Abstract

- **Title:** A System of Systems Approach to e-Enabling the Commercial Airline Applications from an Airframer’s Perspective

- **Abstract:** Alan Mullaly (former Boeing Commercial Airplane Company President) challenged Boeing leadership to develop a comprehensive approach to “e-Enabling” the Boeing fleet. We launched an e-Enabled Airplane project focused on developing a strategy and technical architecture to facilitate making the airplane network-aware and capable of leveraging computing and network advances in industry. Shortly after launching this effort it became apparent that the airplane was one component of a much larger system. As a result, Boeing shifted the objective to a much broader context making the airline the focus. The project grew to include many ground based architectural components at the airlines and at the Boeing factory, as well as other key locations such as the airports, suppliers and terrestrial Internet Service Suppliers (ISPs).

  The e-Enabled project took on the task of defining a system of systems engineering solution to problem of interoperation and communication with the existing, numerous and diverse elements that make up the airlines’ operational systems (flight operations and maintenance operations). The objective has been to find ways of leveraging network-centric operations to reduce production, operations and maintenance costs for both Boeing and the airlines.

  One of the key products of this effort is the “e-Enabled Architecture”. The e-Enabling Architecture is defined at multiple levels of abstraction. There is a single top-level or “Reference Architecture” that is necessarily abstract and multiple “Implementation Architectures”. The implementation architectures map directly to airplane and airline implementations and provide a family of physical solutions that all exhibit common attributes and are designed to work together and allow re-use of systems components. The implementation architectures allow for effective forward and retrofit installations addressing a wide range of market needs for narrow and widebody aircraft.

  The 787 “Open Data Network” is a key element of one implementation of this architecture. It enabled on-board and off-board elements to be networked in a fashion that is efficient, flexible and secure. The fullest implementations are best depicted in Boeing’s GoldCare Architecture and design.

  This presentation discusses Boeing’s e-Enabling project and its objectives. The primary purpose of the presentation is technical and thus it focuses on the technical aspects defined in the e-Enabling Technical Architecture. The architecture is presented at the reference level and is mapped to the 787 airplane implementation. GoldCare environment is described and is used as an example of the full potential of the current e-Enabling activities.
Agenda

- Boeing’s e-Enabled Airline Program
  - Overview
  - Videos
  - e-Enabled Technical Architecture
    - Approach
    - Reference Architecture
  - e-Enabled Applications
  - e-Enabled 787
  - GoldCare Overview
  - Summary & Wrap up
Video Show

- e-Enabled Overview
- Spiral One Demo
e-Enabled Spiral One Demo Video
e-Enabled Program Objectives

- The strategic connection and integration of business processes, people, airplanes, information, assets, and knowledge into a single focused business system

- Centered on breaking through operational constraints
Real-time connectivity across the enterprise

“the real-time connectivity of the airplane to the ground, the delivery of information across the enterprise...”
“and the strategic use of this information through sophisticated applications and software to improve efficiency and increase airplane availability and reliability.”
e-Enabled Efficiency

**Electronic Flight Bag**
- Electronic Logbook, Accurate performance calculations & paperless flight deck driving operational efficiency

**Airplane Health Management**
- Real-time data and information to reduce schedule interruptions and improve asset utilization

**Integrated Materials Management**
- Supply chain management, warehousing, inventory control and “As Flying Configuration”

**MyBoeingFleet.com**

**Airline Flight Operations**
- Web based flight planning, chart distribution and crew management

**Maintenance Performance Toolbox**
- Web based system provides rapid access to technical support information

**Integration and Connectivity**
The e-Enabled Environment

Achieve Competitive Advantage Through Integration and Connectivity

Airplane reports fault through CMC, ACARS, and CoreNet

Pilot observes and records fault in EFB Tech Logbook

Inventory Management and Procurement

Mechanic processes fault with e-Logbook

AHM collects, prioritizes, and organizes data to assist in formulating a plan

Maintenance Operations Control

MOC has visibility to all information associated with the fault and its resolution through one seamless system.

Maintenance ERP

Toolbox provides access to all technical documents related to the part

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e-Enabled Technical Architecture Objectives

- Provide common technical architecture, strategy and vision
- Promote Network-Centric principles
- Remove SOS level roadblocks by looking across enterprise
- Maximize inter-project interoperability
- Maximize re-use
  - Large amortization of equipment
  - Re-use software services within applications
  - Re-use services and applications across platforms and airlines
  - Re-use architecture, certification, security principles, operational procedures etc.
- Propose designs that lead industry
The scope of the e-Enabled architecture includes Airlines, MROs, Suppliers, Boeing and Airplanes and is a fleet-wide and enterprise-wide solution.

