The Joint FAA/NASA Aircraft/Ground Vehicle Runway Friction Program

An overview of progress to date points to a need for continuing testing of runway friction performance of aircraft and ground vehicles in light of improved tires and brakes, according to the author.

by

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There is an imperative need for information on runways that become slippery due to various forms and types of contaminants. Since the beginning of all weather aircraft operations, there have been landing and aborted takeoff incidents and accidents each year where aircraft have either run off the end or veered off the shoulder of low friction runways. From January 1981 to January 1988, more than 400 traction-related incidents and accidents have occurred, according to U.S. Federal Aviation Administration (FAA) and National Transportation Safety Board (NTSB) records. These cases provided the motivation for various government agencies and aviation industries to conduct extensive tests and research programs to identify the factors that cause the runway friction to be less than acceptable.

The continued occurrence of aircraft takeoff and landing accidents emphasizes the need for improved measurement techniques and inspection procedures related to tire and runway conditions. NASA Langley's Landing and Impact Dynamics Branch is involved in several research programs directed towards obtaining a better understanding of how different tire properties interact with varying pavement surface characteristics to produce acceptable performance for aircraft ground handling requirements. This article describes one such effort, which was jointly supported by NASA, the FAA, and by several aviation industry groups including the Flight Safety Foundation.

Special Boeing 737 Acts as Test Model

The Joint FAA/NASA Aircraft/Ground Vehicle Runway Friction Program is aimed at obtaining a better understanding of aircraft ground handling performance under a variety of adverse weather conditions and seeks to define relationships between aircraft and ground vehicle tire friction measurements. Major parameters influencing tire friction performance such as speed, contaminant type and amount, test tire inflation pressure and runway surface texture, were evaluated during the test program. These tests involved a specially instrumented FAA Boeing 727 and a NASA Boeing 737 (shown on the cover during test runs).

Several different friction measuring vehicles used during the program are shown. The diagonal-braked vehicle developed by NASA measures locked wheel sliding friction values.

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Diagonal-Braked Vehicle

The FAA mu-meter trailer monitors side force variation on two tires yawed to an included angle of 15 degrees. Both the surface friction tester automobile and Swedish BV-11 skiddometer trailer measure tire braking friction near the peak of the tire friction/slip ratio curve. A relatively new runway friction tester van also measures peak tire braking friction. Both a Tapley meter and a Bowmonk brakemeter were installed in the runway condition reading (RCR) vehicle to indicate vehicle braking deceleration levels under snow and ice conditions.

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Mu-Meter & BV-11 Skiddometer Trailers

Dealing With Differing Test Results

With known differences in ground vehicle test tire operational modes, different levels of tire friction measurements were expected, and obtained, for the same runway surface condition. Between June 1983 and March 1986, we performed tests on 12 different concrete and asphalt runways, grooved and nongrooved, including porous friction coarse, under dry, truck-wet, rain-wet, snow-, slush-, and ice-covered surface conditions. A limited assessment of some runway chemical de-icing treatments was also made. More than 200 test runs were made with the two transport aircraft and more than 1,100 runs were made with the different ground test vehicles.

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Surface Friction Tester

Most of the dry and the truck-wet runway surface test runs were performed at NASA Wallops Flight Facility in Virginia and the FAA Technical Center airport in New Jersey. A limited number of rain-wet tests were performed at Langley Air Force Base, VA, Pease Air Force Base, NH, and Portland International Jetport, ME. All the winter runway test conditions were evaluated at Brunswick Naval Air Station in Maine. The test procedure for wet runway conditions was to

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Runway Friction Tester

make ground vehicle runs before and after each aircraft braking run.

For the winter runway conditions of compacted snow and solid ice, a series of ground vehicle runs were made immediately following the aircraft test runs on each surface contamination condition. At loose snow depths equal to or greater than 2 inches, test runs with the two trailer devices were suspended because constant speed could not be maintained.

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Runway Condition Reading Vehicle

Analyzing the Test Results

A substantial tire friction database has been collected during this Joint FAA/NASA Runway Friction Program with extensive data reduction and analysis being accomplished at NASA Langley. All of the runway friction data will be discussed and analyzed in a soon-to-be-published NASA technical report that has undergone both FAA and NASA technical reviews. Only a very limited amount of aircraft and ground vehicle friction data are presented herein to indicate some of the major test findings and data trends.

• **Wet runways:** The range of Boeing 737s and ground vehicle friction measurements obtained on nongrooved and grooved surfaces under truck-wet conditions is shown in Figure 1. As expected, the grooved runway surface friction data is significantly greater than the nongrooved data, particularly at the higher speeds. Most of the ground vehicle friction values were higher than those developed by the Boeing 737 because of differences in braking test mode, tire tread design and tire inflation pressure. When these major factors are properly considered using techniques and methodologies being developed at NASA Langley, aircraft wet runway braking performance can be estimated from ground vehicle friction measurements.

The relationship between actual braking friction coefficient for the Boeing 737, and estimated braking friction coefficients of the airplane obtained from the ground vehicle measurements, is shown in Figure 2. For most of the ground vehicle friction measurements, the estimated aircraft performance is in good agreement with the actual measured aircraft braking friction level. The data suggest that the ground vehicle friction measurement for wet runway condi-

Figure 1. Range of B-737 aircraft and ground vehicle friction measurements.

