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Boeing 787: Integration's Next Step

From its central processor to its common data network, surveillance system and navigation system, the theme of the Boeing 787 Dreamliner is integration.

James W. Ramsey

Moving beyond current jetliners in the integration and openness of its architecture, [Boeing](#) sees the 787 Dreamliner's avionics suite as a major contributor to the economies it promises with the new mid- to long-range airliner.

[Boeing](#) has commitments for 203 of the twin-engine, twin-aisle 787s scheduled to begin service in 2008. It touts the 787's higher speed and greater fuel savings, compared with airliners of similar size and range. By cutting black boxes and wiring, Boeing promises an avionics suite 2,000 pounds (907 kg) lighter than earlier-generation systems. The increased level of integration is meant to help achieve the 787's touted 20 percent fuel burn reduction and enable enhanced situational awareness and ease of operation and maintenance.

Central Processing

Key to the new system, which Boeing is developing with partners, Smiths Aerospace, Rockwell Collins and Honeywell, is a central computing function that Boeing calls the common core system (CCS). It replaces multiple computers and hosts up to 80 avionics and utility functions.

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"The net result is that we took these other computing devices and incorporated them into the central system. More than 100 different line replaceable units (LRUs) were eliminated and rolled into an integrated CCS," says Mike Sinnett, chief systems engineer for Boeing's 787 program.

In addition to the weight savings afforded by the new computing system, the integrated avionics suite will feature the largest displays on any commercial aircraft, but with a layout similar to other Boeing airliners, Sinnett says. Also, having dual head-up displays (HUDs) as standard equipment is an industry first, Boeing claims. Electronic flight bags (EFBs) will be standard, too.

Like the Boeing 777, the Dreamliner will have a Honeywell digital fly-by-wire flight control system and use the familiar wheel and column, not a sidestick. In fact, commonality with the triple-seven flightdeck will result in pilots' transitioning from the 777 to the 787 in five days or less, with no motion-based simulator training required.

Supplier Role Expanded

In a change in philosophy, Boeing is giving its first-tier suppliers more integration responsibility for their system "packages" than in the past. In addition to the CCS supplied by Smiths, Honeywell will provide the navigation package and a crew information system/maintenance system (CIS/MS). Rockwell Collins will provide the display, communications and surveillance systems. The 787 marks a milestone for Collins, which is providing more content for the aircraft than it has for any aircraft it has supplied before, according to a company spokeswoman.

"These are packages that encompass more than just Rockwell Collins products--we have subcontractors under each of these packages," explains Bryan Vester, director of marketing for Rockwell Collins' Air Transport Systems.

Yet, while Smiths builds the core computer, "Boeing still retains the overall integration responsibility of all user functions on that system," Sinnett points out. "We are still the overall integrator of the avionics suite."

Boeing's movement towards an open systems architecture in the 787 reduces the cost of change and increases the ease of upgradeability, Sinnett says. To achieve this, Boeing is using an ARINC 653, industry-standard operating system for its CCS.

"With a standard interface and operating system that's defined within industry standards, if 10 years from now you want to add functionality to the airplane--such as a clear air detection system--we're not held hostage by the maker of that central core system," says Sinnett. He feels this change will make development more competitive while providing quicker time to market for functions that can enhance the safety of the aircraft.

Common Core System

Smiths describes the common core system as the 787's central nervous system. It includes dual common computing resource (CCR) cabinets that host processing and power control modules (cards), along with network switches. Application specific modules (ASMs), provided by third parties specified by Boeing, can be installed in the cabinets.

A second element of CCS is the common data network (CDN), provided to Smiths by Rockwell Collins. This comprises network switches located inside the CCR cabinets and externally mounted throughout the aircraft. CDN is a fiber optic Ethernet that connects all the systems that need to communicate with the CCS and each other. CDN technology is being worked through industry committees and is expected to be adopted under the ARINC 664 standard.

