred in each of June and July which are the two months in which most shows are scheduled. On the other hand, sixty-six per cent of non-designated fatalities occurred in May and June with the remainder being distributed equally between March, July and September. There has never been a fatal air display accident in November, December, January or April in the years 1956 to 1974.

Only one designated aerobatic pilot has been killed in a properly authorized prebriefed airshow during the eighteen years from 1 March, 1956 to 1 March, 1974. All other airshow fatalities have occurred during training, during an unauthorized or spontaneous airshow, or have involved non-designated aerobatic pilots.

Time of Day

Nine out of twelve (or 75%) of actual airshow accidents occurred between 1500 and 1700 hours local. Two occurred between 1000 and 1200 hours and the remaining accident occurred at 2100 hours. This time pattern is consistent with the routine scheduling of airshows which usually start in the early afternoon and terminate between 1500 and 1700 hours. Six of the nine aircraft which crashed between 1500 and 1700 hours were flown by non-designated pilots and two of the three designated pilots were involved in deviations from authorized plans. The eight remaining accidents occurred in training and were distributed without any apparent pattern throughout the normal flying day. The pilots' flying time on the day of the accident was recorded in only twelve cases; however, of these eight or 75% occurred on the second flight of the day.

Pilot Age

In both fatal and control pilots, the age ranged from 23 to 37 years. The age distribution of the killed pilots was unimodal with 47% being 25 years of age. The control pilots had a bimodal distribution with peaks at ages 25 and 29 years; however, statistical analysis showed that the two groups could not be differentiated on the basis of age at the 90% level of confidence.

TABLE I

COMPARISON OF THE AGE CHARACTERISTICS OF CONTROL PILOTS AND FATALITIES

	Mean Age	Standard Deviation	Range
Control Pilots	28.29 yrs	3.18	14
Fatalities	27.16 yrs	3.58	14

$P > 0.10$

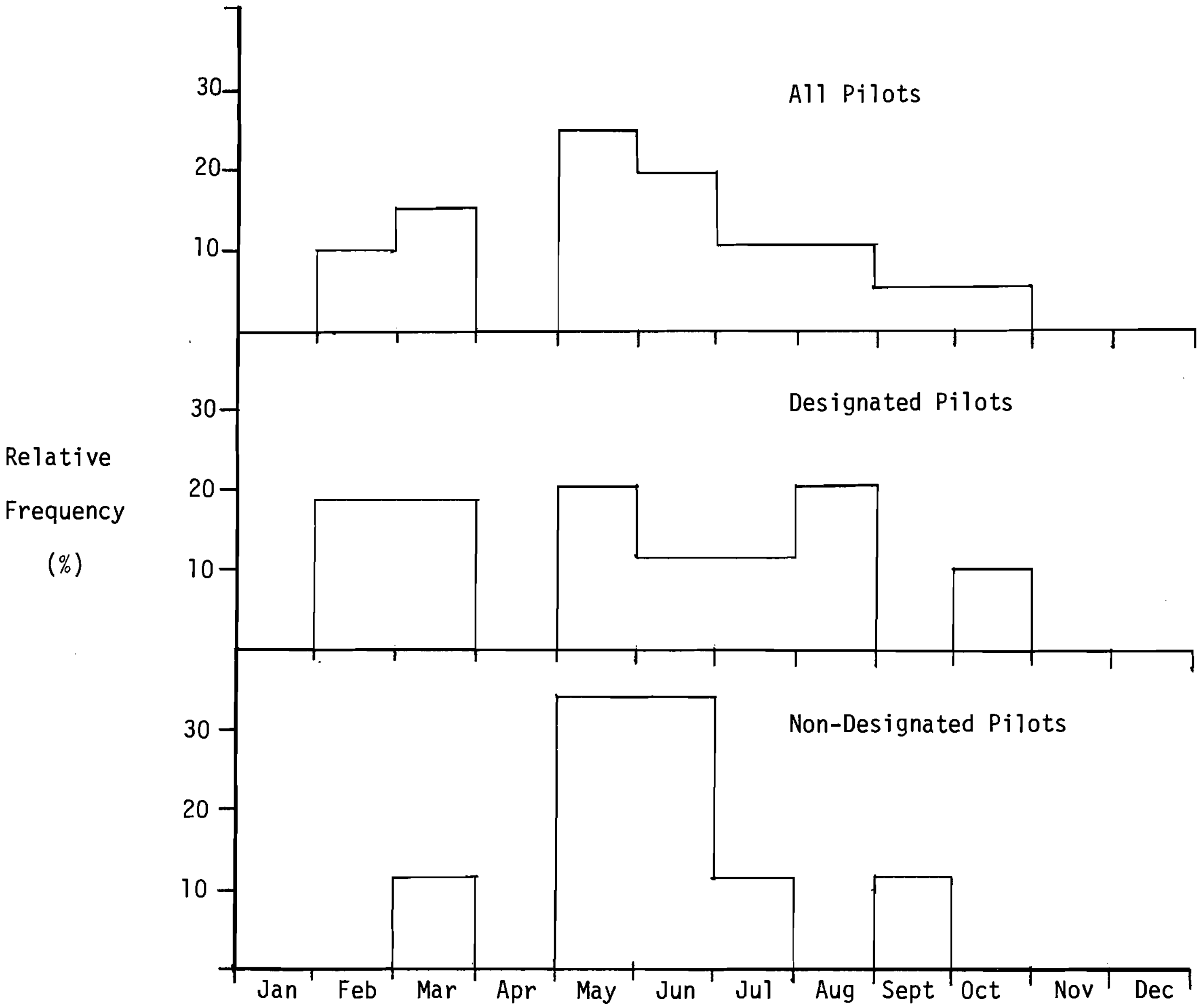

Fig. 1 Relative frequency of airshow accidents per calendar month for period 1956-73 inclusive

Marital Status

Table II shows a significant difference between the control and killed pilot groups. Eighty-seven per cent (87%) of the surviving pilots were married whereas 52% of the killed pilots were separated or single. The two pilots who were separated had lived separately for more than one year and had in effect resumed single status. Marital status was shown to be highly significant (P<0.001).

TABLE II

MARITAL STATUS OF CONTROL PILOTS AND FATALITIES

	Married		Single		Separated	
	No.	%	No.	%	No.	%
Control Pilots	48	87.3	7	12.7	Nil	-
Fatalities *	9	47.4	8	42.1	2	10.5

P 0.001

* In the case of one fatality there is no record of the marital status of the pilot concerned

Total Flying Time

Control pilots total flying time ranged from a minimum of 961 hours to a maximum of 4,726 hours. Killed pilots had a range from 641 hours to 5,495 hours. Only two of the killed pilots had a total time in excess of 2,500 hours. One of the two had 11.7 hours on type and the other was the most experienced aerobatic pilot in Canada at the time. Statistical analysis of the data revealed that there was a significant difference between the total flying times of the control and killed pilots. (P<0.01)

TABLE III

TOTAL FLIGHT TIME OF CONTROL PILOTS AND FATALITIES

	Mean	Standard Deviation
Control Pilots	2,738 hrs	766.3
Fatalities	2,014 hrs	1,069.6

P<0.01

Time on Type

Control pilots' time on type ranged from 30 to 2,217 hours whereas killed pilots ranged from 11.7 to 1,812 hours. Statistical analysis showed a significant difference between the two groups. ($P<.05$)

TABLE IV

TIME ON TYPE FOR CONTROL PILOTS AND FATALITIES

	Mean	Standard Deviation
Control Pilots	1,074	529.3
Fatalities	717	503.7

$P<0.05$

Time on Team

The ten fatally injured designated team members were killed at times ranging from nine days to seven months after joining the unit; however, seven of the ten were killed within 90 days of commencing training. The three pilots killed after the initial 90 day period were all involved in accidents which were caused by factors predominantly beyond their control.

Flight Time in Preceding 90 Days

The figures shown in Table V indicate that the fatally injured pilots had been flying fairly intensively prior to their accidents. Thirty-eight hours per month is a substantial but not an excessive workload for a fighter pilot.

TABLE V

AVERAGE FLIGHT TIME PRIOR TO DEATH FOR FATALLY INJURED PILOTS

	90 Days	30 Days	48 Hours
Fatalities	107 hrs	37.7 hrs	4.1 hrs

Deviation From Plan

The three non-training accidents which occurred outside the 1500 to 1700 hours time frame share a common factor of deviation from pre-arranged plans. One pilot was flying contrary to specific orders to remain on the ground. Very little is known about the flight except that the pilot had deviated from the original flight plan and had attempted a landing while considerably in excess of the maximum safe landing weight. In another case, the flight had been authorized at the local level; however, it was an unscheduled, hastily arranged and an ill-advised trip which terminated in a fatal crash at 2100 hours. Three of the nine pilots killed in an actual airshow between 1500 and 1700 hours were designated aerobatic pilots but two of three were involved in deviations from authorized plans. One aircraft was, together with the rest of the team, recovering from a spontaneous aerobatic display whilst another was performing improperly authorized co-ordinated aerobatics under marginal weather conditions.

Human Failure

Each accident has been completely reassessed in an attempt to isolate more definitely the human failure that caused the accident. The logical breakdown of human failure is into the operations, maintenance, and design phases. For the purpose of this study failure in the operations was subdivided into human failure in the cockpit (HFC) and human failure in supervision (HFS). This latter category includes both immediate supervision and supervision at higher levels. Human failure maintenance (HFM) and human failure design (HFD) are self-explanatory. A fourth category, human failure - other (HFO) has been added to include factors such as the responsibility of air traffic control and the second pilot involved in a crash which occurred in 1959. In only four of the twenty accidents has cause been assigned totally to one area of human failure in that three were assessed 100% HFC and one was assessed 100% HFM.

Table VI shows the assessed cause factors for the period 1956 to 1974 and compares them with the experience of the years 1967 to 1974. There was an incremental decrease in accidents caused by HFC and HFS with an increase in those caused by HFD. These changes are not statistically significant.

TABLE VI

CAUSE FACTOR OF CANADIAN MILITARY AIRSHOW ACCIDENTS FOR THE PERIOD 1956-1974 INCLUSIVE

	1956-73	1967-74
Human Failure Cockpit	49.5%	47.5%
Human Failure Supervision	32.5%	29.3%
Human Failure Maintenance	7.5%	6.7%
Human Failure Design	8.5%	13.3%
Human Failure Other	2.0%	3.2%

DISCUSSION

Half of all airshow fatalities involved non-designated pilots. There is not sufficient information available to calculate exposure rates; however, designated pilots normally perform 150 or more training and display shows per annum whereas non-designated pilots have often performed without any special workup and have seldom had more than 10 hours of training. This makes it very clear that properly trained designated pilots have a vastly higher probability of completing a particular airshow safely than a non-designated pilot.

Official aerobatic teams operated in 1956, 1959-63 inclusive, 1967 and 1972-74 inclusive and it is noted that six out of ten of the fatal accidents involving designated pilots occurred in the first year of operation of a team. The four remaining designated fatalities involved pilots who were in their first year with a team or the Red Knight Programme. There has been only one fatally injured designated pilot with more than one year's aerobatic experience. Even in this case the individual was flying on a new team in an aircraft which had substantially different design and flight characteristics from those in which he had previous aerobatic experience and the accident was caused by factors beyond his control.

