AERO

BOEING

No. 23

Aero magazine is published quarterly by Boeing Commercial Airplanes and is distributed at no cost to operators of Boeing commercial airplanes. *Aero* provides operators with supplemental technical information to promote continuous safety and efficiency in their daily fleet operations. ■ The Boeing Company supports operators during the life of each Boeing commercial airplane. Support includes stationing Field Service representatives in more than 60 countries, furnishing spare parts and engineering support, training flight crews and maintenance personnel, and providing operations and maintenance publications. ■ Boeing continuously communicates with operators through such vehicles as technical meetings, service letters, and service bulletins. This assists operators in addressing regulatory requirements and Air Transport Association specifications.

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Pan Am flight crew disembarking model 314, circa 1939

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PERSPECTIVE

MIKE CAVE
SENIOR VICE PRESIDENT
COMMERCIAL AVIATION SERVICES
BOEING COMMERCIAL AIRPLANES

We at Boeing Commercial Aviation Services have one goal: to ensure your success by providing top-quality, high-value services. This pledge requires all of us at Boeing to commit first and foremost to meeting your needs, putting your success first, and remembering that only when the air transport industry is successful can we all be successful.

In January 2003, Mike Cave was named senior vice president of Boeing Commercial Aviation Services. Cave previously served as senior vice president and chief financial officer of Boeing Commercial Airplanes. He replaced Mike Bair, who now leads the Boeing 7E7 program.

Providing world-class fleet support is imperative for us. We will continue to pull together the right people, technology, and tools to create and implement innovative ways to support you. Examples of how we've partnered to reduce airline operating costs include the ever-increasing use of MyBoeingFleet.com and user-friendly, more efficient service bulletins as well as the replacement of our existing customer communications tool, BOECOM.

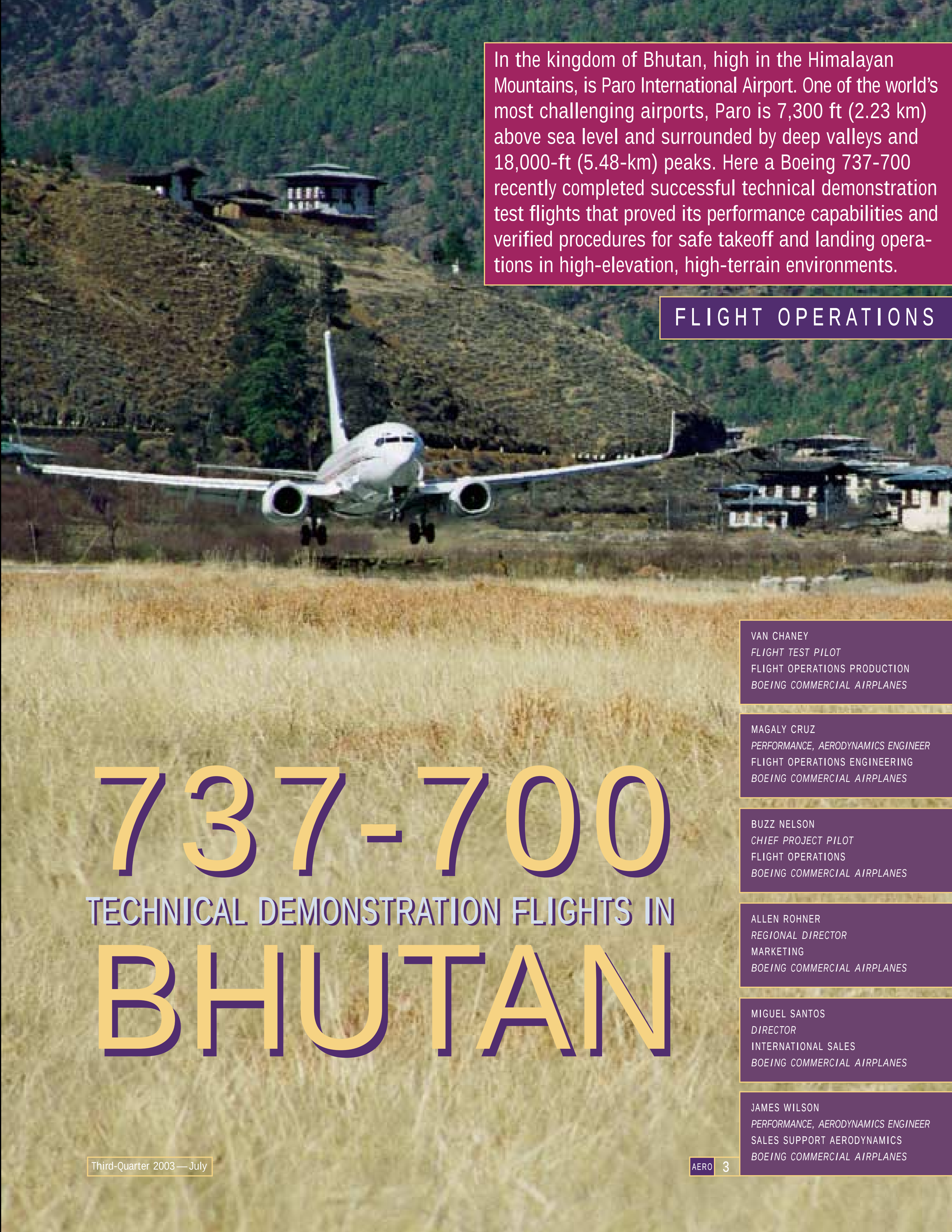
In addition, we are implementing a phased approach to growing our revenue business. Our initial emphasis is to ensure that our core businesses—Maintenance Services, Technical Services and Modifications, Flight Services, and Spares—are healthy, lean, and efficient.

During the next two phases, we will leverage our strengths, build partnerships, and help reshape airline economics by delivering tailored solutions for crew productivity, fleet performance, and maintenance efficiencies. We will create comprehensive services and solutions to leverage scale, standardization, and customer and supplier partnerships. Solutions such as e-enabled airline operations will deliver significant benefits to you, our customers, while positioning Boeing Commercial Aviation Services as a large-scale service provider.

The business environment is challenging for all of us in the aviation industry. But I am excited about our long-term strategy and our commitment to your success.

I hope you enjoy this issue of *Aero*!

Mike



FLIGHT OPERATIONS

737-700
TECHNICAL DEMONSTRATION FLIGHTS IN
BHUTAN

In the kingdom of Bhutan, high in the Himalayan Mountains, is Paro International Airport. One of the world's most challenging airports, Paro is 7,300 ft (2.23 km) above sea level and surrounded by deep valleys and 18,000-ft (5.48-km) peaks. Here a Boeing 737-700 recently completed successful technical demonstration test flights that proved its performance capabilities and verified procedures for safe takeoff and landing operations in high-elevation, high-terrain environments.

VAN CHANEY
FLIGHT TEST PILOT
FLIGHT OPERATIONS PRODUCTION
BOEING COMMERCIAL AIRPLANES

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Paro International Airport, in the kingdom of Bhutan, is high in the Himalayan Mountains. At 7,300 ft (2.23 km) above sea level, with a runway 6,500 ft (1.99 km) long, surrounded by deep valleys and 18,000-ft (5.48-km) peaks, Paro is one of the world's most difficult airports for takeoffs and landings.

In February 2003, a Boeing 737-700 successfully completed 11 test flights at Paro International Airport. The series included two technical demonstration flights and eight customer relations flights with Druk Air Royal Bhutan Airlines, the national airline of Bhutan. Druk Air, which operates two 72-passenger BAe 146-100 jets from Paro to six cities in five countries, is considering upgrading its fleet and extending its routes. The rigorous test flights proved that the 737-700 is capable of meeting all performance and procedural requirements for safe operations at Paro and other airports in high-elevation, high-terrain environments.

The 737-700 performed flight maneuvers as predicted and met or exceeded performance expectations for simulated one-engine-inoperative maneuvers, which were accomplished by reducing thrust on one engine to idle power. The expected performance levels proved conservative when compared with the demonstrated performance of the 737-700.

Test flight data were verified by flight data recorder (FDR) information, indicating that predicted airplane performance is representative of actual airplane performance as recorded by the FDR.

The test flights verified procedures for takeoff and landing operations at Paro. The 737-700 demonstrated engine-out takeoff procedures, which is required for Paro operations, engine-out missed approach and go-around procedures, and Druk Air procedures for landing on both directions of the runway at Paro.

This article discusses

1. Technical demonstration test flight airplane.
2. Technical demonstration test flights description.
3. Technical demonstration test flight analysis.

1 TECHNICAL DEMONSTRATION TEST FLIGHT AIRPLANE

The demonstration airplane was a 737-700 Boeing Business Jet (BBJ) configured with blended winglets and a business jet interior (fig. 1 and table 1). The 737-700 BBJ used for the demonstration flights is aerodynamically equivalent to the commercial variant of the 737-700 being offered to Druk Air.

2 TECHNICAL DEMONSTRATION TEST FLIGHTS DESCRIPTION

On February 6, 2003, two technical demonstration test flights were accomplished from runways 33 and 15

The kingdom of Bhutan is located near Nepal, between China in the north and India in the east, south, and west. The kingdom, which is roughly the size of Switzerland, has a population of 750,000 people. The Bhutanese value their rich natural environment and ecosystem, which includes 770 species of birds and 5,500 species of plants.

1 FIGURE 737-700 TECHNICAL FLIGHT DEMONSTRATION AIRPLANE

at Paro International Airport. Boeing pilots Captain Buzz Nelson and Captain Van Chaney flew the 737-700 accompanied by the Druk Air chief pilot on the first flight and a senior first officer on the second flight.

To prove the capability of the 737-700 at Paro, the technical demonstration flights had to show that the airplane could take off following a simulated single engine failure at the most critical point during the takeoff ground roll (V_1) and safely return to the airport on one engine.

Terrain in the valleys surrounding Paro limits takeoff performance. Flight operations into and out of Paro only occur when the visibility in the valley is clear. This visibility is required to allow an airplane to turn around safely within the steep valley walls and reach the minimum safe altitude to depart the valley or return to the airport in the event of an engine failure.

The technical demonstration flight profile consisted of a takeoff with a simulated single engine failure at V_1, a turnback within the river valley, a missed approach, a go-around, a turnback at the opposite end of the valley, and landing, with one engine remaining at idle (representing the engine failure) throughout the demonstration. One technical flight demonstration was accomplished in each direction from the runway at Paro.

1 TABLE DEMONSTRATION AIRPLANE SPECIFICATIONS

Airplane model	Boeing 737-700 BBJ
Registration number	N184QS
Manufacturer's serial number	30884
Maximum taxi weight	171,500 lb (77,791 kg)
Maximum takeoff weight	171,000 lb (77,564 kg)
Maximum landing weight	134,000 lb (60,781 kg)
Maximum zero fuel weight	126,000 lb (57,153 kg)
Fuel capacity	9,700 U.S. gal (36,718 L)
Engines	CFM56-7B

Runway 33 Technical Demonstration Test Flight

The first technical demonstration test flight was performed from runway 33 (fig. 2). After takeoff, a right bank was initiated for a heading change of approximately 30 deg to avoid terrain that extends from the west valley wall. This maneuver was followed by a left bank to position the airplane along the east wall of the west fork of the river. The climb continued close to the east wall until the turnback initiation point. A teardrop turnback was initiated just after passing abeam the Chhukha village. Here the terrain falls away off the right wing where a stream empties into the river. The turnback was flown with a 30-deg bank while maintaining speed throughout the turn.

After completing the teardrop maneuver, the pilots performed a flaps 15 (engine-out landing flap) missed approach to runway 15. This was followed by a go-around and a teardrop turnback south of the runway using the Druk Air runway 15 turnback procedure. The condition was completed successfully with a normal flaps 40 landing using the Druk Air straight-in landing procedure.