CCS also includes remote data concentrators (RDCs) that replace traditional, dedicated signal wiring. These remote

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devices concentrate analog and digital signals from the remote sensors and effectors and put them onto the network. (Sensors are devices that provide a signal input, and effectors are devices that provide a signal output. Effectors typically control something by providing an excitation signal, such as a drive voltage to an actuator, while the sensor provides a reading or measurement, such as temperature or pressure.)

Smiths manages overall CCS design and integration, while Collins supplies the CDN elements to Smiths, including a device called the end system. "If you are Honeywell or Hamilton Sundstrand, and you want to have a network connection, you have to buy this end system--which is actually a chip set--and design it into your box so it will talk on the network," explains Mike Madden, Smiths' program director for the 787 common core system.

If legacy equipment, such as an off-the-shelf radio that has only an ARINC 429 interface, is brought onto the 787, "you could connect that to one of our remote data concentrators and get on the network that way," Madden says. The RDCs have a digital gateway function--like an ARINC 429 bus. They give the aircraft integrator a lot of flexibility on how to configure the avionics system--"whether you want to use legacy equipment and take advantage of cost or are designing new equipment to reduce space, weight and power," Madden explains.

Boeing and Smiths are working together to integrate applications from a number of suppliers into the CCS. While the flight management function on existing airplanes would consist of a dedicated LRU, "that functionality, which is basically software, is going to be hosted on the CCS," Madden says. (Smiths provides traditional flight management systems for the 737.) Smiths will build the CCR cabinets with the processors and power supplies at its Grand Rapids, Mich., facilities and the remote data concentrators in Cheltenham, UK.

Display System

The 787 will feature significantly more display area than the 777 but with fewer displays. The 787 will have five 9-by-12-inch Collins primary flight displays: four in a horizontal bank across the instrument panel and one below on the center pedestal forward of the throttles. These 15-inch diagonal liquid crystal displays (LCDs) compare with the six 8-by-8-inch displays on the 777, five across the top and one below.

The dual head-up displays will be manufactured by Rockwell Collins' Flight Dynamics business unit in Portland, Ore. Collins also provides the display control panels, the multifunction keypads, and cursor control devices that select what is to be shown, as well as display software applications that run on the Smiths' general-purpose processor module in the CCS. And Collins furnishes the graphics generator module in the CCS. Japan's Sharp Corp., a large-scale commercial LCD manufacturer and longtime Collins supplier, provides the glass.

The increased situational awareness provided by dual HUDs "warrants their inclusion on all new airplanes as basic [standard] equipment" incorporated into the basic design, Sinnett says. He doubts that adding dual HUDs as a "bolt-on" would bring the same benefits. The HUDs also could provide users a competitive advantage through improved capabilities for low weather visibility (reduced minimums) takeoffs. (Air France plans to have dual Thales HUDs on its A380s.)

Thales is supplying the 787's integrated standby flight display (ISFD). This LCD presents aircraft pitch and roll attitude, airspeed, altitude, heading and landing approach deviation data in a format similar to primary flight displays. The same Thales display is found on all of Boeing's newer aircraft.

Dreamliner Com

The B787's communications system is also a Collins design. The VHF 2100 radio, to be released this year, is software-upgradeable to VDL Mode 3, Vester says. "There is growth in there if we have to go to other waveforms for future CNS/ATM [communication, navigation, surveillance/air traffic management] applications." In moves that should boost

reliability, Collins has slashed the parts count by 30 percent (going from four circuit cards to two), cut weight by 25 percent, and decreased power consumption by 20 percent, compared with current radios.

The equally new SAT 2100 satcom system can handle three channels of Aero H, Aero H+ or Aero I. Its three channel cards and high power amplifier are packaged in a single 8-MCU box, replacing the three-box SAT 906. Collins provides the HST 2100 high-speed terminal as a separate LRU but integrates it with the SAT 2100. This design will enable dual-channel Swift 64 data com, with growth to Inmarsat's BGAN (broadband global area network) platform, which will support data rates up to 432 Kbits/s. Using SAT 2100 and HST 2100, the system can accommodate five channels--three voice and two data--simultaneously, Vester says. Collins also provides the HF radio.