Figure 2. Relationship between actual and estimated B-737 aircraft braking performance.

tions can estimate aircraft tire friction performance to within about 15 percent of the actual measured aircraft friction values and in some cases, within five percent. The relationship between ground vehicle estimated and actual aircraft tire friction values will vary with changes in wetness conditions. Hence, ground vehicle friction measurements should be taken on a runway for a range of wetness conditions related to different precipitation rates and surface winds.

• **Snow-and ice-covered runways:** A comparison of Boeing 737 braking performance for snow- and ice-covered runways as well as dry, truck-wet, and flooded conditions is given in Figure 3. The range of aircraft effective friction coefficients is from nearly 0.5 on dry runways to 0.05 on the solid ice surface at Brunswick Naval Air Station (BNAS).

Similar results were obtained during the Boeing 727 tests. For compacted snow- and ice-covered conditions, the friction measurements obtained with the various ground test devices indicated that forward speed had little effect on the magnitude of the friction values. Furthermore, the friction values obtained from each vehicle showed no significant

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Figure 3. Comparison of B-737 aircraft braking performance.

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Figure 4. Ground vehicle friction reading correlation table.

NOTES:

(1) Mu-meter equipped with smooth RL-2 tires inflated to 69 kPa (10 lb/in.^{2})

(2) Runway friction tester equipped with smooth RL-2 tire inflated to 207 kPa (30lb/in.^{2})

(3) Surface friction tester and BV-11 skiddometer equipped with grooved aero tire inflated to 690 kPa (100 lb/in.^{2})

(4) Ambient air temperature range, -15 to +5^o C (5 to 41^{o}F)

(5) Test speed range, 32 to 97 km/h (20 to 60 mph)

Figure 5. Aircraft braking friction performance on compacted snow- and ice-covered runways.

difference between compacted snow- and ice-covered conditions.

The Tapley and Bowmonk meters were both installed in the Navy runway condition reading vehicle and the manually recorded friction values for each instrument were in close agreement for a given test run. Figure 4 provides a listing of the range of ground vehicle friction values obtained for compacted snow- and ice-covered runway conditions. Tire conditions, ambient temperatures and test speeds are indicated in the notes accompanying the figure. Qualitative verbal braking action terms, namely: excellent, good, marginal, and poor, were used to identify four distinct levels or ranges in friction readings for each device. In general, the excellent friction readings were close to some wet surface values, e.g., 0.5 and above, whereas, the poor friction readings were normally below a friction level of 0.25.

The BV-11 skiddometer and the surface friction tester values were similar as expected since the test tire and braking slip operation were identical. The range of friction values at each of the four qualitative levels is nearly the same for the mu-meter, Tapley meter, runway friction tester and the Bowmonk meter. Slightly higher friction values were obtained with the surface friction tester and the BV-11 skiddometer probably due to the use of a higher test tire inflation pressure and the use of a grooved tread pattern on the tire instead of a smooth tread.

The range of aircraft effective braking friction coefficient values as a function of ground speed for compacted snow- and ice-covered runway conditions is shown in Figure 5. The data symbols and line codes denote the different test conditions and aircraft. The best fit, least squares linear curve for the compacted snow-covered surface friction data, denoted by the solid line, has a value nearly four times greater than the data from the glare ice-covered surface denoted by the dashed line. These aircraft results differ from the ground vehicle measurements which indicated no significant difference between compacted snow-covered runway condition and the solid ice-covered condition.

The difference in braking performance shown in Figure 5 between the two test aircraft under these winter runway conditions was considered insignificant. The aircraft braking performance on the snow-covered and ice-covered surfaces was relatively insensitive to ground speed variations which was also found for the ground vehicle measurements.

Since each test aircraft indicated a significant difference between the compacted snow-covered and ice-covered surface conditions, two ranges or means of aircraft braking friction data were selected to define the relationship with the ground friction measurements. The resulting aircraft and ground vehicle friction correlation chart is shown in Figure 6, where the compacted snow-covered and ice-covered surface condition is delineated for the two aircraft.

For the compacted snow-covered surface condition, an aircraft effective braking friction coefficient value of 0.21 was selected for the highest braking action level and 0.12 was used for the lowest braking action level. An effective braking friction coefficient range from 0.055 to 0.01 was selected for comparable aircraft braking action levels on the ice-covered surface condition. The dashed line in Figure 6 depicts comparable values for ground vehicles and the two aircraft/surface conditions comparable to an RCR value of 15.

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Figure 6. Aircraft and ground vehicle friction correlation chart.

From an aircraft operator's viewpoint, these values of friction for a snow- or ice-covered runway must be considered in respect to the actual runway geometry and such real time environmental conditions as pressure altitude, winds, and ambient temperature. It should also be recognized that aircraft operations can occur on runways which have a combination of compacted snow-covered areas and exposed solid ice-covered surfaces. In such circumstances, additional ground vehicle friction measurements need to be taken to adequately determine average friction numbers for each runway. How well this established relationship between aircraft and ground vehicle friction values remains for other aircraft types is somewhat questionable although the available data tends to suggest a similar relationship.

The use of actual friction numbers in place of qualitative braking action terms is strongly recommended because with experience, these runway friction values measured by a ground vehicle will provide the pilot a more precise and accurate gage on the safety margins available for landing on a given runway. Proper use of snow removal equipment and runway chemical treatments to minimize or remove snow and ice contaminants is still recognized as a necessity.