The information presented indicates that non-designated pilots who are tasked to conduct an airshow or flypast are at a relatively high risk of becoming involved in a fatal accident. Designated pilots are at a much lesser but still appreciable risk during the first year of operation of a new aerobatic team and it is thought that this is caused by a break in the continuity of techniques and procedures used by a permanent team. Individuals joining an established team have a low risk of being killed and pilots flying for a second or third year with a permanent team appear to be at negligible risk.

Consideration of the data concerning time on team prior to death shows that designated pilots who have been killed usually died in training and 70% of the designated deaths occurred during the first 90 days with the team. None of the non-designated pilots died in training and the fact that these 10 fatalities all occurred in front of an audience is probably indicative of inadequate training.

Analysis of the personal information data on killed and control pilots has revealed significant and unexpected information. Contrary to widely held belief, pilot age in itself does not provide any significant protection against involvement in a fatal accident ([12]). In the past, team selectors have on occasion been chastized for selecting individuals in their early twenties as designated pilots. The data presented shows that young pilots are at no greater risk than their older counterparts if their flying experience is equivalent.

Aerobatic pilots who are married have a vastly reduced chance of being killed. ($P<0.001$). This variable is independent of flying experience. A factor significant at this level of confidence cannot be overlooked and when aerobatic pilots are being selected married personnel should be given preference over others when other factors are approximately equal.

Flight experience is also significant. Survivor pilots had more total time than their killed counterparts and this was statistically significant ($P<0.01$). Time on type appeared to be less important but was significant ($P<0.05$). Using the mean time and standard deviation of control pilots it can be calculated that 1,236 hours is the minimum safe total flight time a pilot should have before being considered for selection fo a team. A similar but less reliable calculation shows that no pilot with less than 36 hours on type should be considered for team selection. If these absolute minima had been observed, four (or 20%) of the accidents described would not have occurred. If the minimum figures had been increased to 2,000 and 100 hours respectively, only three of the pilots killed would have been eligible for team membership. Using the same criteria would have eliminated only six or 16.6% of the 36 survivors from eligibility.

Flight time prior to death indicates that all the pilots involved had been flying at a substantial but acceptable level. In this type of work each hour of flying time involves about another two hours of pre-flight preparation and post flight debriefing and admininstration. From this it may be seen that the killed pilots were averaging 26.75 hours of work per week directly related to flying. In addition to this, designated pilots were expected to make frequent radio and television appearances and otherwise make themselves available for public relations purposes whenever possible. The assigned work-load does not seem to have been inappropriate; however, there is a possibility that accumulated fatigue contributed to the increased accident rate observed in designated pilots in the month of August.

Deviation from pre-arranged and briefed plans was observed in 40% of the accidents. The magnitude of the deviation varied from a flight in which the pilot was strictly and specifically forbidden to fly to another case in which aerobatics were conducted in accordance with "Authorized Arrival Procedures". This resulted in a professional aerobatic team doing aerobatics in a circuit with other aircraft in the vicinity. The aerobatics were quite normal for the team but provided a sudden and unexpected hazard for other aircraft with the result that a fatal collision occurred. The fact that 40% of airshow accidents involved deviations from plan indicates that spontaneity is highly undesirable in the precise and unforgiving world of the aerobatic pilot.

The statistics regarding human failure are a cause for sombre reflection. It must be recognized that these are based solely on the authors' thorough re-evaluation of each Board of Inquiry in an attempt to specifically locate the areas of human failure causative in each accident. The evaluation undoubtedly contains bias and must be suspect because an attempt has been made to quantify intangible factors. However, the same bias is applicable to each accident and therefore the figures have some merit. It is gratifying to observe that human failure in the cockpit accounted for slightly less than 50% assigned of all accidents as opposed to the 65 to 70% assigned to this factor in accidents occurring in routine operations. This may reflect the superior standard of pilots usually selected for aerobatic duties. However, it is extremely disturbing to consider that inadequate supervision accounted for approximately 30% of the cause factors attributed to fatal airshow accidents and it is unacceptable that this factor has been reduced by only an incremental amount over the past five years.

It is disturbing to recognize that insufficient knowledge has been learned from 25 years of jet fighter operations to permit a reduction in the percentage of airshow accidents caused by human failure in the cockpit and in supervision. So long as aircraft are flown by humans there will be occasional split second errors in judgment which result in accidents. However, some of the accidents which have occurred in the past five years are like their predecessors in that they reflect major defects in judgment on the part of either the pilot concerned or one or more of his supervisors. It is clear that there is a requirement for increased vigilance in preventing the two primary causes of airshow accidents - human failure in the cockpit and human failure in supervision.

SUMMARY

It has been demonstrated that certain characteristics tend to differentiate fatally injured aerobatic pilots from their counterparts who were not involved in fatal accidents. Single and separated pilots are at very high risk compared with their married counterparts. Most survivor pilots had more than 2,000 hours total flying when they joined a team and most of the killed pilots had less time than this. A similar but less pronounced trend was observed in relation to time on type. Age in itself was unrelated to the incidence of fatal accidents. Non-designated aerobatic pilots without special air display training are at high risk of being killed as are all aerobatic pilots who permit themselves to spontaneously deviate from carefully prepared pre-arranged plans. Human failure in the cockpit is less frequent in airshow fatalities than in fatal accidents occurring in routine operations but still accounts for nearly 50% of the accidents. Human failure in supervision accounts for 30% of the cause factors a figure much higher than in non-aerobatic fatal accidents. Finally, the disbandment and subsequent reformation of a new aerobatic team places the members of the new team at increased risk. Members of permanent fulltime professional teams on which part of the team rotates annually have a low risk of being involved in a fatal accident.

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PROCEDURES FOR IDENTIFICATION OF MASS DISASTER VICTIMS

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SUMMARY

The problems of identification of mass disaster victims need not be insurmountable if approached in a logical, meticulous, stepwise manner. The identification process is basically the collection of identifying information about the missing persons, observation of identifying features of the victims, and comparison of the two groups of information. Certain techniques, such as comparison of fingerprint and dental records, are more reliable and are believed to provide positive identification. On the other end of the reliability scale are such characteristics as height, weight, skin color, and hair color, which may be subjective, may be difficult to measure, and are subject to change but which in combination may provide reliable and, in some case, the only identification. The "odd man out" method is a practical technique for screening identification.

Careful application of these techniques and observations of the pitfalls will enable even the inexperienced investigator to collect valuable information to simplify and shorten the identification process. It is only by practice that the inexperienced become experienced.

INTRODUCTION

Accurate identification of persons who have been fatally injured in an aircraft or other mass disaster is an essential element of an adequate investigation, and one obvious reasons for identification is to allow families to recover the correct body for burial, as is customary in our culture (1). In past investigations, identification has often been incorrectly or inadequately attempted by persons with little experience or knowledge of problems of identification. In many of those cases, identification was made solely on the basis of visual inspection, by "dog tags", or by articles of clothing (1). Families have simply been allowed to claim portions of bodies even when no identifying characteristics were present, and in mass disasters involving victims whose religious beliefs require proper burial or prompt burial, families have been quick to claim any body. Conversely, the emotions following death of a family member have on occasion resulted in denial reactions, and families have refused to accept unequivocally positive identification of their relative. While in most cases even visual inspection is more than adequate, the investigator must be aware of possible subsequent litigation or insurance claims that may hinge upon documentation that the victim was, in fact, as purported.

Time spent on pre-disaster planning will be more than recovered from the resulting expediting of the identification process following occurrence of a disaster. Likewise, structuring of the individual efforts and implementation of the previously designed plan can effectively be the most important step taken when a disaster does occur (2).

A central headquarters must be established to control and monitor progress in the investigation and maintain necessary liaison. This headquarters must be easily accessible to transportation and communications. Accommodations for eating and sleeping may be

(NOTE: The opinionsor assertions contained herein are the private views of the author and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense) necessary, as well as suitable isolation for families, news media, and other persons who have a legitimate interest in the investigation but whose presence may distract investigators, resulting in errors of identification.

Subordinate commands may be located at the diaster site, at the treatment facility, and at the mortuary, or identification facility. Strict security is desirable at these subordinate commands as well, to enable efficient operation with a minimum of interruptions.

Establishment of an effective communications system should have high priority. Information for correlation with identifying characteristics must be sought from outside sources.

The conditions under which the investigators must work will often influence the speed with which the problems can be resolved. Especially in adverse climatic conditions, work schedules should be established. Errors made as a result of fatigue, hypoglycemia, or cold can delay the investigation far more than any possible time-saving from extended hours of work under adverse conditions.

DETERMINATION OF WHO IS MISSING

The ability to answer accurately the question, "Who is missing?", as early in the investigation as possible will determine how long the investigation will take, what methods will have to be used, and the types of additional assistance that may be required.

The easiest situation to contend with is a manifested affinity group. An example is military members who are aboard a military aircraft that crashes. In this case, a manifest, or list, of persons who boarded the aircraft will almost certainly be available. Since the crew members are probably from a single organization, information for identification should be readily available from that organization. In addition, it is improbable that persons who were not on the manifest were aboard the aircraft. A problem arises, however, when there is a last-minute crew change without a change in the manifest or when passengers board the aircraft at the last moment and are not included on the manifest.

The most difficult situation arises in the case of a disaster that occurs without a pre-existing list of persons suspected of being missing. For example, if migrant farm workers have entered a country illegally and are involved in a fatal motor-vehicle accident, an extraordinary degree of international cooperation may be necessary to develop a list of the missing persons. Otherwise, it might be months before families realize that their relative, believed to be hard at work on a farm, is actually missing. Hardly a large medical examiner's or coroner's office has not had a body that has remained unidentified for months until a "missing persons" report is filed by a relative.

Somewhere in between these types of situations lies the problem of disasters at airport, bus, or train terminals and sports stadiums (3). There may be little to do but wait for reports of missing persons.

Additional problems arise when people travel under assumed names. Immediately, questions of illegal activity and foul play arise. More innocent circumstances are usually the case, however. An example is that caused when a large corporation makes travel reservations for an employee but at the last minute sends a different employee instead; another is that of an executive who sneaks off with his secretary for a little holiday fun. Of course, simple errors such as misspelled names on a manifest can also pose serious problems in discovering the identity of the missing persons.

DETERMINATION OF WHETHER ALL OF THE BODIES HAVE BEEN RECOVERED

If it is certain that all of the bodies have been recovered, it may be possible to identify some of the victims by a process of elimination. If it is reasonably certain that the "missing persons" list does correspond to the identities of the recovered bodies, the problems of identification are greatly simplified. In this situation, the degree of presumptive identification necessary to approximate a positive identification need not be as great. Identification cannot be presumed, however, unless all of the bodies have been recovered and the list of missing persons is complete.

