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New Jackscrew Design Increases Safety Through Redundancy

A failsafe jackscrew mechanism designed to improve the safety of space launch operations might have prevented the fatal January 2000 crash of an **Alaska Airlines** [ALK] twinjet.

Engineers who developed the new jackscrew design to support Space Shuttle operations say it can readily be applied to commercial aircraft and, indeed, can be retrofitted to hundreds of existing aircraft to provide an assured means of trim control.

On the Alaska MD-83, pitch trim is controlled by the horizontal stabilizer; it moves nose-up and nose-down by means of an electric motor driving a jackscrew assembly. This device is comprised of an electric motor which drives an acme screw through an acme nut. In this distinctive T-tail arrangement, the aluminum-bronze alloy acme nut is affixed to the tailfin. The motorized steel jackscrew, attached to the horizontal stabilizer, moves up and down through the acme nut. Safe operation of the mechanism depends on proper lubrication and periodic checking of the "end play" between the threads of the screw and nut.

In its ongoing investigation into the Alaska crash, **National Transportation Safety Board** (NTSB) investigators found improper mixing of lubricants, which may have accelerated wear on the acme nut. Additionally, during the airplane's last heavy maintenance check in 1997, the wrong tool was used to check the "end play," which was right at the "no go" margin. Without a spare jackscrew and acme nut in stock – the two are mated, serialized parts – the end play was checked again, found to be within limits, and the airplane was put back in service. The airplane flew for more than two years until this improperly-maintained assembly broke in flight, and the airplane plummeted into the Pacific Ocean waters off Los Angeles, killing all 88 passengers and crew aboard.

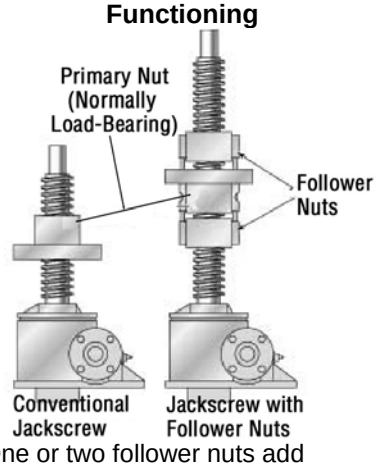
When It Absolutely Has to Work

A failsafe jackscrew ensures that the uppermost service arm for the Space Shuttle and its associated oxygen vent hood moves away from the external tank, shown here, moments before launch. The tank is loaded with liquid oxygen and liquid hydrogen. If the jackscrew should fail when the vent hood is rotated, first up and then away, it could collapse onto the tank with catastrophic consequences. The failsafe jackscrew has numerous applications for aircraft. *Photo: KSC*

When the wreckage was pulled from the water, the motorized jackscrew and acme nut were found bereft of lubrication, and the threads in the acme nut were almost completely worn away by the abrasive action of the jackscrew *(see ASW, Jan. 1, 2001, p. 1)*. In truth, the steel jackscrew acted like a machine tool on the softer metal of the acme nut, shearing the threads, the remains of which were found wrapped crazily around the jackscrew, conjuring the image of a broken child's slinky toy *(see box, p. 3)*.

During hearings December 13-16, 2000, NTSB investigators were dismayed to discover that the design might not be failsafe. Should the steel jackscrew break, a torque tube inside it provided fallback

Follower Nut for Failsafe Functioning



One or two follower nuts add protective redundancy. Upon shearing of the thread in the primary nut, the primary nut would push against one of the follower nuts, which would take up the load. *Source: KSC*

protection against catastrophic failure. But if the acme nut failed, the redundancy built into the jackscrew was irrelevant. **Boeing** [BA] engineers asserted that the two threads machined into the acme nut represented two independent and therefore redundant load paths. However, the engineers were at pains to describe a scenario in which damage to one thread would not affect the other. As it turned out, the threads on the acme nut from the accident aircraft were worn almost completely down. To the touch of a finger, they felt like slight bumps. In other words, no threads, no redundancy.

With the acme nut threads sheared to a nubbin, there was nothing to hold the elevator in position; it flipped up like the tailfin of a whale just before it dives. Like a piece of plywood in a hurricane, the stabilizer promptly broke off in the airstream. With no control over pitch, the airplane flipped end-over-end as it plummeted to its doom.

Engineers at Florida's **Kennedy Space Center** (KSC) have designed a jackscrew mechanism that adds a follower nut. According to a September 2002 KSC technical bulletin, the failure of a jackscrew used during Space Shuttle launches provided the stimulus for a fail-safe design. At the end of the uppermost service arm to the Space Shuttle, a jackscrew rotates the oxygen vent hood upwards, away from the Shuttle's main fuel tank, just moments before launch. Once rotated upward, the arm and attached vent hood are swung away from the Shuttle to a safe position for launch. Should a jackscrew structurally fail during the vent hood rotation, the hood could crush the expendable fuel tank, which is loaded with liquid oxygen and liquid hydrogen. Such a failure would be catastrophic (e.g., the ruptured tank could explode). "A fail-safe design was needed to mitigate the possibility of such a single-point failure," according to the KSC technical note.

