BOEING

QTR_03
12

A QUARTERLY PUBLICATION
BROUGHT TO YOU BY
THE BOEING EDGE

AERO

Cover photo: *737-800 Engine Fan Blades*

AERO

Contents

AERO

***AERO* Online**
www.boeing.com/boeingedge/aeromagazine

The Boeing Edge
www.boeing.com/boeingedge

BOEING EDGE

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 Edge 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 continually 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.

Print copies of *AERO* are not available by subscription, but the publication may be viewed on the Web at www.boeing.com/boeingedge/aeromagazine.

Please send address changes to me.boecom@boeing.com. Please send all other communications to *AERO* Magazine, Boeing Commercial Airplanes, P.O. Box 3707, MC 21-72, Seattle, Washington, 98124-2207, USA.
E-mail: WebMaster.BCA@boeing.com

AERO is printed on Forest Stewardship Council™ Certified paper.

FSC www.fsc.org MIX Paper from responsible sources FSC® C102835

Enhancing Suppliers' In-Service Support to Airlines

Providing our valued airline customers with the best fleet support possible is the cornerstone of how we do business at Boeing. That includes working closely with our suppliers to ensure that their in-service performance meets our customers' expectations.

One of our most important efforts in this area involves surveying our airline customers on the in-service support provided by airplane suppliers and working on issues that are negatively affecting the performance of the Boeing in-service fleet.

These customer assessments provide us with industrywide information on supplier performance, enabling us to better manage key supplier issues and concerns. Thanks to airlines' participation in these surveys, we are able to provide suppliers with specific, actionable information to improve their performance and airline customer satisfaction.

We recently completed our assessment of 777 suppliers. Airline customers were asked to rate supplier performance in a number of categories, such as repair turn time, spare parts support, and component reliability. The resulting ranking of 777 suppliers is now available on the Web portal MyBoeingFleet.com in the "Supplier Customer Support" section.

We are meeting with each 777 supplier listed and creating action plans for improvement. These action plans are being tied to existing supplier performance improvement plans. Later this year, Boeing will host a forum at which suppliers will present their plans for improvement to airline customers.

Our next scheduled assessment will be on the Next-Generation 737, which we will begin in the third quarter of this year.

Our goal in introducing these customer-generated supplier assessments is to focus our suppliers on product improvements that enhance and add value to your operations. Thank you for your participation.

If you have any questions, please contact us at SMCASTCS@boeing.com.

DAN BLANKINSHIP
Director
In-Service Supplier Support
Boeing Commercial Airplanes

Engine manufacturers have developed systems that represent nearly a two-generation jump in technology.

787 Propulsion System

The 787 Dreamliner is powered by new-generation engines from GE and Rolls-Royce that offer improvements in fuel consumption, noise, and emissions.

By Stephen F. Clark, Senior Technical Fellow, Propulsion Systems

The 787 uses new engines from GE and Rolls-Royce. Advances in engine technology are the biggest contributor to the airplane's overall fuel efficiency improvements. The new engines represent a two-generation jump in technology over the 767.

This article gives an overview of the basic features of the 787 propulsion system, comparing it to the 767 system it replaces. The article focuses on how the design achieves fuel consumption, noise, and emissions improvements and discusses operating and maintainability features as well as overall cost-of-ownership reduction benefits.

THE EVOLUTION OF AIRPLANE ENGINES

Starting in 2002, Boeing's analysis indicated a strong market demand for a twin-aisle airplane with 767-class payload capability at significantly enhanced range. This finding was consistent with airline evolution from a hub-and-spoke to a point-to-point operational model. Enabling enhanced range in this seat class demanded significant advances in overall airplane design with a large portion of this burden given to the propulsion system.

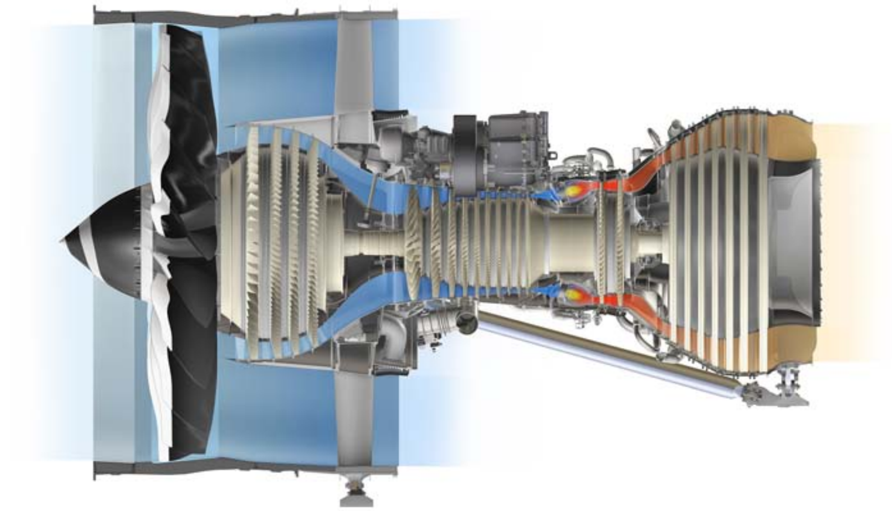
Boeing and engine manufacturers approached this challenge by improving fuel burn in four traditional performance areas and introducing a significant architectural innovation (see fig. 1):

- Higher propulsive efficiency through increased bypass ratio.
- Higher engine thermal efficiency through increased overall pressure ratio and improved component efficiencies.
- Improved thrust-to-weight ratio through the application of advanced materials.
- Introduction of a novel dual-use electrical power generation system that doubled as the engine start system.

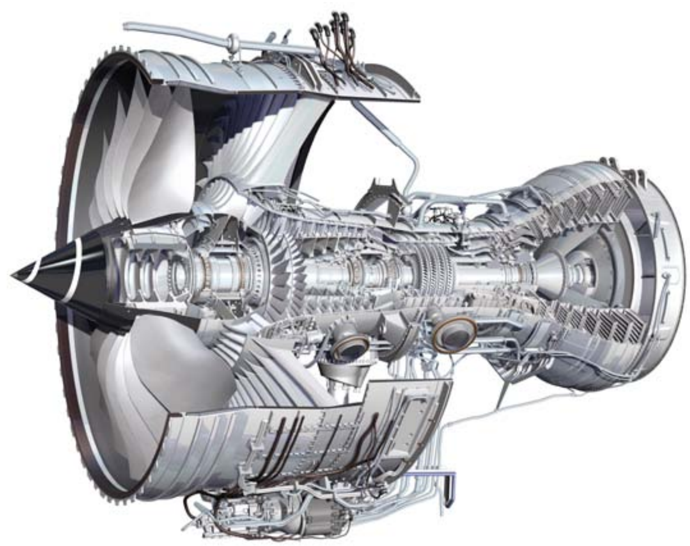
Figure 1: 787 Engines

Comparison of GEnx-1B and Rolls-Royce Trent 1000 with a table that compares key characteristics of these engines to 767 engines.

GE GEnx-1B



Rolls-Royce Trent 1000



	787 Engines: GEnx-1B Trent 1000	767 Engines: GE CF6-80C2 RR RB211-524G/H
Bypass Ratio	~10	~5
Overall Pressure Ratio	~50	~33
Thrust Class	53,000–74,000 lbf	53,000–63,000 lbf
Fan Diameter	111–112 in	86–93 in
Specific Fuel Consumption	15% lower	Base
Noise	ICAO Chapter 4	ICAO Chapter 3
Emissions	CAEP/8 (2014)	CAEP/2

Figure 2: Starter generator

The variable frequency starter generator delivers many benefits, including the replacement of the heritage bleed air system.

Variable Frequency Starter Generator

In addition to the improved fuel burn requirements, the 787 propulsion system also had to meet more stringent noise and emissions requirements. Finally, in order to maximize the capital value of the airplane, Boeing decided that the propulsion systems should be designed for full interchangeability between the two engine types.

ELECTRICAL POWER SYSTEM

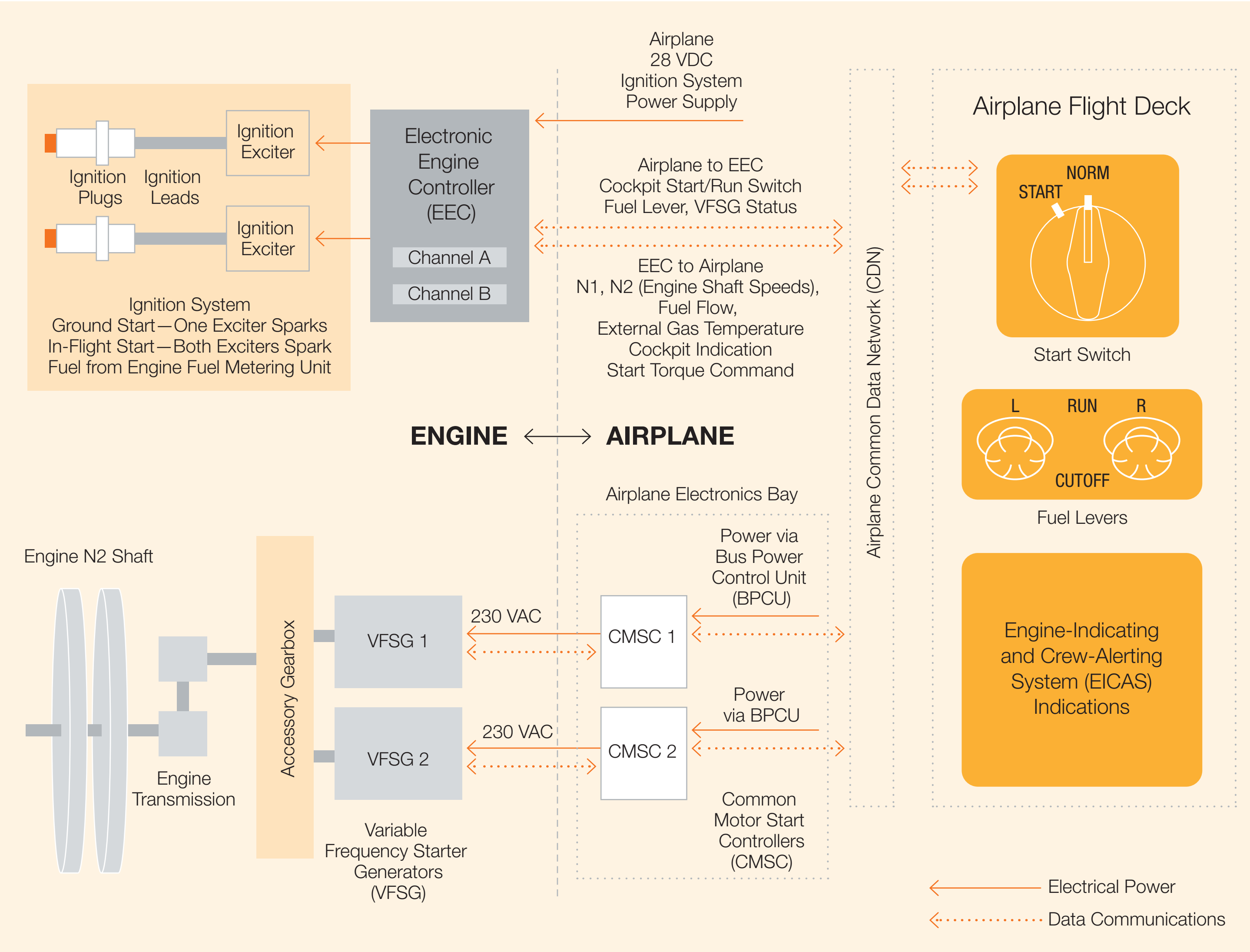
A principal foundation of the 787 architecture was the incorporation of the variable frequency starter generator (VFSG) system (see fig. 2). The VFSG delivers many benefits:

- Replaces the heritage bleed air system used to feed the airplane's environmental control system, thereby realizing direct weight savings through the elimination of relatively heavy bleed air components such as regulation valves, ducting, and coolers.
- Eliminates the energy loss of the bleed air system pre-cooler.
- Eliminates the throttling losses of bleed air provided from discrete engine compression stages.
- Eliminates the single-purpose air turbine starters and their associated oil system and maintenance.
- Simplifies the auxiliary power unit (APU) design to be a shaft power-only machine.
- Provides high flexibility with existing airport ground support infrastructure.
- Is fully self-contained with its own lubrication system and the ability to be disconnected self-protectively, manually or remotely, through flight deck controls.