The takeoff weight for runway 33 is limited by the turning radius required

FIGURE 2 PARO RUNWAY 33 TECHNICAL DEMONSTRATION TEST FLIGHT OVERVIEW

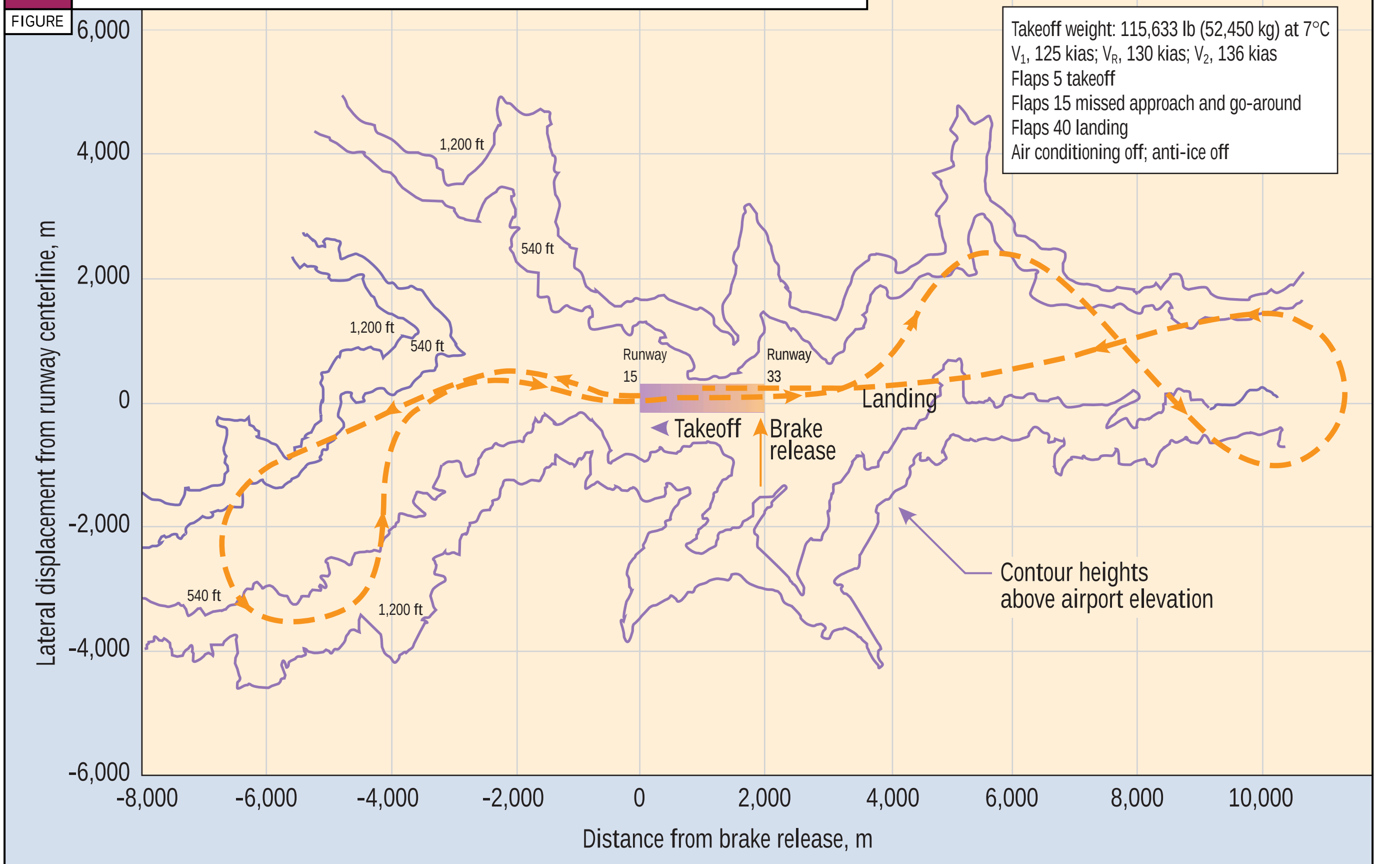


TABLE 2 DEMONSTRATION AIRCRAFT TAKEOFF GROSS WEIGHT

Runway 33	Zero fuel weight*	100,433 lb (45,556 kg)
	Fuel	15,200 lb (6,895 kg)
	Takeoff weight	115,633 lb (52,450 kg)
Runway 15	Zero fuel weight*	100,433 lb (45,556 kg)
	Fuel	13,900 lb (6,305 kg)
	Takeoff weight	114,333 lb (51,861 kg)

*Includes the weight of three crewmembers, ten passengers, amenities, and potable water.

to perform a 30-deg bank turnback. The available turning radius is based on the valley width at the net height achievable while maintaining not less than 492 ft (150 m) of lateral separation to the terrain and all obstacles on either side of the intended track. The limit weight calculations were based on the valley width at the net height for turnback initiation, assuming that the airplane was positioned within 492 ft (150 m) of the valley wall.

The takeoff gross weight for the technical demonstration was calculated based on the airplane empty weight and the weight of the crew, passengers, and fuel on board (table 2). Table 3 lists the airport conditions and airplane configuration and takeoff speeds.

Engine failure was simulated by throttling back the left engine to idle at 125 kias, the V_1 speed for takeoff.

Runway 15 Technical Demonstration Test Flight

The second technical demonstration test flight was performed from runway 15 (fig. 3).

After liftoff, a right bank was performed for a 10-deg heading change, followed by a left bank for a 60-deg

TABLE 3 PARO RUNWAY 33 TEST FLIGHT PARAMETERS

Airport conditions

Takeoff time: 03:58 Zulu
Landing time: 04:10 Zulu
Tower-measured temperature: 7°C
Tower QNH: 1,021 mbar = 7,140 ft pressure altitude
Tower wind: 190 deg at 6 kn

Airplane takeoff speeds

V_1, 125 kias; V_R, 130 kias; V_2, 136 kias

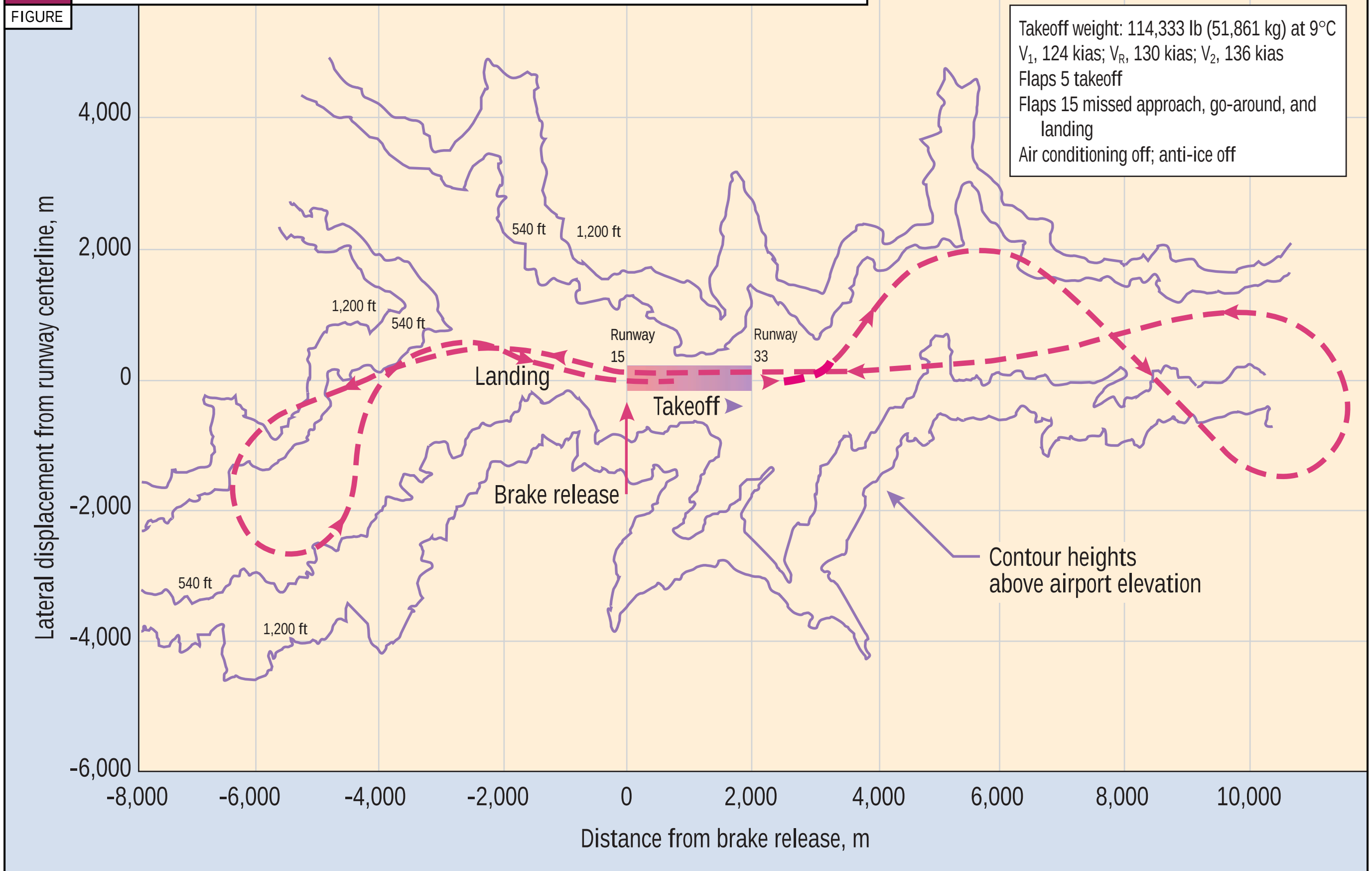
Airplane configuration

Takeoff gross weight: 115,633 lb (52,450 kg)
Takeoff thrust rating: CFM56-7B26
Center of gravity: 18.1%MAC
Stab trim: 5.25 units
Flaps 5 takeoff
Flaps 15 missed approach and go-around
Flaps 40 landing
Air conditioning off; anti-ice off
Left engine pulled to idle at V_1

3

FIGURE

PARO RUNWAY 15 TECHNICAL DEMONSTRATION TEST FLIGHT OVERVIEW



heading change. The left bank took the airplane across the valley toward the east wall and avoided a hill that extends from the west wall of the valley.

A right bank was then held for an approximate 95-deg heading change, which directed the airplane from the east side of the valley back toward the west side and the Silung Nang village. The airplane flew over Silung Nang and the ridge behind it, which required an altitude of 9,100 ft (2.77 km). After the airplane cleared the ridge, a turnback was initiated with a 30-deg bank while maintaining the designated V_2 speed.

After completing the turnback maneuver, the pilots performed a flaps 15 (engine-out landing flap) missed approach to runway 33, followed by a go-around and a teardrop turnback north of the runway using the runway 33 turnback procedure. The condition was completed successfully with a normal flaps 15 landing using the Druk Air straight-in landing procedure on runway 15.

The turnback procedure limit for runway 15 originally was determined to be the turning radius required to perform the 30-deg bank turnback. This limit was based on the valley width at the net height achieved while maintaining a minimum 492-ft (150-m) splay outside the intended track.

However, before the technical demonstration flights, Boeing and Druk Air pilots flew practice flights. After these flights, the pilots determined that the critical requirement was clearing the ridge beyond the village of Silung Nang, which requires a net height of 9,100 ft (2.77 km) at the turn initiation point. The limit weight calculations were based on the requirement to achieve this height on the net flight path. The turn radius

4

TABLE

PARO RUNWAY 15 TEST FLIGHT PARAMETERS

Airport conditions	Airplane configuration
Takeoff time: 04:22 Zulu	Takeoff gross weight: 114,333 lb (51,861 kg)
Landing time: 04:30 Zulu	Takeoff thrust rating: CFM56-7B26
Tower-measured temperature: 9°C	Center of gravity: 18.1%MAC
Tower QNH: 1,020 mbar = 7,140 ft pressure altitude	Stab trim: 5.25 units
Tower wind: 140 deg at 6 kn	Flaps 5 takeoff
Airplane takeoff speeds	Flaps 15 missed approach, go-around, and landing
V_1, 124 kias; V_R, 130 kias; V_2, 136 kias	Air conditioning off; anti-ice off
	Right engine pulled to idle at V_1

was not limiting at this condition, assuming a 30-deg bank.

Table 2 shows the airplane takeoff gross weight for the runway 15 technical demonstration flight. Table 4 lists the airport conditions and airplane configuration and takeoff speeds.

Engine failure was simulated by throttling back the right engine to idle at 124 kias, the V_1 speed for takeoff.

3 TECHNICAL DEMONSTRATION TEST FLIGHT ANALYSIS

FDR Analysis

FDR information was downloaded from the airplane after the technical demonstration test flights. The FDR flight paths were compared with profiles of predicted performance to verify the capability to match actual flight profiles.

Figures 4 and 5 show the ground tracks and altitude profiles for the demonstration test flights from runways 33 and 15, respectively. The calculated flight paths with one engine pulled back to idle thrust closely match the demonstrated flight paths.