When bodies are fragmented, special care must be taken in collecting, tagging, and identifying each fragment (4). It is not difficult to visualize the problems that arise when eight persons are missing and body fragments including 17 feet are found. Obviously, the identity of the nonth missing person must be sought, and the entire process of identification will be much more difficult and time consuming than if the identity of the ninth missing person is known.

Even small fragments of tissue may aid the identification process, especially if the fragment consists of teeth, or printable skin from the fingers (5). Special efforts must be made to search the scene carefully, inch by inch, to insure that nothing have been overlooked.

In some instances, such as in disasters at sea, the reality of the situation may be that it will be impossible to recover all of the bodies. Three issues then arise: First, a determination must be made as to when any further search efforts will be futile. Second, the possibility may exist that there may have been more victims than persons reported missing. Third, the possibility of foul play may have to be resolved by other aspects of investigation.

SELECTION OF IDENTIFICATION TECHNIQUES

From a practical standpoint, there are three general rules to follow: First, do the best you can with what is available. Second, do the easiest things first. Finally, don't release a body until positive identification has been made.

Positive identification of a person is made when a sufficient number of objective features are identified that belong to that person and only to that person. All of the methods of identification that are currently used involve comparison of observed characteristics of the bodies with known or reported characteristics of persons missing or presumed dead. There is no doubt that it is possible, theoretically at least, for two people to have certain characteristics that are similar enough to be, for all practical purposes, identical. For this reason, a certain degree of probability must be assigned for each method of identification. The greater the number of identical characteristics found, the more certain is the probability that the identification is positive. For example, the certainty of identification is much greater if 25 fingerprint or dental characteristics are found than if only comparable features are blood group substance A.

How many presumptive correlations are necessary to approximate a positive identification? No set number can be stated unequivocally. Correlation of three characteristics such as height, weight, and hair color will usually not have as much weight as correlation of evidences of operations and other scars, congenital defects, and dental restorations. On the other hand, if only one of the missing persons weighed over 150 pounds, and if he happens to weigh 250 pounds, this might be a very significant identifying characteristic indeed.

A high degree of negative correlation may also be of great value in limiting the number of persons under consideration. For example, if it is determined that 20% of the victims have blood group substance A, the missing persons known to have blood groups AB, B, or O are not likely to provide a match.

In some cases, methods that could not be used to establish identification when applied to a large number of bodies may be used as good evidence of identification by the method of "odd man out". The odd-man-out theory was proposed by Mason for evaluation of distinctive injury patterns in reconstruction of the cause and sequence of events in an aircraft accident (6), but it is equally applicable as a technique for preliminary identification of fatalities. Initial screening examination of the bodies will almost always reveal that certain of the bodies have characteristics on which the investigator feels comparison data will be easy to find. Pregnancy, the presence of a glass eye, or an artificial limb are typical of kinds of identifying data that are not usually sought in identification questionnaires and yet can be extremely valuable information when found. The presence of any one body with features different from all other bodies found in the wreckage sets the odd-man-out process in motion.

The "odd man out" method does not require that the characteristics be totally unique to simplify the process of identification. If all of the passengers and crew were male except for one female flight attendant, the only female body found would be presumptively identified as the female flight attendant. Unfortunately, there may be times when an identifying characteristic is found that almost certainly must be unique, that only one person in the whole world could possibly have, and yet on which no antermortem record of missing persons can be found to substantiate the finding.

In another form of application of the "odd man out" theory, consider the situation in which 10 persons are found in the wreckage. If half of the persons were blood group A and the other five were blood group B, the determination of blood group would not establish even presumptive identification of any of the fatalities. If eight of the bodies had already been positively identified by means of fingerprints, however, and if one of the two remaining bodies was blood group A and the other was blood group B, then reliable presumptive identification would be established.

There are certain pitfalls to be avoided in application of the "odd man out" method. There is a temptation to think of the odd man as being positively identified. This is not a valid assumption. The greater the certainty that the 10 victims found are the 10 persons reported missing, the greater the probability that the odd man will be identified. Also, great care must be exercise to insure that the odd man is not eliminated too early in the investigation on the basis of a characteristic that was improperly described or was, in fact, not unique. Again, the investigators should be cautioned to avoid the temptation to release bodies on the basis of inadequate identification.

TOOLS OF IDENTIFICATION

Dentition. With the exception of visual recognition, dental identification is probably the most widely used method of identification of unknown remains (7). More people have dental records than have fingerprint records, and the techniques of dental examination are almost, if not equally, as accurate as fingerprint identification. Even when the actual dental record cannot be obtained, it is possible to obtain the necessary information by telephone from the dentist of the suspected missing person.

There are certain problems inherent in dental identification. It is essential that there be at least a general idea as to who is the victim, since you must ask for his records, and there is no central repository of coded dental records, as there is for fingerprints.

Another major problem is that the dental chart does not necessarily show the actual dental characteristics but the examining dentist's interpretation of his findings from the examination. In many cases, this information is verbally transmitted to a technician, who records it on the dental chart. There are many possible sources for errors in this system, and it is not unusual to find "left" recorded when "right" was intended or "buccal" recorded when the actual location was "lingual". This problem of erroneous information has been somewhat alleviated by introduction of other dental records than just the dental chart (5, 8). Dental x-ray films as well as plaster casts may be available. Comparison of the root structure of the teeth in antemortem and postmortem x-ray films may establish identification even if no restorative dental work has been performed.

A fourth problem area is encountered when a victim has had dental work performed subsequent to the last known dental record. For example, if person B is believed to have 32 teeth and no restorations, then a victim whose third molars are absent would not seem to be a likely possible match; but it could be that the absent teeth had been extracted subsequent to the date of the record available for comparison. Great care must be taken that possible matches are not eliminated by errors such as this, and comparison of x-ray films is usually helpful in avoiding problems of this type. Again, as with fingerprint records, it may take a great deal of time to obtain these dental records, but time can be saved by taking the x-ray films and doing the dental charting of the victim while the investigator is awaiting the antemortem roentgenograms and charts.

If necessary, the teeth can be removed en bloc and retained for later comparison (1). Using a bone saw, the portion of the maxilla and mandible containing the teeth can be easily removed without disturbing the location of the teeth. In disasters involving massive forces and tissue destruction, the maxilla is frequently loosened sufficiently that the entire maxilla, with the upper teeth, can be removed with only a scalpel.

The person's name of other identifying information is often inscribed on artificial dentures (9). In many other cases a person's dentist will be able to recognize dental work that he has personally performed, or he may recognize other characteristics of the person's mouth.

Fingerprints. Fingerprint identification has been demonstrated to be one of the most accurate and reliable methods for identification of unknown remains. Experienced investigators can examine fingerprints obtained from disaster victims and, using various coding methods, search the massive files that are kept at organizations such as the Federal Bureau of Investigation in the United States (10).

Fingerprint identification is not always the panacea that it at first would seem to be, however. The use of fingerprints as a means of identification is dependent upon the availability of previous known fingerprints for comparison. In many countries no fingerprint records are kept. In other countries, these records are not available on anyone other than convicted criminals. Even in the United States, where a large file of fingerprint records is maintained by the FBI, probably less than 25% of the population has been fingerprinted.

Nevertheless, fingerprints remain one of the most reliable and accurate means of obtaining positive identification. Even when no fingerprint records are available it may still be possible to make identification by means of fingerprints, as it is often possible to develop latent fingerprints from the missing person's home, office, or vehicle. Drinking glasses and door knobs are objects from which good latent prints may be found. Certainly this is not a technique for the novice, but knowledge of the technique may greatly shorten the process of identification. When latent prints must be obtained, more than just fingerprints may be necessary. For example, the prints from the palm of the hand may be present on a drinking glass, and in this case, prints of the entire hand must be taken for comparison. Comparison of prints found on a check the missing person wrote may require that prints be obtained from the side of the hand as well as the fingers and palm.

Assistance of local law-enforcement agencies should be enlisted in obtaining fingerprints, since personnel of these organizations are generally more experienced in the techniques of obtaining prints. When assistance is not available, the investiga or can collect satisfactory prints for later comparison with prints on the records.

Whatever surface (e.g., fingers, palms, feet of the victim) is to be printed should be clean and dry. Almost any ink may be used. The ink should be applied to the surface to be printed from an ink pad or roller to ensure even distribution without excess ink. The surface should then be applied smoothly and firmly to a clean paper surface. It is not necessary that special fingerprint forms be used; almost any paper that will retain the sharp definition of the prints is satisfactory. The individual prints must be labeled as to their source, and each separate finger must be clearly identified.

The next task is to find known fingerprints for comparison. This is the step that actually determines how useful the fingerprint method of identification will be in any individual case. If the personel effects found on the body include an indentification card that has fingerprints, the process may be very simple and rapid. If the possibilities as to the identity of the victim are limited, as when the aircraft had a complete passenger manifest or when presumptive identification has been made using another identification method, and if previous fingerprint records can be obtained, then positive identification can easily be made. If no fingerprint records are available, however, or ir there are no persons reported to be missing, the number of problems of fingerprint indentification may be at least time consuming, if not insurmountable.

The fingerprint screening method to be described may be applied to situations in which fingerprint records for comparison are available. In addition, it should be understood that this simple procedure is a <u>screening</u> method and for use in conjunction with other identification techniques. The <u>final</u> comparison for positive identification should be left to experts.

There are three basic patterns of fingerprints: the loop, the whorl, and the arch. These patterns are easily recognizable with minimum training. For example, if a missing person is known to have a whorl pattern on the left index finger, a body that has a loop pattern on the left index finger can almost certainly be eliminated from consideration.

<u>Body Characteristics.</u> Body characteristics other than fingerprints and teeth can be used to assist in screening and identification. The value of an individual characteristic in establishing a positive identification depends upon the uniqueness of the characteristic or combination of characteristics. Some features are easily documented with great accuracy. On the other hand, certain characteristics are affected by subjective observations of the examiner. Observations of color are especially subject to interpretation, and burning or other effects of heat make measurements of height and weight less reliable.

Height, weight, and sex are easily determined, and comparison information is usually available from previous medical records. Problems may be encountered when the body is fragmented.

Estimates of age can be made on the basis of physical appearance, teeth, roentgenograms, and direct observation of bones.

Color, length, texture, and distribution of hair may be helpful, but the interpretation of them tends to be subjective (5). Beards and moustaches are usefull, especially if photographs are available for comparison.

Postmortem and thermal effects on skin often make determination of race on the basis of skin color very difficult.

Pierced ears and indications of circumcision should be noted.

The presence of surgical scars, moles, tattoos, or deformities should be noted. Comparison ith antemortem photographs may be helpful, depending upon whether the photos have been retouched. Medical photographs are not usually retouched. Postmortem artifactual changes often render skin color an unreliable means of comparison.

Teeth and hands should be examined for clues as to occupation and personal habits, such as callouses in laborers and nicotine stains in smokers. These should be noted.