The 787 main electrical power generation and start system is a four-channel variable frequency system with two 250 kVA VFSGs on each of the two main engines. The power from these generators is supplied to the main load buses through generator

Figure 3: 787 Engine start system schematic—GEnx

The variable frequency starter generator is a six-pole machine within an aluminum housing driven directly from the main engine gearbox. The generator is a brushless, three-phase, alternating current, and variable frequency synchronous machine. It has a nominal rating of 235 volts alternating current (VAC), 250 kVA, three phases, and 360–800 Hz output.



feeders and generator circuit breakers (see fig. 3).

Controlling each VFSG is a dedicated generator control unit (GCU). The GCU is a line replaceable unit (LRU) housed inside the aft electrical equipment bay. The GCU's principal function is to provide voltage regulation and fault current limiting while in the generate mode. The GCU also supports the main engine start function.

Managing the power distribution between the VFSGs is the bus power control unit (BPCU). The BPCU performs several functions:

- Controls bus configuration and engine health monitoring.
- Provides standby system control, generating source load management, and main and APU engine horsepower load management.
- Acts as the electrical power system communication gateway with other systems and flight deck.

Built-in redundancy in the BPCU enhances system reliability and operational flexibility.

The common motor start controllers (CMSCs) are used to control the VFSG start function and properly regulate torque during the start sequence. Once the engine is started, the CMSC switches over to controlling the cabin air compressors, thereby performing a second function.

The electric start system affords maximum flexibility from a variety of power sources: APU generators, external power cart, and cross engine (opposite engine VFSGs). The VFSG system provides full maintenance diagnostics for both the entire system and all LRUs.

Figure 4: Nacelle design: expanded view

This view of the nacelle shows the inlet, fan cowls, thrust reverser, exhaust plug, and nozzle.

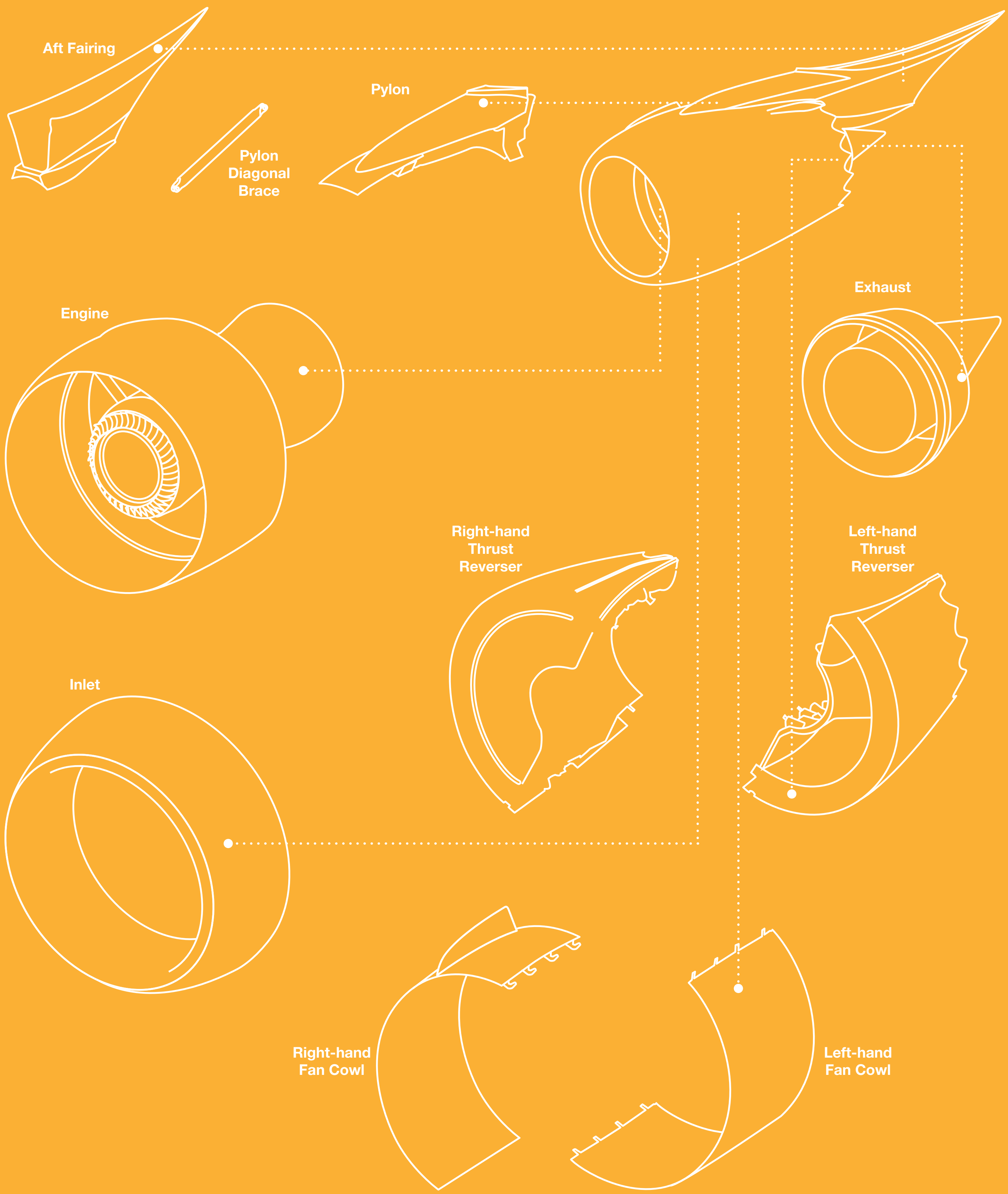
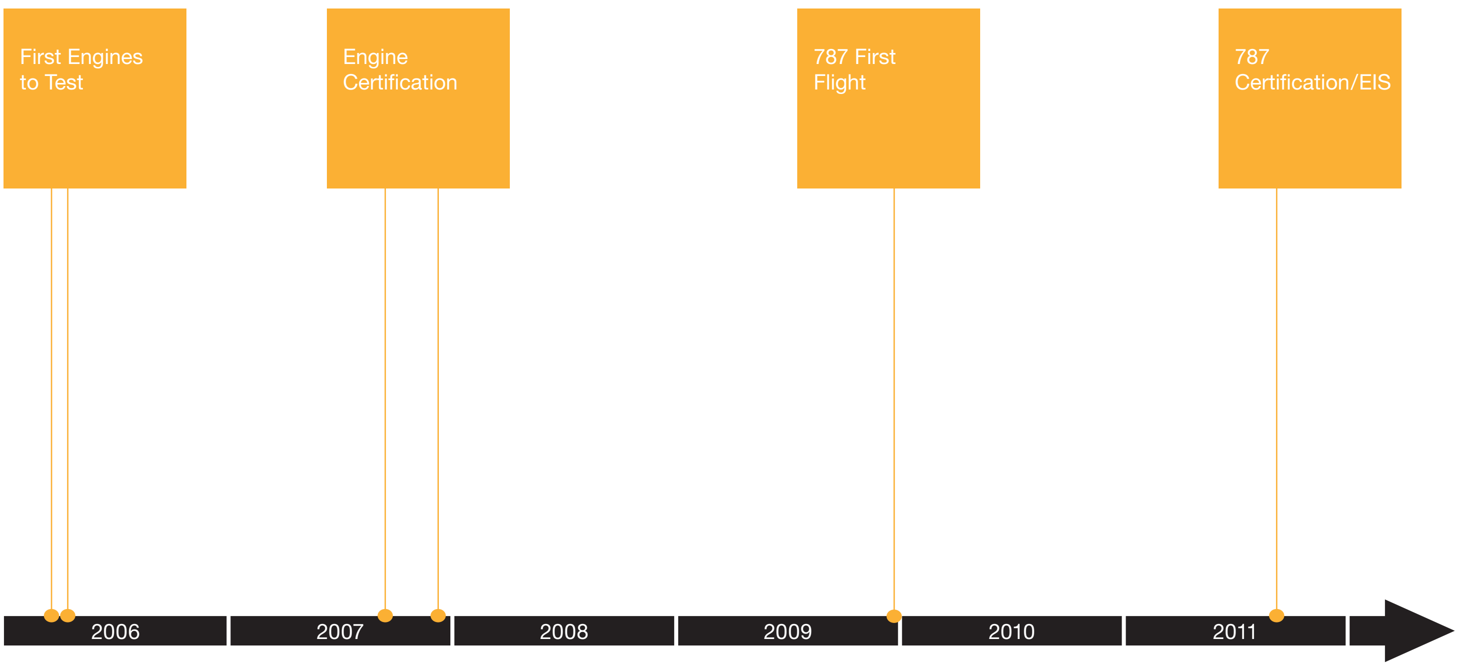


Figure 5: Engine test program

Intense engine development and 787 flight test programs contribute to the engines' service readiness and durability.

Accumulated Experience at Entry into Service (EIS)

>12,000	>15,000	>4,800	>1,800
Engine Test Hours	Engine Cycles	Flight Test Hours	Flights



ENGINE DESIGN HIGHLIGHTS

Both 787 engine manufacturers incorporated the latest technology offerings from their extensive research and product maturation programs.

