BOEING FLIGHT DECK DESIGN PHILOSOPHY

Harty Stoll
Boeing Commercial Airplane Company
FLIGHT DECK DESIGN GOALS

747-400

The design of the 747 flight deck is based on the recent successful 757/767 programs as well as on the experience gained from millions of flight hours on Boeing commercial jet transports. Special emphasis is placed on the latest digital technology and control/display integration to provide uncluttered instrument panels, improved reach and scan capability, and optimized crew workload. The result is enhanced safety and productivity through improved crew comfort, performance, and workload optimization.

GOALS

- Enhanced Safety
- Improved Operational Capabilities
- Performance/Workload Optimization
- Increased Reliability/Maintainability
- Reduced Operating Cost
- Improved Crew Comfort

TECHNOLOGY

- Digital Computers/Microprocessors
- Integrated Displays
- Integrated Flight Management
- CDU's
- Laser Gyro Inertial Reference
- Advanced System Monitoring
- Central Maintenance System with Standardized BITE
FLIGHT DECK DESIGN CONSIDERATIONS

INDUSTRY

- AIRLINE INPUT
- FAA STUDIES
- NASA STUDIES
- NTSB
- SAE RECOMMENDATIONS
- ATA
- FLIGHT SAFETY FOUNDATION
- COMPETITIVE AIRFRAME MANUFACTURE
- SYMPOSIUMS
- WORKSHOPS
- AIAA
- ARINC
- RTCA
- ICAO
- ALPA, IFALPA, APA
- MISC. STUDIES (1969 UAL-ALPA)
- ASRS
- MILITARY - AIR FORCE, NAVY, ETC.
- HUMAN FACTOR ORGANIZATIONS

BOEING

- ACCIDENT/INCIDENT DATA
- BOEING FLIGHT TEST
- CREW TRAINING
- BOEING IR & D
- CUSTOMER SERVICE UNIT
- DATA ON EXISTING BOEING MODELS
- RELIABILITY AND MAINTAINABILITY
- QUESTIONNAIRES TO AIRLINES

Functions Allocated to Crew

- Guidance
- Control
- Separation
- Navigation
- Systems Operation
DESIGN PHILOSOPHY

- CREW OPERATION SIMPLICITY
- EQUIPMENT REDUNDANCY
- AUTOMATED FEATURES

Simplicity Through Design Refinement
Wing Fuel Tank Development—Example

<table>
<thead>
<tr>
<th></th>
<th>Original 3-Tank</th>
<th>5-Tank Proposal</th>
<th>Revised 3-Tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wing Structure Weight</td>
<td>Base</td>
<td>Large Decrease</td>
<td>Large Decrease</td>
</tr>
<tr>
<td>Fuel System Weight</td>
<td>Base</td>
<td>Moderate Increase</td>
<td>Small Increase</td>
</tr>
<tr>
<td>Total Weight</td>
<td>Base</td>
<td>Moderate Decrease</td>
<td>Large Decrease</td>
</tr>
<tr>
<td>Crew Operation</td>
<td>Simple</td>
<td>More Complex</td>
<td>Simple</td>
</tr>
</tbody>
</table>

Jan '78 | Jun '79 | Jan '80
REDUNDANCY
(EXAMPLES)

- TRIPLEX
  - INERTIAL REFERENCE SYSTEMS
  - ELECTRONIC FLIGHT INSTRUMENT SYMBOL GENERATION
  - AUTOMATIC FLIGHT CONTROL AND FLIGHT DIRECTOR SYSTEM
  - ILS RECEIVERS
- DUAL
  - FLIGHT AND ENGINE INSTRUMENTS
  - FLIGHT MANAGEMENT COMPUTER
  - NAVIGATION RADIOS
  - COMMUNICATION RADIOS
  - AIR DATA SYSTEMS
  - WARNING AND CAUTION ALERTS

AUTOMATION
(WHAT DOES IT MEAN?)