4 FIGURE PARO RUNWAY 33 TEST FLIGHT GROUND TRACK AND ALTITUDE PROFILE

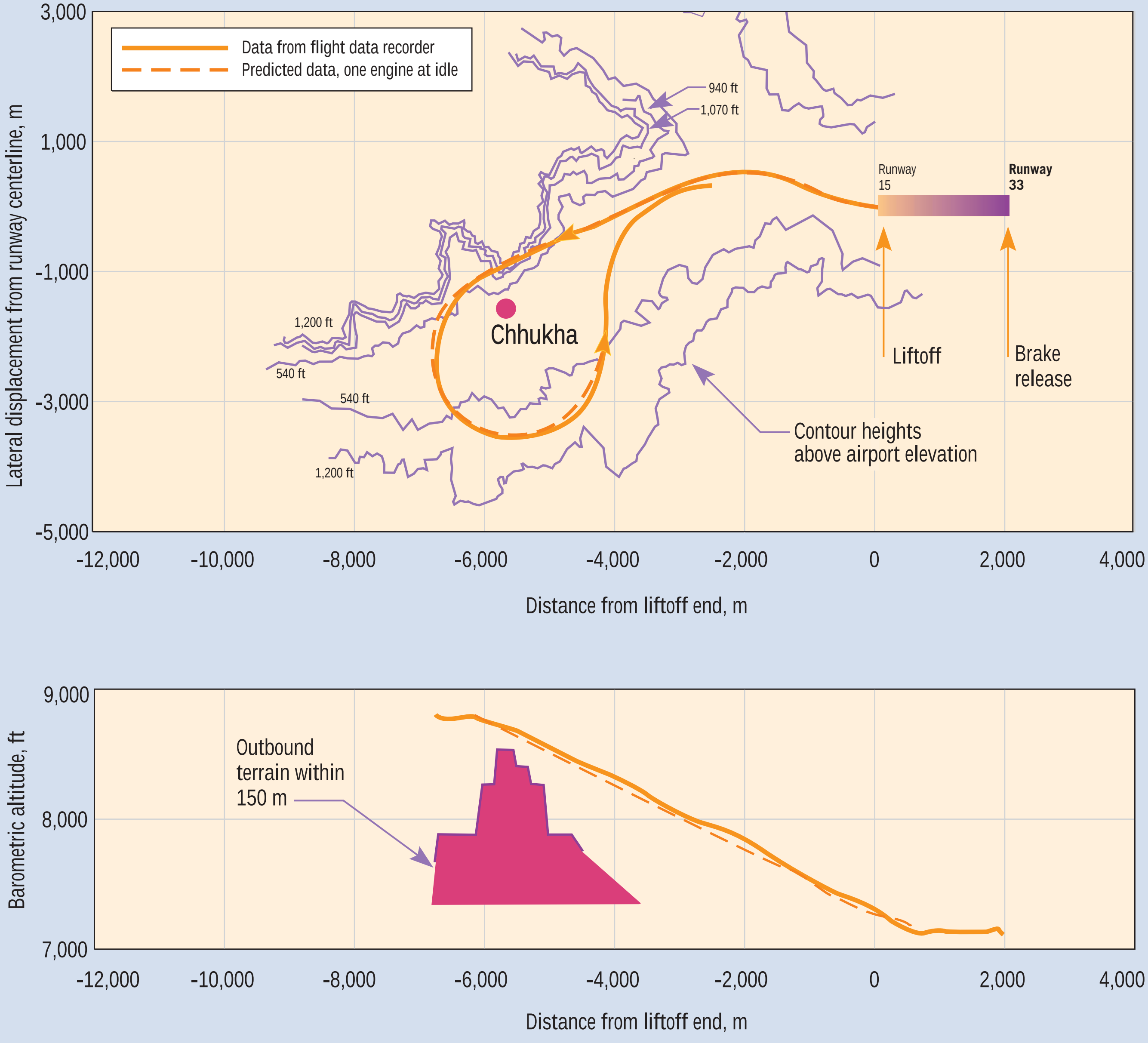
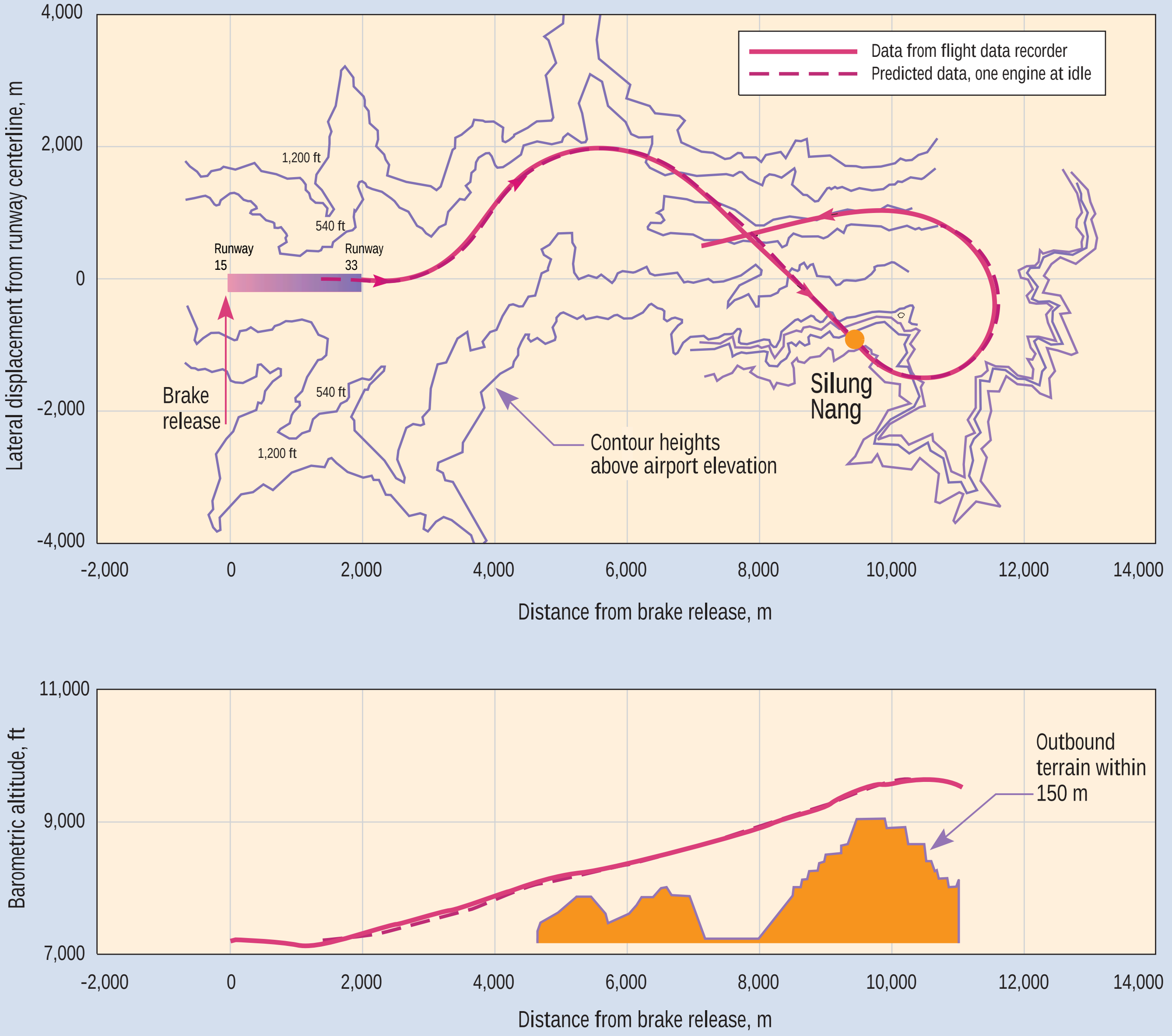


FIGURE 5 PARO RUNWAY 15 TEST FLIGHT GROUND TRACK AND ALTITUDE PROFILE



The calculated altitudes at the turnback initiation points for both flights were within 50 ft (15 m) on the conservative side of the predicted altitudes.

Turn Procedure Optimization

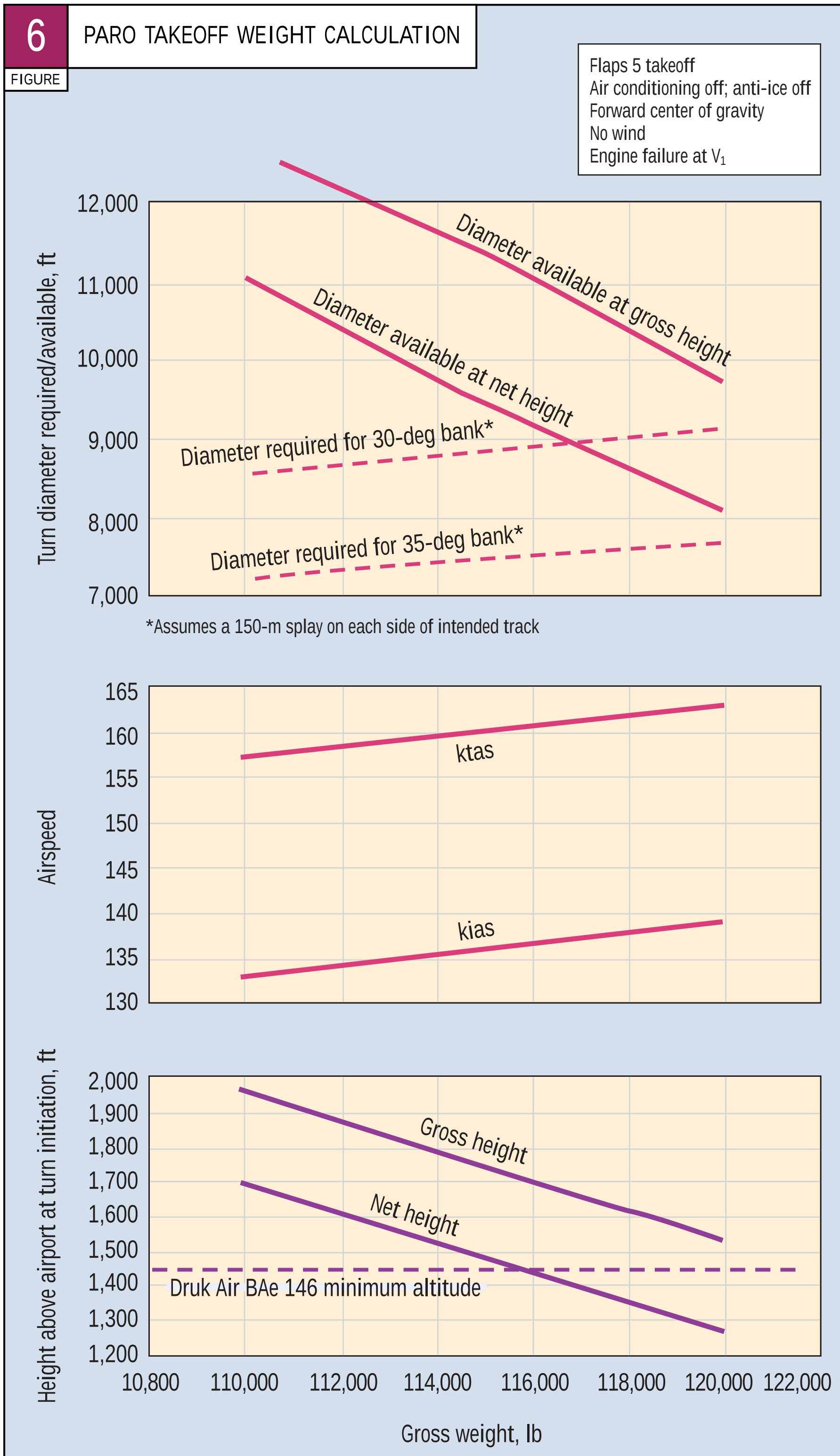
For the technical demonstration test flight from runway 15, takeoff weight was limited by the Druk Air procedural requirement to fly over a ridge after flying south over Silung Nang. To clear the ridge, a net altitude of 9,100 ft (2.77 km) is necessary at the turn initiation point.

Flying parallel to the valley wall near Silung Nang instead of crossing the ridge removes the requirement to reach 9,100 ft (2.77 km) and allows a greater takeoff weight. The performance then becomes limited by the width of the valley. Through careful selection of the turn initiation point, additional takeoff weight is possible.

The available turn radius as a function of altitude was determined by computing the maximum turn radius available in the valley at each altitude line on a digitized topography map. Maximum takeoff weight was calculated by plotting the available turn radius and the turn radius required as a function of gross takeoff weight.

Figure 6 is an example takeoff weight calculation. The bottom plot shows the airplane altitude at the turn initiation point. The middle plot shows the corresponding airspeeds. The top plot shows the turn diameter required for a 30-deg bank, which

6
FIGURE
PARO TAKEOFF WEIGHT CALCULATION



*Assumes a 150-m splay on each side of intended track

is solely a function of true airspeed and bank angle, and the turn diameter available at the corresponding net height.

Boeing continues to investigate product and operational improvements as part of its commitment to ensure that current and potential customers can maximize payload capability during safe takeoff and landing operations in high-elevation, high-terrain environments.

SUMMARY

The success of rigorous technical demonstration test flights at Paro International Airport in Bhutan validated the capability of the Boeing 737-700 to perform as predicted in a high-elevation, high-terrain environment.

The test flight data demonstrate that the 737-700

- Met or exceeded performance expectations for simulated one-engine-inoperative flight maneuvers, proving that predicted performance is representative of actual performance as recorded by the FDR.
- Verified procedures for safe takeoff and landing operations at Paro, one of the world's most challenging airports.

Editor's note:
Druk Air Royal Bhutan Airlines only operates BAe 146-100 jets at this time; Boeing is not maximizing the payload capability of the BAe jets.

IMPORTANCE OF SPEED DURING TAKEOFF TURNBACK PROCEDURES

Proper speed is essential when flying takeoff turnback procedures. Lower speeds decrease the climb capability and thereby reduce terrain clearance. Higher speeds increase the turn radius and bring the airplane closer to valley walls.

The pilots had the option of overbanking to stick-shaker speed or the initial buffet speed to achieve a smaller turn radius. They also could have combined pitch and roll to trade speed for altitude and reduced turn radius. Although these maneuvers are non-normal and were beyond the scope of this study, the pilots discussed their potential use to avoid terrain in an emergency or in high, unexpected cross-canyon wind conditions.

Optimal performance was achieved during the takeoffs from Paro by accelerating the airplane to a speed that was 10 kias faster than the minimum safety takeoff speed (10 kias of improved climb). This allowed for 30 deg of bank angle and provided the climb gradient necessary to initiate the turnback.

TAKEOFF CAPABILITY REFINEMENT

After the technical demonstrations, several performance options were studied to improve the takeoff weight capability from Paro. These included additional optimization of the turn procedures, increased takeoff thrust, use of alternate forward center of gravity positions, and installation of a weather station to allow use of Druk Air procedures B and C for runway 15. Using these procedures, the 737-700 can take off from Paro with 114 passengers and 4,850 lb (2,200 kg) of payload. Other enhancements that were studied, such as potential runway extensions and the removal of obstacles surrounding the airport, will further improve safe operation at Paro.

INCREASE TAKEOFF GROSS WEIGHT USING CFM56-7B26/B2 THRUST RATING AND ALTERNATE CENTER OF GRAVITY

The technical flight demonstrations were performed using the CFM56-7B26 thrust rating, which currently is the highest thrust rating certified on the 737-700. A new thrust bump rating, CFM56-7B26/B2, has been offered to Druk Air as a new product. The CFM56-7B26/B2 thrust rating will produce at least 2% more thrust than the CFM56-7B26 rating at the Paro International Airport elevation. The additional thrust is worth approximately 2,100 lb (953 kg) of additional takeoff gross weight at Paro.

