Flight Path Management – Thinking Outside The “Boxes”
Paul D Maher | 787 Chief Technical Pilot
8 March 2017
What do we do?

Design Airplanes
Design Systems
Build Airplanes
Write Procedures
Provide Operational Data
Support Services
Is that all?
Our shared responsibilities – Where do they meet?

- Boeing
- Regulators
- Operators
- Industry

Safety
Efficiency
Reliability
Training
Operational Use of Flight Path Management Systems

18 Recommendations from the Final Report of the Flight Deck Automation Working Group

- Manual Flight Operations
- Autoflight Mode Awareness
- Information Automation
- FMS Documentation, Design, Training, and Procedures for Operational Use
- Verification and Validation for Equipment Design
- Flight Deck System Design
- Guidance for Flightcrew Procedures for Malfunctions
- Design of Flightcrew Procedures
- Operational Policy for Flight Path Management
- Pilot-Air Traffic Communication and Coordination
- Airspace Procedure Design
- Flight Deck Design Process and Resources
- Pilot Training and Qualification
- Instructor/Evaluator Training and Qualification
- Regulatory Process and Guidance for Aircraft Certification and Operational Approvals
- Flight Deck Equipment Standardization
- Monitor Implementation of New Operations and New Technologies
- Methods and Recommended Practices for Data Collection, Analysis and Event Investigation That Address Human Performance and Underlying Factors
Crew Interface
- Design Processes
- Improvements
- Simplification of Complex Tasks

FMC
- Blind Faith
- Procedures & Management

Automation
- How much is too much?
- Reversion to Manual Handling

Training
- Training Goals
- New Generations
- Areas of Emphasis
Crew Interface Design
# Design - Methods & Tools

<table>
<thead>
<tr>
<th>Understanding the User</th>
<th>• Surveys &amp; Questionnaires</th>
<th>User Working Groups In-Flight Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Ethnographic Studies</td>
<td></td>
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<tr>
<td>Analytics</td>
<td>• Mission &amp; Function Analysis</td>
<td>Information Analysis What If Analysis</td>
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<tr>
<td></td>
<td>• Workload Assessment</td>
<td></td>
</tr>
<tr>
<td>Modelling</td>
<td>• 2-D &amp; 3-D CAD Models</td>
<td>3-D Human Modeling Cognitive Models</td>
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<tr>
<td></td>
<td>• Perceptual Models</td>
<td></td>
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<tr>
<td>Testing and Prototyping</td>
<td>• Desktop Prototyping</td>
<td>Mission Simulation Ground &amp; Flight Testing</td>
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<tr>
<td></td>
<td>• Mockups &amp; Prototyping Rigs</td>
<td></td>
</tr>
<tr>
<td>Regulatory</td>
<td>• Design Philosophy</td>
<td>Regulations/Advisories Lessons Learned</td>
</tr>
<tr>
<td></td>
<td>• Industry Standards</td>
<td></td>
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</table>
Airplane Design is a Myriad of Constraints

Interface Design
Crew Interface – Evolution
Mission Statement – Flight Deck Human Factors

“Leverage technology to improve visual acquisition of information to improve situational awareness”.

<table>
<thead>
<tr>
<th>Situational Awareness has three main components:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Systems</strong></td>
</tr>
<tr>
<td>• Continual monitoring and reporting of changes to aircraft systems, configuration, energy and performance</td>
</tr>
<tr>
<td><strong>Spatial</strong></td>
</tr>
<tr>
<td>• Awareness of aircraft’s geographical location, projected flight-path, weather, terrain, ATC, route and other aircraft.</td>
</tr>
<tr>
<td><strong>Flight Deck</strong></td>
</tr>
<tr>
<td>• Awareness of the condition, workload and mental model of other crewmembers</td>
</tr>
</tbody>
</table>
Spatial Situational Awareness Improvements
Large Displays
PFD Improvements
Head Up Displays
Vertical Situation Display
Systems Situational Awareness Improvements
Engine Indicating and Crew Alerting System (EICAS)
Electronic Checklist

NORMAL MENU  RESETS  NON-NORMAL MENU

预制检查（PREFLIGHT）

- OXYGEN..........................SET
- PASSENGER SIGNS..................SET
- FLIGHT INSTRUMENTS...............SET
- AUTOBRAKE..........................RTO
- PARKING BRAKE......................SET

√ FUEL CONTROL SWITCHES............CUTOFF
Central Flight Deck Management interfaces that serve all three elements
Class III Electronic Flight Bag