More to be Done

A substantial tire friction database has been collected from our tests with two instrumented transport aircraft and several different ground test vehicles on a variety of runway surfaces and wetness conditions. A better understanding of the major factors influencing tire friction performance has been achieved. The relationships defined between the different ground vehicles and between ground vehicle and aircraft tire friction performance are very encouraging. Greater use of ground vehicle friction measurements at airports is strongly encouraged to help define runway surface maintenance requirements and to monitor current runway friction levels under adverse weather conditions.

In October 1988, a Runway Friction Workshop was held at NASA Langley to discuss, with the aviation community, the preliminary test results from the joint program and to obtain comments and recommendations. Some 18 formal presentations were made to approximately 80 attendees representing U.S., Canadian and Swedish government agencies, airframe manufacturers, airlines and pilots, airport managers, ground test vehicle manufacturers and suppliers and aircraft tire and brake companies; Allen K. Mears, director of special projects, represented FSF. Separate presentations were given concerning similar work being conducted in Sweden, England, France, Japan and Canada.

Based upon workshop discussion, the Joint Runway Friction Program draft report was modified and improved. Future plans include a Joint NASA/FAA Surface Traction Program using the Aircraft Landing Dynamics Facility at Langley to evaluate radial-constructed transport aircraft tires. Work in designing a new standardized form for use at all U.S. airports for reporting and documenting ground vehicle aircraft friction data will be initiated.

Additional meetings are planned at FAA Headquarters to discuss how the joint program test findings impact existing advisory circulars, standards and regulations. With improved test tires, brake systems and other equipment becoming available for airport operations, there is a need for continued testing of aircraft and ground vehicle runway friction performance. ♦

Microwave Landing System

Much work remains if this international program for a new standard approach aid can be implemented worldwide by its 1998 deadline.

"The concept of MLS has been oversold and underdelivered." This statement from Richard P. Arnold, manager, U.S. Federal Aviation Administration (FAA) MLS Program Office, explains why this 10-year-old program still is considered to be developmental in nature.

Allen K. Mears, director of special projects for FSF, attended the FAA's MLS Regional Associate Program Manager's Conference in Palo Alto, California, on February 28, 1989. The Foundation was invited by Arnold because of its stated concerns about the worldwide implementation of MLS. These concerns are well-founded, since MLS as a concept has not been validated or proven by computer modeling and site demonstrations.

In the summer of 1988, the FAA acknowledged that the MLS program was not addressing the total problem. According to Joseph Del Balzo, executive director for system development at the FAA, the last three or four years saw the program losing user support because of contractor disputes, lack of hardware and no demonstrated advantage to MLS over ILS. By establishing the program office under Arnold, the FAA is attempting to expedite the program.

The two major issues to be addressed are to quantify the benefits of MLS and to quantify the magnitude of the frequency interference problems in the ILS band.

MLS is not solely a concept for U.S. operations. In the later 1970s, the International Civil Aviation Organization (ICAO) adopted MLS as the landing system to replace ILS. The ICAO standard will take effect in 1998. The target is to have 211 international runways equipped with MLS by that year. Will these runways be dual ILS/MLS in 1998? Maybe. That depends on how closely the FAA, ICAO, and the contractors can adhere to schedules. In the United States, the intent is to dual-equip airports until parity plus five years. Parity will be achieved when the number of installed MLS units equals the number of ILS units. The users will then have five years to convert their aircraft to MLS. This time period is based on commercial air carrier overhaul schedules.

What is the benefit of MLS? Since MLS has not been validated, the benefits are speculative, but intriguing nonetheless. Some of the claimed benefits are: better reliability, cheaper maintenance costs, compatibility with the National Airspace Plan, relatively clear operating frequencies, establishment of precision approach capabilities where none now exist, increased airport capacity under Category III conditions, and ease of noise abatement compliance.

Since MLS is an ICAO initiative, there is already a great deal of coordination between the FAA and ICAO. The FAA recently participated in an ICAO European user forum in Frankfurt, Germany, and chaired an ICAO MLS planning conference in Bangkok, Thailand, in October 1988. Forthcoming is an ICAO Caribbean/South American Regional Air Navigation Meeting in Lima, Peru, in May 1989. ICAO has an Air Navigation Commission (ANC) program for MLS introduction. That work program covers 27 operational and technical tasks from MLS transition activities to flight crew certification.

To address all 27 tasks, ICAO is utilizing five panels; All Weather Operations (AWOP), Operations (OPSP), Obstacle Clearance (OCP), Study Group for Air Craft Certification (SGCAS) and the Visual Aids Panel (VAP). The All Weather Operations Panel has the broadest responsibilities and is further divided into three working groups; Engineering, chaired by Seymour Everett (U.S.), Operational, chaired by David Schrier (The Netherlands), and Air Traffic Control Integration, chaired by Bjorn Bergland (Sweden). The groups already have begun to hold meetings.

A further indication of the international focus on MLS is the number of bilateral agreements and related activities in place between the U.S. and The Netherlands, the Union of Soviet Socialist Republics, the United Kingdom, Canada and Japan. These countries have, or are planning for, specific MLS site installations. Additionally, France, Norway, Italy, Denmark, Sweden and Germany are establishing MLS activities.