Basically, the redesigned jackscrew adds a follower nut. Functioning is described thusly:

> "The two nuts rotate together but only the primary nut carries the load. In the event of a failure of the primary nut, the load is transferred automatically to the follower nut. In addition, a mechanical or electronic indicator provides a non-intrusive measurement of the wear of the primary nut."

In summary, the design "will eliminate single-point failure of the jackscrew assemblies when nut wear and subsequent thread shear occur," according to the KSC technical note *(see box, above)*. The engineers involved clearly saw its applicability to commercial aviation, and mentioned the Alaska crash specifically in the potential application of their fail-safe design *(see boxes, p. 3)*. *(Cont'd on p. 4)*

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Alaska Flight 261 and Single-Point Failure

Broken jackscrew (*upper two frames*) and acme nut (*lower two frames*) assembly from the Alaska Flight 261 accident aircraft. The worn threads in the acme nut left the jackscrew with nothing to grip, leading to separation of the horizontal stabilizer and loss of control in flight.
Source: NTSB

The Failsafe Jackscrew and Preventing Tragedy

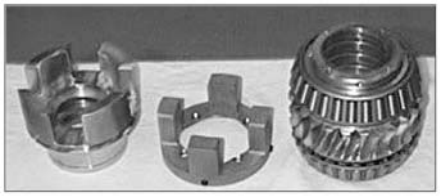
This design has tremendous technology transfer aspects … Alaska Airlines Flight 261 crashed and killed all 88 people on board because of the failure of the jackscrew used on the horizontal stabilizer.

A failsafe jackscrew system might have prevented that tragedy. It will certainly provide an easy, cost-efficient way to check for nut and thread wear thereby increasing the likelihood of preventive maintenance.

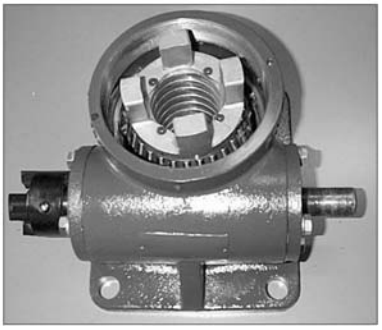
In the event the primary nut does fail, a secondary failsafe continue-to-operate nut provides a complete backup capability which enables the [air]craft to be landed safely.
Source: KSC Core Technical Infrastructure Support Success Stories, Sept. 2002 ■

The Failsafe Continue-to-Operate Jackscrew

The assembled jackscrew



Follower nut, rotator, and primary nut (*from left to right*)



Rotator and primary nut installed in jackscrew housing

The design features a piggybacking secondary threaded nut that "follows" the primary and carries the feedback instrumentation device for checking and alerting on wear tolerance of the load-carrying primary. It can also act as a backup load-carrier in the event of a primary thread failure – via the castellated interlock. The stabilizing presence of the secondary nut may actually reduce the rate of wear over a limited threaded mating surface (lack of lubrication over this limited surface also can aggravate the wear rate). The backup arrangement may actually increase the threaded mating "run," although the primary nut remains the sole load-carrier (short of its failure).
Sources: Photos, KSC; interpretive comment, John Sampson, IASA ■

One commentator familiar with the KSC design hailed it as "brilliant, simple and logical and totally puts to shame the simplistic jackscrew arrangement that gets airborne in so many airplanes nowadays."

Additional details are in order. The failsafe jackscrew has only been approved for use in ground support operations at KSC, and it will be installed on one launch pad within 6-8 months, with the next pad to follow a few weeks later.

The KSC engineers already have thought about how this technology might be incorporated into a commercial aircraft. Two options are under consideration:

(1) The warning light option: A cockpit warning light would illuminate when a predetermined wear point was reached. This light would advise the pilot that the primary nut needs replacement but that the second nut would take over, providing immediate protection. This arrangement would provide ample time for maintenance to be scheduled and completed.

(2) The mechanical wear warning option: In this scenario, an indicator would be placed on the nut where maintenance personnel could readily see it during inspection. When positioned between two red lines, the indicator would signify that all was well – wear was within limits. If the indicator were not between the two red lines, this position would signal that it was time for maintenance.

From start to design certification, the process took two years and $200,000. The failsafe jackscrew has been tested to 4,000 cycles with no failure. When engineers encountered their first failure, the second nut took over the load, as designed, and was run for around 100 more cycles beyond that. Clearly, more work and testing needs to be done to certify the design for in-flight use, but KSC's failsafe jackscrew was designed, tested and certified in about the same time that the Alaska jet flew with its jackscrew steadily wearing itself to the point of failure. The design also has come from concept to fruition in about the same period of time that has elapsed since the crash *(see box, p. 5)*.