The communications management function (CMF) software developed by Honeywell, as part of the aircraft's nav package, replaces the traditional communications management unit. Collins is procuring all flight data and cockpit voice recorders through subcontracts.

Core Network

Collins also developed the "core network" for the 787 and subsequent retrofits. This system houses multiple file servers and supports both cabin and flightdeck applications. A firewall in the core network cabinet isolates lower-criticality, cabin applications from higher-criticality, flightdeck systems.

"This [core network cabinet] is where the Connexion by Boeing applications that use broadband capability reside, along with other aircraft software applications," Vester says.

Collins' CISS 2100 configurable, integrated surveillance system combines the traffic alert collision avoidance system (TCAS), Mode S transponders, terrain awareness warning system (TAWS) and weather radar functions into a single unit. Although a first for the company, the system reflects an industry move to reduce volume, weight, power consumption and cost. Honeywell provides a similar system for the A380.

The surveillance system comprises the ISS 2100 processor, PMR 2100 weather radar pedestal, and receiver/transmitters use a fiber optic link to get the data from the radar transceivers back to the ISS processor, and then all the weather information is processed along with TAWS and the TCAS for display on the flightdeck," Vester explains.

Collins will provide the TCAS, Mode S and weather radar elements of the surveillance package but subcontract out the TAWS system. The TCAS is new, Vester says. The weather radar, repackaged to fit the new hardware platform, is based on Collins' MultiScan hazard weather detection system. The Cedar Rapids, Iowa, company is in the initial phases of integration, moving towards development and design work before the aircraft design freeze later this summer. Collins expects to deliver hardware and software at the end of 2006, leading to a maiden flight in 2007.

Honeywell Navigation

Honeywell supplies the 787's nav package, which includes the flight management function, inertial reference system (IRS), air data system, and two integrated nav receivers (INRs). The INRs contain ILS (localizer and glideslope), marker beacons, VOR, GPS and GLS (GPS landing system) all in one box. They provide capability for Cat IIIB ILS and Cat I GLS approaches.

In addition, as part of the nav package, Honeywell provides two DME transmitters, two radar altimeters and two (optional) ADF radios. It also supplies the emergency locator transmitter (ELT). The air data system software includes six remotely located air data modules that connect to pitot probes and other sensors. It relays that information digitally to the air data computational software hosted on the CCS.

The inertial reference system part of the nav package includes two micro-IRS units, packaged in smaller boxes, but with the same basic functionality as in any other IRS.

"This is essentially an off-the-shelf unit that we use in our regional aircraft applications," says Don Morrow, director of Boeing business development for Honeywell Commercial Electronics Systems in Phoenix. Honeywell's inertial business unit in Minneapolis makes it.

"We're also providing two super AHRS [attitude heading reference system] boxes that are not full-blown inertials, but are capable of providing attitude and heading in case you had a dual failure of the IRUs [inertial reference units]," Morrow says. "It's an extremely remote possibility, but we decided it was the right configuration to have."

CIS/MS

Boeing is procuring Honeywell's crew information system/maintenance system as one package. The MS portion consists of onboard health management, "a sort of a roll-over of what Honeywell did on 777 with the central maintenance computing [CMC] function and airplane condition monitoring function," Morrow says. The CMC consolidates all of the maintenance information coming from all of the airplane systems and then helps isolate faults and provide troubleshooting direction to a maintenance technician.

The CMC and the airplane condition monitoring function are software packages that will be hosted in the common core system. The airplane condition monitoring function is an engineering tool designed to set up trend monitoring and screening routines for engines and buses.

Data Loading

Data loading and configuration management are separate functions provided by the maintenance system. The data loader supports the insertion of data loads (operational software) into the appropriate avionics systems. "If you wanted to load a new piece of flight management software, it would come through this function," Morrow explains. A configuration management function tracks what version of software and hardware is on every 787 system.