Takeoff gross weight can be increased further by using the optimal airplane takeoff center of gravity (CG) location instead of the conservative forward-limit location specified by the standard airplane flight manual (AFM). The increase is achieved by using the AFM-alternate CG takeoff performance option on the 737-700, which allows the operator to select one of two specified CG locations. Using CG locations aft of the forward limit decreases airplane drag and lowers stalling speeds, thereby increasing takeoff performance. For example, using a 23%MAC CG location instead of the forward-limit location for

runway 15 increases 737-700 takeoff gross weight by 1,200 lb (544 kg).

Airport conditions and terrain constraints limited the demonstration takeoff gross weight to approximately 115,000 lb (52,163 kg). However, by optimizing the turn procedures and using the CFM56-7B26/B2 thrust rating and alternate CG performance, takeoff gross weights in excess of approximately 120,000 lb (54,431 kg) are achievable. This improvement would allow Druk Air to fly a 737-700 with a full passenger payload from Paro to all its current initial destinations.

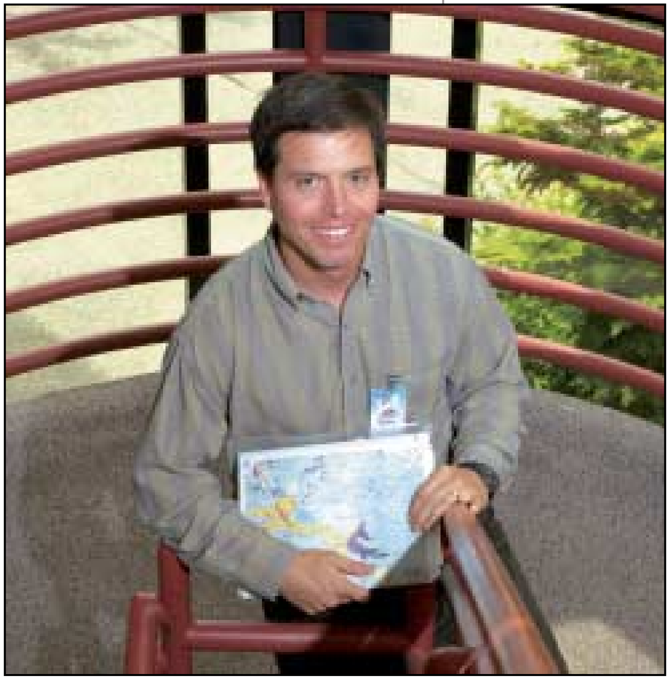
Miguel Santos is director of international sales for countries in Asia and Africa. During his 24-year career with Boeing, he has held engineering and management positions in advanced engineering, marketing, sales support engineering, marketing management, customer requirements, and sales organizations. Miguel has bachelor's and master's degrees in aerospace engineering and an MBA.

Allen Rohner is regional director of marketing for countries in the Indian Ocean, Indian subcontinent, and Africa. In his 30 years at Boeing, Allen has held technical analyst positions in aerodynamics engineering, working on the 747, 767, and 777 programs in sales and marketing support and product development. Allen was key in facilitating and organizing the effort that made the technical demonstration test flights in Bhutan happen.

Capt. Van Chaney has almost 20 years of aircraft testing experience, both as a test pilot and an aerospace engineer. A 737 and 757 pilot, Van has worked at Boeing for seven years and conducts research in the company's H-295 Helio Courier and Cessna 206. He is a member of the Society of Experimental Test Pilots and has authored several professional papers.

About the Authors

Magaly Cruz is a performance engineer with five years of experience in aerodynamics. Magaly was instrumental in developing takeoff procedures for the Paro technical demonstration flights.



James Wilson, lead engineer, supports the sales of all Boeing airplane models by providing aerodynamic performance information. During his 18 years with Boeing, James has worked in aerodynamics on 747-400 certification, 747 and 767 fleet support, and 747, 767, and 777 fuel mileage.

Capt. Buzz Nelson has flown more than 14,000 flight-hours during his 40-year aviation career. He is qualified on all models of the 737, 747, 757, 767, and 777 and has been involved in their development and certification programs during his 30 years with Boeing. For almost 10 years, Buzz was a member of the Society of Automotive Engineers S-7 committee, which writes design practices for the handling qualities of large commercial airplanes and flight deck designs.

EFB

Boeing brings a new level of digital information delivery and management to the flight deck with the Jeppesen Electronic Flight Bag, which is a major step toward the e-enabled airline. This modular, integrated hardware and software package calculates performance figures, displays charts, improves taxi positional awareness, provides video flight deck entry surveillance, and allows electronic access to documents. A scaleable offering of three configurations — portable, semiportable, and installed avionics — provides airlines with flexibility in choosing their solution. The Electronic Flight Bag will help airlines reduce costs, improve taxiway and flight deck safety, and establish convenient access to digital documents.

DAVID ALLEN
CHIEF ENGINEER
CREW INFORMATION SERVICES
BOEING COMMERCIAL AIRPLANES

TECHNOLOGY/PRODUCT DEVELOPMENT

ELECTRONIC FLIGHT BAG


VIEW
MENU
CHK
EMG
PREV
LOW BAT
PWR
LOGBOOK
RESET PANELS
LOG SUMRY
BACK
FLIGHT LOG
FAULT REPORT
FIND IT
Select a Panel:
Flight Deck
Select a Fault:
A/P amber warning annunciator light
A/T amber warning annunciator light
Aileron
Does not go back to neutral
left
right
left and right
Air conditioning compartment light
Air inlet door, for the APU
Air mode
Air outlet, foot
Air outlet, windshield
AIR TEMP indication
AIR TEMP indication not correct
Airspeed display
EICAS MSGS
OBS FAULTS
MAINT
EXPAND LIST
COLLAPSE LIST
XFER TO LOG
ENTER
ENTER
BRT
DIM

Boeing offers airlines e-enabled solutions that put innovative, valuable information technology on board airplanes. A prime example is the Jeppesen Sanderson, Inc., Electronic Flight Bag (EFB). The EFB is a major step toward e-enabling the entire air transport system — from the flight deck to the cabin, maintenance, and the airport.

The EFB is offered in three configurations: portable, semiportable with mount, and installed avionics. Common software for all three types will allow airlines to implement any combination in their fleets while maintaining common training and operating procedures. This article describes the installation and operation of the Class 3 EFB system, which is the initial system being certified.

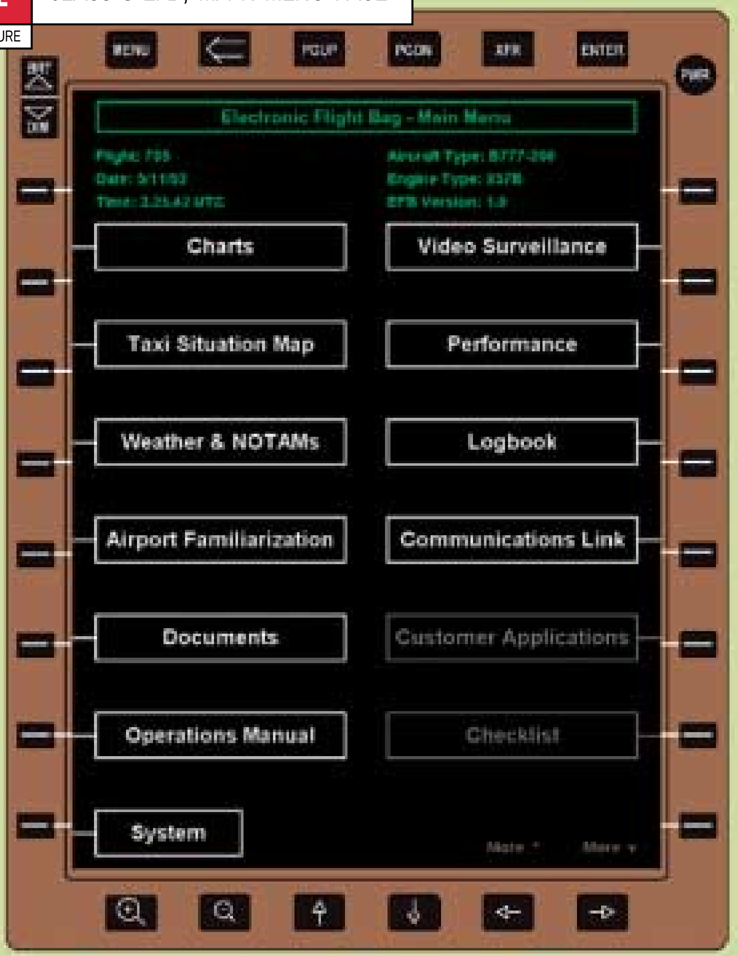
Through its unique combination of modular content, applications, and services that integrate the data generated by an entire flight operation, the EFB will provide key, meaningful information to pilots, flight attendants, operations workers, mechanics, and other personnel (fig. 1).

The EFB display integrates well with the look and feel of other flight deck instrumentation and is consistent with the flight deck design philosophy and operation (fig. 2).

Airlines will realize many benefits with the EFB, including

- **Reduced fuel and maintenance costs through precise, accurate calculations.** Current takeoff and landing calculations are conservative and often are based on early dispatch weight and balance information, which adds delay and cost to each flight. The EFB will save airlines costs while increasing payload by providing more accurate calculations based on real-time information. These calculations can result in lower thrust ratings, which reduce engine maintenance costs.

FIGURE 1 CLASS 3 EFB, MAIN MENU PAGE



- **Improved taxiway safety.** The taxiway environment can be challenging for pilots, especially when visibility is limited or during the night at unfamiliar airports. The Class 3 EFB enhances pilot runway and taxiway situational awareness by integrating onboard georeferencing equipment (e.g., Global Positioning System [GPS] technology) with Jeppesen electronic airport taxi maps. Pilots have greater awareness of position — from the runway to the gate — which improves safety and reduces taxi time. (The Class 2 EFB presents a moving map of the airport but does not indicate current airplane position.)

- **Flight deck entry surveillance for compliance with current International Civil Aviation Organization recommendations.** Class 2 and Class 3 EFB displays can host cabin-to-flight deck video feeds, providing airlines with flight deck entry surveillance.

- **Future integration capabilities for e-enabled airlines.** Initial

FIGURE 2 EFB INSTALLED IN 777 FLIGHT DECK

implementations of the EFB will allow connectivity through the terminal wireless local area network unit. The system also can integrate with the ARINC 763–compliant CoreNet Connexion by Boeing^{SM} server to provide seamless wideband airline administrative connectivity on the ground or in the air.

- **Elimination of paper from the flight deck and access to digital documents.** Eliminating paper from the flight deck saves weight and reduces clutter. For example, without the EFB, a single 777-200ER flight requires 77 lb of paper. Accessing digital documents on the flight deck is an efficient, convenient way for pilots to quickly obtain the information they need. Configuration-controlled documents such as aeronautical charts, fault reporting and operations manuals, minimum equipment lists, and logbooks are available at the pilots' fingertips. The distributed data management (DDM) system provides an airline logistics system to ensure that all airplanes will have up-to-date information.

Future EFB upgrades will support real-time updates of time-sensitive data such as in-flight weather reporting, notices to airmen (NOTAM), and an onboard electronic checklist (for non-777 airplanes). Boeing is working with Jeppesen to install Class 2 and Class 3 EFB systems on Boeing airplanes, both in production and through retrofit. Class 1 portable EFB systems, which also are available, do not require installation. The first EFB implementation will be a Class 3 system on a production 777-200ER airplane for KLM Royal Dutch Airlines.

This article describes

1. EFB applications.
2. EFB communications and data management features.
3. EFB architecture and certification.

Right-side EFB installation, 777 cab

1 EFB APPLICATIONS

The current EFB applications are

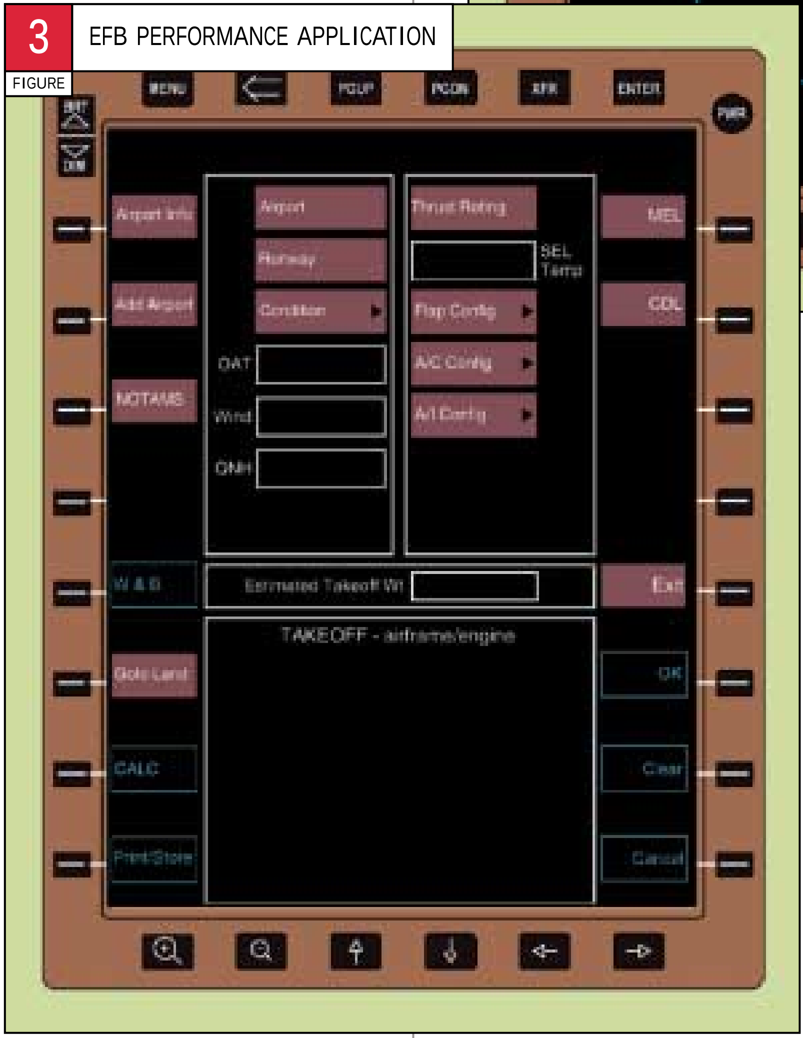
- Performance.
- E-documents.
- Charts.
- Taxi positional awareness (airport moving map).
- Video surveillance.