A couple of observations are in order. The problem with the T-tail jackscrewed stabilizer has always been one of nil redundancy. **Federal Aviation Administration** (FAA) certification officials accepted the argument that the jackscrew wasn't part of the "flight control system," but was rather a structural component. This suspect argument was one of the primary reasons former NTSB Chairman James Hall announced an investigation into the FAA's airworthiness certification practices and procedures.

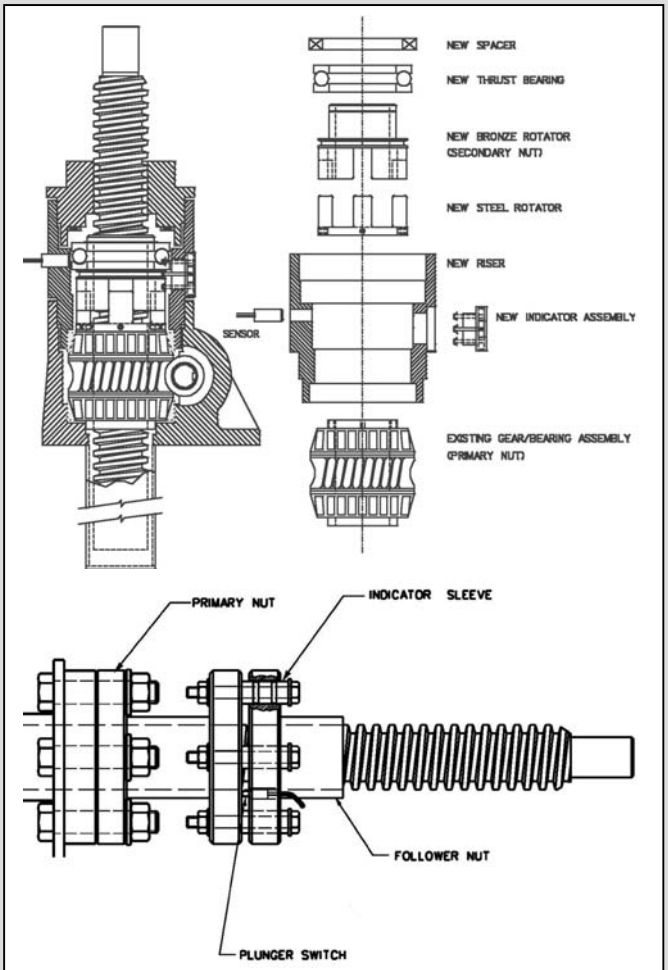
One of the other potent lessons of the Alaska Flight 261 accident is that "on condition" monitoring and maintenance of wear-prone and lubrication dependent components can be open to cunning interpretations by maintenance personnel under pressure to return an airplane to service, and who don't have a replacement jackscrew assembly on hand.

They measured and remeasured the jackscrew end play, with the wrong tool, until the "right" answer (within tolerance) was produced. At 40 thousandths of an inch slack, the assembly was within tolerance. At 41 thousands of an inch, the end play was deemed excessive and the jackscrew and acme nut had to be replaced with a matched pair.

One might say that however much "play" was tolerated, an unfortunate amount of "freeplay" was being exercised in the maintenance operation until, inevitably, the assembly "screwed up" big-time. *>> For further information, access the Technical Support Package (TSP) at www.nasatech.gov under Machinery/Automation, item KS12187/291/92 <<* ✈

Jackscrews 101 and The Failsafe, Continue-to-Operate Concept

Redundant nut increases reliability and facilitates inspections



Design details of the failsafe jackscrew show how a wear indicator could easily be incorporated into the assembly. *Source: KSC*

A fail-safe, continue-to-operate design concept for machine jackscrews calls for the incorporation of a redundant follower nut that would assume the axial jack load upon failure of the primary nut. Heretofore, the way to design for increased reliability of jackscrews has been to provide for multiple jackscrews operating in unison. The present fail-safe, continue-to-operate design concept offers an alternative for preventing catastrophic failures in jackscrews, which are used widely in aeronautical, aerospace, and industrial applications.

A conventional jackscrew contains only one nut made of a material softer than that of the threaded shaft. With prolonged use, the thread in the nut wears away. If not inspected and replaced when wear becomes excessive, the nut eventually fails by shearing of the thread under load. A typical jackscrew according to the present fail-safe, continue-to-operate concept would include a redundant follower nut in addition to the primary nut. The follower nut is mechanically attached to the primary nut and free to move axially relative to the primary nut. The follower nut would bear no axial load and would have negligible wear as long as the primary nut continued to function normally.

In the absence of thread wear and play, the follower nut would be axially separated from the primary nut by a distance comparable to the thread pitch. Increasing wear would cause a change in this distance that would be taken as an indication of the amount of wear prior to failure of the primary nut. The redundant follower nut assumes the axial load in the event of primary nut wear and subsequent thread shear failure. Hence, the jackscrew would continue to operate with the follower nut bearing the load until a repair could be made.