Medical and dental records are good sources for comparison information. They may not be readily accessible, however, and problems arise when an observer has inadvertently reversed observations of left and right. X-ray films can be helpful, not only for estimates of age but also for locating artificial heart valves, pacemakers, orthopedic plates and pins, and metal surgical sutures. Characteristics such as sex, hair length and color, height, weight, and skin color may be of greatest value in the screening procress when combined with other information, and these may provide as positive an identification as will be obtained under the circumstances. It would be impossible to list all of the possible body characteristics that might be observed in a specific disaster victim. Therefore, an awareness of possibilities on the part of the investigator is essential as he pursues his investigation.

Personal Effects. Items of clothing and personal effects provide helpful clues of identity. Jewelry and articles of clothing often are inscribed with names or initials. Wallets contain identification and credit cards, photographs, and other information. Some identification cards contain a photograph and fingerprints. Clothing may be recognized by family members, and labels in clothing may give a clue as to the city of origin (11). Laundry marks can also be used.

Blood Type. Determination of the victim's blood type may aid in the initial screening process in some instances, but this is not usually the case. At best the determination of blood type can be only a screening tool. The antemortem record of blood type may not be readily available. Errors in recording antemortem blood type may be 20% or higher. The problems of accurate postmortem determination of blood type are even greater. Certain blood-group substances deteriorate rapidly after death, and some bacteria produce blood-group substances that can produce misleading results.

APPLICATION OF TOOLS AND TECHNIQUES

Common sense will enable the investigator to record observed characteristics that are unusual enough that he believes someone should remember and associate it with one of the missing persons. The distribution of sexes, hair color, and body sizes in the group of victims is important. The presence of persons with distinctive dental work, tattoos, surgical scars, or congenital defects should be noted. Personal effects such as distinctive clothing, clothing labels or sizes, photographs, and identification cards can be helpful.

This preliminary examination for distinctive c 'eristics will suggest the relevant questions that must be asked of the relativ ımily members or other persons can provide helpful information when questioned in a ıtic manner. Particularly, they should be asked about the characteristics observe he preliminary screening examination. Even if the "missing persons" report includes a questionnaire that lists identifying characteristics, it still may be necessary to request additional information about observed potentially identifiable f atures.

The questionnaire on identifiable characteristics should include at least:

1. Location of fingerprint or footprint records.

2. a. Location of dental records.

   b. Name and telephone number of dentist.

3. a. Location of medical records and x-ray films.

   b. Operations, hospitalizations, injuries, and identifiable congenital features.

   c. Name and telephone number of personal physician.

4. Age, sex, height, weight, and skin color.

5. Hair color and distribution.

6. Distinctive jewelry and clothing.

7. Clothing sizes and colors.

After reviewing the information given on questionnaires, the investigator should conduct a comprehensive examination of each body, taken special care to search for the identifiable features suggested by the answers on questionnaires. Features that do not correlate can be equally important.

Fingerprints should be made and dental charts prepared. While the investigation continues, other personnel can attempt to locate fingerprint records, dental charts, x-ray films, and other materials for comparison.

A list of characteristics should be prepared for each missing person (Example shown in Table 1). Observed positive (+) or negative (-) correlation for each characteristic should be recorded.

	CHARACTERISTIC AND EVALUATION *					
PERSON	SEX	HEIGHT	WEIGHT (lb.)	EVIDENCE OF OPERATIONS	PRESSENCE OF HAIR OR LENGTH	ELIMINATION
Person A	M	6' 0"	200	Appendectomy	None (bald)	
Victim 1	M +	5'10"	195	None -	None (bald) +	X
Victim 2	M +	5' 8" -**	200	Appendectomy +	Short -	
Victim 3	M +	6' 1"	185-***	Appendectomy +	None (bald) +	
Victim 4	F -	5' 2" -	130	Appendectomy +	Long -	X
Victim 5	M +	6' 0" +	205	None	Short -	X

* Correlation is shown by plus sign (+), elimination by minus sign (-).
** Was body intact and complete?
*** Had Victim lost weight recently?

TABLE 1. EVALUATION OF OBSERVED CHARACTERISTICS OF VICTIMS WITH THOSE OF PERSON A

In the example in Table 1, Victim 4 is eliminated on the basis of sex. Victims 1 and 5 are eliminated because they have not had appendectomies. Only Victims 2 and 3 appear to remain for consideration, and Victim 3 seems to provide the best match with Person A, but the recorded characteristics of height and weight are not exact correlations. Several possibilities must be evaluated. Was the body of Victim 2 intact? Are the antemortem and postmortem measurements accurate? Are the other bodies intact and complete? Did Victim 3 lose weight prior to the accident? Also, it is necessary in this case to verify that the Person A did, in fact, have an appendectomy. Additional characteristics should be examined. Of course, if dental records are available, comparison will probably quickly resolve the problem. Screening of other characteristics should be continued.

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MANAGEMENT OF A MAJOR AIRCRAFT ACCIDENT INVESTIGATION

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INTRODUCTION

In every organization one should have goals for which one should strive. I would like to highlight the goals for accident investigation of the National Transportation Safety Board.

1. Maintain objectivity at all times and assure that each investigation is conducted with orderly thoroughness so that a proper assessment of the probable cause can be made.

2. Assure that every investigation is studied sufficiently to identify hazards for which practicable safety recommendations can be developed which, when effectively implemented, would promote safety in transportation.

3. Assure that all personnel have the perseverence, dedication, and training essential to the successful completion of every investigation.

4. Assure that all available skills and facilities of both Government and Industry are used in each investigation to the extent necessary to fully develop the facts, conditions, and circumstances and the underlying causes involved in each accident.

5. Produce high quality reports in a timely manner.

To achieve these goals the Safety Board's professional staff follows and complies with a series of procedural regulations which have been developed and which delineate the procedures and requirements for aircraft accident notification and for aircraft accident investigation. In addition, accident investigation procedures are standardized and are outlined in detail in the Board's Accident Investigation Manual.

NATIONAL TRANSPORTATION SAFETY BOARD PROCEDURAL REGULATIONS

The Safety Board's Procedural Regulations, Title 49 C.F.R., Part 830, "Rules Pertaining to the Notification and Reporting of Aircraft Accidents or Incidents and Overdue Aircraft, and Preservation of Aircraft Wreckage, Mail, Cargo, and Records" and 49 C.F.R., Part 831, "Rule of Practice in Aircraft Accident Investigations" are the two primary regulations which control how we do our business. In addition, 49 C.F.R., Part 801, "Public Availability of Information" outlines our procedures for the availability and the timely release of information to the public. However, this one area is one of the most frustrating jobs that the investigator is confronted with during the field phase of aircraft accident investigation. This one subject will be discussed in detail later during this meeting.

The Independent Safety Board Act of 1974, and Title VII of the Federal Aviation Act of 1958, are the legislative authority for making rules and regulations governing notification and reporting of civil aircraft accidents, for the investigation of such accidents and reporting the facts, conditions, and circumstances relating to each accident and the probable cause thereof; make safety recommendations which will tend to prevent similar accidents in the future; to ascertain what will best tend to reduce or eliminate the possibility of or recurrence of accidents by conducting special studies, and investigation on matters pertaining to safety in air navigation and the prevention of accidents, and to make such reports in such form and manner as deemed to be in the interest of the public.

READINESS TO RESPOND

In carrying out our investigative responsibilities, the Safety Board's Bureau of Aviation Safety maintains a staff of accident investigation and technical specialists that are on standby 24 hours a day, 7 days a week. Major catastrophic air carrier accidents involving large aircraft, are investigation by a "Go-Team" consisting of 10 to 12 air safety investigators and technical specialists headed by an investigator in charge. The safety Board's field offices which are located strategically throughout the United States and Alaska also provide investigative and logistic support to the major investigation teams.

The Safety Board's field offices and its headquarters' investigatory staff are tied into an elaborate communications network operated by the Federal Aviation Administration.

When an accident, as defined in the Board's Procedural Regulations, Part 830, occurs, the NTSB Duty Officer and the investigator in charge are notified immediately by either the nearest NTSB field office, the operator involved or the Federal Aviation Administration's Communication Centre.

Upon notification, the investigator in charge or Duty Officer notify and alert the NTSB Board Member on Duty and all specialists Go-Team Members. All Board personnel on standby status are equipped with mobile telephone signalling devices (Bellboys) and can receive notification of telephone calls within a 25-mile radius of a metropolitan relay station.

When the crash location has been confirmed, the investigator in charge arranges for immediate air transporation (or surface transportation if the crash site is nearby) for the entire team to the accident site.

Also at this time one of the NTSB's eleven (11) field offices, nearest the scene of the accident, will dispatch at least one investigator to the scene to effect the necessary liaison with local law enforcement and disaster control agencies and establish a security system. The local investigator will also coorindate with Federal or State, military authorities to effect assistance with search, rescue and/or recovery operations.

Upon arrival on the accident scene, a preliminary examination of the crash site is conducted by the investigator in charge and designated team members to determine what type of logistic support will be required to conduct the on-scene investigation. Several investigators are assigned to search for and recover the Cockpit Voice Recorder and the Flight Data Recorder and forward them by the most rapid means available to the NTSB's Washington Laboratory, vehicles, cranes, tractors, or whatever other support equipment is necessary are procured from either military, state, municipal or private sources which are within the proximity of the crash site.

The investigator in charge then establishes a command post at a suitable facility close to the accident site, and in cooperation with local telephone company officials establishes direct communications between the command post, the accident site, and security personnel. He will provide a brief preliminary status report to the Accident Investigation Manager at the Washington Headquarters. The Accident Investigation Manager is the Bureau of Aviation Project Manager responsible for the overall direction of investigations into major aircraft accidents. At this time it must also be ascertained that all parties who may contribute technical expertise to the investigation have been notified and are proceeding to the scene of the accident. Such parties include technical specialists from the Government agencies, the operator of the aircraft, professional organizations composed of airline pilots, flight engineers, dispatchers, air traffic controllers and aircraft mechanics, technical experts from the manufacturers of the aircraft, its powerplants and other key components.

Once the majority of the prospective participants in the investigation have arrived, the investigator in charge (IIC) convenes the accident organizational meetings. At this meeting, the IIC will first determine that no members of news media or attorneys representing litigants are present. He will then open the meeting by explaining the responsibilities of the Board and designated parties to the investigation. All participants present should remember that their participation in the investigation is not a right but an invitation by the Board for the purpose of assisting the Board in developing a complete factual record and likewise enabling responsible safety officials, whose products or services might be involved, to have immediate access to facts regarding the accident from which it may initiate preventive and/or corrective action. All persons participating in the investigation must be in a position to contribute specific skills which would otherwise not be available to the Safety Board. No participating organization is permitted to be represented by a person or persons whose interests lie beyond the safety objective of the accident investigation and prevention.

It is during the organizational meetings that the coordinators and investigative group members from the parties to the investigation are appointed. It is through the coordinators and groups members that safety information is passed on to responsible personnel who are in the best position to effect corrective action. It is by this system that the technical group members from the parties to the investigation can present their inputs into the investigation and keep their respective coordinators adequately briefed as to the findings learned during the investigation.

In recent accidents the Safety Board investigators have received criticism from the coordinators that they are not receiving adequate investigative information; however, we have found that the data were always available from the Board's investigators but the coordinators and some of their group members were not communicating with each other.