For MLS to be properly validated and proven, international efforts and communications must be increased. It is incumbent upon ICAO to expand its international dialogue with agencies and users as 1998 draws closer. ♦

Reports Received At FSF

Federal Aviation Regulations:

Amendment Numbers 43-30 and 91-206.

The Federal Aviation Administration has issued a final rule revising the U.S. Federal Aviation Regulations (FAR) to permit certain aircraft, for which an approved Master Minimum Equipment List (MMEL) has not been developed, to be operated with inoperative instruments and equipment not essential for the safe operation of the aircraft.

Amendment Numbers 43-30 and 91-206 permit rotorcraft, nonturbine-powered airplanes, gliders, and lighter-than-air aircraft, for which an approved MMEL has not been developed, to be operated with inoperative instruments and equipment not essential for the safe operation of the aircraft. These amendments also permit general aviation operators of small airplanes, gliders, and lighter-than-air aircraft, for which a MMEL has been developed, the option of operating under the minimum equipment list concept or in accordance with the provisions of this final rule.

The pilot-in-command, owner, or operator will be required to identify the inoperative instruments or equipment, consult the aircraft's approved flight manual or owner's handbook, and review FAR Part 91.30[d](2). After the pilot-in-command ensures that an inoperative instrument or equipment is not required, the aircraft may depart provided:

a. The inoperative instrument or item of equipment is deactivated or removed, the cockpit control of the affected instrument or item of equipment is placarded with the word "Inoperative," and the discrepancy is recorded in the aircraft's maintenance records. If the inoperative instrument or item of equipment is being removed from the aircraft or if deactivation requires maintenance, a certified and appropriately rated maintenance person will be required to accomplish the removal and maintenance task; and,

b. At the next required inspection, the inoperative instrument or item of equipment is repaired, replaced, removed, or inspected as appropriate.

Copies of Amendment Number 43-30 and 91-206 regarding Inoperative Instruments or Equipment are available from: U.S. Government Printing Office, Superintendent of Documents, Washington, D.C., U.S., 20402-9325. Telephone (202) 783-3238.

Reports:

Application of Triggered Lightning Numerical Models to the F106B and Extension to Other Aircraft. Poh H. Ng, Roger A. Dalke, et al. Electro Magnetic Applications, Inc. December 1988. NASA contract NAS1-17748. NASA CR-4207. 244 p. Available from NTIS.*

The goal of the F106B Thunderstorm Research Program is to characterize the lightning environment for aircraft in-flight. This report documents the application of numerical electromagnetic models to this problem. Topics include: extensive application of linear triggered lightning to F106B data; electrostatic analysis of F106B field mill data; application of subgrid modeling to F106B nose region, including both static and nonlinear models; extension of F106B results to other aircraft of varying sizes and shapes; application of nonlinear model to interaction of F106B with lightning leader-return stroke event.

Development of an Intervention Program to Encourage Shoulder Harness Use and Aircraft Retrofit in General Aviation. James F. Parker, Jr. and Diane G. Christensen. BioTechnology, Inc. May 1988. FAA Contract No. DTFA-02-87-C-87086. Available from NTIS.*

A study by the NTSB in 1985 indicates that full use of shoulder harness restraint systems in general aviation could lead to a dramatic reduction in fatalities and serious injuries in accidents. The purpose of this project was to examine the feasibility of developing an intervention program designed to increase use of existing harnesses and encourage their installation in private general aviation aircraft which are not presently equipped with usable shoulder harnesses. The resulting intervention program may be implemented by the FAA, which is responsible for promoting aviation safety. The recommendations for the structure of the intervention program include: National in coverage with direction from FAA Headquarters; Finite in duration, lasting perhaps for a two-year period; Aimed both at increasing shoulder harness use and encouraging retrofit of older aircraft; Development of a comprehensive database describing current shoulder harness use, regional differences, and rate of retrofit; Special project goals should be established.

* U.S. Department of Commerce, National Technical Information Service (NTIS), Springfield, VA 22161 U.S. Telephone: 703-487-4780.

U.S. Commuter Air Carrier and On-demand Air Taxi Accident Statistics — Calendar Year 1988

U.S. air carriers operated under 14 CFR 135 in calendar year 1988, including both scheduled and non-scheduled service, were involved in 117 accidents, 30 of them fatal, accounting for a total of 78 fatalities. Twenty of the fatal accidents occurred in descending or in approaching for landing; only four occurred in takeoff initial climb; six accidents occurred during normal cruise. A breakdown of the fatal accidents by phase of operation vs. meteorological conditions is shown in Table 1.

Table 1 - Commuter Air Carrier and On-Demand Air Taxi Fatal Accidents by Phase of Operation

Meteorological		Phase of Operation				
Condition	Descent	Approach	Landing	Takeoff	Cruise	Total
Instrument	2	7	2	0	2	13
Visual	4	5	0	4	4	17

Commuter Air Carrier

Commuter air carrier refers to those aircraft operators which operate at least five-time scheduled service per week between any city pair under 14 CFR 135. In 1988, commuter air carrier total accidents dropped to 20 from 34 in 1987.

The figure is the third lowest in commuter air carrier safety records for the past decade. Two of total accidents were fatal, accounting for 21 fatalities, down from 61 in 1987. The accident rates per 100,000 departures was 0.714, compared with 1.740 in 1987 and 0.563 in 1986.

