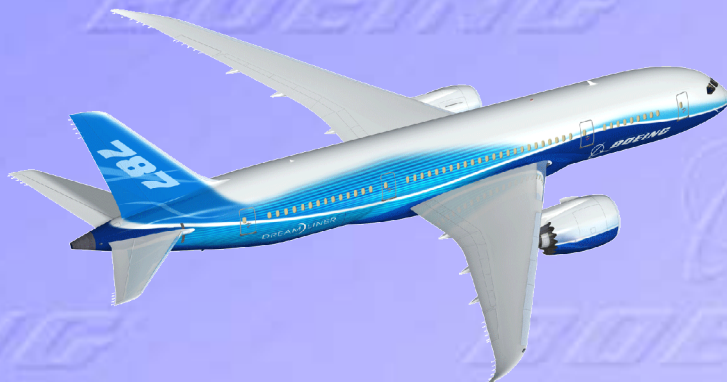




Datalink on the 787 Airplane

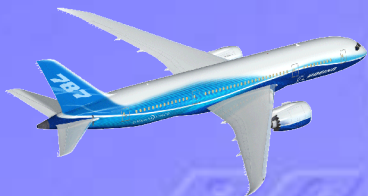


Gordon Sandell

ATN 2005

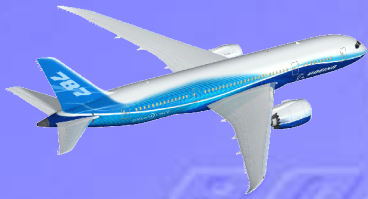
London

September 20, 2005



Discussion Points

- **Industry Trends/Directions**
- **787 Mission/Concept**
 - **Architecture**
 - **FANS Features**
 - **ATN Features**
- **Operator Interfaces**
 - **747 (MCDU-based)**
 - **777 (MFD-based)**
 - **787**
- **Operational Scenario**



What We're Discussing

- This presentation covers:
 - Addressed datalink to/from Avionics systems using traditional media (VHF, HF, SATCOM)
 - Emphasis on ATS (ATN in particular)
- What it doesn't address:
 - ADS-B/Elementary or Enhanced Surveillance
 - Datalinks used for functions like GLS
 - Ethernet-based systems using Gatelink and Connexion by BoeingSM
 - Dataload

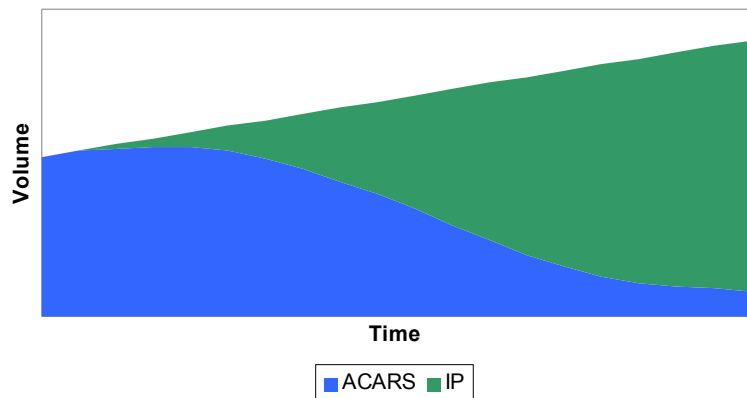


Long-Term Industry Datalink Trends

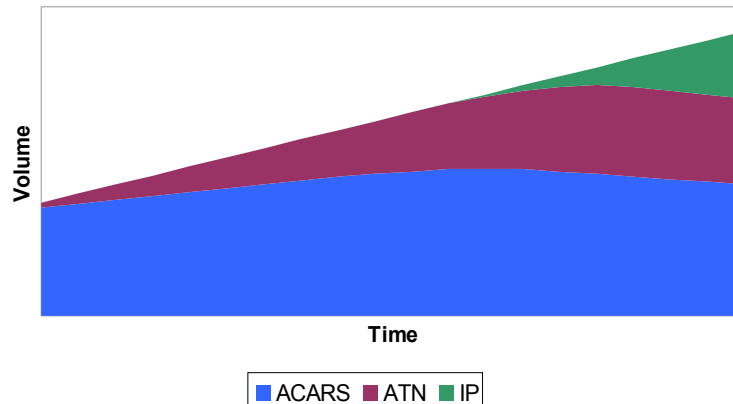
>90 % Traffic

<10 % Traffic

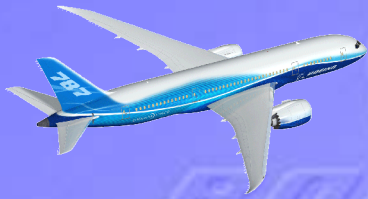
Airline Operational Control (AOC) Datalink Traffic