Performance

The performance application calculates precise takeoff and landing performance figures for each airplane under any conditions (fig. 3). The calculations are based on a combination of preloaded and pilot-entered data.

FIGURE 4 EFB E-DOCUMENTS APPLICATION

FIGURE 3 EFB PERFORMANCE APPLICATION



Preloaded data include

- Airport characteristics (e.g., elevation, runway data, obstacle data).
- Airplane data (e.g., tail number, engine type and rating, flap configuration).
- Airline policy information (V_1 type used or menu items).

Pilot-entered data include

- Current runway conditions.
- Current environmental conditions (e.g., outside temperature, wind velocity).
- Specific airplane configuration (e.g., flap position, airplane status).
- NOTAM data that may affect performance.
- Deferred maintenance items (e.g., minimum equipment list, configuration data list) that affect performance.

E-Documents

The e-documents application allows flight crew members to view and search current electronic documents on the flight deck (fig. 4). Available documents include the flight crew operating manual, U.S. Federal Aviation Regulations, and the *Aeronautical Information Manual.*

Airlines also will be able to use the e-documents application to author and host documents. Documents are best viewed as XML format, which supports searching and text wrapping. The e-documents ground administration tool can convert structured and unstructured PDF files into HTML documents for viewing. E-documents also accept scanned images (which are shown as pictures) in GIF, JPG, TIF, and CGM formats.

Charts

The charts application allows flight crews to view terminal procedure charts, airport origin and destination charts, and arrival and departure charts (selection aided by data provided by the flight management system) (fig. 5). Additional charts can be accessed through the browse and search capabilities.

The ChartClip function allows flight crew members to preselect charts for quick access to all charts in the ChartClip list. An en route chart access capability is planned for a near-term upgrade.

Taxi Positional Awareness

The taxi positional awareness (TPA) application is a set of highly accurate airport maps that graphically portray runway, taxiway, and other airport features to support taxi operations (fig. 6). (TPA also is referred to as airport moving map and taxi situational awareness.)

For the Class 3 system, the GPS provides an "ownship" position that is portrayed on the taxi map along with the heading from the inertial reference system. Class 2 systems center the map based on GPS position but do not indicate an ownship position. Flight crews use TPA to identify, by external visual references, their location in relationship to runways and taxi holding points, taxi turn points, or gates. The TPA should be used in conjunction with U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 120-74, *Flightcrew Procedures During Taxi Operations*, which requires outside visual references and controller instructions.

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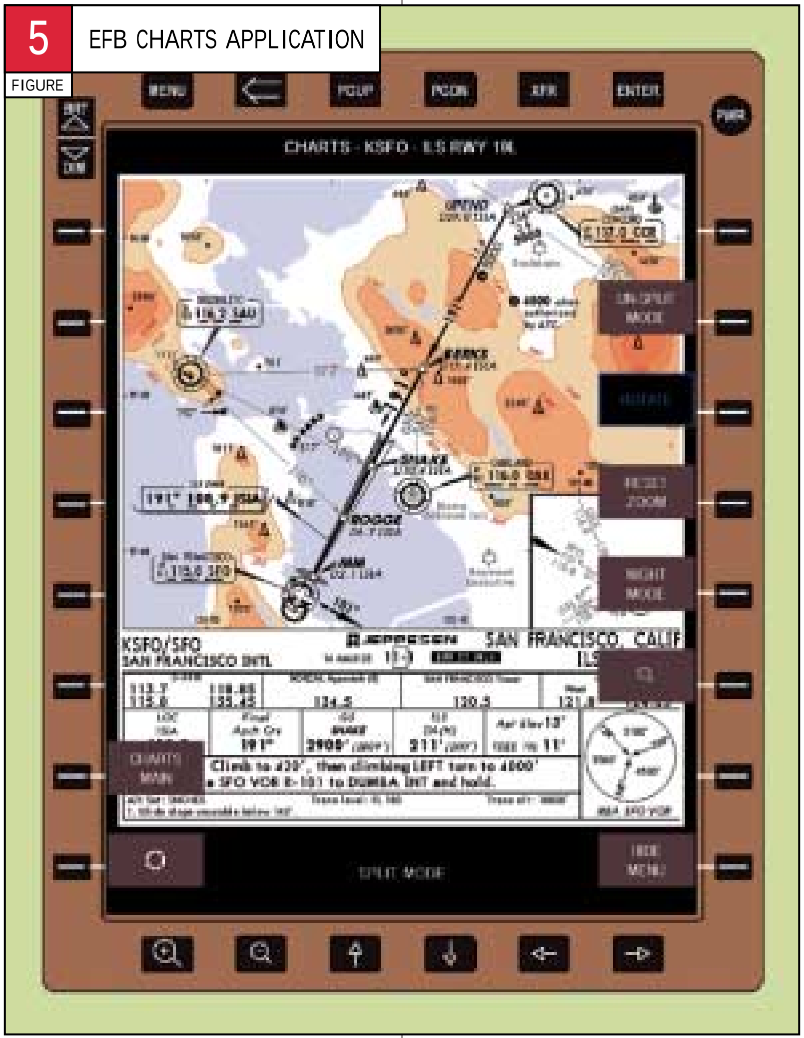
FIGURE

EFB CHARTS APPLICATION



Video Surveillance

The video surveillance application allows airlines to leverage their video surveillance investment with operational improvements enabled by the EFB (fig. 7). The video surveillance application uses installed buyer-furnished equipment (BFE) (i.e., camera, camera interface unit).

The EFB receives digital video through an Ethernet connection from the camera interface unit. Users can select output from the installed cameras and display it on the screen. After the airline and its BFE supplier decide on the number and location of cameras, Boeing will integrate the system and make the video surveillance application available.

2 EFB COMMUNICATIONS AND DATA MANAGEMENT FEATURES

In addition to the performance, terminal charts, e-documents, TPA, and video surveillance applications, the EFB provides communications interfaces and data management capability between the EFB and the airline operational control.

Communications Interface

The EFB system uses a communications management function to interface with the airplane communications subsystem, which will allow airlines

FIGURE 6 EFB TPA APPLICATION

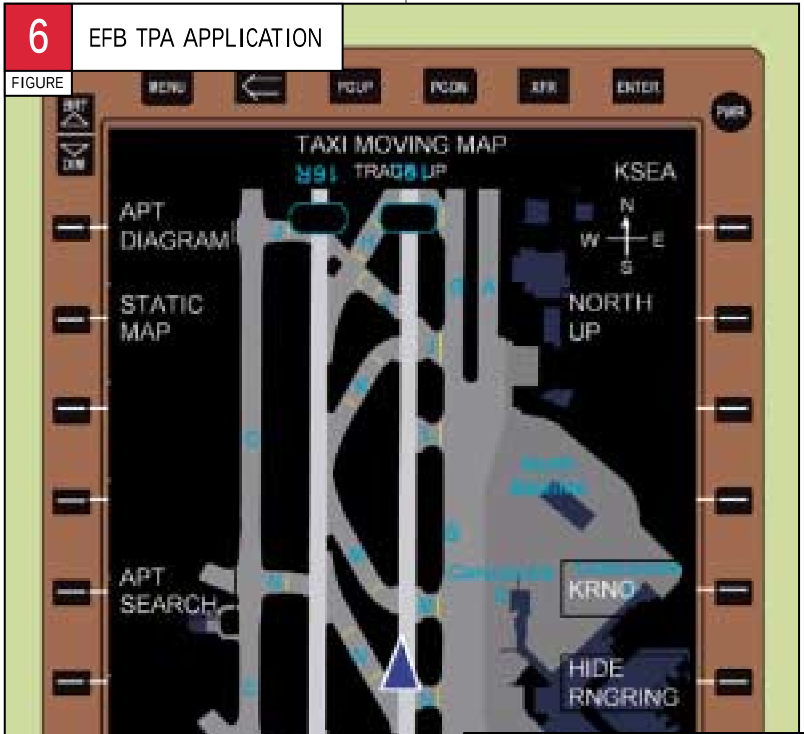
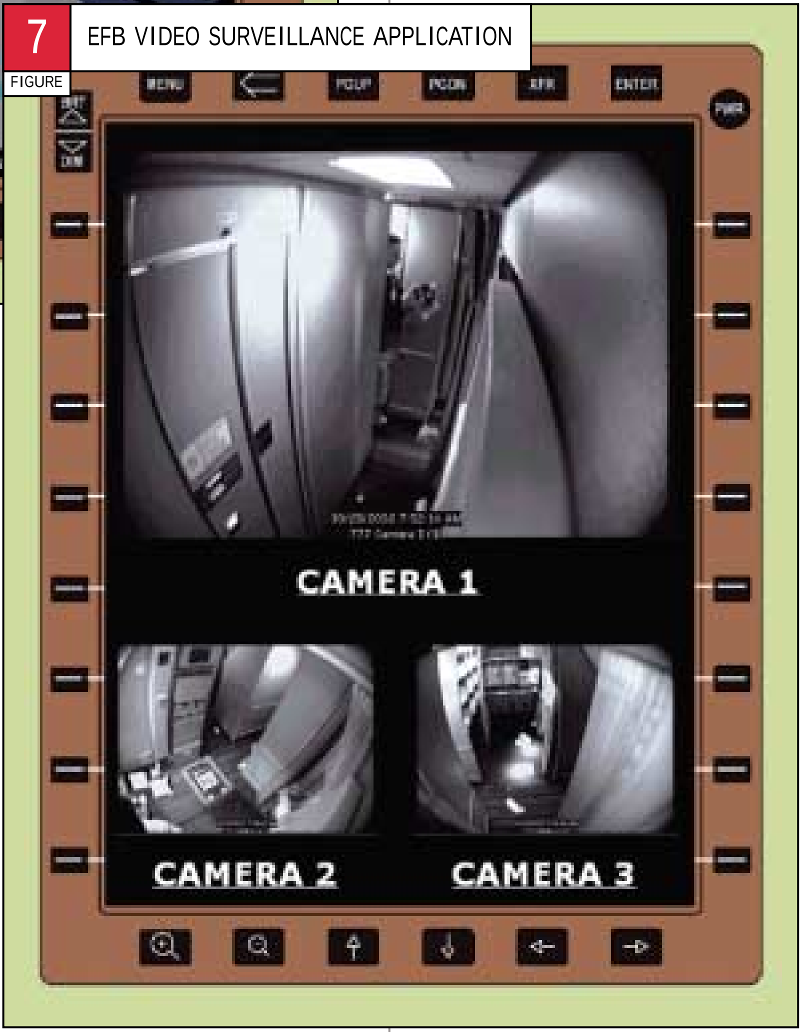


FIGURE 7 EFB VIDEO SURVEILLANCE APPLICATION



to specify the preferred communication for each EFB application. For 777 airplanes, an airplane information management system update is required to allow access to the existing cabin terminal port. For other airplanes, this involves connecting the EFB to the airline airplane communication addressing and reporting system and communications management units cabin terminal port.

Boeing also will offer a direct connection to a terminal wireless gatelink system, which will provide an IEEE 802.11b high-bandwidth link to an airport terminal server. EFB applications will have access to this link and will provide staged data loads that can be initialized later by maintenance personnel.

The EFB is designed to integrate with the CoreNet and Connexion by Boeing system. This integration allows EFB applications to use the integral data router and Connexion by Boeing link.

Distributed Data Management

The DDM service will allow airlines to automatically manage and schedule content delivery to airplanes. The content can be copied from CD-ROMs or directly from the DDM system into a compatible ARINC 615A data loader and then can be loaded into the EFB. The service also can send data through the terminal wireless gatelink, which allows data loads to be staged incrementally. A completely staged data load can be an installed action by appropriate airline personnel.

3 EFB ARCHITECTURE AND CERTIFICATION

Class 1 Architecture

The Class 1 EFB is a commercial off-the-shelf laptop computer that

EFB location in 737 cab

can host the following applications:

- Performance calculations.
- Electronic documents.
- Charts.

This system can use airplane power if that option has been installed. The portable computer must be stowed during the takeoff and approach phases of flight. The current Boeing Laptop Tool for performance calculations will migrate to this Class 1 offering.

Class 2 Architecture

The Class 2 EFB architecture comprises a portable pen tablet computer installed in a crashworthy mount. This EFB can be removed from the mount, which provides a power interface for the system, without maintenance action.

An airline may choose installation of an airplane interface module that will provide read access to various avionics systems (which can provide data for EFB applications) and data link capability for various EFB applications. Because the EFB is installed in a crashworthy mount, it can be used during all phases of flight.

Class 2 EFB applications include

- Performance calculations (with automatic field updates enabled by airplane interface).
- TPA moving map (without ownship position).
- E-documents.
- Charts, including approach charts.

Class 3 Architecture

The open architecture of the EFB Class 3 system will allow airlines (or third-party suppliers) to develop software for the Microsoft Windows® processor using a software development kit provided by Boeing and Jeppesen. The software development kit will include application programming interfaces that will provide access to onboard communications and the flight deck printer.

The EFB Class 3 architecture has two flight deck–mounted display units (DU) and two electronic units (EU) mounted in the main equipment bay (fig. 8). The EUs provide the display to the DUs, which show the selected applications, allow transfer of display between the two DUs (so flight crew members can view each other’s display), and control unit brightness.