The fatal accident rate was 0.071 per 100,000 departures compared with previous record-low 0.075 in 1986. An annual comparison of total accidents fatal accidents and rates for the period 1978 through 1988 is shown in Table 2.

On-Demand Air Taxi

On-Demand air taxi refers to those aircraft operators under 14 CFR 135 other than commuter air carrier. In 1988, on-demand air taxi operators were involved in 97 accidents, two fewer than 1987; about one-third of them, or 28 were fatal accounting for 57 fatalities. The total accident rate of 3.36 per 100,000 aircraft hours was the record-low in the past decade and the fatal accident rate of 0.97 per 100,000 aircraft hours was the second lowest. An annual comparison of total accidents, fatal accidents and rates is shown in Table 3. Table 4 presents briefs of all commuter and air taxi fatal accidents.

Table 2
Accidents, Fatalities and Rates
U.S. Air Carriers Operating Under 14 CFR 135
All Scheduled Service
(Commuter Air Carriers*)
1978 - 1988

Year	Accidents Total	Accidents Fatal	Fatalities Total	Fatalities Aboard	Aircraft Miles Flown#	Aircraft Hours Flown#	Departures#
1978	61	14	48	48	226,187,000	1,302,136	1,995,728
1979	52	15	66	66	192,493,000	1,169,921	1,883,705
1980	38	8	37	37	192,200,000	1,175,588	1,776,999
1981	31	9	34	32	193,001,000	1,240,764	1,835,144
1982	26	5	14	14	222,355,000	1,299,748	2,026,691
1983	17	2	11	10	253,572,000	1,510,908	2,328,430
1984	22	7	48	46	291,460,000	1,745,762	2,676,590
1985	21	7	37	36	300,817,000	1,737,106	2,561,463
1986	15	2	4	4	321,629,000	1,738,239	2,663,327
1987	34	12	61	58	350,649,000	1,953,746	2,719,476
1988P	20	2	21	21	363,335,000	2,018,000	2,800,000

Accident Rates +

Year	Per Million Aircraft Miles Total	Per Million Aircraft Miles Fatal	Per 100,000 Aircraft Hours Total	Per 100,000 Aircraft Hours Fatal	Per 100,000 Departures Total	Per 100,000 Departures Fatal
1978	0.270	0.062	4.685	1.075	3.057	0.701
1979	0.270	0.078	4.445	1.282	2.761	0.796
1980	0.195	0.042	3.232	0.681	2.138	0.450
1981	0.161	0.047	2.498	0.725	1.689	0.490
1982	0.117	0.022	2.000	0.385	1.283	0.247
1983	0.067	0.008	1.125	0.132	0.730	0.086
1984	0.075	0.024	1.260	0.401	0.822	0.262
1985	0.070	0.023	1.209	0.403	0.820	0.273
1986	0.047	0.006	0.863	0.115	0.563	0.075
1987	0.097	0.034	1.740	0.614	1.250	0.441
1988P	0.055	0.006	0.991	0.099	0.714	0.071

P Preliminary data.
Source of estimate: FAA
+ Rates are based on all accidents including some involving operators not reporting traffic data to RSPA.
* Includes accidents involving all-cargo air carriers when those accidents occurred during scheduled 14 CFR 135 operations. All-cargo air carriers no longer meet the RSPA definition for “Commuters”. May also include accidents involving carriers whose FAA operating specifications permit scheduled revenue operations under 14 CFR 135, but who have not received a RSPA fitness determination.

Table 3
Accidents, Fatalities and Rates
U.S. Air Carriers Operating Under 14 CFR 135
Non-Scheduled Operations
(On-Demand Air Taxis)
1978 - 1988

Year	Accidents Total	Accidents Fatal	Fatalities Total	Fatalities Aboard	Aircraft Hours Hours Flown#	Accident Rates per 100,000 Aircraft Hours Total	Fatal
1978	198	54	155	152	3,545,753	5.58	1.52
1979	160	30	77	73	3,684,321	4.34	0.81
1980	171	46	105	101	3,617,724	4.73	1.27
1981	157	40	94	92	2,895,827	5.42	1.38
1982	132	31	72	72	3,256,763	4.05	0.95
1983	141	27	62	57	2,574,883	5.48	1.05
1984	146	23	52	52	3,079,007	4.74	0.75
1985	152	35	76	75	2,782,696	5.46	1.26
1986	116	31	65	61	2,913,358	3.98	1.06
1987P	99	29	64	—	2,877,002	3.44	1.01
1988P	97	28	57	—	2,890,000	3.36	0.97

P Preliminary data.
\# Source of estimate: FAA

Table 4
Fatal Accidents and Fatalities
Air Carriers Operating Under 14 CFR 135
Calendar Year 1988
(Preliminary Data)

All Scheduled Service (Commuter Air Carrier)

Date	Location	Aircraft Type	Damage	Fatalities	Weather	Remarks
1/19	Colorado	Fairchild Swear-ingen SA-227A	D	9	IMC	Crashed during an instrument approach.
2/19	North Carolina	Fairchild Swear-ingen SA-227A	D	12	VMC	Crashed shortly after takeoff.