The GE engines:

- Leverage the highly successful GE90 composite fan blades with the latest swept aerodynamics.
- Incorporate an entirely new composite fan case for significant weight savings.
- Field the enhanced twin annular pre-swirl combustion system that achieves significant emission reductions while preserving low pattern factor for turbine durability as well as excellent re-light characteristics.
- Introduce surface air-oil coolers to compactly reject the VFSG and engine oil heat.
- Incorporate state-of-the-art titanium aluminide (Ti-Al) blades in the last two stages of the seven-stage low pressure turbine. Ti-Al achieves significant weight savings over traditional nickel alloy.

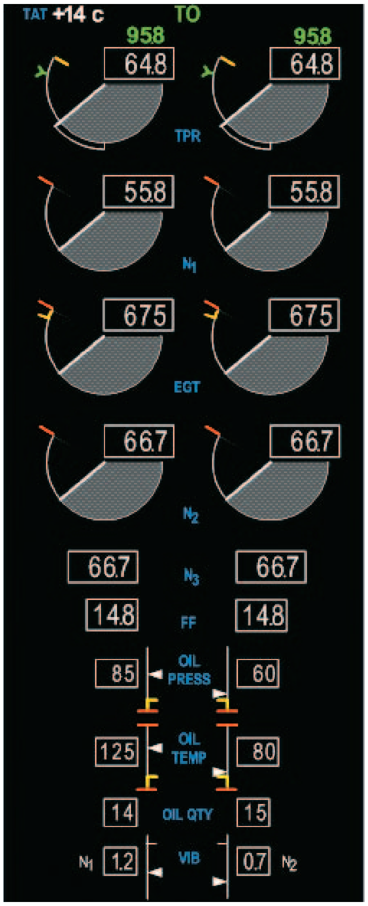
The Rolls-Royce engines:

- Incorporate the latest swept aero hollow-fan-blade technology evolved from the predecessor Trent 900 engine.
- Utilize the proven benefit of the Trent three-spool engine architecture. In the case of the Trent 1000, the three-spool design affords intermediate pressure power off-take with demonstrated benefits in engine operability and fuel consumption.
- Incorporate surface coolers for compact and efficient rejection of VFSG and engine oil heat.

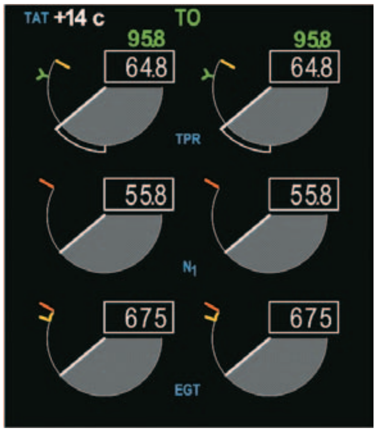
Figure 6: Flight deck displays

The flight deck displays can be set to show the full normal display with both primary and secondary engine parameters (left) or an abbreviated compact display with only primary parameters (center). A normal display (right) shows the location of engine-indicating and crew-alerting system (EICAS) messages.

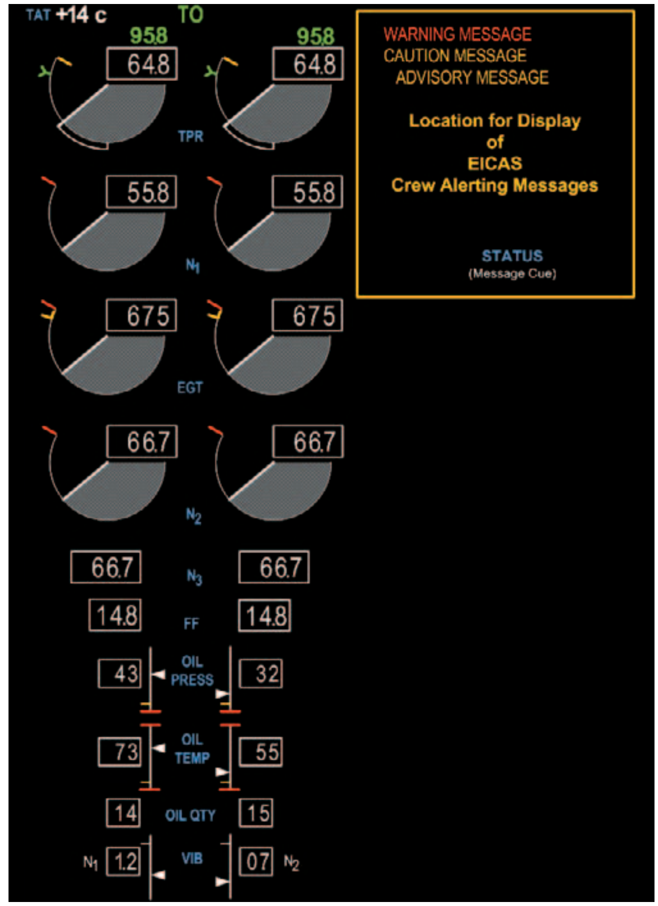
Normal Display



Compact Display



Normal Display with Alerts



- Design the Trent 1000 with the latest computational fluid dynamics-enabled 3D aerodynamics for high efficiency and low noise.
- Allow power to be extracted for each VFSG through the second of the three engine shafts. This unique solution using the Trent 1000 engine architecture brings with it lower engine idle speeds, which reduce fuel burn and noise on the 787.

NEW NACELLE FEATURES IMPROVE ON LEGACY DESIGNS

The nacelle design (see fig. 4) maximizes composite and weight-saving materials to improve maintenance cost and fuel burn. Highlights include:

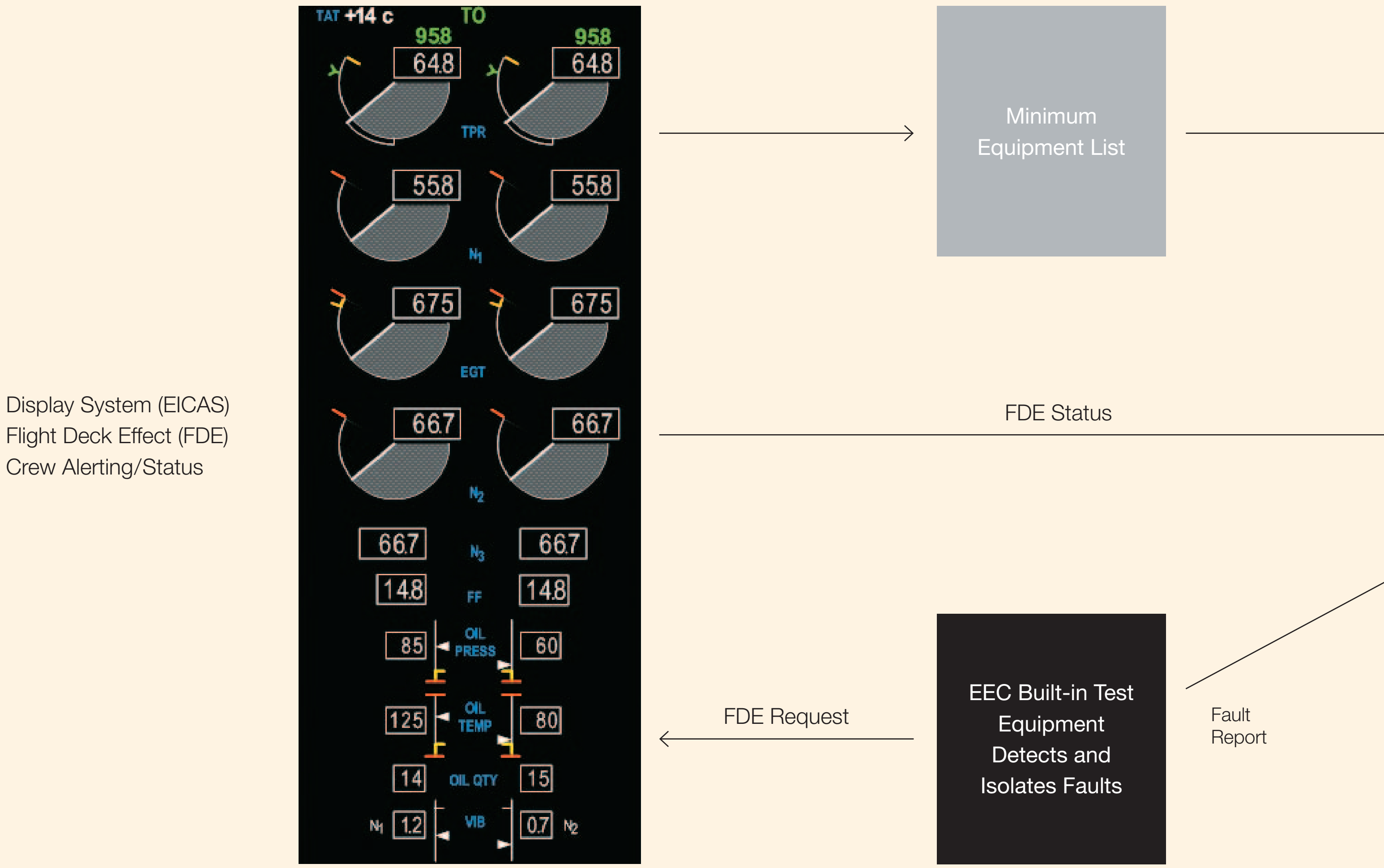
- A single-piece inlet barrel construction for low noise.
- Lightweight composite fan cowls.
- A proven translating sleeve thrust reverser system that utilizes compact state-of-the-art 5,000 pounds per square inch (psi) hydraulic actuation.
- Advanced titanium alloy exhaust system components.
- A single-piece aft fairing.
- Composite diagonal brace.
- Advanced titanium alloy strut.

EXTENSIVE ENGINE AND FLIGHT TESTING

The 787 propulsion system was rigorously tested, both to achieve basic certification and to demonstrate full service readiness and extended operations (ETOPS) capability when the 787 entered service (see fig. 5).

Figure 7: Onboard maintenance system

The 787 onboard maintenance system helps mechanics rapidly isolate faults and guides appropriate maintenance action.



The engine test program incorporated more than 20 dedicated test engines between the two engine manufacturers. Beyond testing for basic engine certification, each engine type completed 3,000 cycles of ETOPS flight testing. The engine test program was started far in advance of the Boeing flight test program. Multiple flying test beds identified necessary modifications prior to the Boeing flight test program. A two-year, six-airplane 787 flight test program led to type certification in August 2011 and entry into service in October 2011.