Air Traffic Services (ATS) Datalink Traffic

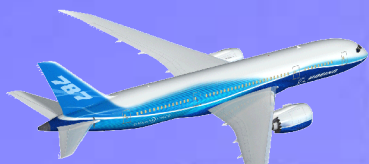


- AOC will move towards broadband IP, by-passing ATN
 - No industry consensus on architecture or standards yet
- ATS will migrate towards broadband IP, but not in the near future
 - ATN will be an interim step
 - Depends on AOC for standards, etc.
 - After performance proven in AOC trials
- ACARS and ATN will continue to exist for the foreseeable future
 - Broadband IP only after extensive standards work

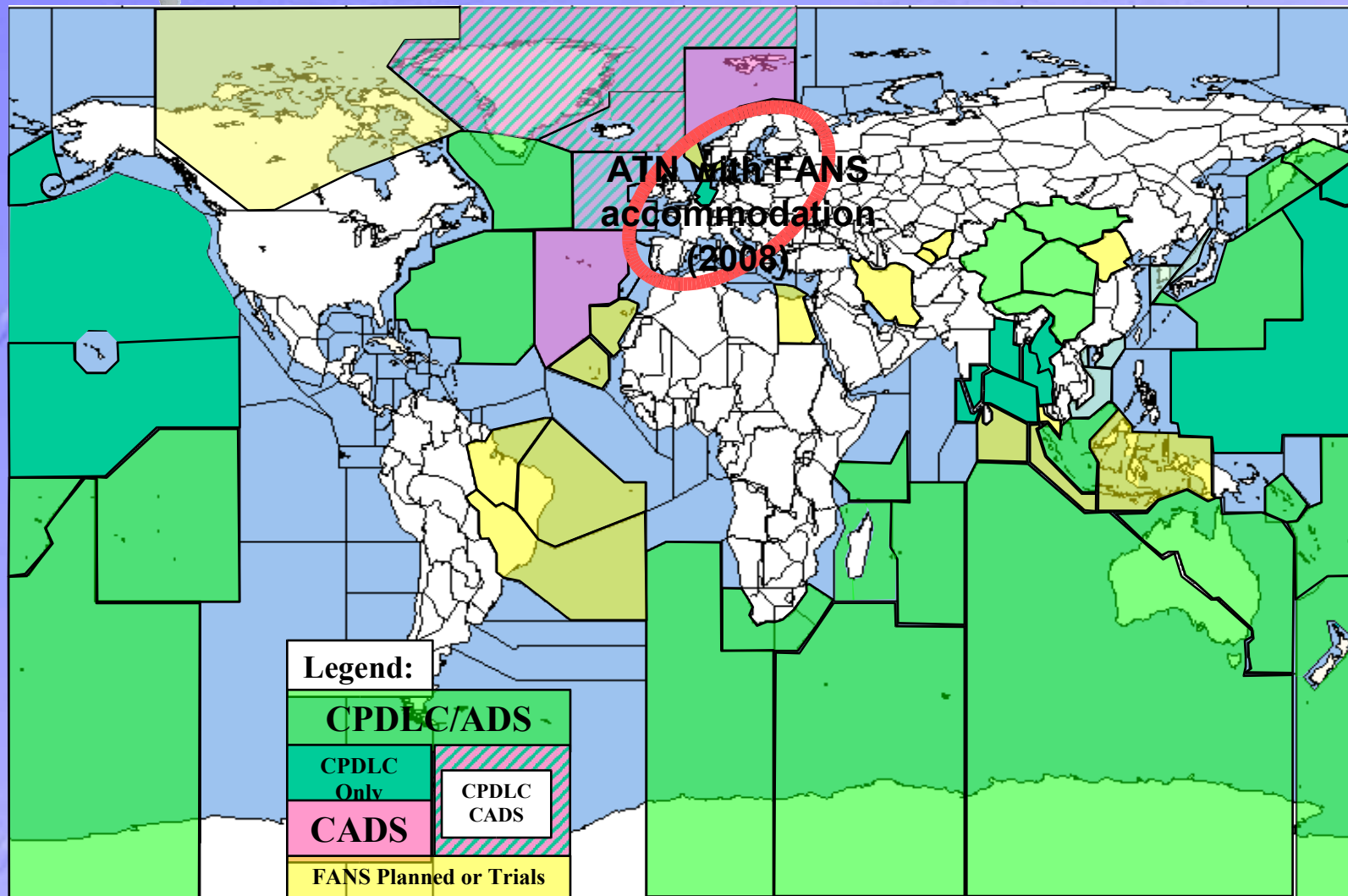


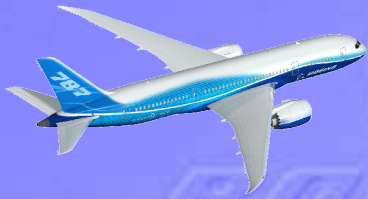
787 Mission

- **Long-range airplane**
 - **Intercontinental flight (8500NM range)**
 - **Continental→ Oceanic→ Continental airspace**
 - **Mixed ATC datalink capability (FANS/ATN) needed**
 - **2010+ environment**
 - **EU mandate**
 - **ATN program revival in US?**
 - **Continued long-term FANS operations**
 - **Broadband IP not in the immediate future**



Datalink Today (August 2005)



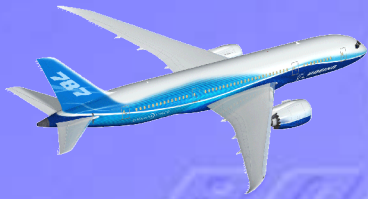


787 Datalink Concept

- Build on 777 capabilities
 - Design user interface for commonality with 777