All Non-Scheduled Service (On-Demand Air Taxi)

Date	Location	Aircraft Type	Damage	Fatalities	Weather	Remarks
1/4	Illinois	Cessna T21ON	D	1	VMC	Crashed on un-controlled approach.
1/8	Louisiana	Gates Learjet 36A	D	2	VMC	Crashed on un-controlled approach.

All Non-Scheduled Service (On-Demand Air Taxi [continued])

Date	Location	Aircraft Type	Damage	Fatalities	Weather	Remarks
2/3	Montana	Cessna 421A	D	3	IMC	Collided with high terrain on approach.
2/19	New Jersey	Piper PA-31-325	D	3	IMC	Crashed on approach in bad weather.
2/19	Connecticut	Piper PA-34-200T	D	2	IMC	Undershot on landing.
3/3	Missouri	Beech D18S	D	2	IMC	Encountered adverse weather and crashed.
3/10	Michigan	Beechcraft E185	D	3	VMC	Loss of control in descending.
4/1	Missouri	Beech H-18	D	1	IMC	Crashed during IFR circling for landing.
4/4	Minnesota	Cessna 207	D	1	VMC	Crashed on approach go-around.
4/8	Idaho	Aero Commander 680FL	D	2	VMC	Collided with objects on descending.
4/17	California	Aerospatiale AS355F	D	2	VMC	Inflight collision with object.
5/17	Arkansas	Aero Commander 690A	D	1	VMC	Inflight collision with collision with terrain on approach.
5/18	Alaska	Piper PA-32-260	D	3	VMC	Collided into high high terrain during cruise.
5/24	Alaska	Aerospatiale AS350D	D	2	VMC	A midair collision during initial climb.
5/25	South Carolina	Cessna 402B	D	1	VMC	Collided with trees and terrain in un-controlled descent at night.
7/14	Louisiana	Aerospatiale SA330J	D	1	VMC	Crashed shortly after takeoff.
7/30	Alaska	Cessna 185	D	3	VMC	Crashed due to loss of control on maneuvering.
8/17	Alaska	Cessna C-402-B	D	2	IMC	Collided with terrain on descending.

All Non-Scheduled Service (On-Demand Air Taxi [continued])

Date	Location	Aircraft Type	Damage	Fatalities	Weather	Remarks
8/18	Alaska	Dehavilland DHC-2 Mark	D	1	VMC	Inflight loss of control on descend-ing.
9/5	Alaska	Britten Norman BN-2A	D	1	IMC	Crashed on maneuvering in severe weather.
10/16	California	Piper PA-32-300	D	5	VMC	Crashed on cruise due to loss of power.
11/2	Texas	Piper Aerostar 601B	D	1	IMC	Collided with object on approach.
11/4	Louisiana	Aerospatiale AS355F-1	D	4	VMC	Crashed during initial climb.
11/5	Pennsylvania	Cessna 207	D	1	IMC	Collided with terrain inflight.
11/13	Florida	Piper PA-28-181	D	4	IMC	Crashed after collision with object on missed approach.
12/14	Alaska	Dehavilland	D	1	VMC	Crashed on approach.
12/20	California	Bell Helicopter Textron 206	D	1	IMC	Collided with terrain on descending.
12/22	Missouri	Bell 206	D	3	IMC	Crashed on approach in adverse weather.

Weather: VMC - Visual Meteorological Condition.
IMC - Instrument Meteorological Condition.

Source: NTSB.

Accident/Incident Briefs

Air Carrier

Turbulence Near Touchdown

United Kingdom - January

Lockheed L-1011 Tristar: No damage. No injuries.

The widebody air carrier was en route from Tampa, Fla., to Bermuda and received information that the surface wind at the destination was 101 degrees at 35 to 48 knots. The pilot elected to begin the approach and monitored the continuous wind readings provided by ATC.

At 100 feet (ILS decision height was 290 feet) the surface wind report was 202 degrees at 30 knots and the turbulence was severe enough that the approach had to be broken off. The pilot executed a go-around and the airplane was diverted to New York where a normal landing was accomplished.

The turbulence was confirmed by the airplane's flight data recorder, which showed that the missed approach was begun at a radar altimeter height of 50 feet with the lowest height recorded at 39 feet.

Engine Failure

Burma - February

Fokker F.27 Friendship: Aircraft destroyed. Fatal injuries to 26, injuries to seven.

The twin-engine air carrier was departing in the early morning from Rangoon for a flight to Keng Tung. According to reports, an engine failed during takeoff and the aircraft hit a tree. The airplane veered to the left and crashed through trees and electric lines in front of the non-commissioned officer's mess building at an adjacent military base.

Of the 25 passengers and four crew members aboard the airplane, 26 including all of the crew were killed. Three passengers and four persons on the ground were injured.

Swerve after Touchdown

Bolivia - December

Curtiss C-46 Commando: Damage to belly and propellers. No injuries reported.

The two-engine World War II-vintage cargo airplane was landing at Trinidad, Bolivia, in the early morning. After touchdown, the aircraft veered to the left. The pilot applied brakes to avoid a drainage ditch and the nose tilted down, resulting in a ground strike by the propellers. The lower fuselage was scraped on the ground, also.

Hazardous Souvenir

Spain - December

McDonnell Douglas DC-9: Cargo hold damage. Minor injuries to one.

Two soldiers each were bringing home a souvenir of their military training exercise on Majorca.