The first EFB implementation will be a Class 3 system on a production 777-200ER for KLM.

An EU contains two single-board computers, each with a dedicated, atmospherically sealed disk drive and memory. One computer runs the Linux operating system (OS), which is certified through DO-178B. That computer controls the TPA display, TPA activation, and the applications on the other computer, which runs the Windows OS. The Windows applications are operationally approved. Six Ethernet ports on each EU provide communication between the EUs.

EFB installation on the 777-200ER uses existing side display provisions as installation sites (fig. 9).

Certification

The EFB follows guidance set forth in AC 120-76A, *Guidelines for the Certification, Airworthiness, and Operational Approval of Electronic Flight Bag Computing Devices.*

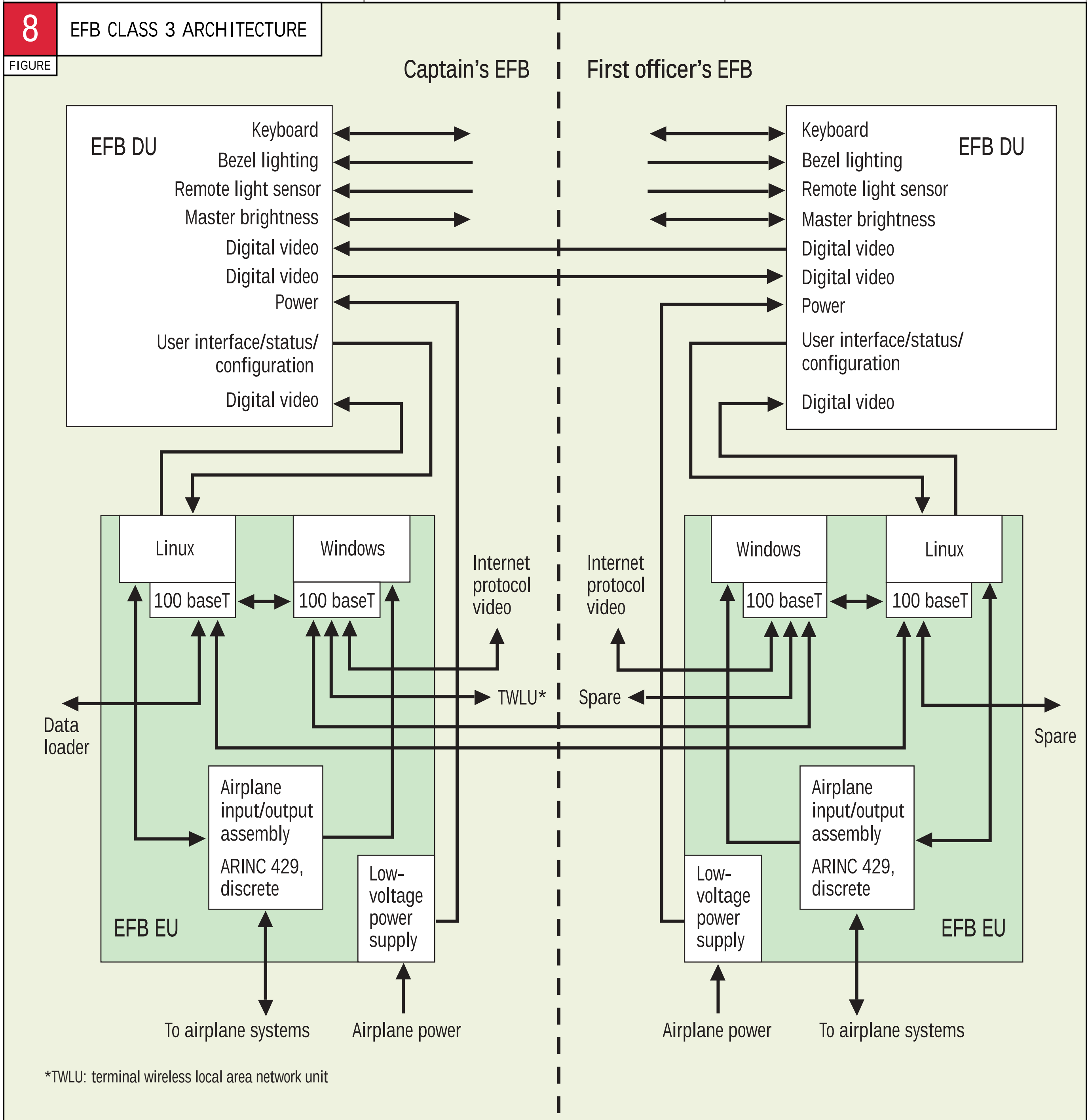
For the Class 3 EFB, installation of the DUs, EUs, and associated wiring will be certified through an amended type certification.

The Class 3 Linux OS will be certified through the same amended type certification. The TPA function will be certified on the Linux side as part of the same amended type certification. The remaining applications on the Windows processor will be operationally approved using the guidance provided in AC 120-76A.

Class 2 EFB Part 25 certification is limited to the mounting device and airplane system interfaces. The Class 2 computer itself will be operationally approved along with the applications.

Class 1 EFB systems are operationally approved only.

8 FIGURE EFB CLASS 3 ARCHITECTURE



*TWLU: terminal wireless local area network unit

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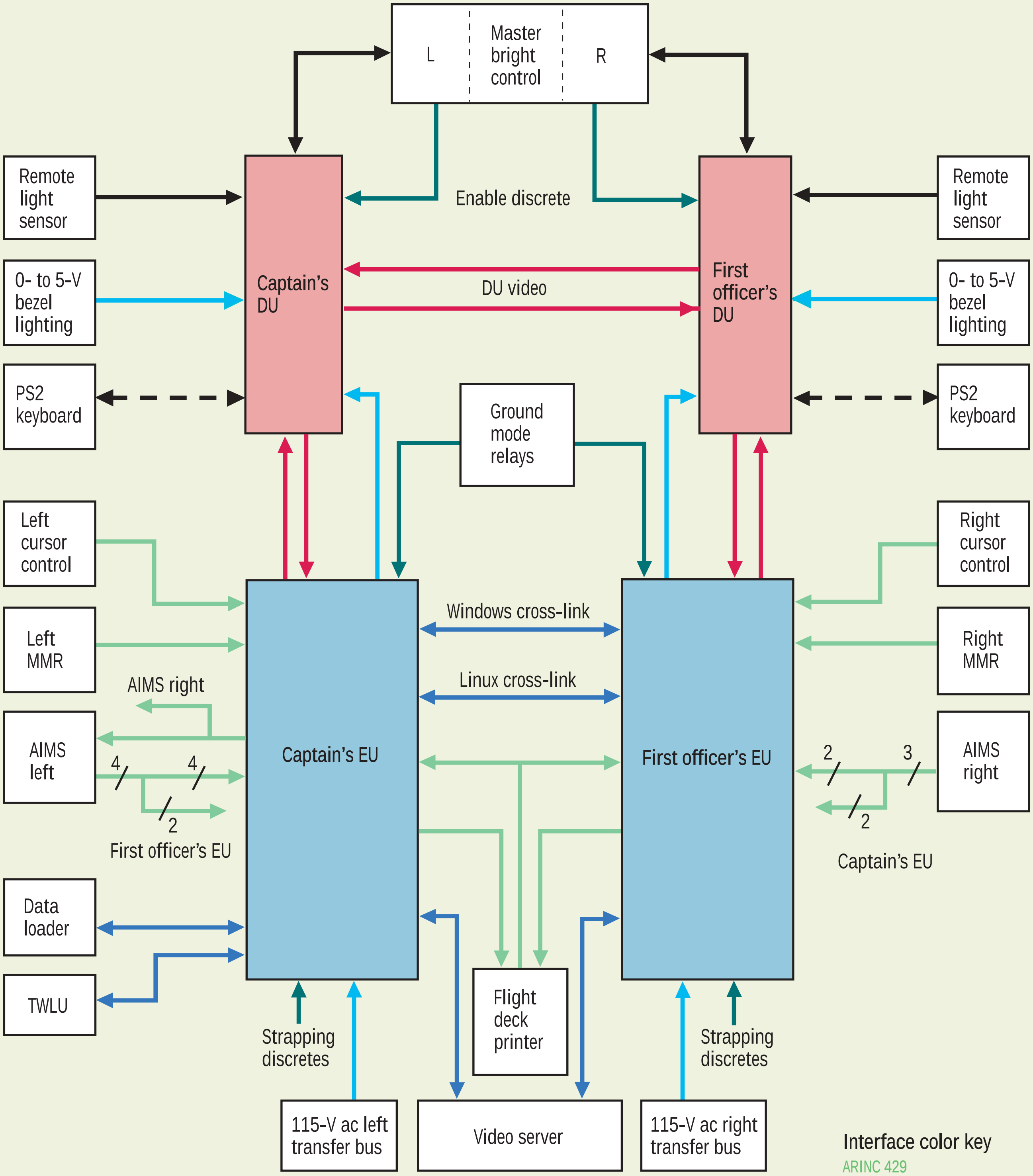
FIGURE

FUNCTIONAL HOOKUPS FOR INSTALLATION ON THE 777-200ER

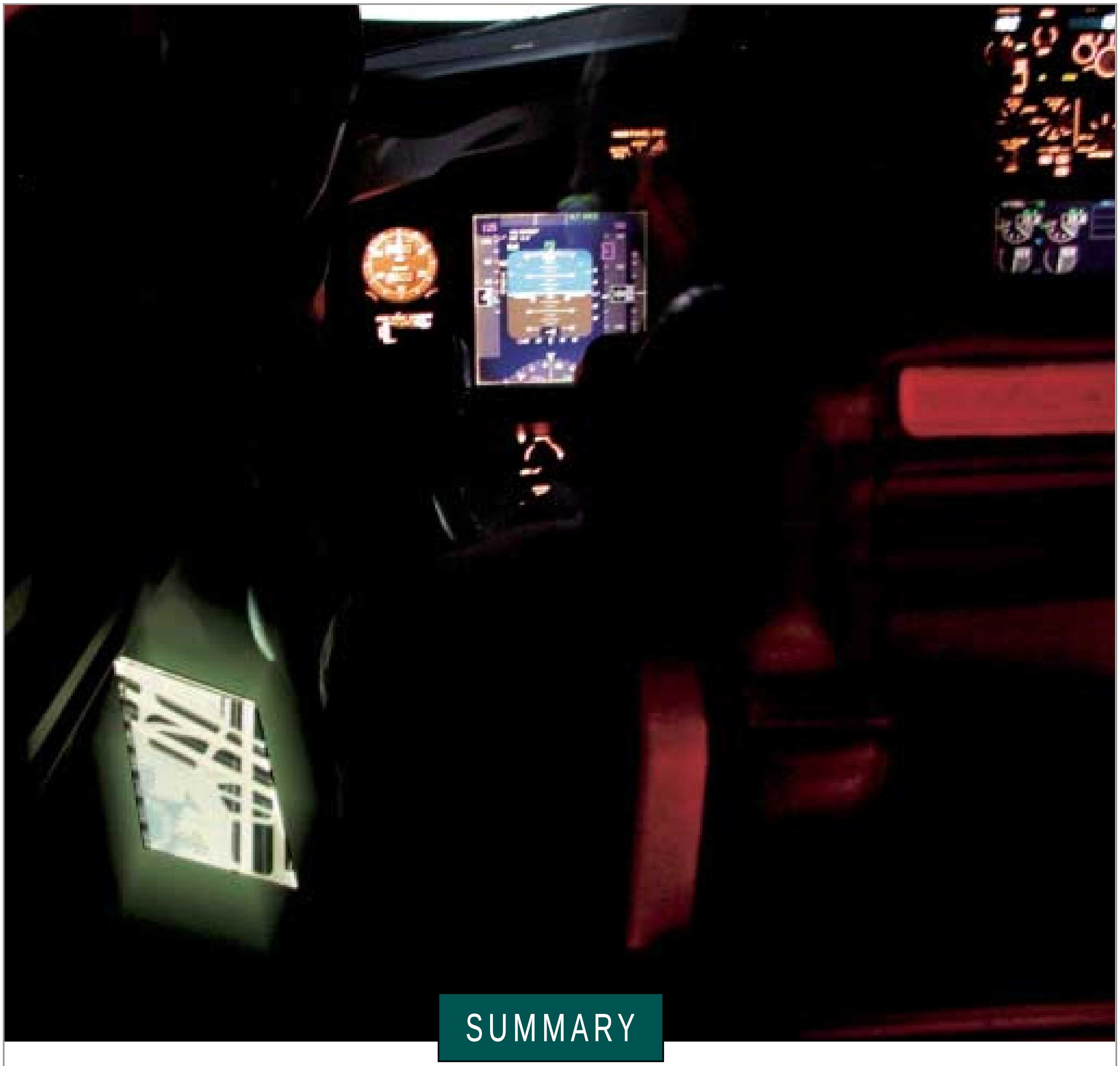


Definitions

AIMS: airplane information management system
MMR: multimode receiver
TWLU: terminal wireless local area network unit