- FANS as standard feature
 - Facilitates oceanic operations
- SARPS-compliant ATS application (ATN) as option
 - Baseline 1 CPDLC functionality
 - Meet EU incentives requirements
 - Build for future expansion outside EU area
 - Design for common operations
- User-programmable company datalink
- Flight Information (ARINC 623) datalink certified to appropriate integrity level (C) for major hazards
- Single operator interface design for ATS that minimizes user errors and provides optimum response capability

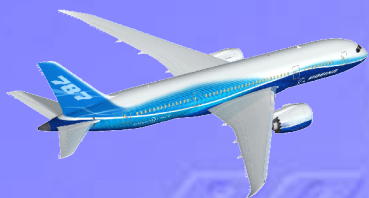
ATC	FLIGHT INFORMATION	COMPANY
REVIEW	MANAGER	NEW MESSAGES
ATC		
ALTITUDE REQUEST	WHEN CAN WE EXPECT	EMERGENCY REPORT
ROUTE REQUEST	VOICE CONTACT REQUEST	ATC REQUESTED REPORTS...
SPEED REQUEST	LOGON/STATUS	POSITION REPORT
CLEARANCE REQUEST		FREE TEXT MESSAGE
EXIT MENU		

ATC	FLIGHT INFO	COMPANY
REVIEW	MANAGER	NEW MESSAGES
ATC		
ALTITUDE REQUEST	WHEN CAN WE EXPECT	EMERGENCY REPORT
ROUTE REQUEST	VOICE CONTACT REQUEST	REQUESTED REPORTS...
SPEED REQUEST	FREE TEXT MESSAGE	CONDITIONAL CLEARANCES
CLEARANCE REQUEST	LOGON/STATUS	POSITION REPORT
MONITORING REPORT		
EXIT MENU		