Unlike the case of a conventional jackscrew, it would not be necessary to relieve the load to measure axial play or disassemble the nut from the threaded shaft to inspect for wear. Instead, wear could be determined by measuring the axial gap between the primary and follower nut. This could be accomplished by visual inspection, or possibly with the help of a simple measuring tool. Another option could incorporate electronic or mechanical wear indicators to monitor the gap during operation and assist during inspection. These devices would be designed to generate a warning when the thread was worn to a predetermined thickness *(see box, above).* Note: A half-thickness value is the wear tolerance recommended by major manufacturers of jackscrews.

The fail-safe, continue-to-operate concept applies to all types of machine jackscrew designs. It can be applied equally well to ball screw jacks. >> *This work was done by John G. Fraley, Ivan Velez, and Charles G. Stevenson of Kennedy Space Center and Richard T. Ring, Jr., of United Space Alliance. Velez, e-mail Ivan.Velez-1@ksc.nasa.gov; Stevenson, e-mail Charles.Stevenson-1@ksc.nasa.gov* << ■

ACCIDENTS AND INCIDENTS 1				
DATE/SITE & INVEST. ID#	**AIRCRAFT & REGISTRATION**	**CIRCUMSTANCES**	**DEATHS & INJURIES**	**PRELIMINARY ANALYSIS2**
17 Oct. 02 0230Z Chicago-Ottawa	CL-600 (2B19) RJ Reg: C-FRIL	**Flt ACA-1042 had EICAS fail lt for flaps. No flap landing.**	Nil/35 on board	Probable flap asymmetry lock-out.
25 Oct. 02 2221Z Edmonton Alb	737-2H4 of WestJet C-GWJT FltWJA31	**On appch, flaps stuck at posn 1. Landed no-flap 2nd appch.**	Nil	An asymmetry trip in the trailing edge flap system.
27 Oct. 02 1630Z Toronto Ca	CL600 2B19(RJ) of Air Canada Reg: ACA503	**After dept for Thunder Bay crew was unable to retract nose landing gear.**	Nil/34 on board	Burnt off fuel & landed. Damaged nose landing gear proximity sensor.
29 Oct 02 1940L Auck - Sydney	747-200 of QANTAS Flt: QF44	**Engine shut down due to heavy vibration**	Nil/131pax	RB211-F24D4 fan blade base lube procedures not i.a.w. RR (mfr) recs.
30 Oct 02 1548Z JFK- Heathrow	Concorde of BA Reg: G-BOAD	**Shut down an engine & executed an emergency descent to FL310**	Nil	Five other conflicting aircraft were quickly deconflicted with flight BAW-2.
1 Nov. 02 2003Z Toronto Ca	A319-112 of Air Canada Flt: ACA758 RJ-700 Regional Jet of JAZZ Flt JZA 7751	**CRJ7 on dept Toronto was just leveling at 7,000 feet when crew responded to a TCAS resolution advisory (RA) by descending. Opposite direction descending A319, leveling at 8,000 feet, did not receive an RA.**	Nil	A further example of how non-standard climb/descent rates on level-off and 1000 ft (only) separation standards can cause "cry wolf" RA's in a dense ATC environment.
1 Nov. 02 2300L Monterrey Me	DC9-32 of AeroMexico	**Runway overrun upon arrival from Guadalajara.**	12 minor/90 on board	Landed hot and long on a wet runway. Moderate damage.
1 Nov 02 1846Z Ottawa Ca	737-201 of WestJet Flt: WJA-109	**Hamilton bound flight returned after eng failed**	Nil	No further details.
2 Nov 02 JFK	A320-232 of JetBlue Flt: JB003 Reg: N503JB	**Emergency landing on runway 22R**	Nil	Experienced unsafe undercarriage problems.
2 Nov 02 Sligo, Irish Rep	F27-500RF Friendship G-ECAT Flt: ECY406	**Overran 3937ft runway into the sea on arrival**	Nil/50 pax and 4 crew	EuroCeltic a/c is a write-off. For extensive further details see www.iasa.com.au/sligo.htm.
2 Nov. 02 0209Z Newark-Heathrow	777-200 of UAL Flt: UAL906 Reg: N773UA	**Emergency landing in Gander with #2 engine fire light illuminated.**	Nil/267 on board	False indication remained on after extinguishers fired.
2 Nov. 02 1518Z Boston-Quebec	EMB135 of Eagle Aviation Flt: EGF701	**Declared flight control difficulties (ailerons)**	Nil	Landed runway 24 at 1603Z after a protracted hold.
3 Nov. 02 Heathrow-JFK	Concorde of BA Flt: BAW1	**Due engine failure, a/c descended to FL 280**	Nil	G-BOAG requested a return to Heathrow at Flight level 280.
3 Nov. 02 Pt Alsworth Ak	DC-3 TransNorthern Reg: N32-TN	**Final appch 05L, l wing hit unmarked mast on bulldozer.**	Nil/2 on board	14ft of left wing severed and left elevator damaged. Cargo flight.
3 Nov. 02 Dusseldorf	A320-211 of Air France flt:AF1007	**Flock of birds struck on T/O run causing abort**	Nil	F-GFKV suffered damage to both engines, flaps and landing gear.
4 Nov. 02 1259Z Toronto-O'Hare	A319-114 of Air Canada Flt:ACA813	**Ret due to hydraulic problems (incl nose steering)**	Nil	Landed on runway 23 at 1341Z.
4 Nov. 02 1105 Gatwick-Malta	A320 of MyTravel Flt: MYT453	**Landed on one engine after port EGT ran off the clock**	Nil/185 on board	Fuel control unit failure just short of Malta.
4 Nov. 02 JFK-Paris	Concorde of AF	**AF001 desc from FL560 to FL 330 after an eng failed**	Nil	Arrived Paris CDG an hour late.
5 Nov. 02 Amsterdam	747-446 of JAL Flt:JL411	**Ex Tokyo (Narita),major birdstrike on finals AMS**	Nil	Substantial damage to eng #3 for airframe Reg: JA8089.
6 Nov. 02 Berlin-Luxembg	Fokker F50 of Luxair LX-LGB Flt LG9642	**Crashed approx 6nm final in fog during ILS 24(RVR250m)**	20fatal/22 on board	Pilot & one pax survived. 3rd Luxair hull loss. Worst for Luxemb. Engine failure suspected.
6 Nov. 02 Tarakan Indonesia	BN2A Trislander of Dirgantara Air Svc	**Crashed on takeoff. 2nd fatal crash in 4 months on this route to Longbawan**	7fatal/3inj/10 on board	Overloaded and experienced engine failure. See FAA EAD (2002-20-51) of Oct 1, 2002 (crankshaft gears).
6 Nov. 02 1534L Norfolk Va	757 of AA Flt:2084	**Diverted under escort due suspicious activity aboard**	Nil/51 on board	Santo Domingo for Boston Logan. One person taken into custody.
6 Nov. 02 Orlando Fla	MD-82 of AA Reg: N479AA	**Flt1258 enc mod turb on desc fm 11,000ft in VMC**	1serious/ 5 crew/71pax	F/A broken ankle. Airmet in effect for mod turbulence <15,000 ft.
7 Nov. 02 0710L Merced A/P Calif	Fokker F-27 Flt: EGF71	**Fire indication #2 on final approach.**	Nil/27 aboard	No further details from operator American Eagle.
8 Nov. 02 0735L Brussels Intl A/P	Avro RJ85 of SN Reg: OO-DJY	**Flt SN2711 returned BRU after vibns in #3 after T/O**	Nil	No further details.
8 Nov. 02 1245L Groningen Ne	F27-100 of SAE Eur Reg: 9G-AIR	**Landed Groningen-Eelde Intl A/P after losing an engine.**	Nil/3	Enroute Malmo – Jersey (delivery flt Sweden to Sobel Air (Ghana)