Shortly after their airliner landed at Madrid's Barajas International Airport, a baggage handler was removing suitcases from the aircraft's baggage hold and the firing pin apparently was dislodged from one soldier's "souvenir" — a training hand grenade. There was a loud blast, a cloud of smoke, the baggage handler's eardrums were ruptured and the inside of the cargo hold was damaged somewhat.

The two soldiers were arrested and the second grenade was deactivated by civil authorities. One of the soldiers said he was taking the grenade home to show his family during Christmas leave. Military authorities said that the training grenades are designed only to make a loud noise and smoke, but that they have no explosives.

Who Needs Wheels?

Pakistan - December

Fokker F.27 Friendship: Minor belly damage. No injuries.

The air carrier was arriving at Saidu Sharif in mid-morning after a flight from Islamabad with a crew of four and 18 passengers aboard. When the pilot dropped the gear prior to landing, the left gear appeared to be not locked in the down

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Accident/incident briefs are based upon preliminary information from government agencies, aviation organizations, press information and other sources. The information may not be accurate.

position. He decided to return to Islamabad where better emergency facilities were available.

After burning off excess fuel and requesting that the runway be foamed, the pilot landed at Islamabad at noon. After touchdown, he was able to keep the airplane within the foam strip along the runway for some 3,000 feet before the airplane departed the runway to the left and came to rest tilted on the left wing tip.

The airplane was only slightly damaged and there were no injuries to the 22 persons aboard.

AirTaxi/
Commuter

Heavy Case of Aft CG

United States - November 1987

Beech Aircraft Corp. 1900C: Aircraft damaged extensively. Fatal injuries to 18 of 21.

The final report of the U.S. National Transportation Safety Board (NTSB) found that the crash of the commuter liner occurred because "the crew improperly supervised the loading of the aircraft, displacing its center of gravity and leading to its loss of control while landing at Homer [Alaska]."

The flight had been returning to Homer from Kodiak Island with most of the passengers being hunters who were bringing along packaged venison. The NTSB found that 600 pounds more meat than the 1,500 pounds the first officer had requested was placed on board. This resulted in the center of gravity being eight to 11 inches to the rear of the aft allowable limit, according to later NTSB calculations. By the time the airplane reached its destination, fuel burn would have moved the CG even further aft.

When the flaps were extended during the landing approach at Homer, pitch control was reduced because of the aft CG condition and the pilots were not able to lower the nose of the aircraft. Consequently, the commuter liner stalled, hitting the ground flat with a high rate of descent several hundred feet short of the runway. The airplane was damaged extensively. Both crewmembers and 16 of the 19 passengers were killed by the vertical impact forces.

Flight tests conducted on a similar airplane after the accident indicated that control could be lost by extending the flaps when the CG was about seven inches beyond the aft allowable limit. Although some rime ice had accumulated on the leading edges of the wings on the accident airplane, it was not enough to have caused the loss of control, according to the Board.

Further, investigators found that the worksheet normally used by the crew to figure weight and balance had not been filled out correctly. According to the Board, the crew had disregarded company procedures when loading the aircraft, failed to properly complete the weight and balance card before taxi and failed to accurately determine within an acceptable CG range the amount of cargo that should have been put on board. Further, said the NTSB, the crew recorded an incorrect CG in the airplane log.

The NTSB final report also recommended new seat strength requirements for commuter aircraft having 19 seats or fewer since the seats on the accident airplane failed because of extremely strong vertical "G" forces. Recent FAA seat strength rules apply to regional aircraft with more than 19 seats. Although the "G" forces during the Homer accident exceeded even the new seat strength requirements, the Board said the severity of occupant injuries would have been less and that more passengers may have survived with stronger seats.

Bounce, Bounce, Bump

United Kingdom - October

Short Brothers SD 3-30: Nose gear, nose gear doors and linkages damaged. No Injuries.

The Skyvan had flown from Barrow on Walney Island to Southhampton with 24 male passengers and a crew of two aboard, and was returning with its passengers to its original departure point.

The VFR approach back at Walney Airfield was normal, but the airplane bounced twice and landed on the nose wheel first. The airplane was at its maximum landing weight for the conditions and as a result of the touchdown on the nose gear, it collapsed and the aircraft came to a halt halfway along the runway. There was no fire and the occupants left the airplane without further incident.

Not hearing the pilot's radio call, but having noticed the bounced landing, the tower controller sent emergency equipment to the airplane when he saw the passengers disembarking from the airplane that had stopped on the runway.

Later examination of marks left on the runway revealed that the nose gear had collapsed approximately 1,000 feet prior to the point where the airplane stopped. Damage to the nose gear mechanism was indicative of failure caused by overload. A part of the downlock mechanism fractured, allowing the nose gear to retract to the rear even though the downlock pin, although bent by the overload forces, evidently had been properly engaged. As the nose of the airplane contacted the runway, further damage had occurred, including gear linkages, gear doors and the tire. VHF and DME antennas, mounted beneath the airplane, had been torn off, which was considered the reason the pilot's distress call had not been heard by the tower controller.

Direct Crosswind

United Kingdom - December

Cessna T303: Right engine and propeller damaged plus nacelle damage.

The pilot had flown from Edinburgh to Gamston and was cleared for the early evening landing to Runway 03 that had a 10- to 12-knot wind from 300 degrees — a direct crosswind from the left.