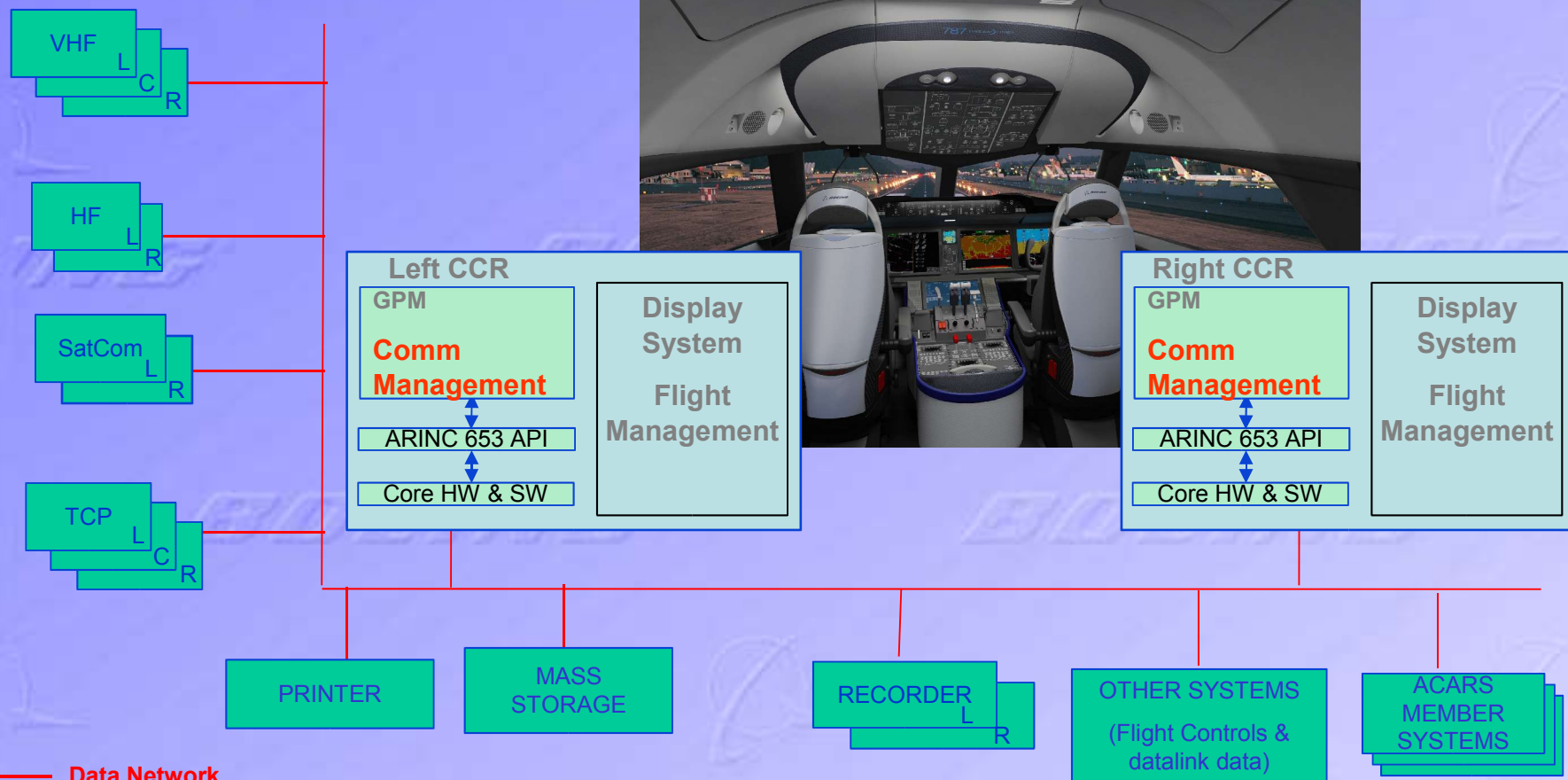


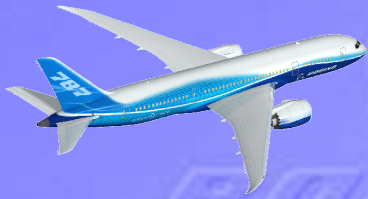
Communication Management Function - Overview

- Major Functions are:
 - Aircraft Communication Addressing & Reporting System (ACARS)
 - FIS, CPDLC, AFN, ADS, AOC/AAC
 - VHF, HF, and Satcom
 - Aeronautical Telecommunication Network (ATN)
 - CM, CPDLC, ADS
 - VDL Mode 2 and Satcom Data 3
 - Cockpit Datalink Displays
 - Datalink Recording (ED-112)
- Dual synchronized architecture
- Core CMF software shared with Honeywell CMU product
- Communication Management is a software application in an IMA environment
 - Common Computing System (CCS) with ARINC 653 API



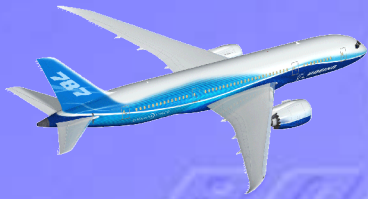
787 Communication Management Function Architecture