Once the investigation groups are organized under the direction of a Safety Board Group Chairman, all participating members are advised that one set of group notes will be developed; each group member will have in his possession a copy of such group notes prior to his release from the working group to which he is assigned. Each group member will have participated in a complete review of the group notes for technical accuracy and adequacy of the scope of the investigation in his particular area of technical expertise. The group chairman will obtain each group member's concurrence and/or signature signifying that the group member has reviewed these notes and that any existing discrepancies reflected in these notes have either been corrected or resolved. Courtesy copies of group chairmen's final reports will be provided to the participating group members at a later time. It is with this procedure that the group member can make his contribution to the investigation.

The scope and extent of the investigation will largely depend upon the facts developed during the early stages of the investigation. The primary data source during the early phase will be the Cockpit Voice Recorder (CVR) and the Flight Data Recorder (FDR) In the case of a wide-bodied aircraft, the Digital Flight Data Recorder (DFDR) is used, and, also, many times an early review of ATC communications tapes provide siginficant evidence as to prime suspect areas and can limit the scope of the investigation.

It is the early concentrations in these prime suspect areas that reduces the tendency to expend extensive resources in nonproductive areas.

If, for example, the DFDR indicated a normal cruising speed at an assigned altitude with all parameters indicating normally, and then a sudden period of unexplained violent manoeuvres followed by uncontrolled descent into the ground, accompanied during the same period of time by flightcrew comments on the CVR of sudden vibration or control problems, the prime area of investigation will be initially directed toward determining possible reasons for control system malfunctions, evidence of structural or major powerplant failures, auto flight system malfunction, etc.

If, for example, a major control system component such as a control actuator was found suspect the unit would first be subjected to X-ray or fluoroscopic examination under the direct supervision of the NTSB Group Chairman -- the part would at all times remain in the custody of the NTSB Group Chairman -- any tests, disassembly, etc., would be conducted in the presence of all group members at the facilities of the manufacturer, or the operator, when specialized and highly sophisticated test equipment is not available elsewhere. Independent sources such as: National Aeronautics and Space Administration, Naval Research Laboratories, National Bureau of Standards, Universities, etc., are utilized, if possible.

The manufacturer's own design, test, and operating specifications would be examined and compared vs the performance of the unit by all group members, i.e., the NTSB Group Chairman, who has had experience and training on flight control systems; a flight control specialist from the air carrier, FAA, flight engineers, airline pilots' representative, and any others deemed necessary by the Group Chairman. Thus, a careful check and balance system is maintained by the presence and total participation of all parties which could conceivable have opposing interests in the outcome of the investigation.

We are aware, that on occasions, parties of the investigation may have interests which lie beyond probable cause determination and accident prevention; however, it is the responsibility of the NTSB investigator in charge and the group chairman to manage the investigations and to keep the "Red Herrings" out of the investigation. This is not to say that the Safety Board will not consider all possible avenues; however, we do not investigate to assess blame, fault or liability at the expense of others.

This is one area where the Safety Board's investigations have been questioned by Consumer Advocate Groups, and just recently from a certain committee in the Congreee. During the investigation, if investigative findings indicate a design deficiency, deficiencies in air traffic control procedures or services, questionable exercise of operational control, operational procedures, dangerous performance characteristics of the aircraft, a deficient or questionale manufacturing process, crashworthiness, deficiencies in design criteria relating to appropriate interface between the human and mechanical aspects of the total system, or inadequate controls by regulatory agencies, etc., immediate corrective action activity is initiated toward the formulation of a safety recommendation. This activity is initiated during the field investigation and is finalized by the Headquarters' technical staff review and investigation and in coordination with the IIC and the accident investigation manager.

As evidence is obtained during the field phase of the investigation and need for corrective action appears to be warranted, the view of the parties to the investigation are also solicited by the Board's investigators.

Before a decision is reached to conclude the on-scene investigation, a positive determination must be made that all physical evidence available at the accident site has been thoroughly documented and examined for evidence which may be related to accident cause(s) or contributing factors.

When such wreckage examination at the accident site and other investigative activities at or near the accident site are completed the wreckage is normally released from Board custody to the registered owner or his authorized representative.

Parts, suspect components or pertinent documents are retained by the Board for further investigation. Metallurgical specimens may be taken to the Board's Washington Laboratories for examination by specially trained Board Metallurgical Engineers.

The wreckage site which may contain seriously damaged or destroyed personal property, structures, etc., is also released to the custody of owners and security restrictions are lifted to again allow free access to the area.

The investigator in charge, prior to leaving the area of the accident site must ensure that all law enforcement, military, and state authorities are appropriately debriefed regarding their involvement in the investigation and must also ascertain that any financial obligation which may have been incurred on behalf of the Board are satisfied.

Telephone and other communication services must be properly terminated and leased equipment such as cars, tractors, cranes, bulldozers, or other specialized equipment and operators must be released and financial obligations therefore satisfied.

If the NTSB public affairs officer has been at the accident site, final contacts with the news media are completed by him. If no public affairs officer was at the site, a final briefing of the news media is normally conducted by the IIC.

Briefly, I have attempted to outline our procedures in the conduct of major accident investigation. I will be happy to answer any questions on the subject later during this meeting.

LOW LEVEL WIND SHEAR AND ITS EFFECTS ON APPROACH AND CLIMB-OUT

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INTRODUCTION

On June 24, 1975 an Eastern Airlines Boeing 727 crashed on final approach in Kennedy Airport. This accident was the last straw, which triggered the aviation community to seek a solution how to predict, detect and fly on wind shear environment.

Undoubtedly there have been many other accidents in which the influence of wind shear has remained undetected and unacknowledged. What we need first, is to understand better the motion of the air and the forces that it exerts on objects moving in it.

Then, we have to understand the aerodynamic effect, the wind shear have on the aircraft, because it changes the effective airflow over the wings, thus affecting aircraft lift. And for evidence of the crucial role played by wind shear in the landing phase accidents we are using now the sophisticated new digital flight data recorders (DFDR) with the 96 parameters.

WIND SHEAR TERMINOLOGY

At the present time, each paper on wind shear uses a different system of definition and an agreement of terms within the aviation community, would help. Wind shear has been misunderstood at times, as it is used differently in aviation and in meteorology. In aviation, the effect of wind shear is felt on indicated airspeed (lift) and sink rate, as the aircraft penetrates the weather fast and is a function of time variation of winds. Also the direction is taken along the flight path. In meteorology the weather moves relatively slowly over the airport measuring devices and registers isolated elements of actual weather.

Dr. Theodore Fujita, Professor of Meteorology and Director of Satellite and Mesometeorology Research Projects in the Department of the Geophysical Sciences of the University of Chicago, in his research paper, introduced the following terms:

I. HEADWIND SHEAR (Indicated airspeed increases suddenly and aircraft gains altitude)
II. TAILWIND SHEAR (Indicated airspeed drops suddenly and aircraft sinks)
III. CROSSWIND SHEAR (Aircraft drifts to the right or left)

Dr. Fujita is bringing also a new name MESOMETEROLOGY, which deals with relatively small air masses, usually involving areas from 1 to 60 miles in horizontal diameter. From the pilots point of view, in order to coordinate the inflight reporting with the cockpit instruments presentation, I would go along with the proposition made by Captain John B. Clark, from American Airlines, at the last Symposium in San Francisco who gave us the following definitions:

POSITIVE SHEAR (when we experience a sudden increase in indicated airspeed)
NEGATIVE SHEAR (when we experience a sudden decrease in indicated airspeed).

PAPER DISCUSSION POINTS

1. How to predict wind shear
2. Detection during flight and on the ground
3. How the aircraft is affected
4. Flight recommendations
5. Conclusions

Part I - PREDICTING THE EXISTENCE OF WIND SHEAR

This may become the most pressing single requirement of meteorology in the 1970s jet age. Wind shear is created principally by two weather factors:

A. Thunderstorms
B. Frontal (both cold and warm)

A. Thunderstorm Outflow Shear

At the Boeing Flight Operations Symposium held this year, anaanalysis was made which revealed the effect of thunderstorm outflow near the ground, upon aircraft trying to fly through the cells or under the base. The flow if air beneath thunderstorm cells can be very complex. Cold air flows out from the cell from directions nearly vertical with respect to the surface and changes to a horizontal direction of flow. Above that, warm air is flowing up and into the cell, at a direction opposite from the cold air. Abrupt wind direction change beneath the thunderstorm creates severe wind shear in addition to the violent downdrafts. Furthermore, running ahead of a mature thunderstorm is the "leading edge" or the GUST FRONT.

Gust fronts can be extremely hazardous to arriving and departing air traffic. Since gust fronts contain little or no precipitation, they are transparent to air traffic control surveillance radar and cannot be detected by airborne radar. Gust front is sometimes described as Thunderstorm Squall winds. Although this front may be as much as ten miles or more ahead of the thunderstorm, a clue to the pilot that shear may be present is the thunderstorm itself. Through the gust front, violent winds of 60-80 Kts have been observed and also a sudden change of up to 4 millibars in barometric pressure. Let's see how the gust front appears in FAA wind shear programme.

A very valuable contribution in this field was made by Dr. Theodore Fujita who analysed the weather at JFK on June 24, 1975. Dr. Fujita's research has not only identified the previously unrecognized phenomena of DOWNBURSTS and SPEARHEAD ECHOES, but will also serve as an additional stimulus for accelerating the development of systems for providing pilots with the information, when it is needed most-during the take-off or the approach phase of the flight. Detailed examination of the meteorological conditions revealed that the growth rate of the JFK thunderstorm was at its peak when the accident occurred. The radar echo of the storm appeared as a spearhead moving faster than any other echo in the vicinity. Hidden in the spearhead echo were four to five cells of INTENSE DOWNDRAFTS which are to be called "DOWNBURSTS CELLS". Apparently, those aircraft which flew through the cells encountered considerable difficulties in approach, while others landed between the cells, without even noticing the danger areas on both sides of the approach path.

A spearhead echo is a radar echo with a pointed appendage, extending toward the direction of the echo motion. The appendage moves much faster than the parent echo, which is being drawn into the appendage. During the mature stage, the appendage turns into a major echo and the parent echo loses its identity. Ground based weather radar will be able to detect a spearhead echo 100 miles away. It is not known at this time wheather airborne radar will be able to d tect such a spearhead echo. The life of a spearhead echo appears to be relatively short. The appendage of the JFK echo started forming at 1910 GMT, reaching its mature stage in about 50 minutes. A downburst is defined, as a localized intense downdraft with vertical currents exceeding 12 feet/second (80 MPH) at 300 feet above the surface.

Effects of Downburst and Wind Shear

In general, the air near the ground spreads out violently from the "outburst centre", the spreading centre above the ground. If an aircraft flies straight into the outburst centre, its indicated airspeed will increase for a short time, followed by a high rate of sink. Before the aircraft can break out of the downburst cell, its indicated air speed will drop suddenly, due to a sudden increase in tailwind component. It happened to Eastern __ and also we have evidence that this is what happened to a Lockheed 1011 who performed a missed approach just after Jack Bliss approach. The pilot was able to keep the wings level, while involved with the low air speed and high rate of descent. The aircraft continued sinking, until it started recovering altitude at about 60 feet above the ground. In order to explain the intense vertical current and the fast travelling speed of the downburst's cells, Dr. Fujita postulated a downburst cell originating in the lower-most stratosphere. The initial feature seen beyond the anvil top level is the overshooting top which may reach 45,000 feet to 70,000 feet.