9 Nov 02 Atlanta-Hartsfield Georgia	MD-11 of Delta Reg: N813DL	**Tug detached for reposition & a/c slipped from chocks and rolled into work-stands.**	Nil	Major damage - while being towed into maintenance hangar.
9 Nov. 02 Taos New Mexico.	Westwind 1124 bizjet –Richmor Avn	**Clipped power-line and crashed on highway.**	2 fatal/ 2 on board	Departed Las Vegas. Unknown cause for attempted highway ldg.
9 Nov. 02 Hurgada Egypt- Antalya Turkey	Antonov 26 of Tyumen Aviatrans Reg: RA-26012B	**Hit power line Antalya A/P and then grounded 500m short of threshold.**	28inj/19pax /9crew	A/c destroyed during night approach in strong winds. 8 suffered minor injuries, 20 others hospitalized.
10 Nov. 02 Dallas-LaGuardia	MD-80 of AA Flt:710	**Smoke filled cockpit and cabin during taxi-in.**	5 inj/74pax & 6 crew	Smokey hydraulic leak caused pilot to order emerg evac on taxiway.
11 Nov 02 0607L Manila Bay	F-27-600 of Laoag Reg: RP-C6888	**Crashed in bay shortly after t/o- pilot declared emergency.**	20fatal/34 on board	Video shows smoke trailing from left eng. Suspect maint practices.
12 Nov 02 Bishkek Kyrghyzs	TU154 of Kyrghyzstan	**Overran after landing on 13,780ft r/way.**	Nil/90pax	Returned Bishkek after instrument failure 30mins into flt to Urumqi Ch