Interface color key

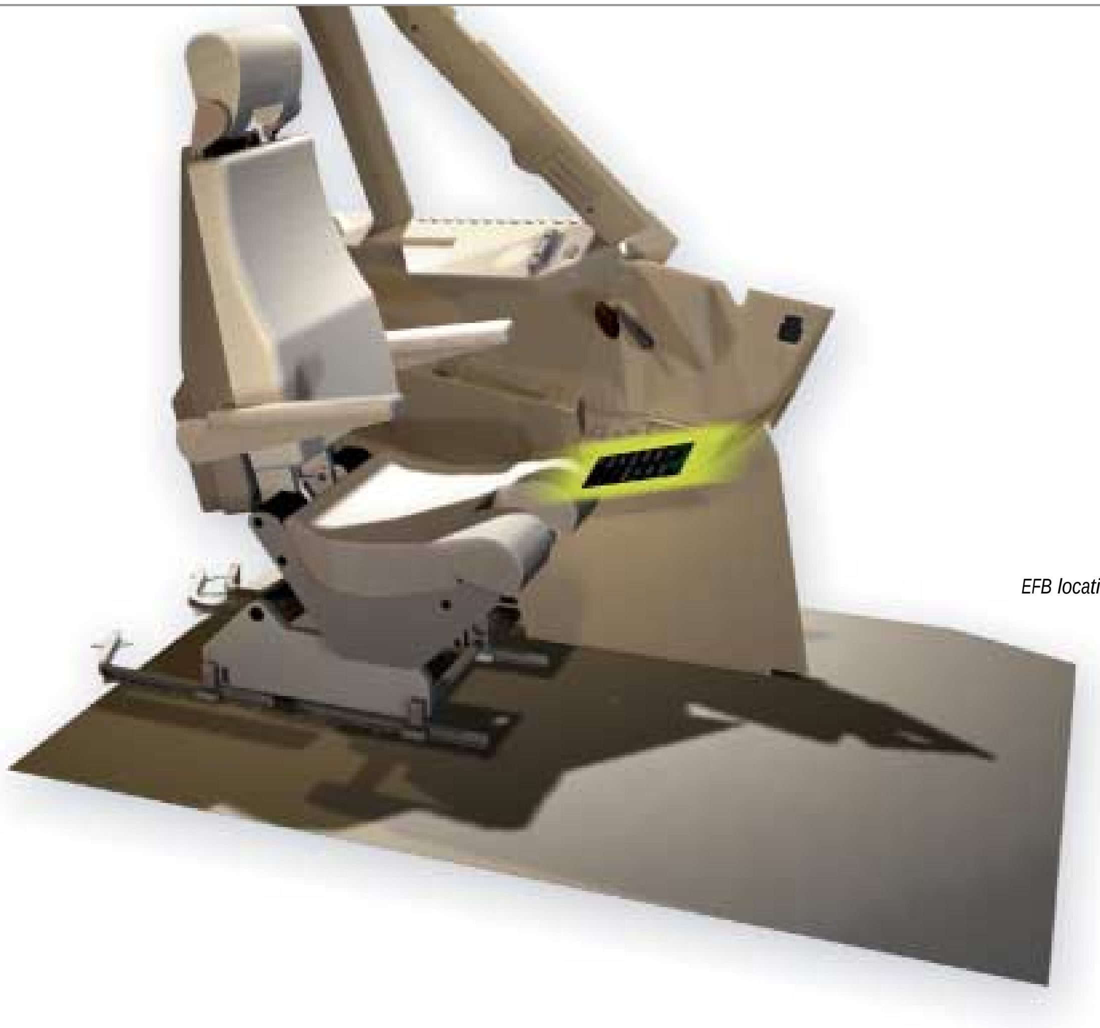
ARINC 429
10/100 baseT Ethernet
1000 baseSX (digital optical)
Discrete
Power
Analog
Serial digital (— — —)



SUMMARY

The Electronic Flight Bag is a major step toward e-enabling the air transport system for all airplanes. Through its integrated, modular applications, the Electronic Flight Bag brings a new level of digital information delivery and management to the flight deck. Airlines will realize flight operations and maintenance cost savings, improved safety, and enhanced document accessibility and configuration control.

Editor's note: For more information about the Electronic Flight Bag, call Jim Proulx, Boeing Crew Information Services, at 206-766-1393.



EFB location in 747 cab

About the Author

David Allen oversees the development and installation of the Electronic Flight Bag and its supporting infrastructure. During his 25 years with Boeing, David has worked on avionics software and hardware projects and was project engineer on the Future Air Navigation System, which integrated airplane avionics with satellite communication and navigation for air traffic control. He has been a software and systems-designated engineering representative of the U.S. Federal Aviation Administration and received the International Air Transport Association Global Navcom Laurel Award for communications, navigation, and surveillance functions in commercial aviation.

ERRONEOUS

Erroneous flight instrument indications still contribute to airplane accidents and incidents despite technological advances in airplane systems. To overcome potential problems, flight crews should follow recommended piloting techniques and procedures when they encounter a flight instrument anomaly.

DAVID CARBAUGH
CHIEF PILOT
FLIGHT OPERATIONS SAFETY
BOEING COMMERCIAL AIRPLANES

SAFETY

Flight Instrument Information—

SITUATIONS AND GUIDANCE

Preventable accidents and incidents related to erroneous flight instrument information continue to occur despite improvements in system reliability, redundancy, and technology. In particular, modern flight instruments provide more information to the flight crew with greater precision. Flight crews seldom are confronted with instrument problems; however, when these problems do occur, their rarity can make the situation worse.

To overcome the potential problems associated with infrequent failures, flight crews should be aware of the piloting techniques summarized in this article, follow the guidance described in operations and training manuals, and comply with airline training when facing a flight instrument anomaly.

Reviewing the following important information can help flight crews make the proper decisions when encountering erroneous flight instrument indications:

1. Recent erroneous flight instrument incidents.
2. Pitot and static instrument system design.
3. Recognition and recovery techniques.
4. Procedures to assist flight crews.

1 RECENT ERRONEOUS FLIGHT INSTRUMENT INCIDENTS

Controlling modern airplanes generally is a routine task in normal and most nonnormal situations. In this era of aural, visual, and tactile warnings and advanced instrumentation, flight crews consistently are alerted when certain airplane parameters are exceeded. However, flight crews must react properly when confronted with instrument failure, which can cause a significant loss of information. Unfortunately, incidents and accidents have occurred where flight crews have had difficulty with erroneous flight instrument indications.

A previous *Aero* article, "Erroneous Flight Instrument Information" (*Aero* no. 8, Oct. 1999), reviewed four accidents and incidents. During the three recent incidents described here, flight crews were faced with uncertainties about flight instrumentation.

Incident A—Plugged Pitot Probes

An airplane took off with the left and right pitot probes plugged by insect activity. Primary airspeed indications were inactive during the takeoff roll, but standby airspeed was normal. The flight crew noticed the condition at an airspeed assumed to be greater than 80 kias and elected to continue the takeoff.

The captain's airspeed recovered at an altitude between 1,000 and 2,000 ft; the first officer's indicated airspeed remained at 30 kias. The crew performed an air turnback and a normal landing. The airplane had been on the ground for 36 hr before the event. The pitot probe blockage had not been detected during the walk-around conducted by the flight crew.

There have been several in-service reports of insects such as mud-dauber wasps sealing pitot probes. These events raise concern about the potential for a takeoff with erroneous airspeed indications and the possibility of inappropriate crew action, which could lead to a high-speed rejected takeoff or loss of situational awareness in flight.

Incident B—Open Static Port Drains

An airplane departed without the static port drain caps, which had been removed during maintenance but not replaced. As a result, the static lines were open to cabin pressure. There was significant airframe vibration after takeoff. The flight crew deduced that the airspeed indicators were under-reading and observed that the altimeter was not changing. They declared an emergency and returned without incident. After the flight, maintenance discovered that the flaps had been damaged by excess speed.

Incident C—Partially Blocked Pitot Tube

An airplane departed with the captain's pitot tube partially obstructed by insects. The captain's airspeed indication lagged behind the first officer's airspeed indication. The first officer was conducting the takeoff, and by the time the late callouts and erroneous indications were identified, the crew decided to continue the takeoff.

During climbout, several engine indicating and crew alerting system (EICAS) messages were noted, which later disappeared. Airspeed indications appeared to be normal. Upon reaching cruise altitude, the captain's airspeed indicated higher than the first officer's indication but seemed reasonable.

When the first officer started a step climb, the autopilot attempted to reduce speed by pitching up. The vertical navigation function had used the captain's erroneous air data information for the climb and tried to reduce the apparent overspeed. This resulted in an approach to stall warning (stick shaker) and subsequent significant loss of altitude during the recovery. The crew then diverted to an uneventful landing.

Partial pitot probe or static port blockages can present challenges to the flight crew. Knowledge of potential problems and system design aids flight crews in successfully handling these types of problems.

2 PITOT AND STATIC INSTRUMENT SYSTEM DESIGN

Good system design and redundancy have made the rate of instrument and system anomalies very low compared with the number of departures.

On early commercial airplanes, pitot and static information was fed directly to the airspeed indicators, and static information was indicated on the altimeter. The only electrical power required was for instrument lighting.

Later designs replaced pneumatic airspeed indicators and altimeters with servo-pneumatic types. Airspeed information could be displayed either in the central air data computer (CADC) mode or all-pneumatic (backup) mode. The CADCs added compensation for errors and were a significant advance. Eventually, the technology was developed to the point that electric air data instruments were driven only by CADCs, and only the new standby airspeed and altitude indicators were pneumatic.

With the advent of the glass cockpit, air data instruments remained a round-dial, all-electric design, but they received information from digital air data computers through digital data buses. This use of digital information eventually made it possible to display the airspeed and altitude tapes. Standby instruments essentially were unchanged.

The most modern systems today use an air data inertial reference unit (ADIRU), which incorporates the best information from three pitot and static sources and provides a single set of data to both pilots. An ADIRU receives information from air data modules, which are located close to the pressure sources. A secondary attitude air data reference unit is available as a backup. Dedicated standby air data modules provide data to the standby instruments.

Throughout this design improvement process, the reliability and integrity of air data systems have improved greatly, even with the increased number of system functions and interactions. Pitot probes and static ports remain critical sources of data for flight deck instruments.

3 RECOGNITION AND RECOVERY TECHNIQUES

Typically, the crew recognizes problems during takeoff or shortly after liftoff. However, incidents and accidents have occurred in flight, primarily because of icing and its effects. Problems during takeoff most often are caused by plugged pitot probes or static ports.

When a pitot probe is completely plugged, the airspeed indication remains pegged at its lower stop during the takeoff roll. The crew has only a short time during the takeoff roll to recognize erroneous airspeed indications. For example, at maximum takeoff thrust, a 777-200 can accelerate from 30 to 80 kn in 9 to 12 sec, depending on gross weight. If the flight crew does not reject the takeoff, the indicated airspeed will start to increase immediately after liftoff.

As the airplane climbs, indicated airspeed continues to increase through the correct value. The altimeter operates almost correctly during the climb. Eventually, the indicated airspeed can exceed V_{MO}, in which case the overspeed warning occurs. Trusting the erroneous airspeed indicator can be tempting when it appears to begin operating normally. However, the pilot should not increase pitch or reduce thrust or both to respond to erroneous airspeed indications of this type.

When static ports are completely plugged, there is no apparent indication during the takeoff roll. After liftoff, at a constant actual speed, the airspeed indications decay rapidly, reaching the lower end indication. The altimeter remains at the field elevation (assuming the trapped static pressure is that of the field elevation). If the crew relies on the faulty airspeed indicator for information, the typical response would be to lower pitch attitude, possibly causing airspeed limitations to be exceeded.

Total blockages of the pitot or static systems are rare. However, many anomalies are associated with partial blockages, damage, or deterioration of system parts. Anomalies can result when

- Pitot probe covers or static port covers are not removed.
- Pitot or static hoses are disconnected.
- Hoses are leaking.
- Water trapped in the lines freezes during flight.
- Pitot probes or static ports are blocked by volcanic ash.
- The radome is damaged.
- Icing occurs on the pitot probes or static ports.
- Pitot probes or static ports are blocked by insects.
- Pitot probes or static ports are physically damaged.
- Air data pressure sensors fail.

Sometimes a partially blocked pitot port (e.g., incidents A and C) presents more of a problem than a completely blocked pitot port. Situations where static ports are partially blocked or open to cabin pressure can be equally difficult (e.g., incident B). A key aspect in recovering successfully is identifying which instruments are accurate. Tables 1 and 2 list which flight deck instrument information is and is not reliable during pitot or static system anomalies.

The following basic actions are essential to a successful recovery from these problems. Flight crews should

- Recognize an unusual or suspect indication.
    - Monitor airspeed indications.
    - Advise other crewmembers immediately about flight instrument indications that do not agree with the flight conditions.
    - Confirm by crosschecking other instruments, including standby instruments.
- Maintain control of the airplane with basic pitch and power skills.
    - Establish a pitch attitude and power setting that are appropriate to the situation.
    - Allow sufficient time for problem solving.
- Take an inventory of reliable information.
    - Compare pitch and power indications with settings recommended for the phase of flight.
    - Consider items in tables 1 and 2 to determine reliability.
- Find and/or maintain favorable flying conditions, such as daylight visual conditions.
- Obtain assistance from others.
    - Air traffic control can help with position and ground speed.
    - Be aware that air traffic control communication of transponder information could be erroneous.
- Use checklists.
    - Do not trust previously suspected instruments, even if they appear to be operating correctly.
    - Review unreliable airspeed or other appropriate checklists.

4 PROCEDURES TO ASSIST FLIGHT CREWS

Procedures are available to assist flight crews encountering erroneous flight instrument indications. Recent changes in procedures provide guidance on monitoring airspeed indications during the takeoff roll.

During flight, the airspeed unreliable non-normal procedure provides important information. This checklist helps the crew recognize evidence of unreliable airspeed-Mach indications and provides recall steps to emphasize the importance of checking attitude instruments and thrust levels first. The IAS DISAGREE and ALT DISAGREE messages make recognition of anomalies easier. Delay in recognizing a problem and taking corrective action could result in loss of airplane control.