Honeywell's crew information system is a network of applications that includes EFB and a secure crew wireless local area network (LAN). "CIS is really an infrastructure that is going to be installed as a server on the airplane [Collins' core network cabinet] that provides network security for a kind of airplane intranet," Morrow says. "We're also providing wireless LAN interfaces to the hardware and software, allowing the offloading of information wirelessly when [the aircraft is] close to a terminal--similar to systems in the past called gatelink."

"Gatelink is used today for things like passenger e-mail, but this is the first time a maintenance technician with a wireless laptop (equipped with a Wi-Fi card) can walk up to the aircraft and get maintenance info on and off the airplane," Boeing's Sinnett says.

The aircraft crew's secure wireless LAN could be used in conjunction with a wireless LAN infrastructure in airline terminals to wirelessly upload flight plan information, cabin inventories and passenger information, without having to take information physically to the airplane, Morrow points out. "The only other way to do that today is with ACARS--and that costs a lot of money. This is an 802.11 system. We have extended the range to about 300 to 400 feet (91.5 to 122 m), so the airplane doesn't have to be docked and it can still make a connection."

The crew information system is "largely a set of COTS [commercial off-the-shelf] solutions," Morrow says. It is minimally ruggedized, for reliability, but is not designed to avionics standards for flight-critical systems.

EFBs, offered as an option on the 777 today, will be standard on the 787. Jeppesen, a Boeing company, will provide the applications, including airplane performance software, electronic flight manuals and logbook. The EFB hardware provider has not yet been announced.

Fly-by-Wire System

Like the 777 the Boeing 787 will have a digital fly-by-wire flight control system. Honeywell will provide the flight control electronic package--the primary fly-by-

wire flight control computers and the actuator control electronics, plus sensors to support the fly-by-wire computations. It also supplies the mode control panels the pilot typically uses when the autopilot function is affected, as well as some batteries for backup power.

The flight control electronic package includes cabinets containing computer modules and actuator control electronics modules that effectively drive the actuators, along with power conditioning modules. "We have our own power and condition it separately from the avionics, due to the very high criticality of the flight control system," Morrow says.

The system is multiple-redundant with dissimilar processing to protect against generic hardware failure.

Honeywell plans to begin hardware and software deliveries in late 2005 or early 2006. First deliveries will be prototype equipment; a final design will not be locked in until the company is sure there won't be any more changes. Although laboratory integration will take place, systems-level integration for the airplane probably won't take place until 2007, Morrow says.

The airplane's forward section, including the cockpit and electronics bay, is scheduled to be built in Wichita, Kan., by Onyx, a Canadian company. Boeing has not yet decided where the avionics will be installed, but its plan to airship (via B747 freighter) aircraft sections to Seattle for final assembly will be a factor.

"It's probably going to come down to where we are better able to do the build verification testing--in Wichita, in a pre-integration facility or up here [in Seattle]," Sinnett says.

Dreamliner Connexion

Connexion by Boeing's broadband service will be a "selectable option" on the 787, says Stan Deal, Connexion's vice president of commercial aviation. Some of the infrastructure, such as Rockwell Collins' core network, is included in the basic design, "to allow efficient switching and management between the offboard and onboard network of the airplane," he explains.

"We originally left the door open for any broadband system that would be operational, but it is pretty clear now that Connexion will still be the only true broadband system in 2008," says Mike Sinnett, chief systems engineer for Boeing's 787 program.

While the service is not certified to provide safety functions, such as position reporting, Connexion plans to extend its capabilities beyond passenger Internet connectivity to "use our worldwide [satellite-based] network for operational purposes," Deal says. "This could include cabin management and flight crew applications in the future." It could be a long-term replacement for ACARS, Deal adds.

Five airlines now offer the broadband service on 58 aircraft. Boeing expects to reach a total of 11 carriers with more than 100 aircraft by the end of the year.

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