Introducing the 787
- Effect on Major Investigations
- And Interesting Tidbits

Tom Dodt
Chief Engineer – Air Safety Investigation
ISASI  September, 2011
787 Size Comparison

<table>
<thead>
<tr>
<th></th>
<th>767-400</th>
<th>787-8</th>
<th>777-300</th>
</tr>
</thead>
<tbody>
<tr>
<td>~Pax 3-Class</td>
<td>245</td>
<td>250</td>
<td>368</td>
</tr>
<tr>
<td>~Span</td>
<td>170 ft</td>
<td>197 ft</td>
<td>200 ft</td>
</tr>
<tr>
<td>~Length</td>
<td>201 ft</td>
<td>186 ft</td>
<td>242 ft</td>
</tr>
<tr>
<td>~MTGW</td>
<td>450,000 lbs</td>
<td>500,000 lbs</td>
<td>660,000 lbs</td>
</tr>
<tr>
<td>~Range</td>
<td>5,600 NM</td>
<td>7,650 NM</td>
<td>6,000 NM</td>
</tr>
<tr>
<td>Cruise Mach</td>
<td>0.80</td>
<td>0.85</td>
<td>0.84</td>
</tr>
</tbody>
</table>
Composite Structure

- Carbon laminate
- Carbon sandwich
- Fiberglass
- Aluminum
- Aluminum/steel/titanium pylons
- Composites
- Titanium
- Steel
- Other

By weight

<table>
<thead>
<tr>
<th>Material</th>
<th>787</th>
<th>777</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composites</td>
<td>50%</td>
<td>12%</td>
</tr>
<tr>
<td>Aluminum</td>
<td>20%</td>
<td>50%</td>
</tr>
</tbody>
</table>

By weight 787 777

- Composites 50% 12%
- Aluminum 20% 50%
787 Wing Flex - On-Ground
787 Wing Flex - 1G Flight

1G Flight ~12 ft
On-Ground 0 ft

1G Flight

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787 Wing Flex

- Ultimate-Load: ~26 ft
- 1G Flight: ~12 ft
- On-Ground: 0 ft
787 Static Load Test @ Ultimate Load
Investigations with Composite Materials

• Terms: Composites
  disbond
  delaminate
  inter-laminar shear
  water absorption
  fiber architecture
  Aluminum
  fatigue
  beach marks
  striation counts
  corrosion
  metallurgical property

• Material Forensics Techniques will be different

• On-Site with Exposed Composite Fibers
  Eyes - goggles or full face protection
  Nose - HEPA filter
  Hands - gloves
  Exposed Skin - coveralls
787 Cabin Experience
787 Windows
Cleaner Cabin Air

HEPA (high efficiency particulate air) recirculation filters and gaseous air purification filters produce air that is essentially particle free and odor free. The HEPA filters are highly effective in removing bacteria, viruses, and fungi. The gaseous filtration system removes odors and volatile organic compounds.
Ride Quality - Smoother Ride

Vertical Gust Suppression

- Uses the flaperons and elevators
- Counters light to moderate turbulence to improve ride quality
- Passengers have a more comfortable flight

Change in altitude (m)

0 20 40 60 80 100 120 140 160 180

Time (sec)

-2 -1 0 1 2

With Enhanced Gust Suppression

Without Enhanced Gust Suppression
787 Cabin Experience

Windows - Larger
Pressure - Lower
Humidity - Higher
Air Quality - Improved
Ride Quality - Improved
Food Service - Unchanged (sorry)
787 Pax Oxygen

787 - Gaseous Oxy @ 3000 psi
- Steel cylinder

777 - Chem Oxy Generators (2x)
787 Fuel Tank Inerting

Nitrogen Generation
Quiet for Airport Communities

85 dB Noise Contours at Heathrow

- 85 dBA contours
- 3,000 nmi mission

787 noise footprint stays in the airport property
Engine Technology Advancements

- No-engine-bleed-air systems architecture
- Higher bypass ratio
- Low-noise nacelles with chevrons
### Airplane/Engine Architecture

- **No-engine-bleed-air systems**
  - **Wing LE Anti-Ice**
  - **Air Conditioning**
  - **Cabin Pressure**
  - **Engine start**

<table>
<thead>
<tr>
<th></th>
<th>777</th>
<th>787</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wing LE Anti-Ice bleed air</td>
<td>bleed air</td>
<td>electric</td>
</tr>
<tr>
<td>Air Conditioning bleed air</td>
<td>bleed air</td>
<td>electric</td>
</tr>
<tr>
<td>Cabin Pressure bleed air</td>
<td>bleed air</td>
<td>electric</td>
</tr>
<tr>
<td>Engine start bleed air</td>
<td>bleed air</td>
<td>electric</td>
</tr>
</tbody>
</table>