FLIGHT DECK CONTROLS AND DISPLAYS

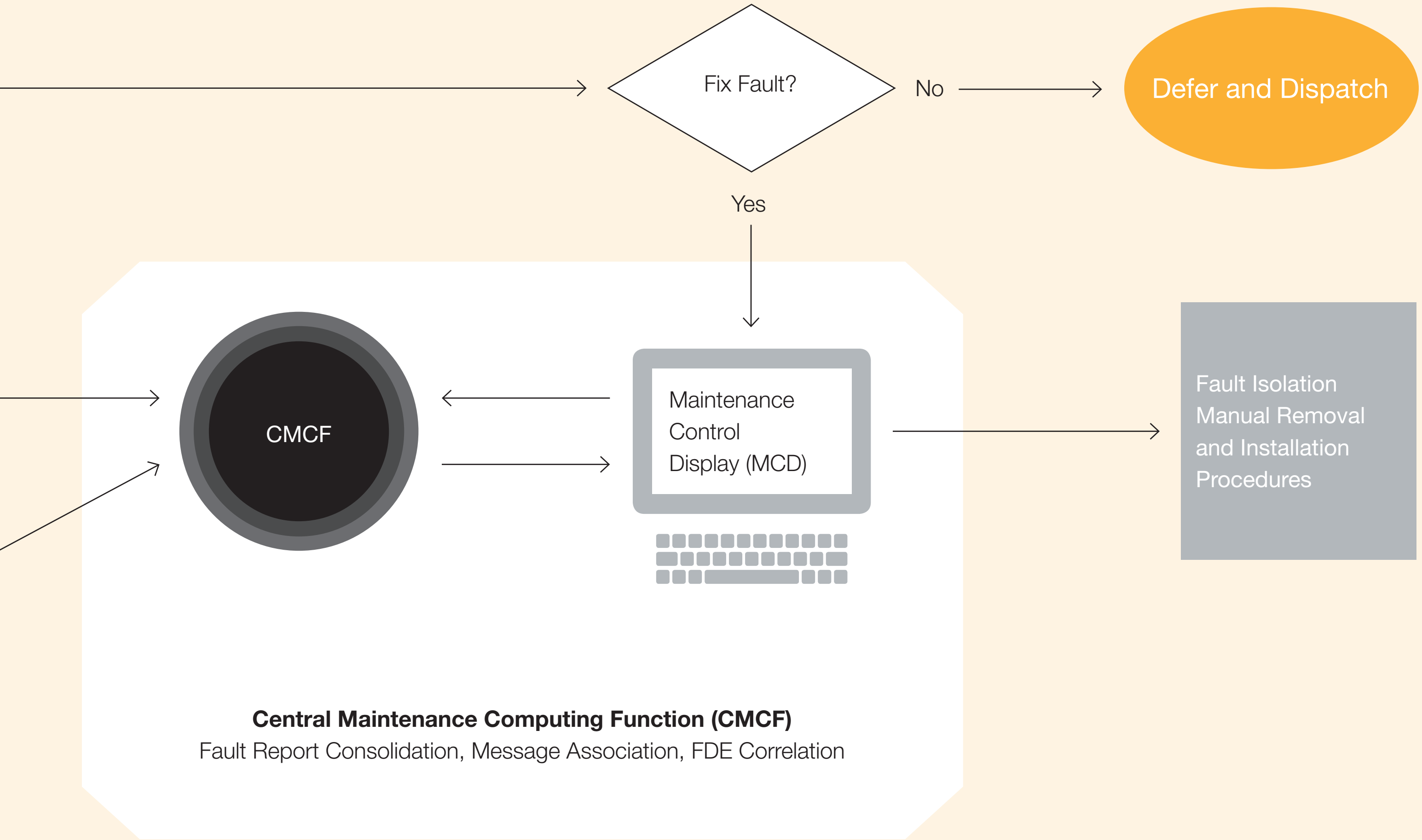
The 787 propulsion controls are designed for maximum commonality with the 777 architecture, while incorporating the latest customer-driven improvements.

The cockpit provides engine-starting controls, forward and reverse thrust manual control, autothrottle control, and engine-indicating and crew-alerting system (EICAS).

During normal operation of the airplane, the flight crew monitors engine data on the primary flight display (see fig. 6). The display can be set to show the full normal display, both primary and secondary engine parameters, or an abbreviated compact display with only primary parameters.

The normal display is the default display. The flight crew may select the compact display when both engines are operating normally. When the compact display has been selected, the normal display appears if:

- An engine is starting.
- An engine has failed.
- An engine is shut down.
- A secondary parameter goes out of normal operating range.
- The display is selected by the flight crew.



To the right of the engine parameter display on the EICAS primary display is the location for displaying flight crew alerting messages. The text of warning, caution, and advisory messages is displayed to alert the flight crew to non-normal conditions.

ENGINE HEALTH MANAGEMENT SYSTEM

The 787 propulsion system incorporates the latest generation of central maintenance and engine health management systems.

Central maintenance system. Through centralized fault reporting, the 787 onboard maintenance system (OMS) aids the airline mechanic in rapidly isolating faults and guiding the appropriate maintenance action (see fig. 7). The OMS is an essential tool in maintaining rapid airplane turnaround rates and maximizing dispatchability.

Engine health management system. Each engine manufacturer provides a dedicated engine health monitor that has vibration monitoring and fan trim balancing functions and sophisticated engine parameter trending for maintenance planning.

SUMMARY

The new-generation engines powering the 787 airplane offer operators improvements in fuel consumption, noise, and emissions. Both GE and Rolls-Royce have developed advanced engine systems that deliver nearly a two-generation jump in technology.

When flight crews are aware and in control of a situation, they are able to make effective and timely decisions to ensure a safe landing.

Reducing Runway Landing Overruns

Working with industry, Boeing is implementing a combination of procedural improvements, flight crew knowledge, and flight deck enhancements to mitigate runway overrun excursions during landing.

By Marisa Jenkins, Flight Deck Surface Operations Principal Investigator, and
Captain Robert F. Aaron, Jr., Safety Pilot, Flight Technical and Safety

Runway overruns during landing are a top safety focus for Boeing, regulatory agencies, and the entire commercial aviation industry. Boeing is working with the industry to develop a comprehensive runway safety strategy — called Situational Awareness and Alerting for Excursion Reduction (SAAFER) — that is based on a data-driven consensus of root causes, risk factors, and interventions.

This article explores the strategy in terms of near- and long-term recommendations to airlines and flight crews to address the causes of runway overruns as well as flight deck design solutions currently under development.

CAUSES OF RUNWAY OVERRUN EXCURSIONS

Boeing event data shows that there are numerous contributors to runway overruns. Causes of landing overruns may begin as early as the approach briefing or occur once the airplane is on the ground and decelerating (see fig. 1). Understanding the root causes of runway excursions is fundamental to mitigating them.

Event data, analyzed collectively from 2003 to 2010, shows the factors contributing to landing overruns occur at these frequencies:

- 68 percent occurred after stable approaches.
- 55 percent touched down within the touchdown zone.
- 90 percent landed on an other-than-dry runway.
- 42 percent landed with a tailwind of 5 knots or greater.

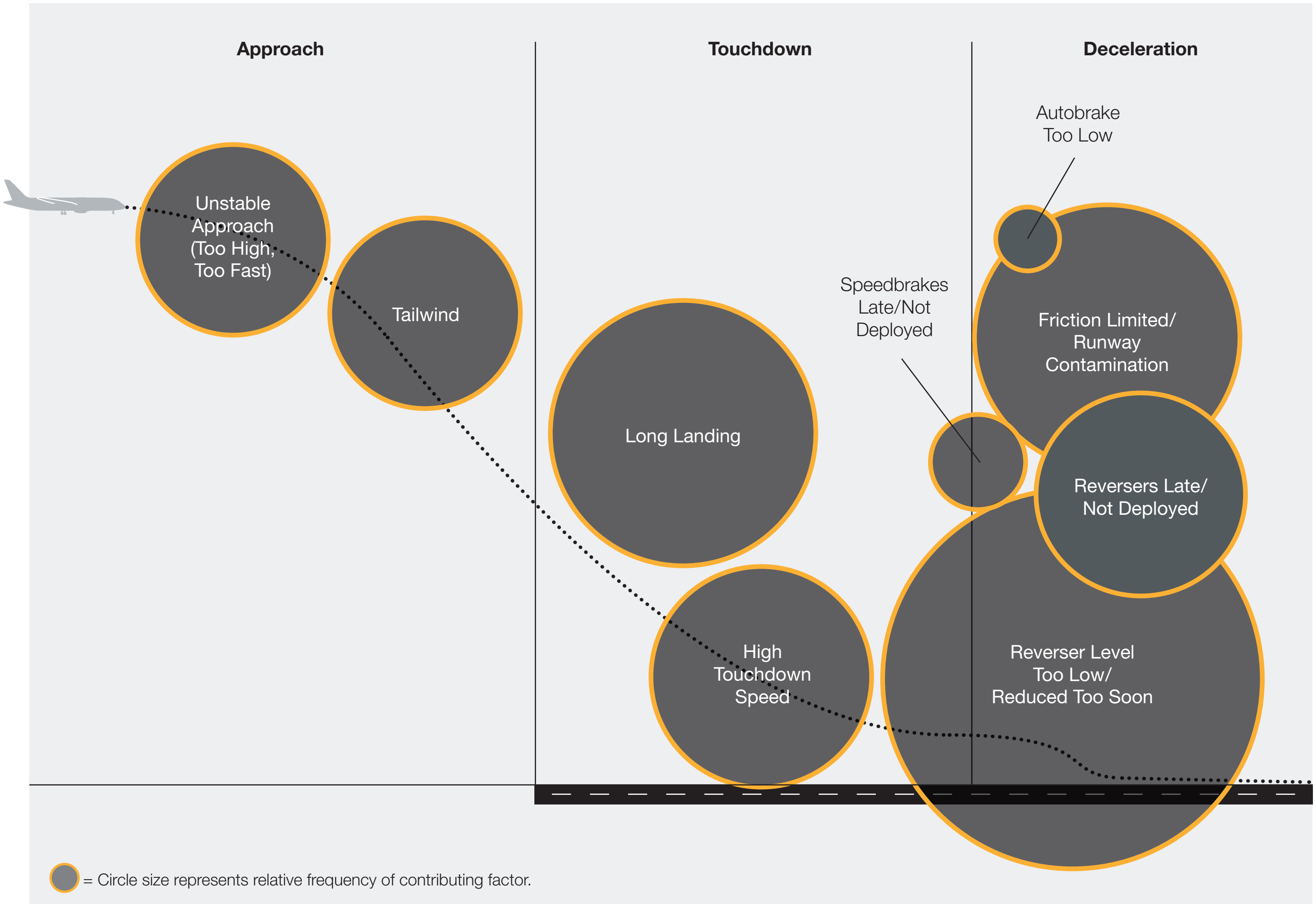
This event analysis was the key driver for developing Boeing's runway safety strategy.

Solving the excursion problem also requires acknowledgment that:

- Excursions are caused by multiple factors.
- Mitigating any one factor will not fix the bigger runway overrun excursion problem.
- More than one type of solution is necessary.

Figure 1: Causes of landing overrun excursions

The circle size represents the relative frequency that the item was a contributing factor to a runway overrun. Frequently, a runway overrun is the result of more than one contributing factor occurring simultaneously.



THE RUNWAY SAFETY STRATEGY

The Boeing SAAFER strategy implements a combination of procedural and flight deck enhancements along with additional crew education (i.e., training aids) to mitigate runway landing overruns. Components of this approach — procedural enhancements, training aids, and existing flight deck technology — are already available to operators. Boeing recommends implementing these excursion mitigations immediately.