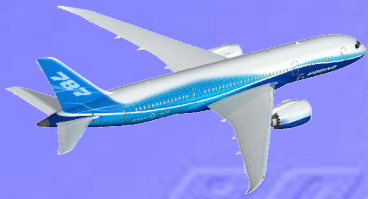
FANS-1 Datalink Functionality

- **CPDLC (aka TWDL) – DO-219 and DO-258A/ED-100A**
 - 183 uplink messages in DO-219 (182 implemented)
 - 80 downlink messages in DO-219 (75+ implemented)
- **ADS – ARINC 745/DO-212 and DO-258A/ED-100A**
 - Periodic, on-demand and event contracts
 - All groups supported
- **AFN – ARINC 622 and DO-258A/ED-100A**
 - Logon (contact) and contact (contact advisory)
 - Fully supported
- **ACF – ARINC 622 and DO-258A/ED-100A**
 - CRC and bit-to-hex conversion, etc.
 - Fully supported



FANS – Lessons Learned

- 787 FANS-1 operation similar to 777 with some enhancements
 - Active ATC Center on uplink displays
 - Loading of MCP and radio Tuning Control Panels (TCP)
 - Expanded FMC-loadable message set
 - Conditional clearance handling/display
 - Resolved use of NDBs
 - Treatment of ARINC 424 waypoints
 - Duplicate waypoint resolution
 - Position reporting of compulsory waypoints
 - Enhanced ADS management
 - AOA (ACARS over AVLIC)
 - Integrated with ATN



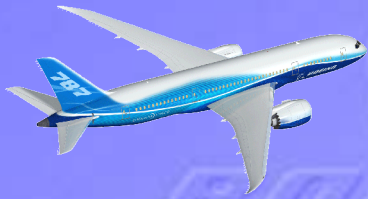
CPDLC Integration with FMF

- Use of FMS flight plan data for route downlinks
- Loading uplinks to FMS flight plan
 - Routes and route modifications
 - Direct clearances
 - Offset clearances
 - Crossing constraints
- Use of FMS data in reports
- Triggering of reports (passing waypoint, reaching/departing altitude)
- Validation of data in requests against route/nav data base
- Validation of uplinks against route/nav data base



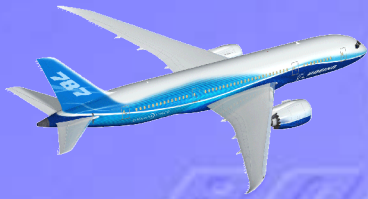
FMF-Loadable Uplinks

Msg#	Uplink Message Element	A340	747	777	787
46	CROSS position AT level			X	X
47	CROSS position AT OR ABOVE level			X	X
48	CROSS position AT OR BELOW level			X	X
49	CROSS position AT AND MAINTAIN level				X
50	CROSS position BETWEEN level AND level				X
51	CROSS position AT time	X	X	X	X
52	CROSS position AT OR BEFORE time	X	X	X	X
53	CROSS position AT OR AFTER time	X	X	X	X
56	CROSS position AT OR LESS THAN speed				X
58	CROSS position AT time AT level				X
59	CROSS position AT OR BEFORE time AT level				X
60	CROSS position AT OR AFTER time AT level				X
62	AT time CROSS position AT AND MAINTAIN level				X
64	OFFSET distance direction OF ROUTE		X	X	X
65	AT position OFFSET distance direction OF ROUTE				X
67	PROCEED BACK ON ROUTE				X
73	predepartureclearance		X	X	X
74	PROCEED DIRECT TO position		X	X	X
75	WHEN ABLE PROCEED DIRECT TO position			X	X
77	AT position PROCEED DIRECT TO position		X	X	X
79	CLEARED TO position VIA route clearance	X	X	X	X
80	CLEARED routeclearance	X	X	X	X
81	CLEARED procedure name			X	X
83	AT position CLEARED route clearance	X	X	X	X
84	AT position CLEARED procedure name				X
27	HOLD AT position MAINTAIN level INBOUND TRACK deg dir				X
28	HOLD AT position AS PUBLISHED MAINTAIN altitude				X