- **Engine Generators**

<table>
<thead>
<tr>
<th></th>
<th>777 240 kVA</th>
<th>787 1000 kVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2 @ 120 kVA)</td>
<td>(4 @ 250 kVA)</td>
<td></td>
</tr>
</tbody>
</table>

- **Generators**
- **Starter/Gen’s**
Variable Frequency Power Generation

**Integrated Drive Generator (IDG): Majority of In-Service Airplanes**

- Engine: Variable Speed
- CSD: Constant Speed
- Gen: Constant Frequency (400 Hz)
- IDG: To All Loads, Local Rectification for Electronic Loads

**Variable Frequency (VF): 787**

- Engine: Variable Speed
- Gen: Variable Frequency (360-800 Hz)
- To All Loads, Local Rectification for Electronic Loads

**777**
- 115 VAC
- 400 Hz

**787**
- 230 VAC
- 360-800 Hz

Variable frequency generation system is the simplest and the most reliable option.
EE vs Pneumatic Power Distribution

Forward E/E Bay

230 Vac Feeder

Generator 2 x 250 kVA

Aft E/E Bay

APU Generator 2 x 225 kVA
Electronic Circuit Breakers

- No physical CBs in Flight Deck
- CB control and state indication are display based.
- Accessible on Multi-Function Display (MFD) and maintenance access devices
- A few Thermal CB are located in the Fwd EE-Bay
Overhead Panels - Circuit Breakers

787

777
Integrated FCE

Equivalent Channel of Flight Controls and High Lift

777

787
**Common Core System**

**Common Computing Resource**
- High integrity computing resources for hosted systems applications

**Common Data Network**
- High Integrity Network
- Open industry standard interfaces A664

**Remote Data Concentrators**
- 21 RDCs
- Remote I/O capability
- Reduces airplane wiring
CCS Hosted Functions

- Avionics Communication and Audio
- Avionics Flight Management and Navigation
- Avionics Thrust Management and Auto-throttle
- Avionics Primary Display Function
- Avionics Crew Alert/Warning and Surveillance
- Avionics Crew Information Services
- Avionics Maintenance and Data Loading
- Cabin Management and Air Show
- Data Interface to Flight Controls Electronics (FCE)
- Interface to Flight Deck Panels and Switches
- Fuel Management and Fuel Quantity Indication
- Hydraulics Control
- Mechanical System Interface Functions in Brakes, Landing Gear, Nose Wheel Steering
- Payloads Interface Functions in Galleys, Water & Waste, Emergency Lighting
- Data Interface to Propulsion Controls in EEC, Engine Fire Detection/Protection, Thrust Reverser
- Specific functionality supported by the CCS is described in the CCS SDD (Ref. 4) as well as in individual 787 CCS hosted function System Description Documents (SDDs) identified in their respective certification plans listed in Ref. 4.)
Landing Gear Systems
New Control-by-Wire

- Landing Gear Actuation
  - Electronic control and sequencing of landing gear and doors

- Brake System
  - Control-by-wire brakes, autobrake and anti-skid
  - Electric Brake Actuators

- Nose Gear Steering
  - Control-by-wire (pedals & dual tillers)
  - Hydraulic actuation
Cabin Air Conditioning System

Heat Exchanger inlet

Cabin Air Compressor Inlet (Deflector door shown deployed)

Cabin Air Compressors

Heat Exchangers

Electric Ram Fan
External Air Sources

- **Heat Exchanger Inlet**
- **Cabin Air Compressor Inlet**
- **Heat Exchanger Exhaust Doors**
787 EAFR
Enhanced Airborne Flight Recorder

• Dual-Combi Architecture

• Both recorders are same P/N
  - self contained acquisition function
  - FRED file in memory (Flight Rec. Elec. Doc. - ARINC 647)
  - flight data 25 hours minimum
  - voice - 2 hours
  - datalink

• FWD EAFR
  - RIPS for voice recording only

• AFT EAFR
  - no RIPS
Aft Recorder
Recording Format

• EAFR Flight Data recording format
  - ARINC 767
  - raw data file size ~800 MB (zips to 200 MB)
  - Approx equivalent to 5000+ WPS recorder

• The 787 "QAR"
  - called "Continuous Parameter Logging" (CPL)
  - stored on the mass storage devices (server)
  - ARINC 767 recording format
Flight Controls - 777 / 787 Common Functionality

Common 777 / 787 Fly-by-wire Functionality

- Stall Protection
- Overspeed Protection
- Bank Angle Protection
- Tail Strike Protection
- Thrust Asymmetry Compensation
- Yaw Damping, Over-yaw Protection
- Gust Load Alleviation
- Fin Load Alleviation
- Flap Load Relief & Autogap
- Lateral Gust Suppression
- Modal Suppression
Flight Controls - 787 New Features

