BOEING FLIGHT DECK DESIGN PHILOSOPHY

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FLIGHT DECK EVOLUTION

- EXTERNAL VISION
- WORKLOAD
- FAILURE MANAGEMENT
- PILOT INCAPACITATION
- FLIGHT MANAGEMENT COMPUTER & MAP
- AUTOMATED MONITORING
- INTEGRATED CAUTION AND WARNING
- QUIET DARK CONCEPT
- SIMPLIFIED CREW ACTION
- COLOR CRT DISPLAYS
- DEDICATED CREW REST AREA
- INCREASED REDUNDANCY
- CENTRALIZED MAINTENANCE COMPUTERS
- IMPROVED FLIGHT MANAGEMENT

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
- SYMPOSIAUS
- 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>
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<tbody>
<tr>
<td>Wing Structure Weight</td>
<td>Base</td>
<td>Large Decrease</td>
<td>Large Decrease</td>
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<tr>
<td>Fuel System Weight</td>
<td>Base</td>
<td>Moderate Increase</td>
<td>Small Increase</td>
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<tr>
<td>Total Weight</td>
<td>Base</td>
<td>Moderate Decrease</td>
<td>Large Decrease</td>
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<tr>
<td>Crew Operation</td>
<td>Simple</td>
<td>More Complex</td>
<td>Simple</td>
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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/AUTO THROTTLE**
  - REDUCE WORKLOAD
  - REDUCE CREW ERROR
Boeing Flight Deck Design Committee

Examples of Accident Data Reviewed
- Subsystem management accidents – worldwide air carriers 1968-1980

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

Allocation of 747-200 Flight Engineer’s Duties to 747-400 Flight Crew

On Ground
- 71% Remaining
- 22% Simplification
- 10% EICAS Monitoring
- 24% Automation

In-Flight
- 29% Tasks Eliminated Via
- 14% Simulation
- 8% EICAS Monitoring
- 2% Automation
747 Procedure Comparison
CREW CAUSED ACCIDENTS VS. AUTOMATION

ALL ACCIDENTS THRU 1988
WORLDWIDE COMMERCIAL JET FLEET

ATTITUDE, HEADING HOLD, AUTOPILOT
VOY MODE ON AUTOPILOT
GO AROUND MODE
FLIGHT DIRECTOR

AUTOTHROTTLE
ATTITUDE 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)
LATERAL & VERTICAL NAVIGATION AUTOPILOT
FULL AUTO SUBSYSTEMS
AUTO CAUTION & WARNING
QUIET/DARK COCKPIT

747 737 737 757/767
-100/-200 -300/-400

AUTOMATION
(THE 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