1 Air carrier incidents or accidents, or other accidents involving serious failures or fatal injuries, investigated by National Transportation Safety Boards.
2 DISCLAIMER: The information obtained from these National Reports is preliminary, possibly incomplete, and may be supplemented by new findings of fact as the inquiry progresses. These assessments, based on a reading of initial reports, are not intended to assert probable cause or liability, but rather are intended to provide insight pending publication of a final report of investigation. 3A/P=Airport.
- Data compiled from National Aviation Authority's documents. Preliminary analysis by John Sampson, Director of Aircraft, Engineering & Technical Operations, International Aviation Safety Association.(IASA)

'Shoe Bomber' First Thought to be Violating In-Flight Smoking Ban

Flightcrew reveals additional dramatic details in national television appearances

Alleged "shoe bomber" Richard Reid shoved and bit as he fought off flight attendants while attempting to ignite the bombs concealed in his shoes, according to new details of the Dec. 22, 2001, episode related by the flight crew on national television.

Pilots and flight attendants of **American Airlines** [AMR] Flight 62 appeared Nov. 8 on NBC's *Today* show and on *Dateline* to relate their experience on the Paris to Miami flight last winter. Earlier, the pilots, two flight attendants and the dispatcher recalled their harrowing experience in a "lessons learned" video prepared by the **Allied Pilots Association** (APA), the union of American Airlines pilots *(see ASW, July 22, p. 1)*. The entire flight crew appeared on the *Dateline* segment, and they shared more details of Reid's attempt to blow up the airplane:

✓ Physically large at about six feet three inches in height, the crew and passengers recalled that the unkempt, aloof Reid stood out from other passengers.

✓ At first, flight attendants thought Reid was trying to smoke. Attracted by the burning smell of struck matches, the first flight attendant admonished Reid, "Excuse me, you know that this is a non-smoking flight."

"Oh, I'm sorry, I'm sorry," the flight attendant recalled Reid saying. He continued to strike matches. Accosted by the flight attendant for the second time, he shoved her backwards.

✓ When she came back, he shoved her again, harder, across the aisle and back three rows. She called for help from another flight attendant. When she grabbed him, determined to stop Reid from igniting more matches, he bit down, hard enough to draw blood. The flight attendant recalled, "At this point, I think it hit me like a ton of bricks … this is totally and completely serious … we're in danger … I started screaming as loud as I could, which was the most bizarre sensation, to be on an airplane full of people and screaming at the top of my lungs."

✓ Reid kept biting her hand until he was forced into submission by a group of passengers who leaped to her aid.

✓ The crew felt that the injection to sedate Reid did not work, as he kept glaring angrily at the flight attendants and passengers who kept a close watch on him for the remainder of the flight. One flight attendant suggested, "Just sedate him, don't kill him."

✓ The flight attendant whose bitten hand was bleeding made her way to the cockpit, sat on the jumpseat and said, "I want to land, I want to land." At least two hours from any alternate airport, her exclamations no doubt added to the level of tension on the flight deck.

✓ A passenger told one of the flight attendants that she had seen Reid at the Paris airport the day before with another man. Fearing other terrorists were on Flight 63, this passenger was led, in tearful anxiety, down the aisles in an attempt to ascertain if this individual was on the airplane.

✓ After Reid was bound and "sedated," another passenger reported smelling smoke. Fearing a possible cargo hold fire, one flight attendant removed her shoes and walked the cabin to feel for heat on the floor (the crew did not say if this "walkabout" was prompted by a smoke alarm in the cockpit, and the *Dateline* reporters did not ask).

✓ Upon landing at Boston's Logan International Airport, the airplane was met by a fully-mobilized phalanx of local and federal law enforcement officials, fire fighting vehicles, ambulances, bomb squads, and so forth. It took the detail that boarded the plane about five minutes to cut Reid out of the seat in which he had been belted, taped, strapped, bound and restrained.

✓ Reid later told investigators that he'd been sent to Israel as part of his training to test what is regarded by many as the world's most stringent airport security. Michael Sullivan, the U.S. attorney in Boston who prosecuted him, said Reid claimed the idea of putting explosive material inside a shoe came to him during one of those visits because he'd noticed that footwear was not being inspected.

Based on these additional details, a couple of observations are in order. It appears that the cockpit door was opened at least three times during this crisis. Once when the bitten flight attendant retreated to the cockpit. The door was opened a second time when the shoes were brought into the cockpit. Then, when the relief pilot smelled the shoes and suspected they contained explosives, the cockpit door was opened a third time as the shoes were hastily removed and placed in the "least risk bomb location" (LRBL) adjacent to door 4R.

The repeated opening of the cockpit door may serve as a stimulus for carriers to review their policies for protecting the cockpit.

The physically imposing Reid was easily able to push away the flight attendants who accosted him. The **Association of Flight Attendants** (AFA) has repeatedly called for defensive training for flight attendants, and the events in this case illustrate the AFA's concern.