• P-Beta control law

• Vertical Gust Suppression (turbulence)

• Enhanced Stall Protection
  - Limits high angles of attack

• Enhanced Thrust Asymmetry Compensation
  - Adds inertial yaw detection on ground
  - Generates rudder & steering for yaw disturbances
P – Beta Control Law

• Wheel commands roll rate (P)
• Pedals command sideslip angle (Beta)
• Opposes disturbances
• Coordinates lateral and directional control
• Automatic aileron & rudder trim
  - No aileron trim switch
Air Data System Design Philosophy

Federated AD & IR
(all previous models)

Fault arbitration by CREW

Voted AD & IR
(777, 787)

Fault arbitration by SYSTEM

AD = Air Data
IR = Inertial Reference
FDI = Fault Detection & Isolation
PFD = Primary Flight Display
Air Data System - Common Mode Vulnerability

• Common Mode Hazards to Pitot-Static sensors
  - Mud Daubers
  - Volcanic Ash
  - Radome failure
  - Pitot covers
  - Maintenance errors
    (pneumatic plumbing)
  - Icing
  - Hail
  - Birds
  - Taped Static Ports

• 787 new capabilities for protection
  - Synthetic airspeed
  - GPS altitude
  - Common Mode Monitor
787 Synthetic Airspeed

• Calculated from angle of attack and inertial data
  - AOA – voted dual sensors plus inertial data
  - Accurate Coefficient of Lift ($C_L$)
  - Airplane Mass from FMC - Validated after Takeoff

• Algorithm developed for enhanced stall protection

• Avoid displaying data known to be bad
  - Loss of valid voted $V_{CAS}$ = Display synthetic airspeed $V_{SYN}$
  - Loss of valid voted $P_{STATIC}$ = Display GPS altitude
Onboard Health Management

Objective: Reduce schedule interruptions and maintenance costs

Integrated data load and configuration reporting

Electronic Distribution of Software

Electronic link to maintenance manuals

Fault Prediction

Airplane level fault consolidation and correlation, and data collection

Media-less data transfer to/from ground stations

Coordinated airplane and ground processing approach
Sat Comm
747
Dream Lifter
Partners Across the Globe are Bringing the 787 Together

U.S.
- Boeing
- Spirit
- GE
- Goodrich

Australia
- Boeing

Canada
- Boeing
- Messier-Dowty

Asia
- Fuji
- Mitsubishi
- Kawasaki
- KAL-ASD

Europe
- Messier-Dowty
- Rolls-Royce
- Latécoère
- Alenia
- Saab

Wing tips
- Seoul, Korea

Fixed trailing edge
- Nagoya, Japan

Moveable trailing edge
- Melbourne, Australia

Wing
- Nagoya, Japan

Nacelles
- Chula Vista, CA

Mid forward fuselage
- Nagoya, Japan

Forward fuselage
- Wichita, KS

Cargo access doors
- Linköping, Sweden

Wing/body fairing
- Landing gear doors
- Winnipeg, Canada

Engines
- GE – Evandale, Ohio
- Rolls Royce – Derby, UK

Center fuselage
- Grottaglie, Italy

Aft fuselage
- Charleston, SC

Passenger entry doors
- Toulouse, France

Main landing gear wheel well
- Nagoya, Japan

Horizontal stabilizer
- Foggia, Italy

Tail fin
- Frederickson, WA

Aft fuselage
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Dreamlifter Route Structure

Section 41
Wichita, KS to Everett, WA

Section 44
Grottaglie, Italy to Charleston, SC

Section 46
Grottaglie, Italy to Charleston, SC

Horizontal Stabilizer
Foggia, Italy to Charleston, SC

Section 11/45
Nagoya, Japan to Charleston, SC

Section 43
Nagoya, Japan to Charleston, SC

Wing
Nagoya, Japan to Everett, WA

Joined
Section 47-48
Charleston, SC to Everett, WA

Joined
Section 43-46
Charleston, SC to Everett, WA

Worldwide operations, less work in process
Dreamlifter Enables Global Operations

• Efficient transport of 787 major sub-assemblies from international partners

• Main deck is 65,000 cubic feet
  - 3x capacity of 747-400 Freighter

• Reduced transportation times versus surface transportation
  - Dramatically reduced final assembly flow times
  - Less inventory
787 Structure from Asia

International partners providing key 787 structure

Fuji Heavy Industries
Kawasaki Heavy Industries
Mitsubishi Heavy Industries
Korean Air
787 Structure from Europe

International partners providing key 787 structure
787 Structure from North America

International partners providing key 787 structure