The e-Enabled Airline Architecture is made up of components and their relationships:
- Components are functional or physical
- Relationships are physical or logical

There is a single reference architecture for the Enterprise:
- It consists of multiple views
- It necessarily is at a high level of abstraction
- Focus is on infrastructure and middle-ware not applications
- e-Enabled Program manages the reference architecture

There are multiple implementation architectures that map to real-world business unit instances.
e-Enabled Technical Architecture Structure

- E-Enabled Technical Reference Architecture Consists of
  - Reference Architecture
    - A single representation of numerous implementations
    - Abstracted from all physical implementations to a functional/logical level to define and illustrate specific common attributes
    - Driven by over-arching business, strategy, technology and vision
    - Centrally coordinated for visibility and maximum synergy
  - Implementation Architectures
    - There are potentially many of them
    - As designed and deployed for customers
    - Development by business units
    - Mapped to the reference architecture
    - Owned by the business units
  - Multiple Views
    - Operational views
    - System views
    - Technical views
On-Board Architecture Imperative Architecture

• Why an *e-Enabled On-board Imperative Architecture*?
  • On-board airplane is TODAY’s Presentation orientation
  • Imperative means concentrating ONLY on NEEDED capabilities (most bang for the buck!)

• On-Board Imperative Architecture Elements
  • FOCUS is on the highest priority on-board components & key network attributes to maximize return on investment
  • PURPOSE is to provide a common framework for interoperability & re-use in multiple customer implementations

• Key ATTRIBUTES:
  • Common lexicon
  • Crisp description of available network infrastructures
  • Crisp description of common/re-usable components
  • Visibly re-usable architecture drawings
Airplane systems have unique networking, computing, security, certification and physical operating requirements that makes bringing them together as a system of systems a daunting challenge.
On-Board Imperative Architecture Context

- On-Board Imperative Architecture is a sub-set of Global Architecture
  - On-board with focus on airplane aspects only
  - Imperative with focus on reference drawings & top 6 components

Global e-Enabled Architecture

- Applications
  - Passenger Broadband
  - Boeing Cabin Apps
  - Gold Flight Care Operations
  - Maintenance Apps
  - Airline Apps

- Services
  - Wide Area Network (WAN)
  - Local Area Network (LAN)

- Networking
  - Comm Mgmt
  - Network Mgmt
  - Networking

- Software Services
  - CNAS
  - Card-level

- Equipment
  - Core
  - Network Controller

On-Board Architecture Scope

Airplane-wide Networks

Air-to-Ground

On-Board Architecture

Common Implementation Drawings

ONLY 12 Drawings Total

Component Description

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On-Board Imperative Architecture Elements

- Total Architecture in 12 Drawings
- Reference Architecture
  - Network architecture
  - Component and Service Layers
  - Name mapping between reference and implementation
- Re-Usable Implementation Drawings
  - Integrated Modular (IMA) Version 1
  - IMA Version 2
  - Component based (federated)
- Component Descriptions with: Name, Owner, Description & Roadmap
  - Top six components selected for current year
On-Board Reference-Level Network Architecture

- Provides common drawing for all implementations and programs
- Shows top-level application and service domains
- Shows each reference component and their inter-relationships
## Component Directory & Service Layers

- Provides directory of re-usable services and components
- Portrays appropriate layer for service or component
- Architecture does not include the applications layer

<table>
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<tr>
<th>Applications</th>
<th>Passenger Broadband Applications</th>
<th>Boeing Cabin Applications</th>
<th>Voice Services</th>
<th>Flight Operations Applications</th>
<th>Maintenance Applications</th>
<th>Airline Applications</th>
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<td>Network Management</td>
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<td></td>
<td>Network Control Services</td>
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<td>Communications Services</td>
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<tr>
<td>Components</td>
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<tr>
<td>Hardware Implementations</td>
<td>FSM</td>
<td>AIM</td>
<td>EGM</td>
<td>CWLU</td>
<td>NFS</td>
<td>ODN Controller</td>
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<tr>
<td>Packaging Architecture</td>
<td>Integrated Modular</td>
<td>Component Based e-Enabled</td>
<td>Next Gen Integrated Modular</td>
<td>Other</td>
<td></td>
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</tbody>
</table>
Reference to Implementation Mapping & Drawing List

- Provides name lookup to map reference component names to one or more implementation component names.

- Provides configuration Management for all drawings with release versions and date.