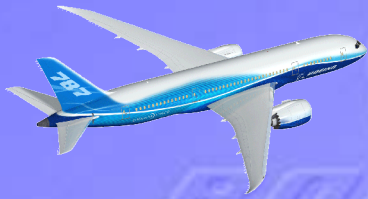
ADS integration

- **Delivers data requested by ATC ground system**
 - Periodic/Demand or Event-based
- **Most requested data comes from FMF**
 - Basic data (position, altitude, etc.)
 - Air and earth-referenced data
 - Meteorological data
 - Flight plan predictions (Predicted Route and Projected Intent groups)
- **Events (waypoint passage, lateral deviation, altitude) determined by FMF**
- **ADS in FANS-1 is integrated with FMF**



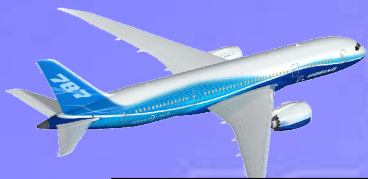
ATN – Introducing the Dual Stack

- 787 will have both ATN and FANS
 - Dual-Stack
- ATN will be:
 - Per ATN Baseline 1 (ED-110 red-line version)
 - Context Management (CM)
 - ADS (with Protected Mode features)
 - Protected Mode CPDLC
 - All mandatory and optional functionality in ED-110
 - Integrated with FANS for seamless operation
 - Integrated with FMF (like FANS)
 - Level C above the Transport Layer
- Subnetworks used for ATN are
 - VDL Mode 2
 - SATCOM Data 3