**PERFORMANCE - TAKEOFF**

<table>
<thead>
<tr>
<th>ARPT INFO</th>
<th>ARPT</th>
<th>ICF</th>
<th>TO (10%)</th>
<th>RTG</th>
<th>CALC</th>
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<tr>
<td>RWY</td>
<td>13R</td>
<td></td>
<td>MAX</td>
<td>ATM</td>
<td></td>
</tr>
<tr>
<td>INTX</td>
<td>MD INTX</td>
<td></td>
<td>S</td>
<td>FLAP</td>
<td></td>
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<tr>
<td>COND</td>
<td>MET</td>
<td></td>
<td>OFF</td>
<td>A1</td>
<td></td>
</tr>
<tr>
<td>WIND</td>
<td>100/05 KT</td>
<td></td>
<td>OPTIMUM</td>
<td>V1</td>
<td></td>
</tr>
<tr>
<td>QNH</td>
<td>2892 IN HG</td>
<td></td>
<td>ALTERNATE</td>
<td>CG</td>
<td></td>
</tr>
</tbody>
</table>

**Takeoff Weight**

<table>
<thead>
<tr>
<th>WT AND BALANCE</th>
<th>396000 LB</th>
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</thead>
<tbody>
<tr>
<td>CG (%)</td>
<td>25</td>
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</tbody>
</table>

**787-8 / GEnx-64B**

<table>
<thead>
<tr>
<th>FLAP</th>
<th>ACCEL HT</th>
<th>V1</th>
<th>119 KT</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1000 ft ACL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RWY/INTX</td>
<td>13R</td>
<td></td>
<td>VR</td>
</tr>
<tr>
<td>TOGW</td>
<td>KG/M TO 10 SEL TEMP</td>
<td></td>
<td>V2</td>
</tr>
<tr>
<td>396000 LB</td>
<td>95.2</td>
<td>14 C</td>
<td>VREF</td>
</tr>
</tbody>
</table>

*EAR Data ECCN 9E991*
# Datalink Communications Interface

<table>
<thead>
<tr>
<th>ATC</th>
<th>FLIGHT INFO</th>
<th>COMPANY</th>
</tr>
</thead>
<tbody>
<tr>
<td>REVIEW</td>
<td>MANAGER</td>
<td>NEW MESSAGES</td>
</tr>
<tr>
<td>COMPANY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLIGHT INITIALIZATION</td>
<td>DELAY REPORTS</td>
<td>WEATHER REQUESTS</td>
</tr>
<tr>
<td>REQUEST AUTO-INITIALIZATION</td>
<td>DEPARTURE REPORT</td>
<td>RE-CLEARANCE</td>
</tr>
<tr>
<td>REQUEST FMC DATA</td>
<td>DIVERSION</td>
<td>GATE ASSIGNMENT</td>
</tr>
<tr>
<td>WEIGHT &amp; BALANCE</td>
<td>ETA REPORT</td>
<td>MAINTENANCE REPORT</td>
</tr>
<tr>
<td>ATIS</td>
<td>ARRIVAL REPORT</td>
<td>MISCELLANEOUS CODES</td>
</tr>
<tr>
<td>CLEARANCE</td>
<td>MESSAGE TO GROUND</td>
<td>SITUATION</td>
</tr>
<tr>
<td>FLIGHT RELEASE</td>
<td>VOICE CONTACT REQUEST</td>
<td>FLIGHT TIMES</td>
</tr>
<tr>
<td>NOTAMS</td>
<td></td>
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FMC Blind Faith

Trust me – I will never let you down
I always have the answer
I fail less than all your other systems

FMC Flight Plan Loss

Abeam Points May Cause Route Deactivation

Takeoff Data Uplink Anomalies When Runway Intersections Are Used

Flight Recorder Anomaly due to FMC Flight Complete Logic

Uncommanded Selection of Glide Slope to OFF When Activating a Route

Spare FMC Not Updating

FMC Route Dump
Good FMC Procedures & Management

- Robust verification procedures
- Enhance FMC procedures
- Integrate into training
- Read FMC bulletins carefully!
- Improvements?
Design Drivers

• Simplicity
• Commonality
• Automation
• Integration
• Envelope Protection
• Redundancy
• Value
Automation
Automation – Boeing Perspective

Understand!

- Modes
- Alerting

Optimize the tools for the best protection of parameters

- Understand the mode limitations

Monitor and be prepared

- Announce and acknowledge mode changes

Appropriate Level?

- Think about stepping down a level before disconnecting
  - Reconnect or go back to the higher level if you can

Provide crews with specific guidance and training on automated systems

Improvements?
How much is too much?

Secondary Mode Autopilot – 777-9X

777 & 787

- Malfunctions leading to Secondary Flight Control Mode
- Lose all envelope protections
- Lose Autopilot

777-X

- Secondary Mode Autopilot
- Limited Autopilot Function – HDG, VS and ALT
- Reduce workload in Secondary
- Terminal manoeuvering

What could possibly go wrong?

Decision made to only use in level flight

EICAS advisory
Manual Handling

Automation is not the enemy

Manual handling in a modern jet:

• Needs to be well trained
• A reversion mode
• An intervention
• Trained in context
## Simplification of Complex Tasks

### Automation Improvements
- Envelope Protection
- LNAV, VNAV, SMAP, BTE,
- Information Automation (EFB, Onboard Network).