### List of Drawings

<table>
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<th>Reference Architecture Drawings</th>
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<th>RA-2</th>
<th>RA-3</th>
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<th>Component Drawings</th>
<th>CD Version</th>
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<td>CD-1. Open Data Network Controller</td>
<td>CD-1: T.003-31596</td>
</tr>
<tr>
<td>CD-2. Terminal Wireless LAN Unit</td>
<td>CD-2: T.003-31596</td>
</tr>
<tr>
<td>CD-3. Application File Server</td>
<td>CD-3: T.003-31596</td>
</tr>
<tr>
<td>CD-4. Available Interface Services</td>
<td>CD-4: T.003-31596</td>
</tr>
<tr>
<td>CD-5. Network Manager</td>
<td>CD-5: T.003-31596</td>
</tr>
<tr>
<td>CD-6. On-board Authentication Service</td>
<td>CD-6: T.003-31596</td>
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<table>
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<tr>
<th>Common Implementation Drawings</th>
<th>CID Version</th>
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<td>SD-1. Common Core Network V1</td>
<td>SD-1: T.003-31596</td>
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<tr>
<td>SD-2. Common Core Network V2</td>
<td>SD-2: T.003-31596</td>
</tr>
<tr>
<td>SD-3. Common Component Based</td>
<td>SD-3: T.003-31596</td>
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Re-Usable Implementation Drawings

- Provides re-usable implementation drawings
- Provides Boeing projects with starting point to build from
- Allows mapping between project-centric implementation drawings and reference architecture
Program Implementation of the On-Board Imperative Architecture

- Reference Architecture Drawings (9)
- Common Implementation Architectures Drawings (3)
- Program owned Detailed Implementation Views (multiple)
Multiple Hardware Implementation

• Architecture is hardware agnostic

• Supports IMA solutions

• Supports federated component based solutions
On-Board Open Data Network Integrated Modular Implementation

• Rockwell Collins “Core Network” provides network and computing capabilities or “Network in a Box”
  • Highly-integrated, and ruggedized electronics cabinet
  • Houses ARINC 763 & ARINC 664 functionality
  • Significant weight, space & power savings over stand-alone LRUs
  • Utilizes commercial open standards
  • Basic offering on 787 Dreamliner

• Contains
  • Avionics Interface Module – provide a gateway function between the information services sub-network and avionics
  • Ethernet Gateway Module - provides standard protocols for routing, network services, IP multicasting, quality and class of service and network management over 6 internal and 18 external 10/100 base-T Ethernet ports
  • File Server Module – provides general purpose processing with 1.2 Ghz Pentium III Intel processor, 1 GB ECC dynamic memory & 40 GB Hard disk drive
  • Four open slots - provisioned for additional File Server Modules
  • Internal AC power - supply with battery back-up
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- Electronic Logbook, Accurate performance calculations & paperless flight deck driving operational efficiency

Airplane Health Management
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Integrated Materials Management
- Supply chain management, warehousing, inventory control and “As Flying Configuration”

MyBoeingFleet.com
- Web based flight planning, chart distribution and crew management

Airline Flight Operations
- Web based system provides rapid access to technical support information

Maintenance Performance Toolbox
- Web based system provides rapid access to technical support information

Integration and Connectivity
Boeing Class 3 Electronic Flight Bag

Over 1000 airplanes sold in production and retrofit

- The Boeing Electronic Flight Bag (EFB) is an integrated system and service which provides enhanced flight deck information management and business process automation capabilities for pilots
- Application software and data
- Flight deck display device
- Aircraft system integration and installation
- Software, systems and processes for moving and managing information to and from the flight deck
- End-user support

*Increases operational efficiency, reduces costs, improves safety, enhances security*
EFB Applications

Application Manager
Weather (future app)
Terminal Charts
Airport Moving Map
Enroute Moving Map (future application)

Onboard Performance
Fault Reporting and eLogbook
eDocuments Browser
Data/Comm Manager (future application)
Video Surveillance
Airplane Health Management

30% of available airplanes enrolled since 2005 introduction

- A hosted software application combining data and information into an integrated decision support tool
- Designed to improve airplane availability while providing Maintenance and Engineering efficiencies.
- Users include:
  - Maintenance Controllers
    - Real-time fleet management
  - Engineers
    - In-depth analysis and trending
  - Mechanics
    - Advance awareness of in-bound airplane health

Real-time “fix or fly” decision support
Maintenance Performance Toolbox

- An integrated suite of hosted software applications
- Solutions are designed to dramatically improve the efficiency and capabilities of your Maintenance and Engineering staff
  - Find critical information faster
  - Collaborate internally, with partners and Boeing
  - Control your content
  - Raise level of proficiency through on-demand training

Electronic performance support system
e-Enabled Products Working Together

Faults and Data

Electronic Log Book (ELB)

Cabin Log Book

Flight Schedule

Electronic Flight Bag

Flight Operations Quality Assurance (FOQA)

In Service Data Program

Reliability Data

Decision Support (AHM)

Work Order

Maintenance Planning System

Maintenance Opportunity

Materials Management

Scheduled Maintenance

Document Management System

Reference Data

ERP

Demand Signal
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787 is Production Designed, Equipped and Delivered e-Enabled Ready
The 787 is the Most Technically Advanced Jetliner Ever

- e-Enabling technologies are a key
- These technologies give the 787 a competitive advantage by
  - Improving operational efficiencies
  - Reducing maintenance costs
  - Dramatically improving the traveling experience for passengers