Flight crews should be aware of the approximate airplane attitude and thrust for each flight maneuver. Knowledge of airplane pitch attitudes for given flight conditions and configurations can help identify potential airspeed anomalies before they degrade to an unsafe condition.

Checklists can direct flight crews to reliable data sources and provide key guidelines, such as directing crews to

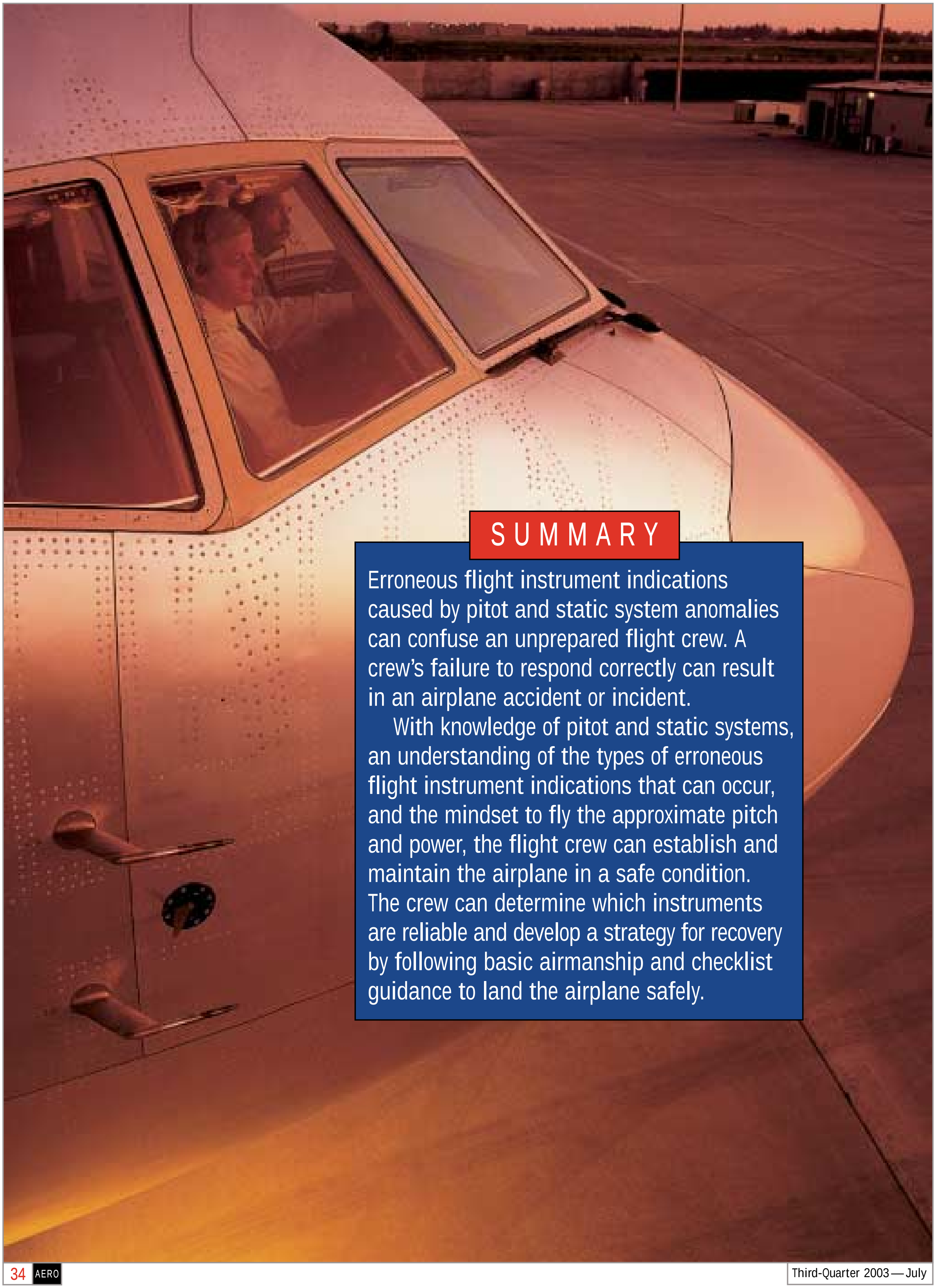
- Maintain visual conditions.
- Establish landing configuration early.
- Use electronic and visual glideslope indicators, where available, for approach and landing.
- Use various sources, such as the navigation display, to determine ground speed and wind effects.

TABLE 1 AVAILABLE RELIABLE INFORMATION

System/indicator	Notes
Pitch and roll	
Engine thrust indication	No EPR, use N_1
Radio altitude	When within normal activation limits
Basic ground proximity warning system (GPWS)	Initial enhanced GPWS (EGPWS)/terrain avoidance warning systems may not be reliable
Geoaltitude-equipped EGPWS	Initial EGPWS/terrain avoidance warning systems may not be reliable
Stick shaker	May not always be available, but reliable if activated
Ground speed	Uses inertial information
Airplane position	Uses inertial information
Track and heading	
Radio navigation aid signals	

TABLE 2 UNRELIABLE INFORMATION

System/indicator	Notes
Autopilot	
Autothrottle	
Airspeed indicator, Mach	
Altimeter	Blocked static system or blocked pitot-static system
Vertical speed	
Wind information	
Vertical navigation	
EGPWS/terrain avoidance	Initial versions of EGPWS
Overspeed warning	
Wind shear warning	
Elevator feel	
EICAS messages	May not identify the basic problem

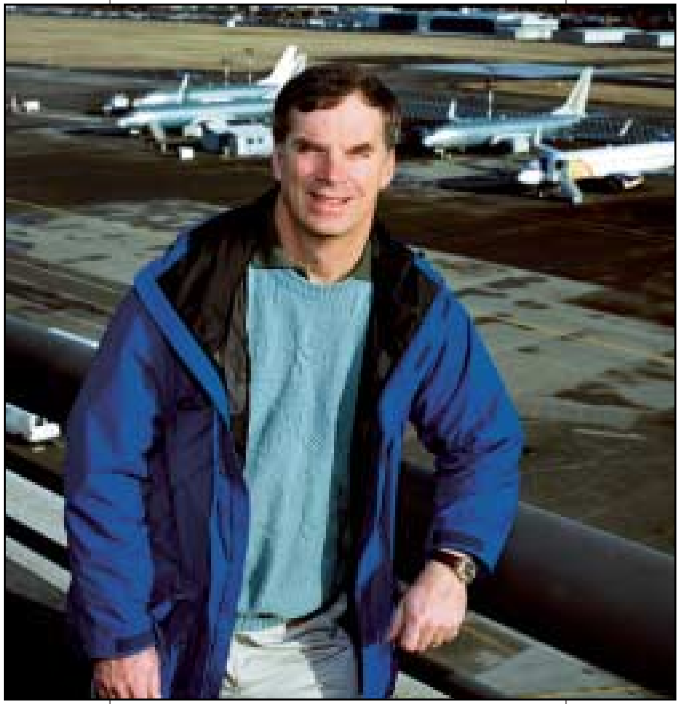


SUMMARY

Erroneous flight instrument indications caused by pitot and static system anomalies can confuse an unprepared flight crew. A crew's failure to respond correctly can result in an airplane accident or incident.

With knowledge of pitot and static systems, an understanding of the types of erroneous flight instrument indications that can occur, and the mindset to fly the approximate pitch and power, the flight crew can establish and maintain the airplane in a safe condition. The crew can determine which instruments are reliable and develop a strategy for recovery by following basic airmanship and checklist guidance to land the airplane safely.

About the Author



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Hamburg	TBD	49-40-5070-3040/3630
Hanover	R. Anderson	49-511-972-7387
Lanarca	S. Mura	357-4-815700
Luxembourg	J. Erickson	352-4211-3399
Madrid	H. Morris	34-91-329-1755
Palma (de Mallorca)	C. Greene	34-971-789-782
Paris (CDG)	A. Adibi	33-1-4862-4192
Paris (ORY)	C. Nienhuis	33-1-4975-2246
Prague	M. Coffin	420-220-562-648
Rome	TBD	39-06-6501-0135
Vienna	L. Rahimane	43-1-7000-75010
Warsaw	F. Niewiadomski	48-22-846-7580
Zurich	K. Goellner	41-1-812-6816/7414

LOCATION	REPRESENTATIVE	TELEPHONE
Director	*E. Berthiaume*	*44-20-8235-5600*
Amsterdam (KLM)	M. Balachander	31-20-649-8102
Amsterdam (TAV)	J. Dingman	31-20-648-4639
Copenhagen	A. Novasio	45-3232-4373
Dublin	C. Lohse	353-1-886-3086/3087
Gatwick	B. Minnehan	44-1293-510465/462972
Helsinki	D. Laws	358-9-818-6450
London	G. Van de Ven	44-20-8562-3151
Luton (BRI)	B. Dubowsky	44-1582-428-077
Luton (EZY)	R. Adams	44-1582-525-869
Manchester	J. Raispis	44-161-232-6693
Oslo	A. Holin	47-6481-6598/6613
Stansted	D. Johnson	44-1279-825638
Stansted (RYR)	J. McMahon	44-1279-666263
Stavanger	E. Fales	47-51-659-345
Stockholm	G. Ostlund	46-8-797-4911/4912
Tel Aviv	J. Sveinsson	972-3-9711147
Vilnius	E. Vlassov	7-095-937-3540

LOCATION	REPRESENTATIVE	TELEPHONE
Director	*S. Sherman*	*86-20-8659-7994*
Addis Ababa	J. Wallace	251-1-610-566
Algiers	T. Alusi	213-21-509-378
Almaty	R. Anderson	7-327-257-3231
Ashgabat	J. McBroom	993-12-51-01-53
Cairo	M. McPherson	20-2-418-3680
Casablanca	M. Casebeer	212-22-539-497
Dammam	R. Cole	966-3-877-4807
Dubai	G. Youngblood	971-4-208-5657
Istanbul	B. Nelson	90-212-662-5284
Jeddah (SRF)	L. Giordano	966-2-684-1184
Jeddah (SVA)	M. Noon	966-2-685-5011/5013
Johannesburg	A. Ornik	27-11-390-1130/1131
Muscat	A. Ostadazim	968-519467/510030
Nairobi	R. Aman	254-20-328-22058
Riyadh (BBJ)	J. Richards	966-1-461-0607
Tashkent	R. Webb	998-71-1206572
Tunis	D. Marble	216-71-781-996

	LOCATION	REPRESENTATIVE	TELEPHONE
Region 6 *Russia/ Southwest Pacific/India*	*Director, acting*	*T. Waibel*	*1-206-544-3450*
	Auckland	R. Lowry	64-9-256-3981
	Brisbane	D. Bankson	61-7-3295-3139
	Honolulu (ALO)	A. McEntire	808-836-7472
	Honolulu (HWI)	R. Owens	808-838-0132
	Jakarta	R. Tessin	62-21-550-8065/1020
	Kiev	R. South	380-44-230-0017
	Kuala Lumpur	M. Standbridge	60-3-7846-2569
	Melbourne	E. Root	61-3-9280-7296/7297
	Moscow (ARO)	V. Solomonov	7-095-961-3819
	Moscow (TRX)	E. Vlassov	7-095-937-3540
	Mumbai	R. Piotrowski	91-22-2615-7262/8091
	Nadi	H. Kirkland	679-672-6071
	Sydney (IMU)	B. Payne	61-2-9952-9596
	Sydney (QAN)	W. Mahan	61-2-9691-7418
	Tbilsi	E. Vlassov	995-32-922-542
	Yuzhno-Sakhalinsk	E. Vlassov	7-095-937-3540
Region 7 *Southeast Asia and Japan*	*Director*	*R. Nova*	*65-6338-9797*
	Bangkok	D. Chau	66-2-504-3493
	Ho Chi Minh	J. Baker	9011-84-8-845-7600
	Incheon	J. Nourblin	NA
	Manila	T. Fujimaki	63-2-852-3273
	Narita	A. Gayer	81-476-33-0606
	Okinawa	E. Sadvar	81-98-857-9216
	Pusan	K. Cummings	82-51-325-4144
	Seoul (AAR)	J. DeHaven	82-2-2665-4095
	Seoul (KAL)	G. Small	82-2-2663-6540
	Singapore	A. Hagen	65-6541-6074
	Sung Shan	R. Kozel	886-2-2545-2601
	Taipei (CHI)	M. Heit	886-3-383-3023
	Taipei (EVA)	D. Bizar	886-3-393-1040
	Tokyo (ANA)	T. Gaffney	81-3-5756-5077/5078
	Tokyo (JAL)	L. Denman	81-3-3747-0085/3977
	Tokyo (JAS)	R. Saga	81-3-5756-8737
Region 8 *China*	*Director*	*T. Lane*	*86-10-6539-2299 x1038*
	Beijing	K. Childs	86-10-6456-1567
	Chengdu	G. King	86-28-8570-4278
	Guangzhou	A. Shafii	86-20-8659-7994
	Haikou	R. Wiggenhorn	86-898-6575-6734
	Hong Kong	R. Brown	852-2-747-8945/8946
	Jinan	P. Lavoie	86-531-873-4643
	Kunming	T. Bray	86-871-717-5270
	Shanghai (CEA)	M. Perrett	86-21-6268-6268 x35156
	Shanghai (SHA)	D. Babcock	86-21-6835-8388
	Shenyang	L. Poston	86-24-8939-2736
	Shenzhen	S. Cole	86-755-2777-7602
	Ulaanbaatar	P. Kizer	976-11-984-060
	Urumqi	D. Cannon	86-991-380-1222
	Wuhan	M. Nolan	86-27-8581-8528
	Xiamen	Y. Liu	86-592-573-9225