Luck may have played its role in this near-tragedy. It had rained in Paris the morning of Flight 63's departure. Reid had struck at least two matches and still the fuse sticking out of the shoe would not light. Had he boarded with a small butane lighter, permissible under the regulations, its more persistent flame just might have lit that damp fuse. ✈

The Attempted Bombing of American Airlines Flight 63

How the "Shoe-Bomber" Incident Affected Responders at Boston-Logan

By
Major Tom Robbins & Sergeant Dave Thompson
Troop F, Massachusetts State Police

Much attention has been focused on the events that occurred on board **American Airlines** Flight 63 surrounding Richard Reid's Dec. 22, 2001, attempt to detonate improvised explosive devices hidden in his shoes. Most of this attention has been directed toward the actions of the flight crew. Their actions saved the lives of everyone on board that flight. However, a videotape produced by the **Allied Pilots Association** (APA) and the transcripts of this videotape generated much discussion among those of us who were the emergency responders on the ground that day *(see ASW, July 22, p. 1 and Aug. p. 7)*. We have been asking ourselves: "How could the flight crew have the impression that it was 'chaos on the ground' "? "Why did the flight crew believe that there was 'an absence of an overall on-scene commander' "? "Why was the comment made that it was a 'circus without a ringmaster' "?

In actuality, the response was very coordinated. Those of us on the ground knew who the overall incident commander was for this incident. Was there some adaptation in moving and processing the passengers? Absolutely. Keep in perspective the fact that this was a very unusual incident. This flight was an international diversion on a very busy travel day. Keeping the passengers on this flight isolated while trying to process them through immigration and customs, then interviewing each and every one of them, was no easy task.

Background on Boston-Logan Airport

Logan International Airport is operated by the **Massachusetts Port Authority** (Massport). Under state law, Troop F of the **Massachusetts State Police** is the law enforcement agency for Logan International Airport. In addition to patrol functions, the State Police also have the following specialty units assigned to Troop F at Logan: An explosives detection K-9 [canine] unit, an explosive ordnance disposal (EOD) unit; an underwater recovery unit, an antiterrorism unit and a detective unit. Massport provides the aircraft rescue and fire fighting (ARFF) response at Boston-Logan. Due to the location of Boston-Logan for approach of Trans-Atlantic flights, the emergency responders here have extensive experience handling in-flight emergencies and diversions.

December 22, 2001

Some of us were enjoying one of the few days off that we had since September 11, rushing around to get our Christmas shopping done, while others were on duty at Logan.

10:30 a.m. (EDT), Initial notification

Massachusetts State Police, Troop F was notified by Massport Operations that American

Airlines Flight 63, enroute from Paris to Miami, was being diverted to Boston-Logan. First reports were sketchy, but we were informed that Reid had attempted to light items on fire, including the tongue of his shoes, and that he had been restrained by the passengers and crew. American Airlines (Boston Operations) contacted us shortly thereafter to advise that the captain was declaring a bomb threat due to a "black wire" in the subject's shoe.

11:15 a.m. Pre-arrival briefing

A briefing was conducted in the Troop F office for all involved agencies, including the **Federal Bureau of Investigation**; **U.S. Immigration & Naturalization Service**; **U.S. Customs**; the **Federal Aviation Administration** and American Airlines.

Due to the fact that this was an international diversion, the U.S. Attorney's Office agreed to prosecute this case. The subject would be removed from the aircraft by State Police and turned over to the FBI for prosecution. In accordance with Logan's Airport Emergency Plan (AEP), the State Police officer in charge would be the incident commander for this event.

12:30 p.m. Staging area

All responding agencies were in place at the staging area. Additional information was received that a physician on-board the inbound flight apparently had sedated the subject with Valium. We were also told that several members of the flight crew were injured, including a flight attendant whose hand Reid had bitten viciously.

The Massport fire-rescue crew chief declared an "Alert 2" due to the suspected explosive device *(see box, below)*. We were advised that the flight was now under escort by two F-15s from Otis Air National Guard Base (Cape Cod).

Alert Levels at Boston's Logan

- Alert 1: Standby, aircraft with mechanical problem. Airport fire-rescue assets deploy.
- Alert 2: A serious mechanical problem on an aircraft and/or possible terrorist threat. Airport is locked down and only emergency vehicles have access to/from airport.
- Alert 3: Actual crash and/or fire.

Source: Troop F

A special agent from the FAA Explosives Unit contacted the Troop F EOD unit to advise that the subject's shoes had been removed and placed in a Least Risk Bomb Location (LRBL).

1:00 p.m. Boarding the aircraft

Flight 63 landed. The F-15s followed it down and then lifted off in an impressive display. The airliner was directed to a pre-designated remote area on one of the closed runways.