Boeing's runway safety strategy provides flight crews with enhanced awareness, guidance, and alerting tools from the approach-planning phase through landing rollout and deceleration. The strategy's goal is to keep pilots aware and in control of this phase of flight and enable them to make correct and timely decisions that will ensure a safe landing.

This approach is considered a strategy because it encompasses more than just flight deck enhancements. It's designed to improve cognition and pilot decision-making during this high workload phase of flight without overloading the pilot.

RECOMMENDED APPROACH AND LANDING PROCEDURES

Boeing recommends that airlines consider modifying their approach and landing procedures to incorporate runway safety recommendations. Augmenting existing landing procedures is a currently available solution that can mitigate runway overrun excursions in the near term without waiting for future technological flight deck enhancements.

- Calculate required runway length. As the flight crew prepares its approach briefing, it should use real-time information to analyze how much runway is required relative to runway available. Performing a landing distance calculation using the real-time airplane and actual runway data (e.g., contamination, wet, grooved, or ungrooved surface) can mitigate runway overrun excursions caused by inadequate runway length.

- Determine go-around point. Calculating and briefing a go-around point or the latest point on the runway by which the flight crew must touch down during the approach briefing also has potential to reduce overrun excursions. This go-around distance calculation can mitigate the approximately 44 percent of runway overrun excursions that are attributed to long landings.
- Add thrust reverser callout. Boeing has added a mandatory thrust reverser callout to the flight crew training manual and the flight crew operating manuals for all Boeing models. It is intended to increase the flight crew's situational awareness of thrust reverser deployment in conjunction with the speed brakes during the landing rollout. This callout, along with using the reversers until the stop is assured (no early stowage), provides a runway excursion mitigation for the approximately 80 percent of excursions where inadequate or late thrust reverser usage was a contributing factor.

Updating approach and landing procedures may not address all runway overrun excursion events that are caused by inadequate runway length when landing long or using inadequate or improper deceleration devices. These runway overrun excursions may require additional pilot situational awareness and involvement. However, these relatively simple, highly feasible, non-equipage enhancements can help reduce runway overrun excursions in the near term.

RUNWAY SAFETY TRAINING AIDS

Runway overrun event data suggests that a number of runway overruns can be avoided if the flight crew has a more thorough understanding of the interrelationship between the landing environment and the potential risks existing that day (e.g., weather, winds, runway conditions, minimum equipment list items, airplane weight).

Pilots need to better understand the relationships among these factors for each flight:

- Flying a stabilized approach.
- Runway contamination, known and accounted for.
- Runway length available versus required.
- Reported conditions compared to actual conditions.
- Approach speed for that flight's approach.
- Energy to be dissipated after landing.
- Speed additives and effect on landing distances.
- Reliability of runway braking action.
- Proper, timely use of all deceleration devices.

A failure or misunderstanding of each of these factors has contributed to runway overrun excursions. For example, many flight crews may not fully understand the importance of using thrust reversers on wet runways. As runway friction decreases due to deteriorating runway conditions, the role of the thrust reverser becomes more important. Additionally, there have been accidents in which the crew had difficulty deploying the thrust reversers and consequently neglected to ensure the spoilers were fully extended during the landing rollout.

Another concern centers on ensuring that the appropriate deceleration devices are used until the airplane is at a stop. This is especially important when there is a known risk of an overrun excursion. It is necessary to ensure all deceleration devices are utilized fully when facing a runway overrun excursion.

The aviation industry has produced a variety of useful tools to help pilots understand these relationships. The Flight Safety Foundation approach and landing accident reduction toolkit and the International Civil Aviation Organization/International Air Transport Association toolkits are available on the Internet. They provide valuable information flight crews can use to help avoid runway overrun excursions.

Boeing is developing an approach and landing training-aid video intended to be viewed by pilots in order to enhance their understanding of their dynamic landing environment, the day's risk factors, available tools, and desired actions and outcomes relating to runway excursions. This training-aid video is scheduled for release in late 2012.

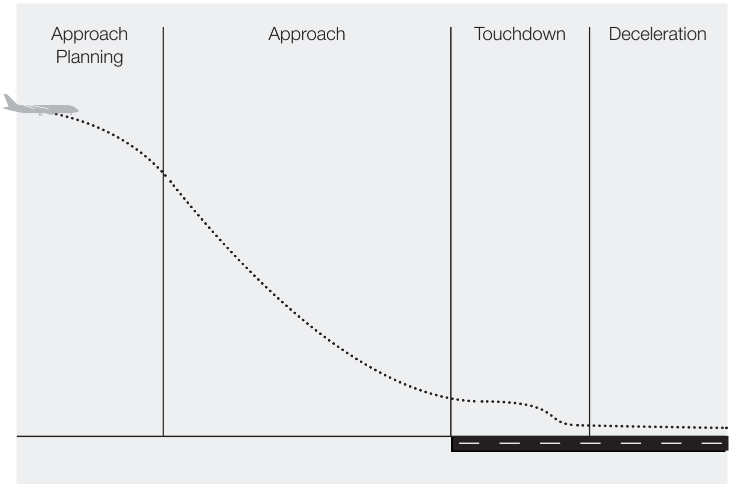
NEW SAFETY TECHNOLOGY

Boeing is focusing on human-factors-driven flight deck design enhancements that are consistent with existing and planned airport, air traffic, and customer operating strategies. These enhancements are targeted at runway overrun prevention through all approach phases: approach planning, approach, touchdown, and deceleration.

During approach planning, flight deck tools and procedures assist the flight crew in determining the required runway length and where on the runway the airplane is expected to stop, given current conditions (see fig. 2). Boeing already offers a landing distance calculator on electronic flight bags. The new strategy augments this existing technology by adding a more effective way to display this information to the flight crew. By graphically depicting the dry and contaminated stopping location during approach planning, the crew can definitively assess its risk of runway overrun before touching down. The pilot also has

Figure 2: New approach planning technology

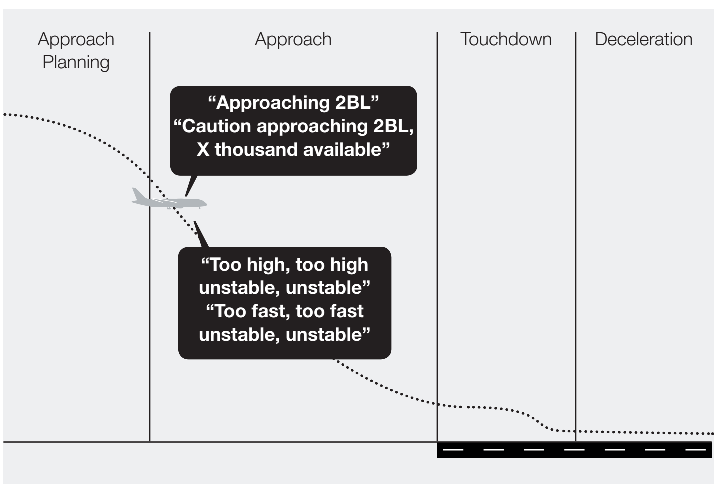
New technology is intended to enhance the existing flight deck during these approach, landing, and rollout phases.

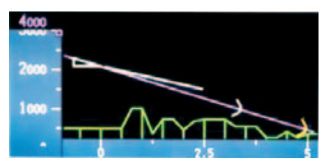


- Display of landing distance for dry/contaminated runways
- Assessment of runway length vs. required

Figure 3: Approach technology

Flight deck enhancements provide aural and visual cues to assist the pilot in flying a stabilized approach.





- Stability (speed, altitude, glideslope) guidance
- Simplified approach technique
- Runway situation awareness and alerting
- Instability alerting

the option of manually entering a reference line. This could be a land and hold short operation, a taxiway exit, or a desired touchdown or go-around point.

During the approach, the airplane's stability and tailwinds are major contributing factors to runway overrun excursions. New flight deck enhancements provide aural and visual cues to assist the pilot in flying a stabilized approach (see fig. 3). Boeing's new runway safety strategy provides a simplified approach technique to reduce workload even in normal conditions. As a final safeguard, the system alerts the pilot to unstable conditions or to a runway that is too short for that landing.

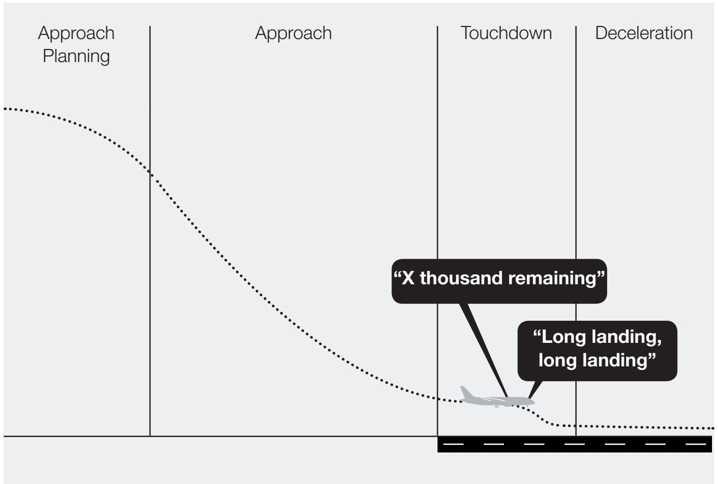
Communication and knowledge sharing in the flight deck are important. For airplanes that are equipped with head-up displays (HUD), the pilot and co-pilot can view the same information on the HUD and on the primary flight display. Even in a single-HUD airplane, both pilots will have the same display of information on which to base their piloting decisions.

After reaching decision height but before touching down, the primary contributing factor to a runway overrun is a long landing (i.e., airplane that exceeds the touchdown zone). Boeing's new runway safety technology provides landing and flare guidance on the HUD and aural and visual runway positional situation awareness on the HUD and primary flight display (see fig. 4). Conformal runway edge lines and runway remaining markers assist the crews' positional situational awareness on the runway even in low-visibility conditions.

After touchdown, the primary contributing factors of runway excursions are the actual runway condition and inadequate or late use of deceleration devices. Boeing's SAAFER strategy provides a visual indication of the predicted stop point on the runway based on real-time deceleration. It also provides a distance-remaining voice callout and alerts the crew when its current deceleration is insufficient and may result in a runway overrun excursion (see fig. 5).