When the top collapses, it undershoots into the anvil transporting large horizontal momentum. One of the greatest sinking velocities of the collapsing tops measured from a Learjet airplane by Dr. Fujita (1974) was 41 m/sec or 92 MPH. When an overshooting top rises and then collapses rapidly, a downburst cell will form on the downwind side of the dome. The cell has a tendency to travel fast because it is fed by fast-moving stratospheric air. A successive rise and fall of the top, will create a family of downburst cells which are moving away from the present thunderstorm. On a PPI scope, the family of downburst cells might appear as a spearhead echo pointing downwind. From a close range, less than 30 miles, an airborne radar may be able to identify a downburst cell, as being a circular area of rain. The pilot of the aircraft which followed Eastern 66 observed a circular cell 2 to 3 miles in diameter, located over the approach end of runway 22 L. That much about thunderstorms.

B. Frontal Wind Shear

The frontal wind shear is present in both cold and warm fronts. On a typical weather system, we have cold fronts and warm fronts, around a low pressure area. The impact zone of the two air masses is the frontal surface and the wind shear line. Not all fronts produce significant wind shear; in fact most fronts have broad transition zones and contain gradual changes in wind direction and velocity. Certain fast moving cold and warm fronts do have sharp, narrow transition zones and are capasbl of producing significant amounts of wind shear. How can you tell? It's difficult, but some progress has been made.

Here I would like to bring the very valuable contribution made by Mr. Daniel F. Sowa who is recognized as one of the world's few authorities on low level wind shear. He is superintendent of Meteorology for Northwest Orient Airlines, where during his 29 year career, he has developed forecasting techniques for various atmospheric phenomena having a direct effect on flight operations.

DANIEL SOWA CRITERIA (For Low Level Wind Shear Forecasts).

A front is expected to contain significant wind shear if:

a. There is a temperature difference immediately across the front (at the surface) of 10°F (5°C) or more.

b. The front is moving 30 knots or more.

In the beginning of this year, he added two new parameters to the low level wind shear forecasts:

c. Determination and reporting of the wind velocities above and below the frontal surface.

d. Definition of the vertical depth of the significant shear as being abrupt or gradual. The term abrupt means that the major shear will be found within a vertical depth of approximately one hundred (100) feet. Gradual shear means the shearing action will occur within a vertical depth of two or three hundred (200 to 300) feet. These presentations are showing an increase in airspeed as the aircraft descends through a front and encounters a sudden headwind. The net result will be instant added lift, with the aircraft pitching up and the rate of climb and altitude increased. On instrument approach the aircraft will climb above the glide slope.

These presentations are showing a decrease in airspeed as the aircraft, after taking off, penetrates a front surface and it is affected by a sudden tail wind. The net result will be, pitch down, increased rate of descend and altitude losing. On instrument approach the aircraft will descend below the glide slope. While the direction of the winds above and below the front can be accurately determined, the state-of-the-art is not so precise as to the height of the front above the airport. As a method of determining the approximate height of the front, consider that:

1. Wind shear is most critical when it occurs close to the ground; this occurs with a cold front, just after the front passes the airport, and for a short period thereafter. If the front is moving 30 knots, or more, the frontal slope will usually be 5000 feet above the airport about three hours after the frontal passage.

2. With a warm front, the most critical period is before the front passes the airport. Warm front shear usually exists below 5000 feet for approximately six hours. The problem ceases to exist after the front passes the airport. There are also some other meteorlogical conditions that may create a wind shear hazard, like low level inversion or low level jet stream but they are yet to be proven.

Here ends the first part of this paper - THE PREDICTION PHASE.

Part 2 - DETECTION DURING FLIGHT AND ON THE GROUND

Here I would like to mention the FAA, Engineering and Development Wind Shear Program Plan, under the direction of Mr. Larry Langweil, which describes the coordinated effort of the aviation community in the U.S.A. to bring solutions to the wind shear hazard.

GROUND BASED EQUIPMENT

The ground based sensor systems which are considered are:

a. Anemometers
b. Acoustic Doppler Systems
c. Barometric Systems
d. Radar Systems
e. Laser Systems

Currently, a prototype GUST FRONT WARNING SYSTEM is installed at Chicago O'Hare International Airport. Also a more complete pressure jump sensor array is being installed at Washington Dulles. In addition, a dual acoustic Doppler/Pulsed Doppler radar system is being evaluated.

Tests and evaluations, regarding lasers have demonstrated that a continuous wave LASER DOPPLER VELOCIMETER (LDV) can accurately measure low level wind velocity at ranges up to approximately 1000 feet. Beyond that, the focusing characteristic of existing optical elements degrades the range resolution to a meaningless value. The shortcoming of the continuous wave is the scanning pattern which is a conical scan above the transmitter only. The answer to this is PULSED LASER. The pulsed laser coverage capability is 1-5 miles along the glide slope. But according to my latest research, the problem yet to be solved on pulsed laser is an advanced technology filter, to be able to solve the fine resolution required. A realistic assessment about the ground based equipment shows at least 2-3 years before we are going to have an operational hardware.

AIRBORNE EQUIPMENT

The detection of wind shear, and the transfer of information to the pilot, so that he is aware of an impending shear encounter, is the basic requirement for an airborne system. Then, based on the severity of the shear, a decision can be made to continue the approach or execute a missed approach. If conditions permit a continuation of the approach, the pilot needs guidance to determine the proper flight technique. Regarding new avionics, in my opinion, special attention is to be given to the TOTAL KINETIC ENERGY CONCEPT, regarding acceleration and deceleration on final approach, HEAD UP DISPLAYS, and the use of INS continuous ground speed readout during the final approach.

Part 3 - HOW THE AIRCRAFT IS AFFECTED BY WIND SHEAR

Continuing the idea of Total Kinetic Energy Concept, we may take a look at an aircraft coming to land, from the Energy viewpoint.

We all probably have seen the kinetic energy formula without ever thinking about it's potential effect on our flying careers.

$$KE = \frac{1}{2} MV^2$$

M = Mass of Aircraft
V = Speed

Let's examine as an exercise, the kinetic energy which is developing when an increase in the rate of descend occurs during final approach. In this exercise V = rate of descend or in other words the vertical component of the kinetic energy of our aircraft. What it really is saying to a pilot, is that the vertical component of the kinetic energy of our aircraft during final approach is equal to 1/2 the mass of the aircraft times the square of its vertical velocity. For example: a jet normally descends at approximately 600 ft/min. If the rate of descend is increased by 50% to 900 ft/min., the vertical component of the aircraft's kinetic energy is more than doubled, i.e......

$$(600)^2 = 360000$$
$$\text{while} \quad (900)^2 = 810000$$

NTSB flight recorders readouts have shown some rates of descend as much as 1800 ft/min. five seconds before touchdown. $(1800)^2 = 3240000$ or 9 times the vertical kinetic energy of that from a (600) ft/min. rate of descend. Is that energy which drives landing gears up through the wings and bends airplanes.

From this exercise, we learned about the role played by the mass of the aircraft on the vertical component of the kinetic energy. We are going to apply this knowledge, to the forward components of the kinetic energy. For an aircraft on final approach this component is the groundspeed.

Before we are going to proceed with the flight recommendation, let's see two presentations from the BOEING Symposium.

Part 4 - FLYING RECOMMENDATION

Here I would like to bring forward again, the recommendations made in San Francisco by Capt Jack Bliss, which I believe are reinforced by the KINETIC ENERGY CONCEPT. The recommendation brings the INERTIAL NAVIGATION SYSTEM into focus. The INS gives you the one thing, which has never been available before, to deal with the wind shear problem, and that is: continuously accurate groundspeed. The use of groundspeed can be important on the final approach, when any wind shear may be present and in fact, it is only through the changes in the groundspeed airspeed relationship that the pilot can be alerted to the existence of wind shear along his course.

A study of the characteristics of groundspeed, will reveal the following facts: Groundspeed is closely related to the mass of the aircraft, so that the only way groundspeed can change is to accelerate or decelerate the mass of the airplane relative to the ground, which takes times and energy. Conversely, airspeed is directly dependent on what changes occur in the relative wind component along the glide slope, as the aircraft traverses different layers of air. Thus, airspeed (and lift) can change instantly in value. It is important to remember that groundspeed cannot change instantly due to the mass of the airplane and the inertia involved, and airspeed can change instantly because of the mass of the airplane, when sudden wind changes occur.

A PREPLANNED GROUNDSPEED can be figured on your computer using the field elevation and surface temperature to convert normal approach indicated airspeed to TRUE AIRSPEED. The recommendation calls that this figure be written on the landing card, along with the surface headwind component to be subtracted from it.

This preplanned GROUNDSPEED should be used as an additional minimum speed all during the final approach. Groundspeed should not fall below this value and also, indicated airspeed should not fall below normal approach airspeed. If when holding the minimum groundspeed, the indicated airspeed is appreciably higher than normal, this indicates that a higher wind exists at your altitude than at the runway,

Conversely, if your groundspeed is higher than the zero wind preplanned, while holding normal approach indicated, then you obviously have a tailwind.

In the first case, where the indicated airspeed is appreciably high, this condition indicates that the pilot will experience a decrease in headwind, and consequently decreasing indicated airspeed (and lift) somewhere during the final approach. This decrease may be gradual or sharp, but if the groundspeed is held, the indicated airspeed should never drop dangerously low. Even if a power increase is then required to keep the airspeed above its minimum, it will be less correction, than would have been required had the groundspeed not been used, and far safer.

In the second case, where the groundspeed exceeds the preplanned, indicating a tailwind component aloft. This procedure is equally important.

The Iberia DC-10 performed a coupled approach in instruments with tailwind during the approach, and did not pay attention to the situation, that the autopilot was on the glide slope but, with low pitch attitude, low power and high rate of descend. The pilot had the approach lights in sight at 200 ft. but not the runway and disconnected the autopilot. In the same time he got the wind shear. He recognized the sink rate 3 seconds too late.

Part 5 - CONCLUSIONS

Regarding forecasting, a complete new thinking is required using Daniel Sowa parameters and new meteorological maps of smaller air masses (mesometeorology) for airport areas. Regarding detection around the airport we should consider very seriously the recommendations of Dr. Fujita, which requires that during severe dynamic weather, it is necessary to conduct a continuous monitoring of the shape and motion of the radar echoes, and an uninterrupted analysis in order to properly evaluate the thunderstorm in motion.

This recommendation implies perhaps that IFR control rooms and airport towers should include meteo teams and equipment working alongside the controllers during bad weather operations.

Now regarding the communications. Detection will be of little use unless procedures are developed for real time communication of the information to the pilots. During severe dynamic weather, the present set-up of detection and warning including ATIS and PILOTS REPORTS is not adequate.