At right above is the state police bomb unit's vehicle, with gear, including a remote-control bomb disarming robot, deployed behind the tailgate. *Photo: Massport*

As per the incident action plan, two State Police bomb technicians and two members of the Special Tactics and Operations Team boarded the aircraft. A State Police lieutenant and the fire-rescue deputy chief remained at the door of the aircraft for communications. All of the passengers were ordered to remain seated. On many occasions when boarding a flight to remove an unruly passenger, we have to push past passengers who are already in the aisles, trying to get their carry-ons out of the overhead bins. But this flight was different. You could have heard a pin drop. All of the passengers were buckled in their seats, staring straight ahead. It was eerie. We knew that whatever went on during this flight had been very bad.

Mr. Reid was located in seat 29J *(see photo, right)*. He had been restrained with flex-cuffs and numerous passengers' belts and headset wires. Our concern was to make sure that Reid was not booby-trapped or had additional weapons. Not knowing his nationality, we wanted to be sure that he understood English and followed our commands. Knowing the method of operation of terrorist groups, we were also concerned that Reid might have accomplices on board who may suddenly attack us.

Seating area after Richard Reid was removed. The fire extinguisher is on seat 29J where Reid was sitting. Note the belts on the floor that were used to restrain him. *Photo: Massport*

After thoroughly searching Reid, he was removed from his restraints, taken off the aircraft and turned over to FBI special agents. He was then transported to the State Police barracks at Logan for questioning by the FBI. Much evidence, including numerous wooden stick matches, was recovered from Reid, as well as from his seating area.

Upon returning to the aircraft, the bomb technicians received a briefing from the flight crew regarding the description and location of the suspected devices. One of the pilots asked, "Do you realize that we have a bomb on this plane?" They must have thought that we were acting too casually. But, just as a flight crew is trained to remain calm during an in-flight emergency, we could not allow ourselves to get excited, as there were many tasks ahead.

1:10 p.m. Evacuating and moving the passengers

We began to evacuate the passengers from the aircraft onto busses. This was done in a very calm manner, but we were also very observant of all the passengers. Unfortunately, in this era of stolen flight crew uniforms and identification, we also had to scrutinize the crew as well.

The passengers were bussed to our International Terminal E. They were processed through Immigration and Customs. Once the passengers cleared Customs, they were bussed to a closed gate area in Terminal C. Here they could be kept isolated from the news media while being fed and allowed to use restroom facilities. The passengers were questioned by several hundred state police detectives and federal agents who were called in from other areas of the state.

Post-evacuation, dealing with the "shoebombs"

Once all the passengers were evacuated from the aircraft, the state police bomb technicians, assisted by an FBI special agent/bomb technician, went to work. Without revealing all of the bomb technicians' techniques we can say that the shoes were examined using established procedures and equipment. An x-ray confirmed the flight crew's finding of a "cord." Further examination showed this to be a time fuse which, when ignited, is used to initiate a detonator. The shoes were eventually removed from the aircraft and remotely opened [recall the robot brought to the site]. It appeared that all of the components were present to make these both functional devices. The shoes were flown to the FBI's Explosives Laboratory in Washington, DC, later that night.

This was a situation in which the bomb technicians adapted their training and experience to deal with "shoe bombs" *(see photo, above)*. The FBI laboratory confirmed they were viable. The shoes' condition allowed the FBI to reconstruct the devices for prosecution and may have helped convince Richard Reid to plead guilty. The techniques used to render the bombs safe are being used to train other bomb technicians for future similar incidents.

We allowed the captain and first officer to remain at the aircraft. They were kept in the company of a state police lieutenant in his cruiser. Coincidentally, the New England Patriots were playing the Miami Dolphins that day. There was some good-natured ribbing between the two Miami-based pilots and our personnel as they tried to listen to some of the game on the radio.

Once the explosive devices were rendered-safe and packaged as evidence, all luggage was off-loaded from the cargo compartments. The luggage and the interior of the aircraft were searched with K-9s and the bomb technicians. They were kept busy until well after midnight.

9:00 p.m.

Eight hours after arriving at Logan, the passengers boarded an aircraft that was flown in by American. This flight left Boston as AAL 9231 enroute to Miami.

One of the shoe bombs after it was rendered safe by bomb technicians. The photo intentionally does not reveal details of the bomb inside the shoe. Its simplicity of construction but complexity of design would frighten many people, according to those familiar with the design details. A detailed photo also would provide a useful blueprint for anyone wishing to build a similar device.

Photo: Massport

Conclusion

One aspect that really worked in our favor is the familiarity that responders have with each other at Boston-Logan. We have a daily security briefing that is attended by key law enforcement officials, Massport aviation operations, facilities, fire-rescue and the various tenant airlines.

The bomb technicians played this incident for real from the beginning. One area that we will "tweak" for future incidents will facilitate better control over the passenger handling process. One area that needs to be improved is the ability to communicate directly with the flight crew prior to landing. Having this capability would go far to alleviate any concern about what will occur when law enforcement officers board the aircraft.

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