Figure 4: Touchdown technology

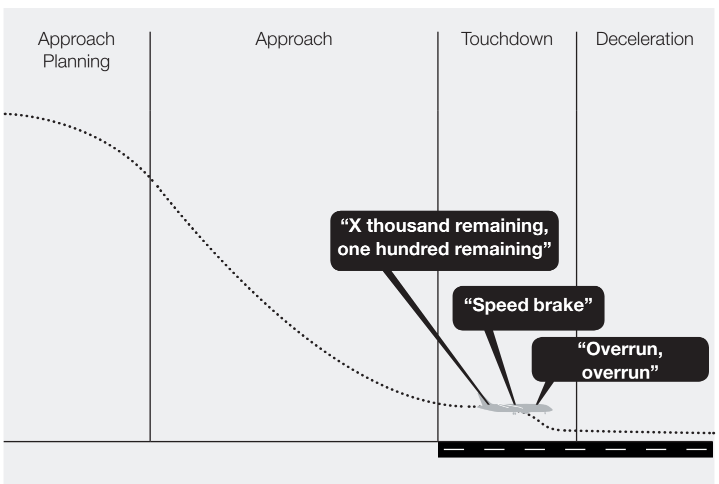
Flight crews receive landing and flare guidance on the head-up display (HUD) and aural and visual runway positional situation awareness on the HUD and primary flight display.



- Landing and flare guidance
- Runway positional situation awareness
- Long landing alerting

Figure 5: Deceleration technology

The system provides a visual indication of the predicted stop point on the runway based on real-time deceleration, as well as a distance-remaining voice callout.



- Runway positional situational awareness
- Display of predicted stop location
- Overrun alerting

The purpose of all these flight deck enhancements is to increase the pilot's situational awareness by providing the guidance and alerting tools during all phases of the approach, landing, and rollout.

AVAILABILITY OF NEW FLIGHT DECK TECHNOLOGY

Advanced flight deck enhancements are in development. Boeing continues to focus on enhancements for in-production and future fleets. It is recognized, however, that the existing fleet can benefit from enhancements that can be feasibly developed and incorporated, and Boeing is also focused on developing cost-effective, model-specific solutions that build off of the model's existing features and architecture. For the in-production fleet, these enhancements are targeted to start in 2015. Out-of-production retrofit packages will occur afterward.

A number of technologies are already available. Boeing encourages fleet uptake of these equipage mitigations currently available:

- Head-up display.
- Vertical situation display.
- Onboard performance tool.
- Runway awareness and advisory system.

SUMMARY

Boeing's SAAFER strategy combines procedural and flight deck enhancements with additional crew education to mitigate runway overrun excursions. When flight crews are aware and in control of the situation, they will make effective and timely decisions to ensure a safe landing.

For more information, please visit www.boeing.com/saafer.

Automating the component removal reduction process means operators get results quickly and identify root causes sooner.

New Process for Component Removal Reduction

The component removal reduction (CRR) process has evolved significantly since an article about it appeared in *AERO* magazine more than 10 years ago. Automating the process can save considerable time and help operators reduce maintenance costs.

By Sidney Oakes, Field Service Representative, Product Support Engineering

The CRR process consists of identifying components removed from an airplane after a short time in service; analyzing the causes of the components' short life in service; and eliminating those causes. Possible causes include failure to incorporate the latest component or airplane modifications, inadequate repair shop processes, failure to follow airplane maintenance manuals, ineffective maintenance manual processes, inadequately trained maintenance technicians, and non-availability of proper tooling.

The CRR process can also identify rogue units that should be scrapped because repeated repair attempts have not improved their life.

This article provides information about how operators can automate the CRR process to get faster results and reduce maintenance costs.

UPDATING THE CRR PROCESS

In the first quarter of 2000, an article published in *AERO* magazine titled "Component Removal Reduction" described a process to help operators solve delay problems and reduce the unscheduled removal of components. The article explained how Boeing established a process that reduced the number of unscheduled removals of line replaceable units (LRUs) for a 737 operator with a fleet of four airplanes. By following this process, the operator was able to reduce the number of replacements for LRUs from 32 to 18 per month. Any operator, regardless of fleet size, could follow the CRR process to reduce the number of LRU replacements.

Although the original manual approach worked well for a small fleet of airplanes, larger operators immediately began exploring ways to make the process less labor intensive in order to save time and money. One large component maintenance and repair organization (MRO) created a computer program based on the CRR process to help find short life units (SLUs), rogue units, and other sources of avoidable

Figure 1: Spreadsheet analysis of component removal reduction data

Each activity record includes the part number, serial number, installation, removal, airplane total hours, and other information as required for analysis.

MR_PCN_	DASH_NB	PART_INS	PTT_HR	ARR_FLT_OR	NOSE_NB	DFCT_TXT	ACTN_TXT	ACFT_POS	VST_STN_ID
29100	000033	Y	44287	16-May-08	2999	HYD PUMP DE	:REPLACED AIR	1	ORD
23994	000047		44333	20-May-08	2999	18MAY SFO D	^{8}20MAY SFO RF		SFO
23994	000058	Y	44333	20-May-08	2999	18MAY SFO D	^{8}20MAY SFO RF		SFO
27860	000060		44456	29-May-08	2999	30MAY IAD R	:INBOUND NO M	2	IAD
24223	000166		44248	14-May-08	2999	APU ELECT W	:REPLACED APU		SFO
24102	000169		44491	31-May-08	2999	26 MAY DEN C	^{8}01JUN LAX RPL	2	LAX
24223	000181	Y	44248	14-May-08	2999	APU ELECT W	:REPLACED APU		SFO
23409	000194		44369	23-May-08	2999	22MAY NRT D	^{8}23MAY NRT RP	1	NRT

Figure 2: Refining data to locate short life units

This summary sheet, which can be produced quickly using a spreadsheet macro, shows the number of hours each unit was in service, with shortest life units listed first.

ACTN_TXT	FT_POSN	/ST_STN_I	RT_REPL_	ATA_CD	ATA_TITLE	FLEET_ID	Hrs on Wing
^{8}11MAY LA	2	LAX	F	314002	LWR EICA	757	1
:REPLACE	4	PUS	F	361200	PNEUMAT	747	1
:REPLACE	CTR	DEN	F	233710	PASGR EN	777	2
:REPLACE	1	SFO	F	235101	PANEL, A	757	3
:ACP MM	1L	IAD	F	276400	SPOILER	757	3
:REPLACE	2	IAD	F	235101	PANEL, A	757	4
:NO VEP A	3	NRT	F	233710	PSGR EN	777	6
:REPLACE	3	DEN	F	344803	CENTER II	757	6

costs. After six months, the quality assurance engineer on the project discovered that the MRO had realized more than $1 million in reduced maintenance cost using the computerized process.

SAVING TIME BY AUTOMATING THE CRR PROCESS

The computerized process reduces the time required to perform the CRR analysis while shortening the time from the removal of an LRU from an airplane until it is identified as an SLU. The process typically leads to identifying the cause of the short life and suggests ways to eliminate the cause(s). The process has two steps.

Extract data from maintenance records. First, operators should design a database query to extract the data that is needed for CRR research. As an example, a query using test data produced a list of almost 4,000 activities involving components removed for failure and related installations during a two-month period. Four thousand activities is an overwhelming amount of data to analyze manually, but these results can be moved into a spreadsheet to simplify analysis (see fig. 1). A spreadsheet enables the analysis to be completed in minutes.

Reduce and refine the gross data. After the relevant data has been extracted, operators can use a spreadsheet macro to automate the process of discovering when a particular part was installed and then later removed, calculating the total hours the part was on the airplane, and determining whether it was an SLU, based on the operator's definition of short life. The resulting summary sheet shows how many hours each unit was in service, with shortest life units listed first (see fig. 2). Once the database query and spreadsheet macro have been created, an operator of a large fleet can arrive at this point in the CRR process in less than 15 minutes.

In this example, the low in-service times (i.e., hours on wing) listed are unacceptable, and corrective action is required to reduce maintenance costs and improve on-time performance. An investigation can be performed for each unit and action taken to eliminate the cause of early removal. The primary focus can be on the life of SLUs or on the most expensive units. For example, the failure of an integrated drive generator would be a higher priority than the failure of an audio panel. The solution for a single unit is often the solution for an entire group with that part number.

DETERMINE CORRECTIVE ACTION

Boeing has created a flow chart that operators can use to determine what corrective action needs to be taken to eliminate the cause of an SLU's short life (see fig. 3).

In addition to the decision tree, Boeing offers three other ways to facilitate the process of determining root cause:

- **Identifying maintenance errors.** Since 1995, Boeing has offered operators a human factors tool called the Maintenance Error Decision Aid (MEDA) for investigating contributing factors to maintenance errors (see *AERO* second-quarter 2007). This process can help identify maintenance errors that may have caused the early removal of a component.

- **Product and process improvements.** Fleet Team Xchange, which Boeing introduced in December 2009, is an online collaboration tool for in-service issues (see *AERO* second-quarter 2010). Fleet Team Xchange, available through the Web portal MyBoeingFleet.com, often includes discussions about component reliability issues. Operators can ask questions regarding issues found in the process described in this article. Many times, other operators have already found the solution for a given issue.
- **Automatic monitoring.** Boeing's Airplane Health Management Performance Monitoring provides automated monitoring of fuel consumption and CO_2 emissions (see *AERO* third-quarter 2009). The module enhances viewing, managing, and researching of, and acting on, airplane performance data to optimize airplane operation and support maintenance decision-making. The module also provides a linkage between the performance and maintenance domains, allowing for a common toolset that addresses systems' condition and fuel performance.