During the landing, the aircraft bounced and the pilot, concerned about losing control, initiated a go-around. After another pattern, he landed successfully. However, later inspection revealed that considerable damage had been incurred during the first landing attempt when the right-hand propeller had contacted the runway: besides engine and propeller damage, the right-hand nacelle had been damaged and there was stress damage to the center section.

Fickle Fuel Gauges

United Kingdom - April

Piper PA 31 Navajo: No damage. No injuries.

A final report of a fuel exhaustion incident gave bad marks to the fuel gauges, and reiterated the need for careful fuel loading practices.

The fuel gauges indicated about 45 imperial gallons usable for the flight being planned from Southend to Lydd. With fuel required estimated at 16 gallons including taxi and power checks, the reserve was considered to be 29 gallons.

The trip was uneventful and, approximately 15 miles out of the destination airport, the airplane was cleared to land at Lydd and the pilot selected the inboard tanks. When the Navajo was about six miles out on left base leg, the right-hand engine began to misfire even though the fuel gauge indicated between a quarter of a tank and empty. The pilot switched to the outboard tank and restarted the engine. Soon thereafter, the left-hand engine did the same thing and the pilot again selected the outboard tank and restarted that engine.

On final approach at about 500 feet above the ground, the left-hand engine stopped. At 200 feet, the right-hand engine surged a few times, but the landing was successful. The pilot was able to taxi in using only the right-hand engine.

Later inspection by a technician revealed that the airplane was completely out of fuel. After 10 imperial gallons of avgas were loaded in each of the four tanks, the airplane was checked for fuel leaks and the engines were ground run. After the engines were shut down, the fuel gauges, with the known quantity of 40 gallons in them, indicated just over 60 gallons.

Low Fire Pass

Italy - January

Canadair CL-215: Aircraft destroyed. Fatal injuries to two.

The fire bomber was engaged in dropping extinguishing agent on a large forest fire in northwestern Italy near the Ligurian Sea. While flying at a low altitude near the coastal superhighway between Genoa and Savona, a wing of the aircraft hit an electric utility pole. The landing gear then hit the roof of a building used to store agricultural equipment and crashed.

The water tanker was completely destroyed in the accident and both of the crew members received fatal injuries.

Possible Engine Trouble

Kenya - December

Cessna twin: Aircraft destroyed. Fatal injuries to two.

The aircraft with two Americans aboard was delivering engine parts to Lokichokio in northwestern Kenya, a distribution point for relief flights into the Sudan. Following an unclear report of engine trouble, the aircraft was reported overdue in the evening. It was established the next morning that the airplane had crashed inside southern Sudan, in an area under the control of the rebel Sudan People's Liberation Army, and that both occupants had been killed.

Mountain Encounter

United States - January

Lightplane: Airplane destroyed. Fatal injuries to two, critical injuries to one.

The light aircraft had departed Santa Barbara, Calif., bound for Colorado. In the early evening, it crashed in deep snow at the 9,200-foot level near Mount San Antonio in the San Gabriel Mountains of California.

The airplane's emergency locater transmitter guided rescuers to the scene the next day, where they found a man dead in the aircraft wreckage that was scattered over a wide area, and two women who were critically injured. The two survivors were airlifted by helicopter to a hospital; one of them died later in the hospital from her injuries.

Over-exuberant Rescuers

United Kingdom - January

Cessna lightplane: Aircraft extensively damaged. No injuries.

The pilot was on the way from from his home base in St. Jasse Sur Mer in northern France, to Le Touquet, when he became lost in thick fog.

With fuel running out, the pilot spotted land and made a successful emergency landing in a field in Kent, England.

The pilot's relief at landing unscathed across the Channel was short-lived, however. An RAF rescue helicopter soon arrived and its downwash flipped his heretofore undamaged airplane into the air and onto its back, inflicting substantial damage.

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Rotorcraft

Built-in Jack

United Kingdom - December

Aerospatiale AS 332L Super Puma: Minor damage. No injuries.

The rotorcraft had taken off from Aberdeen for a flight to Stavanger, but a gear unsafe indicator light prompted the pilot to return to his takeoff point to check it out.

Upon landing back at Aberdeen, the nose gear collapsed during touchdown. The pilot brought the helicopter to a hover and the gear was lowered with the help of personnel on the ground.

The helicopter received very little damage and the three aboard were unhurt.

Crash into Sea

Finland - January

Agusta-Bell 206B JetRanger: Aircraft lost. Three persons suspected drowned.

The helicopter had taken off from a vessel approximately 10 miles from the island of Kokar off western Finland during the evening, when it crashed into the ocean.

Coast Guard searchers found wreckage in the sea but did not spot the Finnish pilot or either of his two passengers. The water temperature in the area was reported to be only slightly above freezing.

Strobe Vertigo

United States - December

Bell 206L: Aircraft destroyed. Three fatal injuries, one serious.

The air taxi rotorcraft was transporting an Emergency Medical Services (EMS) patient to a local airport and encountered deteriorating weather. Flying above clouds and fog VFR, the pilot decided to begin an ILS approach without a clearance.

During the approach, the pilot neglected to turn off the strobe lights before entering the fog and experienced vertigo. The rotorcraft hit wires and fell to the ground. The helicopter was destroyed and the three passengers were fatally injured. The pilot received serious injuries.