The flight deck in the 787 Dreamliner will include the Electronic Flight Bag, which features an electronic logbook and leverages the airplane's satellite connections. The logbook automatically provides reports to airline maintenance teams, allowing mechanics to better plan repairs and pre-position parts prior to airplane arrival.
The e-Enabled 787

- Chris Kettering, e-Enabled program director for Boeing Commercial Airplanes
  - "It wasn't a single specific technology that brought us here; it was the results of a series of advances that gave us an environment the whole world could leverage,"
  - "We're about to see a similar revolution on board the 787 and other fully e-Enabled airplanes."
- Dan Moore, 787 manager of Avionics e-Enabling
  - “The benefit in allowing the airline back-office team to remotely deploy software, parts, data, charts and manuals to airplanes with minimal hands-on mechanic involvement is clear”
The e-Enabled 787 Leverages SOSs

- Boeing is seeking to deploy new technologies and products on the Dreamliner
  - Electronic documents
  - High-bandwidth connectivity
  - Electronic Flight Bag
  - Wireless Ramplink
  - Jeppesen electronic charts
  - Boeing Digital Technical Documents
  - Online support via MyBoeingFleet.com

- These independent products are highly integrated with the onboard maintenance, dataload and crew information systems
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Executive Summary

Gold Care
A golden opportunity for our customers to become lower-cost carriers. Guaranteed.
GoldCare simplifies aircraft ownership by reducing cost & risk throughout the 787’s lifecycle

Qualitative and Quantitative Benefits

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<tr>
<th>Acquisition</th>
<th>Operation</th>
<th>Transition</th>
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<tbody>
<tr>
<td>Enables Favorable Financing</td>
<td>Guarantees Schedule Reliability</td>
<td>Preserves Asset Values</td>
</tr>
<tr>
<td>Minimizes Infrastructure</td>
<td>Ensures Predictable Costs</td>
<td>Reduces Transition Times</td>
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<tr>
<td>Eliminates Inventory Costs</td>
<td>Transfers Risk to Boeing &amp; Partners</td>
<td>Ensures Records Accuracy</td>
</tr>
<tr>
<td>Allows Quicker Introduction</td>
<td>Increases Focus On Core Business</td>
<td>Global Mx Plan Acceptance</td>
</tr>
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</table>
A New Approach in the Industry
787 Integrated Maintenance & Materials

Traditional

- Inefficient
- Redundant
- Expensive

GOLDCare

- Efficient Optimized Infrastructure
- Value Chain Alignment

Airlines

MROs

Manuals
Processes
Training

Boeing

Suppliers

Tools, GSE
Facilities

Inventory

Boeing

MROs

Suppliers

Manuals
Processes
Training

Tools, GSE
Facilities

Inventory

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An e-Enabled solution linked world wide

- 787 collects and transmits data
- Boeing converts data to knowledge
- Knowledge shared with Customer, MRO’s, & Suppliers

GOLDCARE Ops Center

Boeing Hosted I.T. System

MRO Partners / Suppliers

Airlines

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Typical airline operating environment

- Local On-Site Support
- Scheduled Event Planning
- Scheduled Overnight Maintenance
- Maintenance Control
- Unscheduled Maintenance
- Airline Operations Control
- Maintenance Planning
- Production Planning
- Scheduled Maintenance
- Component Overhaul
- Boeing
- Line Maintenance
- Base Maintenance
- MRO
- Integrated Materials Management
- Inventory Provisioning
- Supplier Management
- Logistics

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GoldCare Operating Environment

- Line Maintenance
  - Local On-Site Support
  - Scheduled Event Planning
  - Scheduled Overnight Maintenance
  - Maintenance Control
  - Unscheduled Maintenance
- Airline Operations Control
- Airline
- Maintenance Planning
- Production Planning
- Scheduled Maintenance
- Component Overhaul
- Boeing GOLD CARE
  - GOLD CARE MROs
  - GOLD CARE Suppliers
- Logistics
- Supplier Management
- Inventory Provisioning
- Integrated Materials Management

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GoldCare Key Messages

GoldCare simplifies airplane ownership

- Boeing manages GoldCare, integrates it and guarantees it
- GoldCare provides guarantees to help reduce cost and risk
- GoldCare is a turnkey solution that offers predictable costs

GoldCare enhances airplane values and lowers cost

- GoldCare’s centrally managed program standardizes quality, enhancing residual value and reducing transition costs
- Boeing partners with recognized MRO and 787 OEM suppliers
- GoldCare airplanes may qualify for more attractive financing
- GoldCare lowers infrastructure and introduction costs

GoldCare helps customers address industry change

- GoldCare responds to customer requirements and industry trends
- Parts inventory cost and risk is shifted from customer to supplier
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