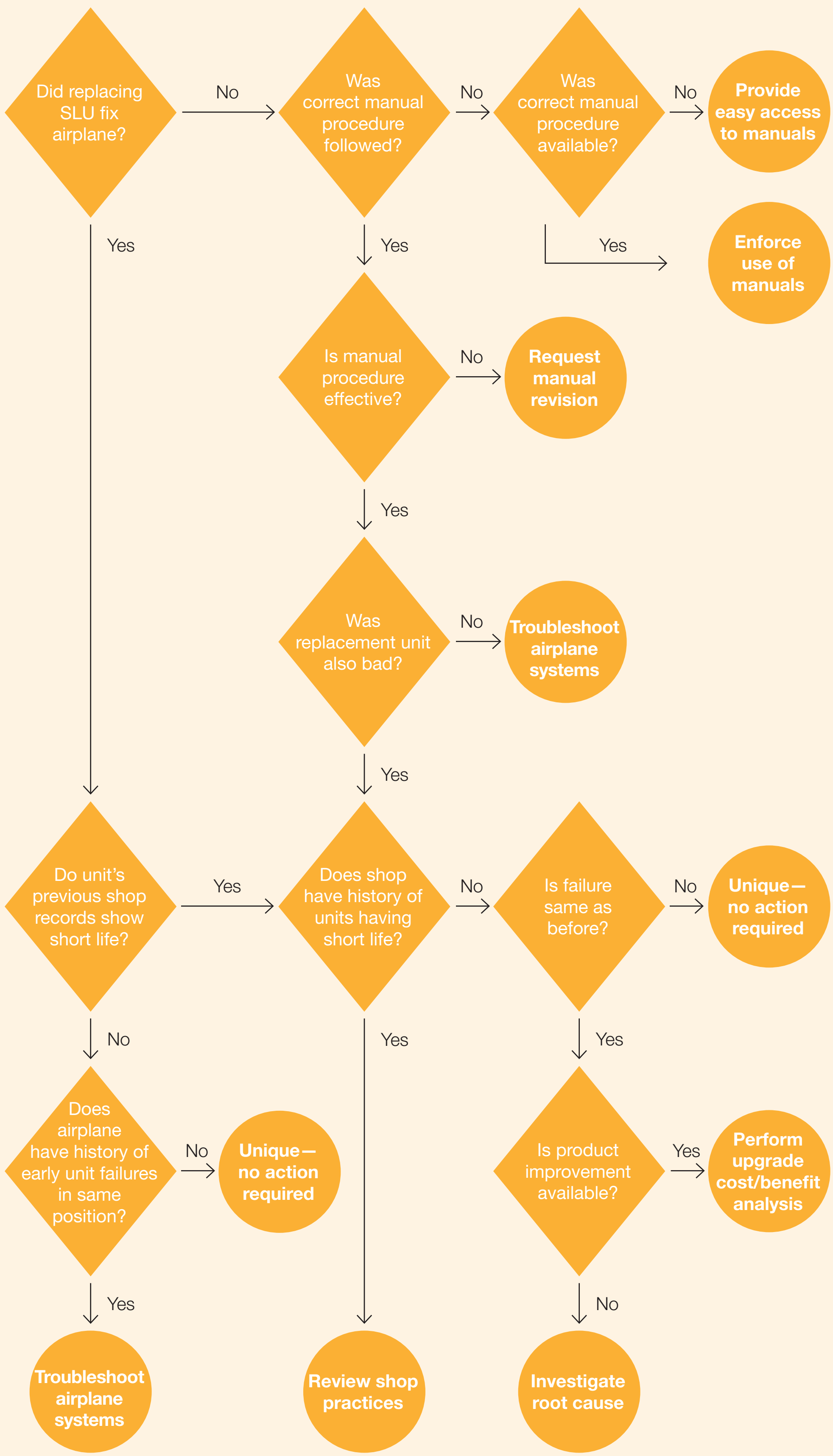
SUMMARY

The CRR process consists of listing components installed in an airplane and removed after a short time in service, analyzing the cause of the short life in service, and correcting that cause. By automating this process, operators can get results quickly and identify root causes sooner, ultimately reducing maintenance cost.

For more information, please contact BFSSSC@boeing.com.

Figure 3: Short life unit (SLU) decision tree

Operators can use this decision tree to determine how to eliminate the cause of an SLU's short life.



Boeing is working with industry to establish a unified cyber strategy and deliver cyber security solutions to airlines worldwide.

Securing Airline Information on the Ground and in the Air

The ability to understand and effectively provide information security services to protect an airline's information and technology assets has become an operational requirement for all airlines. Working with industry and together across the enterprise, Boeing has launched a cyber security effort to develop information security solutions and provide them to airline customers.

By Robert Rencher, Senior Systems Engineer, Associate Technical Fellow;
Stephen Whitlock, Chief Information Security Strategist, Technical Fellow; and
Faye Francy, BCA Enterprise Cyber Security One Team Leader

During the past decade, airlines have made substantial investments in information technology (IT) solutions. These solutions extend throughout the airline's environment and contribute to improved operational efficiency, safety, and customer satisfaction. Securing these investments and protecting the information that these systems manage requires knowledge, leadership, and an effective information security strategy.

The introduction of advanced e-enabled airplanes will provide an increased level of operational efficiency to the airlines. However, this means increased interaction with many information systems that are outside the traditionally defined airline security perimeter.

This article provides an overview of airline information security, outlines the requirements for an information security framework, discusses how digital airplanes influence airline information security, and describes Boeing's information security strategy.

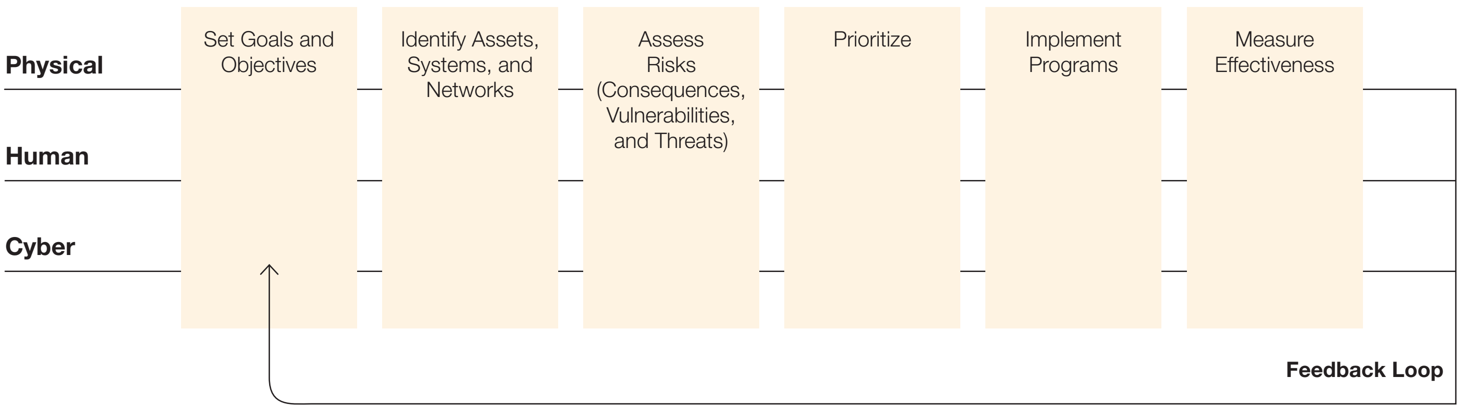
AIRLINE INFORMATION SECURITY

Having and following a well-defined information security strategy safeguards airline customer information, protects the airline's digital assets, and enables the accuracy of information exchanged within the aviation framework. Boeing's holistic approach to IT solutions follows a mature security discipline to protect both Boeing's and the airlines' information.

Pervasive and instantaneous network connectivity, once limited to IT environments, is now part of the global aviation culture. Airline information systems, Boeing's advanced technology airplanes, and other aviation industry partners collectively utilize this connectivity to communicate information, create awareness, and report on the status of the operational environment. The integrity of this aviation digital framework

Figure 1: Effective information security strategy

Continuous improvement of information security strategies is essential for the most effective protection of critical data.



Information security implementation strategy

The implementation strategy for airline information security follows a systematic escalation of system and geographic transition. This requires the prioritization of airline systems. Systems that are deemed as noncritical are evaluated first for demonstrating the process of transitioning to the proposed information security solution. This approach limits the risk exposure to the airline's critical operation systems.

The transition of systems from one region to another must take into consideration the requirement of inter-regional operations. The first geographic priority is to evaluate the autonomy of one area airline region. As two regions have validated the implementation of noncritical system implementation, these two regions must then validate the interoperability of noncritical systems. This again demonstrates the capability without putting critical systems at risk.

requires that all participants adopt and utilize effective information security strategies that are focused on continuous improvement to guard against cyber threats (see fig. 1).

Collaboration within the aviation industry defines, promotes, and ensures that information security best practices are protecting the industry's information assets.

BOEING INFORMATION SECURITY STRATEGY

Boeing believes the commercial aviation industry could benefit from a closed, protected forum in which industry and government can exchange information about emerging information security cyber threats to the air transport and aviation industries.

This type of forum would engage key government and industry participants in the development of the appropriate, coordinated strategies, policies, standards, and processes for aviation. The establishment of such a forum will enable the industry to understand the capabilities of existing and planned cyber security controls and assure that it is prepared for the continuing emergence and escalation of cyber security threats to the aviation industry.

DEVELOPING AN AIRLINE INFORMATION SECURITY FRAMEWORK

The need for airlines to adopt a solid information security framework is clear. Cyber attacks are increasing in number and sophistication. Software vulnerabilities expose intellectual property to unauthorized users. And insider threats to IT infrastructure and proprietary information are increasing.

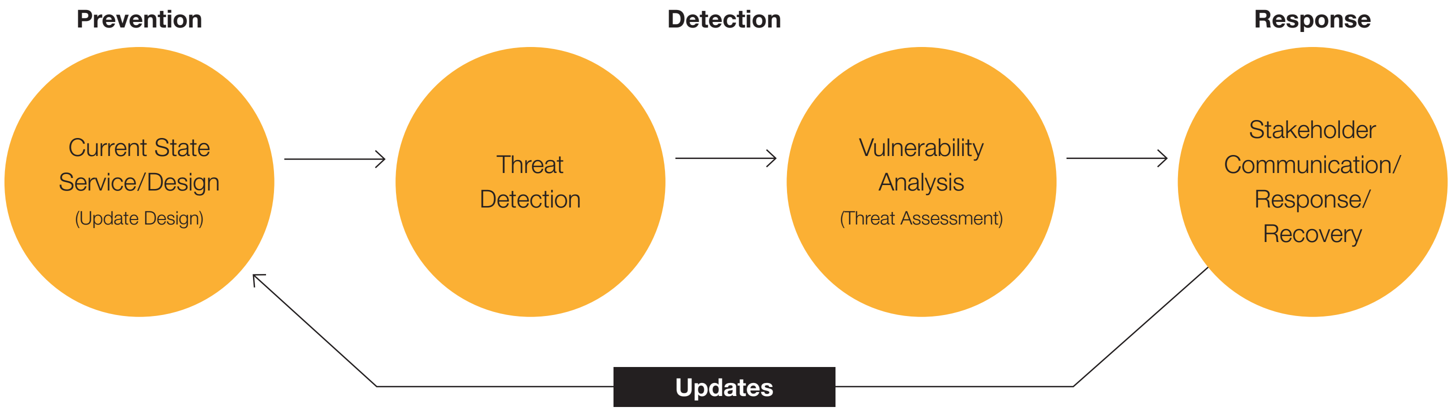
Effective information security risk management requires a framework and methodology that can adjust to this dynamic security threat environment. An airline information security framework should ensure that:

- Managing information system-related security risks is consistent with the organization's mission, business objectives, and overall risk strategy established by the airline's senior leadership.
- Information security requirements — including necessary security controls — are integrated into the airline's enterprise architecture and system development lifecycle processes.

The ideal airline information security framework addresses airplanes in flight, ground operations, and threat management. It consists of three major functions: prevention, detection, and response (see fig. 2).

Figure 2: Prevention/detection/response model

An effective airline information security framework continually prevents, detects, and responds to security threats.



- Prevention addresses the ability to prevent disruption to the current operational state by allowing authorized access to the system services and preventing unauthorized access.
- Detection consists of the ability to detect a security threat and assess information systems' vulnerability to threats. Security threats consist of all methods, both intentional and unintentional, that result in unauthorized use of information systems. Detecting a threat requires a methodology and set of tools to define and evaluate the authorized use of the information systems and detect information system abnormalities.
- Response comprises timely and effective communication to a defined set of stakeholders and the initiation of countermeasures to thwart the active threat and to reconcile disruptions and recover the system.

The information security framework is supported by three qualifying concepts: defense in depth, active management, and configuration control.