- SUBSYSTEM AUTOMATION
  - REDUCE CREW WORKLOAD (3 TO 2 MAN CREW)
  - REDUCE CREW ERROR
- GLASS COCKPITS
  - REDUCE CREW ERROR AND ACCIDENTS
  - IMPROVE PILOT SCAN
  - REDUCES COST
- FLIGHT MANAGEMENT COMPUTERS
  - PROVIDE MAP INFORMATION
  - REDUCE FUEL BURN
  - REDUCE CREW ERROR
- AUTOPILOT/AUTOThROTTLE
  - REDUCE WORKLOAD
  - REDUCE CREW ERROR
Boeing Flight Deck Design Committee
Examples of Accident Data Reviewed

- Subsystem management accidents—worldwide air carriers 1968-1980

<table>
<thead>
<tr>
<th>Accident Related Cause</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew omitted pitot heat</td>
<td>Auto on with engine start</td>
</tr>
<tr>
<td>Wrong position of standby power switch</td>
<td>Automated standby and essential power</td>
</tr>
<tr>
<td>Flight engineer and captain conducted unauthorized troubleshooting</td>
<td>Simplified systems delete maintenance functions</td>
</tr>
<tr>
<td>Electrical power switching not coordinated with pilots</td>
<td>Auto switching and load shedding—no crew action required</td>
</tr>
<tr>
<td>Flight engineer shut off ground proximity</td>
<td>Shut off on forward panel in full view of both pilots</td>
</tr>
<tr>
<td>Faulty fuel management</td>
<td>Auto fuel management with alert for low fuel, wrong configuration, and imbalance</td>
</tr>
<tr>
<td>No leading edge flaps on takeoff</td>
<td>Improved takeoff warning with digital computer</td>
</tr>
<tr>
<td>Confusion over correct spoiler switch position</td>
<td>Dual electric spoiler control</td>
</tr>
<tr>
<td>Crewman did not follow pilot's instruction</td>
<td>Full-time caution and warning system</td>
</tr>
<tr>
<td>Mismanaged cabin pressure</td>
<td>Dual auto system with auto switchover</td>
</tr>
</tbody>
</table>

Allocation of 747-200 Flight Engineer's Duties to 747-400 Flight Crew
SUBSYSTEM CONTROLS & INDICATION COMPARISON

747-400

NOTE: NAV AND COMM PANELS NOT INCLUDED

747 Procedure Comparison
CREW CAUSED ACCIDENTS VS. AUTOMATION

ALL ACCIDENTS THRU 1988
WORLDWIDE COMMERCIAL JET FLEET

AUTOMATION

ATTITUDE, HEADING HOLD, AUTOPILOT
VOR MODE ON AUTOPILOT
GO AROUND MODE
FLIGHT DIRECTOR
AUTOTHROTTLE
ALTITUDE HOLD AUTOPILOT
AUTO SPEED BRAKES
INERTIAL REFERENCE SYSTEM
VERTICAL SPEED AUTOPILOT
AUTOLAND
AUTO BRAKES
FLAP LOAD RELIEF
AUTO FUEL MANAGEMENT
AUTO GENERATOR MANAGEMENT
AUTO AIR CONDITIONING
AUTO PRESSURIZATION
AUTO STANDBY POWER
CONTROL WHEEL STEERING
FULL AUTOPILOT
FLIGHT MANAGEMENT COMPUTER (SINGLE)
GLASS COCKPIT
INERTIAL REFERENCE UNITS
ELECTRONIC ENGINE CONTROL
FLIGHT MANAGEMENT COMPUTER (DUAL)
LATERN & VERTICAL NAVIGATION AUTOPILOT
FULL AUTO SUBSYSTEMS
AUTO CAUTION & WARNING
QUIET/DARK COCKPIT
EFIS/EICAS
AUTO IGNITION
WINDSHEAR ALERT

AUTOMATION
(TH E GOOD AND BAD)

- THE PLUSES
  - SAFETY
  - ERROR REDUCTION
  - WORKLOAD REDUCTION
  - SIMPLIFIED CREW OPERATION
  - COST SAVINGS

- THE PROBLEMS
  - REDUCE CREW UNDERSTANDING
    (AUTO-MANUAL)
  - CREW OVERUSE REDUCING CREW FALL-BACK CAPABILITY
  - PILOT TRANSITION IN AND OUT OF AUTOMATIC AIRPLANES
  - BOREDOM
  - DESIGNER'S INTENT NOT TRANSMITTED TO PILOT