FINAL FLYING CONCLUSIONS

1. The conventional thinking of pilot quick recognition and response is not answering the problem of wind shear. Proper speed should already be in the approach configuration, before encountering the shear, otherwise it is too late. Staying on the glide slope is not enough. New thinking in terms of KINETIC ENERGY is required.

2. When there is a severe thunderstorm over the airport, do not land or take-off. Delay or divert.

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THE PUBLIC'S TOTAL STAKE IN AVIATION ACCIDENT INVESTIGATION

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I. INTRODUCTION

Paragraph one of page I-1-1 of Chapter 1 of the ICAO Manual of Aircraft Accident Investigation begins as follows:

> "The fundamental purpose of inquiry into an aircraft is to determine the facts, conditions and circumstances pertaining to the accident with a view to establishing the probable cause thereof, so that appropriate steps may be taken to prevent a recurrence of the accident and the factors which led to it." (1)*

This is clear. It should be easily understood, and to those well versed in air safety work, it contains some rather basic precepts; for example, reference to factors, plural, which are present in every accident.

However, the work done to reach an investigation's safety objective as stated above extends well beyond air safety per se. Especially in civil aviation, although not limited thereto, an impact exists upon the public; an impact that should make us think of a social accident investigation system rather than one whose boundaries encompass only the relatively technical ramifications leading to aircraft accident prevention.

In the United States, at least, we are living in a period of consumerism and public awareness. Enhanced or perhaps even created by man's now super ability to communicate - accurately or otherwise - people can hear of, inquire about, demand and get more information concerning accidents than was ever dreamed of a decade or two ago. They use this information in many ways, sometimes in a manner seemingly counterproductive to air safety.

This places increased focus of attention on the work of air safety investigators. It suggests a needed reassessment of where we are in this business and where we are going. It mandates a change in our processes if it can be shown that our past practices have failed to meet the public's total needs or are heading that direction.

As will be shown in this paper, some rather serious problems do exist in aviation accident investigation in the U.S. and it is going to take some courageous and enlightened leadership to correct them.

II. THE OBJECTIVES OF THE SOCIAL AVIATION ACCIDENT INVESTIGATION SYSTEM

Listed below as Table (1) are five objectives of accident investigation when considering the public's total perception of the output from those investigations.

*Numbers in parenthesis refer to references noted at the end of the paper.

TABLE (1)

1. ACCIDENT PREVENTION
2. INFORM THE PUBLIC
3. LAW ENFORCEMENT
4. DETERMINE CULPABILITY
5. PROVIDE BUSINESS DATA

Accident prevention is achieved through improvements in education/training, the hardware, operations and management (including procedures or regulations) based on facts derived in the investigation. This closed loop process in which accident investigation is the feedback link in the accident prevention system is shown in Figure (1) and was originally presented in 1969. (2)

Strangely enough, some people still do not understand that accident investigation is just a part of the accident prevention process. They speak of investigation and prevention as separate processes. For example, in a very recent copy of Flying magazine, an editorial states:

> "...Todd (Chairman of the NTSB) believes his accident investigators should be out in the field looking for accidents to prevent when they are not investigating accidents that have already occurred." (3)

Whether this interpretation originates with the editor of Flying or Chairman Todd is for them to decide. In any event it displays a harmful lack of awareness of what accident investigation/prevention is all about; harmful because it confuses those who contribute and administer funds for government's role.

The Flying article goes on to say:

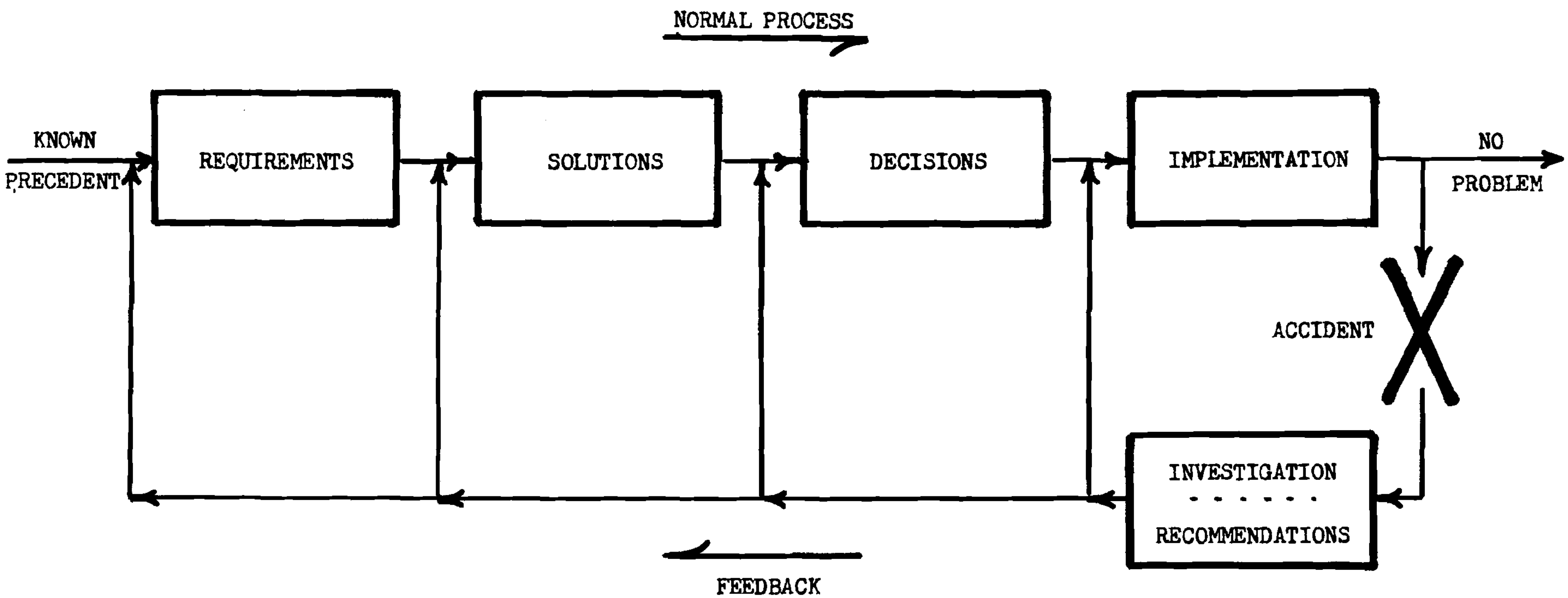
> " (The) two major Government agencies (FAA & NTSB) should not be trying to outdo each other in preventing accidents...There are some good reasons for leaving ... the FAA pursuing the accident prevention business and the NTSB specializing in accident investigation ...
>
> What is needed is an agency that excels at determining causes of accidents and transmitting that information to the appropriate agency that acts in the most realistic and effective way possible to prevent accidents. There should be cooperation ..."

And there is the key, "cooperation". No one organization prevents accidents on its own. Each may have some primary role, but each has a corollary interest in, if not actually an active role in the other group's activities. Accident prevention and, indeed, accident investigation as a subset thereof, is like that.

Furthermore, most authorities in air safety would quarrel with the precept of cause being the singular or perhaps even a necessary determination output from investigative agencies. Especially for a group like NTSB which has a statutory oversight role in transportation safety, as obligation exists to make specific recommendations. It is not a statutory obligation to have those recommendations accepted. The recommendations' acceptance should rise or fall on their merit which, in turn will rise or fall on the excellence of the investigations.

Figure (1)

ACCIDENT PREVENTION SYSTEM



The requirement for formal cause determination is not really required for safety purposes except as a traditional way to classify accidents. It is really more significant when considering the second objective of accident investigation, to inform the public. Here we see a tremendous awareness in the news media, the congress and even in individual households regarding accidents, particularly if either of two situations occur. First is the matter of high fatality density; that is, the number of people killed at one place at one time. Quantitatively, the public arousal number is something on the order of 10-20. Second is the question of preventability. If the story reveals prior knowledge of the hazard or the solution is logically simple to attain, then the public insists on being informed so they can at least vent their wrath. The Paris DC-10 crash typifies both the high fatality density and preventability criteria.

The public wants the story in the simplist way possible; hence they usually ask "what caused the accident." They also seem to seek familiar, though not really understood answers like "pilot error", "weather", etc.

In any case, if the public wants to know something in a democratic society, they usually have a right to know. Hence, investigative methods and procedures must take this into account.

A democratic society is also a nation of laws developed to reflect the will of the majority. To be effective, these laws must not only be reasonable but also they must be enforced. To be enforced, alleged violations need to be investigated. Hence, we come to the third objective of the social accident investigation system, law enforcement.

The FAA Act of 1958 and subsequent statutes recognize the law enforcement requirement pertaining to aviation accidents. They guarantee party status to the FAA in every NTSB accident investigation. This is not true for any other group. Legislation plus rules promulgated by the FAA and the NTSB, which have the force of law themselves, have attempted to keep the procedures aimed at safety and law enforcement somewhat separate; but facts remain facts and this commonality makes it difficult for a witness or potential defendant from telling the difference between a safety and an enforcement proceeding. The commonality really becomes highlighted when it is realized that time is the enemy of valid evidence determination. It is not always practical to wait for the accident prevention investigation to be completed first and then proceed for enforcement or other legal purposes, lest vital evidence become lost or obscurred.

This leads logically to accident investigation objective number four, determination of culpability. Because of even more stringent rules of evidence in tort litigation than in FAA enforcement proceedings, the accuracy and completeness of the factual findings becomes paramount. To deny such information to the judicial process is to challenge the reasonableness of our social justice system. In our lifetime, the U.S. and most other countries have never deviated from the principle of compensation being entitled by those injured through certain acts of others. Arguments ensue as to amounts and source of monies that may become involved; but an investigation is fundamental to establishing who is responsible for the wrong as referenced to some legal standard. Recall the first part of the ICAO definition, "facts, conditions and circumstances". Much of that is identical to what is sought in pursuance of social justice.

In fact a very strong argument is often made that the legal/fault finding process is a major contributor to reaching the accident prevention objective. This is quite true in two respects; laying some fear in the minds of potential contributors to accident causation and providing improved investigative techniques and depth of their use. The search for culpability also has its negative safety input in restricted communications, at least so say most experienced non-lawyer air safety investigators.

The fifth objective shown in Table (1) is a relatively minor one unless you happen to be in the insurance business or in a management position to ascertain needed equipment replacement. If someone does not at least keep score on unwanted and unplanned losses, business disruptions and payments therefore could become quite chaotic. In addition, accidents have been shown to be a measure of management's effectiveness. The trick is for management to see this objectively or accept the views of someone else on such a value loaded subject.