- Defense in depth addresses the need to establish a multilayered approach to ensure that prevention, detection, and response cannot be compromised with a single threat approach or disruption event.
- Active management is the persistent awareness of the network and its configuration. Both scheduled and unscheduled events occurring on the network that would change the configuration of the network are tracked.
- Configuration control is the adherence to a well-documented process that manages all changes to the information system. This change control process falls under the broader discipline of business continuity.

HOW DIGITAL AIRPLANES INFLUENCE AIRLINE INFORMATION SECURITY

As the connectivity of aviation services continues to increase, so does the potential for security vulnerabilities. Information security threats to commercial aviation present some unique challenges.

For example, threats can manifest themselves as internal security deficiencies or attacks from external sources, such as the supply chain and network connections within the industry.

The existing in-service fleet of airplanes contains computerized systems, software parts, software control of devices, and off-board communication capabilities that all require an effective security solution.

Boeing, in conjunction with the aviation industry and the information security industry, is developing a holistic cyber security aviation framework that addresses airplane and ground systems and has a threat management component (see fig. 3).

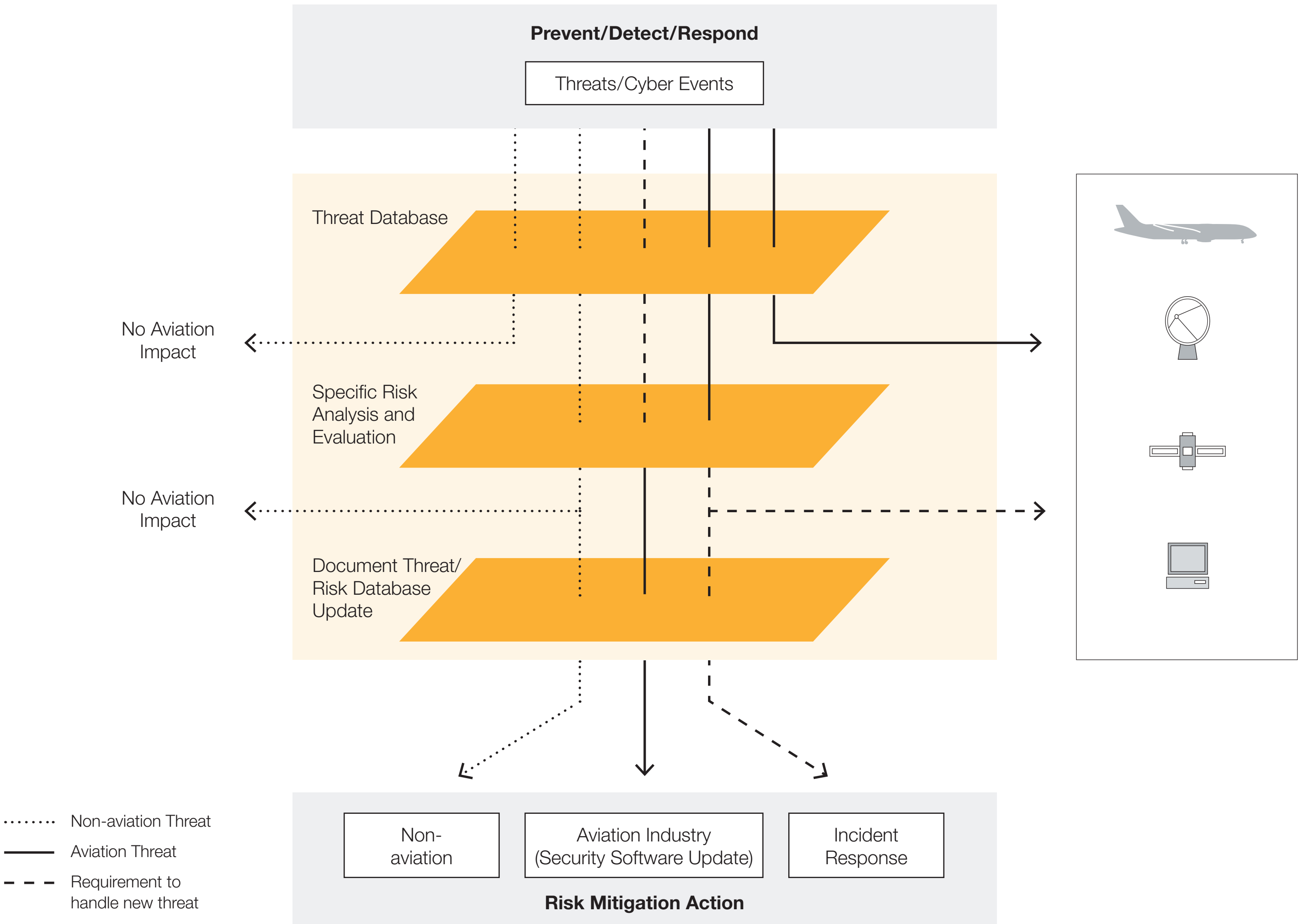
The aviation security framework includes defining emerging threats, guiding incident response, and conducting forensic analysis. These response and analysis services are available through CAS Professional Services.

Boeing's cyber security aviation framework includes the development of an aviation information sharing and analysis center (ISAC) that provides the aviation industry with a unique and specialized forum for managing risks to the aviation infrastructure. Members can participate in conjunction with national and security efforts to strengthen the aviation infrastructure by sharing information and analyzing physical and cyber threats. As a result, airline members will help their companies improve their incident response through trusted collaboration, analysis, and coordination. This will help facilitate decision making by policy makers on security, incident response, and information-sharing issues.

Boeing is committed to establishing an aviation ISAC (A-ISAC). Its mission would be to advance the physical and information security of the aviation industry and to coordinate and collaborate around the world with like-minded organizations to establish and maintain a framework for interaction between and among aviation stakeholders and with governmental entities.

Figure 3: Holistic cyber management

Boeing's holistic cyber security aviation framework is designed to address both airborne and ground-based cyber threats. The aviation industry benefits from the availability of a cyber security information resource that provides a protected venue for exchanging sensitive security information.



BOEING INFORMATION SECURITY SOLUTIONS

To support industry collaboration, Boeing is working with industry to help establish a unified cyber strategy and deliver cyber security solutions to airlines worldwide. This includes establishing a center of excellence for cyber-secure-network-based solutions — including methods, standards, technology, training, and performance — for Boeing commercial airplane systems.

To develop those solutions, Boeing is establishing a Cyber Technical Center that focuses on establishing the ISAC. The Boeing Cyber Technical Center will provide services such as:

- Conducting cyber threat and vulnerability assessments of airborne systems.
- Designing cyber protection for Boeing commercial airplanes.
- Supporting the development of industry standards for aviation security.
- Monitoring and detecting cyber events.
- Offering cyber response and protection services to Boeing airline customers.

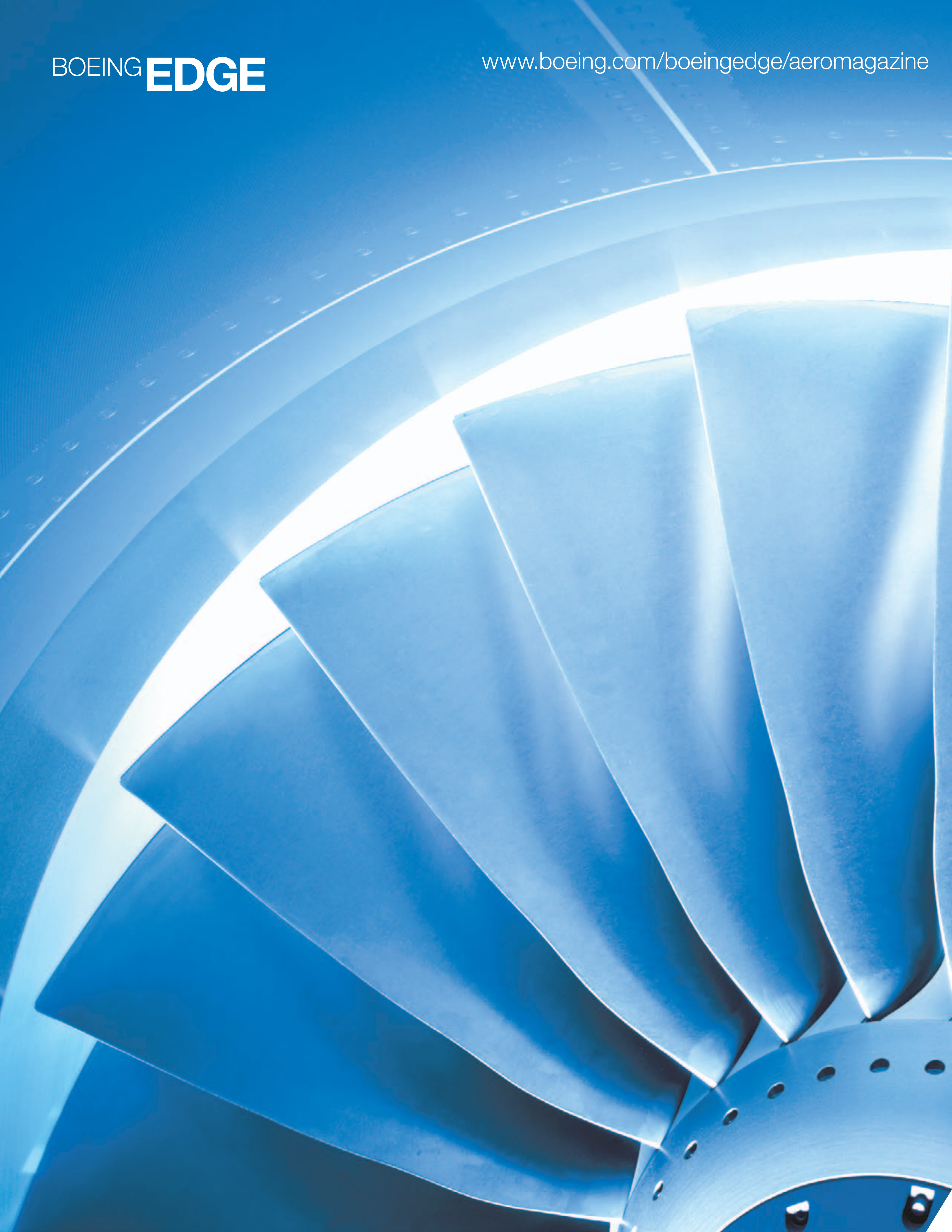
Boeing's cyber security team will provide the means of persistent network mission assurance combined with knowledge management for safe and efficient operations, creating increased value for Boeing customers.

SUMMARY

As airlines continue to make substantial investments in IT systems, securing these investments and protecting the information that these systems manage is critical. The increasing number of e-enabled airplanes makes an effective information security strategy even more important.

Boeing is actively developing a cyber security aviation framework and Cyber Technical Center to support the cyber security needs of our airline customers.

For more information, please contact Robert Rencher at robert.j.rencher@boeing.com.


BOEING EDGE
www.boeing.com/boeingedge/aeromagazine