### Continuous improvement in procedures
- AIRSPEED UNRELIABLE
- SMOKE FIRE FUMES
- ENG FAIL
- FUEL LEAK

### Reducing keystrokes per task
- Accessing menus
- Datalink functions

### Reducing manual calculation functions
- FMC Cold WX temp compensation

### Integration of new systems / regulatory requirements
- RNP, LPV, ADS-B
Integrated Approach Navigation
777-9 – Crew Interface Improvements

- Touchscreens
- Brake to Exit
- ADS-B ground traffic on airport map
- HUD Perspective Runway
- Class 2 EFB Integration
Thinking Outside The "Boxes"
A Balance Between Skills

Things that tend to keep you in the “boxes”

Rule-based Skills (Procedures)
Automation Skills
Technical Skills (Manual Handling Skills)

Things that allow you to go outside the “boxes”

Knowledge-based Skills
Non-Technical Skills (CRM)
Communication Skills

Ability Training
We can’t write procedures for everything

Malfunction probability of 10⁻⁹

We don’t write checklists for multiple system failures

**FCOM – QRH Checklist Instructions**

While every attempt is made to supply needed non-normal checklists, it is not possible to develop checklists for all conceivable situations. In some smoke, fire, or fumes situations, the flight crew may need to move between the Smoke, Fire or Fumes checklist and the Smoke or Fumes Removal checklist. In some multiple failure situations, the flight crew may need to combine the elements of more than one checklist. In all situations, the captain must assess the situation and use good judgment to determine the safest course of action.

**Flight Crew Training Manual**

**Situations Beyond the Scope of Non-Normal Checklists**

It is rare to encounter in-flight events which are beyond the scope of the Boeing recommended NNCs. These events can arise as a result of unusual occurrences such as a midair collision, bomb explosion or other major malfunction. In these situations the flight crew may be required to accomplish multiple NNCs, selected elements of several different NNCs applied as necessary to fit the situation, or be faced with little or no specific guidance except their own judgment and experience. Because these situations are rare, it is not practical or possible to create definitive flight crew NNCs to cover all events.
Boeing - Crew Procedures Continuous Improvement

- Solidify Procedures & Alerting philosophy
- Guard against “over-proceduralizing”
- Encourage some flexibility
- Simplified English
- Improve EICAS and ECL Logic
Skills Development

A holistic approach to training

A solid, consistent procedural environment

Development and assessment of Non-Technical Skills, CRM and TEM
## Non Technical Skills

<table>
<thead>
<tr>
<th>Skill Area</th>
<th>Key Skills</th>
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<tr>
<td><strong>TEAMWORK</strong></td>
<td>• Ability to manage relationships to ensure effective participation in the completion of tasks</td>
</tr>
<tr>
<td><strong>LEADERSHIP AND MANAGEMENT SKILLS</strong></td>
<td>• Ability to manage tasks through recognition, support and consideration of individuals and the team as a whole</td>
</tr>
<tr>
<td><strong>PROBLEM SOLVING AND DECISION MAKING</strong></td>
<td>• Ability to make decisions using analytical, rule and experience-based strategies</td>
</tr>
<tr>
<td><strong>SITUATIONAL AWARENESS</strong></td>
<td>• Ability to gather, interpret and understand information relating to the current and future operational environment</td>
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Training
Training Goals

Resilience Development
- Expecting the unexpected
- Recognize when a “box” or a procedure is not working for you
- Startle & Surprise
- Manual Handling

Evidence Based Training
- Making content relevant
- Recognizing probabilities, risks and threats

Operational Context & Scenario Based
- Systems understanding vs Systems Knowledge
- Phase of flight systems training
- Themes for scenarios

Immersion Training
- Extended Envelope & UPRT

Tools to assess Non-Technical Skills, CRM and TEM
- Behavioral Markers
The New Generation of Pilots
Training – Areas of Emphasis

- Communication, CRM and TEM – Behavioral Markers
- Mode Awareness - Vertical & Lateral
- Energy Management
- Difference between guidance and control
- Procedures for Manual Flight Operations
- Specifying PF, PM roles and responsibilities clearly
- Formalize monitoring and cross-checking procedures
- Dealing with automated system failures or partial failures
- Pilot Intervention Skills
Changing the Training Paradigm

- Move away from the “task patchwork”
- Operational Context
- Holistic approach to Systems, Phase of Flight and CRM
- Focus on Resilience
Old Generation vs New Generation

Stop Comparing!

Don’t stigmatize Automation and the Magenta Line

Different but equally important skill sets in each generation
• Boeing does more than build airplanes
• We have a vested interest in the safe outcome of your flight
• We need your help and feedback to make airplanes better
• We can be part of ...........
Managing Your Flight Path

Thank You