III. THE CURRENT STATE OF AVIATION ACCIDENT INVESTIGATION IN THE U.S.

Implicit in the foregoing discussion are conflicting purposes, organizational uncertainties, misunderstandings between disciplines, and above all, a very complex relationship when considering all components of the social accident investigation system. Couple this with aviation's continual growth, the socio-political upheaval we have experienced in recent years, economic problems and, again, the influence of mass media communication, one should not be too surprised that future shock* has perhaps come to the aviation accident investigation field. It has resulted currently in the lowest overall quality of U.S. aviation accident investigations seen in many years. This is particularly true regarding general aviation cases, but signs are now even present in some air carrier cases. Consider the following:

Case No. 1
A high performance glider was seen to shed a wing in flight. Witnesses had conflicting views as to the attitude of the aircraft prior to the breakup. No structural failure analysis was made or at least documented regarding the wing-fuselage separation point, nor of the horizontal tail section, a piece of which having been found near the wing. Cause was ascribed to the pilot allowing the aircraft to pick up speed too fast. Subsequent investigation found this type aircraft had previously experienced a flutter failure at less than red line speed with some markings near the wing failure point similar to those on the accident aircraft. The airspeed indicator was one with an ambiguity in red line display that could be easily misread.

Case No. 2
A light twin being flown by a qualified, relatively experienced pilot who was IFR rated, was seen to come out of a ragged, low overcast a few minutes after takeoff in a "typical disorientation type accident". Impact was quite steep but no fire resulted. The leading edges of the wings were pushed back accordion style. The wreckage was returned to the owners insurance company after its examination at the crash site. Probable cause was "undetermined" by the NTSB. Examination of the wreckage later by two private air safety investigators working only two days revealed an empty wing tank at time of impact and a fuel system flapper type check valve installed upside down. The report made no mention of fuel state.

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* "Future shock", a phrase coined by Toffler to express the impact of time and gathering complexity of our society. See Reference (4).

Case No. 3
An air carrier aircraft crashed during an approach and landing resulting in a much publicized vilification of the flight crew because of their lack of professionalism. During the NTSB pre hearing conference, the Chairman of the Panel of Inquiry ruled out questioning pertaining to the altimeter in the aircraft which was of a type shown through testing over a decade ago to be subject to 1000' errors when read under dynamic flight conditions. In subsequent investigations, a training illustration of this altimeter was observed to incorrectly depict the configuration of the accident aircraft altimeter, the training device showing warning crosshatching that was not present in the accident situation. Similarly, other lines of human factors inquiries were not pursued and/or related in the Board's final report.

Case No. 4
An air carrier aircraft on a ferry flight stalled and spun in from relatively high altitude because the pitot heat system was not turned on and the airspeed system iced up. Nowhere in the investigative file was there a photograph, finding or discussion concerning the human engineering aspects of the pitot switch location and actuation. The report characteristically said, "The switch was off; it should have been on; the cause was the crew member failed to follow procedures". There was no discussion or documented investigation as to why the switch was not actuated.

There are many, many more such cases. This subject has been discussed with numerous highly qualified people in the past several months. These included truly independent consultants, attorneys on both the plaintiff and defense side of the legal fence, insurance company executives, media personnel and even NTSB and FAA investigators. The story has always been the same, The U.S. aviation accident investigations have been "going downhill for the last several years" and have reached an all time low in quality. These people were speaking with regards to investigation objectives relative to prevention, enforcement, and culpability. The public and the media seem to be happy with what they hear from NTSB in terms of press releases. The business people have not complained about the gross data they have been receiving.

IV. DIAGNOSIS AND PROGNOSIS

At the beginning of the previous section of this paper, reference was made to the enormous complexity of the total social accident investigation system and the general reasons for its present ill health. However three specific reasons are notable which account for the situation as it exists in the U.S. today.

1. Staffing of the Bureau of Aviation Safety (BAS) was not permitted by either the Administration or the Congress to grow commensurate with the increased growth in numbers and complexity of U.S. civil aviation nor was the Bureau's mission allowed to change. The air safety investigators were expected year after year to do more difficult and time consuming investigations with fewer people. In 1974, there were 10-12% fewer technical staff in BAS than existed in the similar Bureau under the Civil Aeronautics Board in 1963.

2. The influence of the Nixon White House staff through on of its emissaries to the Board who was illegally implanted as the Board's General Manager prostituted reasonable quality of investigations for so-called productivity. This was the subject of internal Board memoranda in 1973 and 1974 and was brought out in Senate Aviation Subcommittee hearings. The fact remains, NTSB investigators were credited for getting reports submitted within given deadlines,

yet they were rarely, if ever, chastised for a less than reasonable report, technically speaking. Indeed the internal BAS quality control procedure was decimated upon orders of the General Manager.

3. The NTSB Members, both past and present, have been void of significant safety experience and, in some cases, void of administrative or judicial experience as well. This has occurred despite a provision in the Independent Safety Board Act of 1974 which requires explicitly that at least two of the Board Members have experience in "accident reconstruction, safety engineering or transportation safety". Each of the Members in his or her own way have been fine people. Unfortunately, since the days of the original Chairman, they failed collectively to provide leadership in the mission of the Board; namely, the investigation of accidents and the conduct of special studies in order to prevent future accidents. Prior to 1976, and with exceptions voiced occasionally only by a couple of the Board Members, form rather than substance was the order of the day for NTSB work products. This, in turn, had a devastating effect on the professionalism of the staff, especially when it was coupled with a condescending attitude (unknowingly or otherwise) towards the Nixon Mafia who, above all, did not want effective oversight agencies.

Today, NTSB has three relatively new Board Members including its Chairman. Their precise feelings about the subject under discussion are not known to this author. Nevertheless, an even more serious problem exists. Because of congressional mandates which do have a meritorious intermodal safety objective in mind, the NTSB has reorganized in such a manner that the aviation function has been diluted by the other modes. Four major Bureaus have been instituted, each reporting to a "Managing Director." These are the Bureaus of Accident Investigation, Technology, Plans and Programs, and Administration.* Each Bureau is intermodal; that is, appropriate specialists from all transportation modes are in a given organizational segment and/or a specialist is expected to apply his skills to any kind of a transportation safety problem. Of necessity, Bureau chiefs will have to devote their time to intermodal activities.

This has the benefit of upgrading some of the modes to what some people feel is a better balanced NTSB effort. The disbenefits include the spreading of many people thinner, technically speaking, than they were before and providing a career ladder in an aviation specialty that stops at a GS-15 level now, compared to a GS-18 level that was present two years ago. In other words, if a person wishes to lend his talents only to aviation, he cannot now progress beyond a branch chief level wherein formerly he could aspire to Division or Bureau management positions. The organizational level to which an outside aviation group can go within the Board and be guaranteed to find uniquely qualified people in their field is now well below what it used to be.

Even at the field offices, where most general aviation cases are now supervised and quality controlled, branch level Field Chiefs are obligated to manage an intermodal office. At this writing, at least one office is to be directed by someone without any aviation experience whatsoever.

Another subtle but potentially bad situation in the future is the amplified role of the Safety Board's Managing Director who is now a line official, a boss over the bureau chiefs, in every sense of the word. He is a political

*The Office of Administrative Law Judges remains as it was prior the current reorganization.

appointee not subject to Senate review. In years to come, this could result in a resumption of inadequate daily operational leadership because of lack of combined executive and technical competence. Fortunately, the man in that position now has far better than average qualifications and appears highly motivated for the job. But who will be there in 1977?

The unquestioned result of the current NTSB reorganization will be further degradation of aviation investigations, hence, aviation safety effort, unless steps are taken to counter the current trends. These steps are not a function only of the NTSB.

V. RECOMMENDATIONS

Before providing recommendations which are hopefully constructive, one assumption must be examined. That assumption is that continued aviation progress demands sufficient in-depth investigation of a sufficient number of accidents to provide effective feedback in the sense described early in this paper. Indeed some people do not seem to accept that premise. Reference once again to the Flying editorial wherein it was written:

> "The hard fact is that most aviation accidents can be prevented only by pilots using good judgment. Money can't buy this, nor can more investigators tripping over each other looking for incipient soft spots."

The presumption there seems to be that good judgment can always be understood and applied without detailed investigations.

Years ago, the highly profound first Chairman of NTSB, J.J. O'Connell, used to raise the investigation need question himself. He then always answered it by saying in effect, "We've experienced most of all we really need to know about accident causation and the problem is to remember and use this knowledge. And if we could do that, we would not have to go out into the field any more. But the trouble is we would have to speak in parables as to what to do in the future ... and they nailed the guy to the cross who tried that a couple thousand years ago!" Also, of course, Chairman O'Connell was speaking only to the accident prevention objective of NTSB's investigations.

Accordingly, the assumption is made that professionally performed accident investigations are needed at all levels of the aviation spectrum. It is further assumed that the total objectives exist as stated earlier, that we must realize the present and future economic facts of life, and the powers-that-be inside and outside of government want to do something about the accident investigation quality problems described in this paper. On this basis it is recommended that:

1. The Administration and the Congress remaining or coming into power in 1977 do something to implement the provisions of the Independent Safety Board Act dealing with safety professional competency on the Board.

2. As at least an interim step to the above, the Safety Board should use consultants and/or form an intermodal safety advisory group composed of top safety experts in give modes to advise the Safety Board as to the adequacy of its products as seen from the "outside", and on such other matters as it deems important.

3. The Safety Board should implement the long planned selectivity program for aviation accident investigations which better channels available resources to specific kinds of cases. Similarly, it should obtain statutory relief if necessary to stop required cause determination in those cases in which a reasonable investigation cannot be done for financial reasons. Some consideration should be given to eliminate "probable cause" as the legally defined end point in any of the cases.

4. The Safety Board should cancel part 831.6 (a) of its regulations that precludes parties to field investigations and the hearing if they represent claimants or insurers, and substitute a requirement that all parties, or at least their principal spokesman, be qualified and certified through a process that ensures their contribution in accident prevention efforts as well as fulfillment of their other obligations. Part 831.16 would also have to be amplified somewhat.

5. In support of the recommendation immediately above, The Society of Air Safety Investigators should develop a training curriculum and otherwise propose a professional certification program that it might administer on behalf of NTSB and other countries' investigative bodies.

6. The Safety Board and the FAA should initiate a crash program to upgrade their investigations from a total human factors point of view.

7. The aviation community, (airlines, trade associations, manufacturers, etc.) should prepare for even more extensive participation in accident investigations than in the past, if comprehensive, accurate findings are desired.

VI. CONCLUDING REMARKS

Air safety in the U.S. and throughout the world has reached its present excellent-though-far-from-perfect level through professional air safety investigation work. The other needs of the public - the other dimensions of their stake in aviation accident investigation - have similarly been fulfilled in the past.

Due to reasons well beyond the control of any one air safety investigator or any one activity such as NTSB, the state of the art in aviation accident investigation has regressed in recent years as viewed by recipients of the work products. Unless we, as a society, are prepared to give up on further progress in air safety consistent with continued improvement in air transportation, and unless we as air safety investigators are prepared to rebuff the public in its other demands, we must revitalize our investigative activities.

We, as air safety investigators, cannot do all things for all people. But the organizations we represent, the advocacies we espose, can be brought together more effectively than we are doing now. It requires some dynamic thinking and aggressive actions by those in authoritative positions.

It is hoped this paper is at least a catalyst in effecting such actions.

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