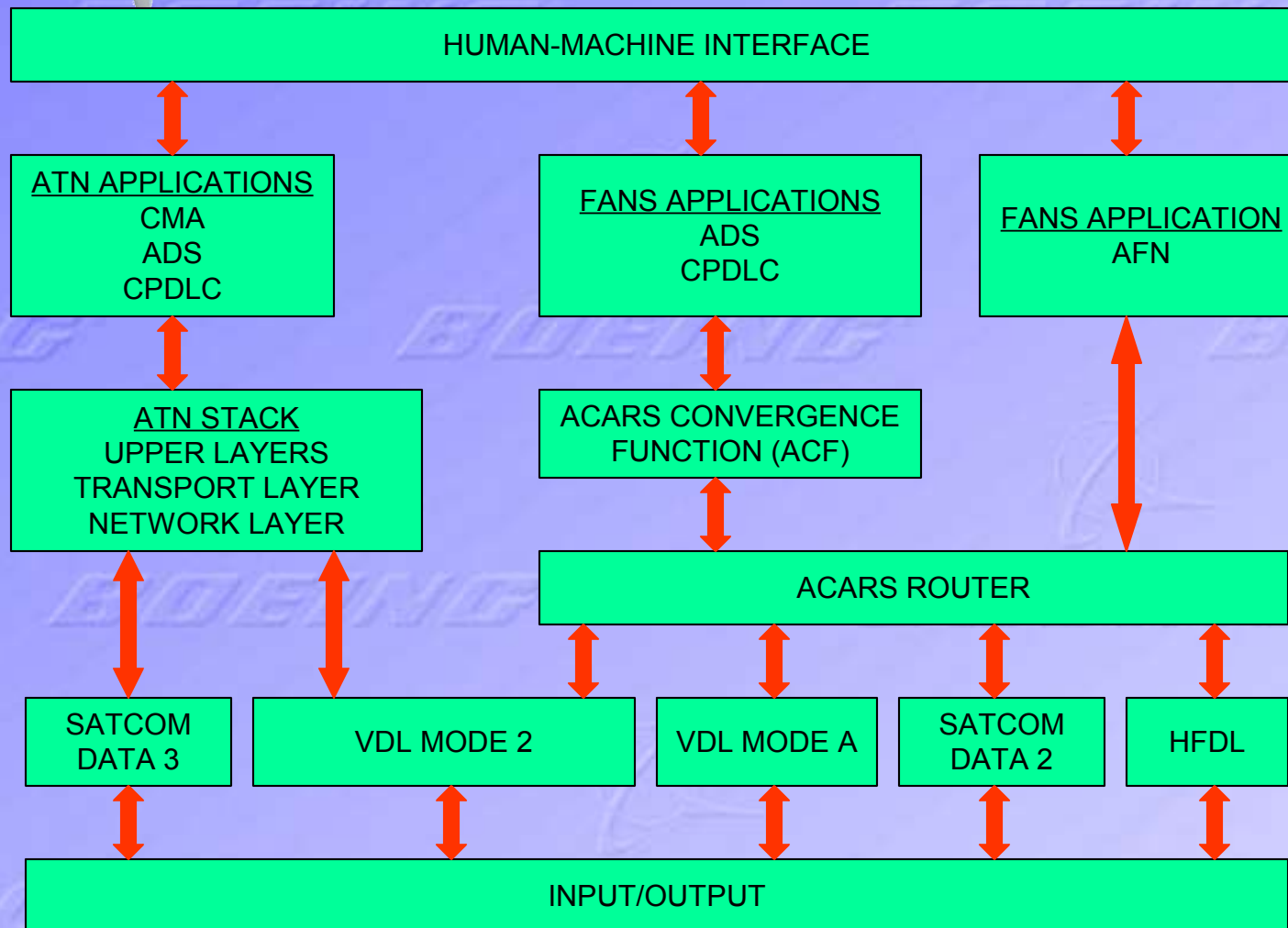


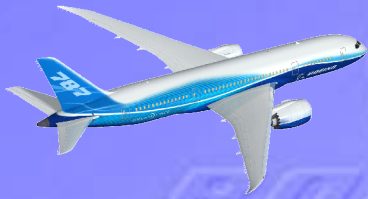
Integration of ATN and FANS

- **Common ATS User Interface**
 - **Single logon screen, with Avionics determining whether to perform FANS or ATN logon**
 - **Single set of displays to construct downlinks**
 - **Unavailable features shown as unavailable**
 - **Common presentation of uplinks (including message log)**
 - **Actual text adheres to respective standard**
 - **Auto-transfers between all centers**
 - **FANS → FANS**
 - **ATN → ATN**
 - **FANS → ATN**
 - **ATN → FANS**



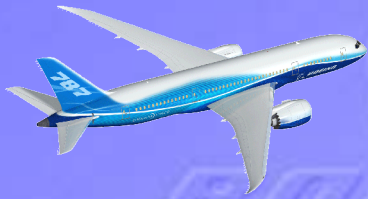
Dual-Stack Architecture





CPDLC Functionality in ATN (1)

- **Baseline 1 (ED-110 redline version 110)**
 - 26 downlinks (out of 114)
 - 62 uplinks (out of 233)
- **FMS Integration**
 - Loading into flight plan in FMS
 - Crossing constraints (um 46, 47, 48, 51, 52, 53)
 - Direct clearances (um 74)
 - Offsets (um 64)
 - Routes (um 79, 80)
 - Holds (um 92)
- **FMS data for reports**
 - Top of descent time (dm 109)



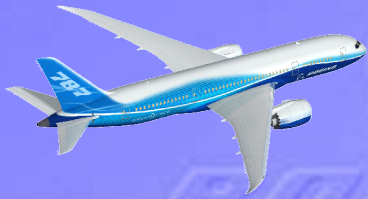
CPDLC Functionality in ATN (2)

- Arming of reports
 - None required in Baseline 1
- Validation of data
 - Waypoint in direct request (dm 22)
- Validation of uplinks
 - No conditional clearances
 - Validation limited to elements loadable in flight plan
- Dial feedback when uplink value is selected in respective system

CLIMB TO FL250

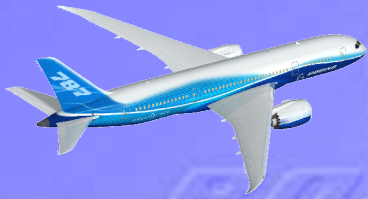
MONITOR KZAK CENTER ON 121.55

- Loading to Mode Control Panel (MCP), Tuning Control Panel (TCP)



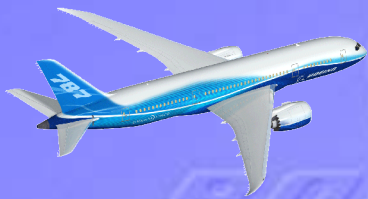
ADS Functionality in ATN

- **Baseline 1 (ED-110 redline version)**
- **Periodic, Demand and Event contracts**
- **Air vector, weather, projected profile and extended projected profile reports**
- **Airspeed, heading and extended profile change event contracts**
- **Intent is to provide for future expansion of datalink (CASCADE)**



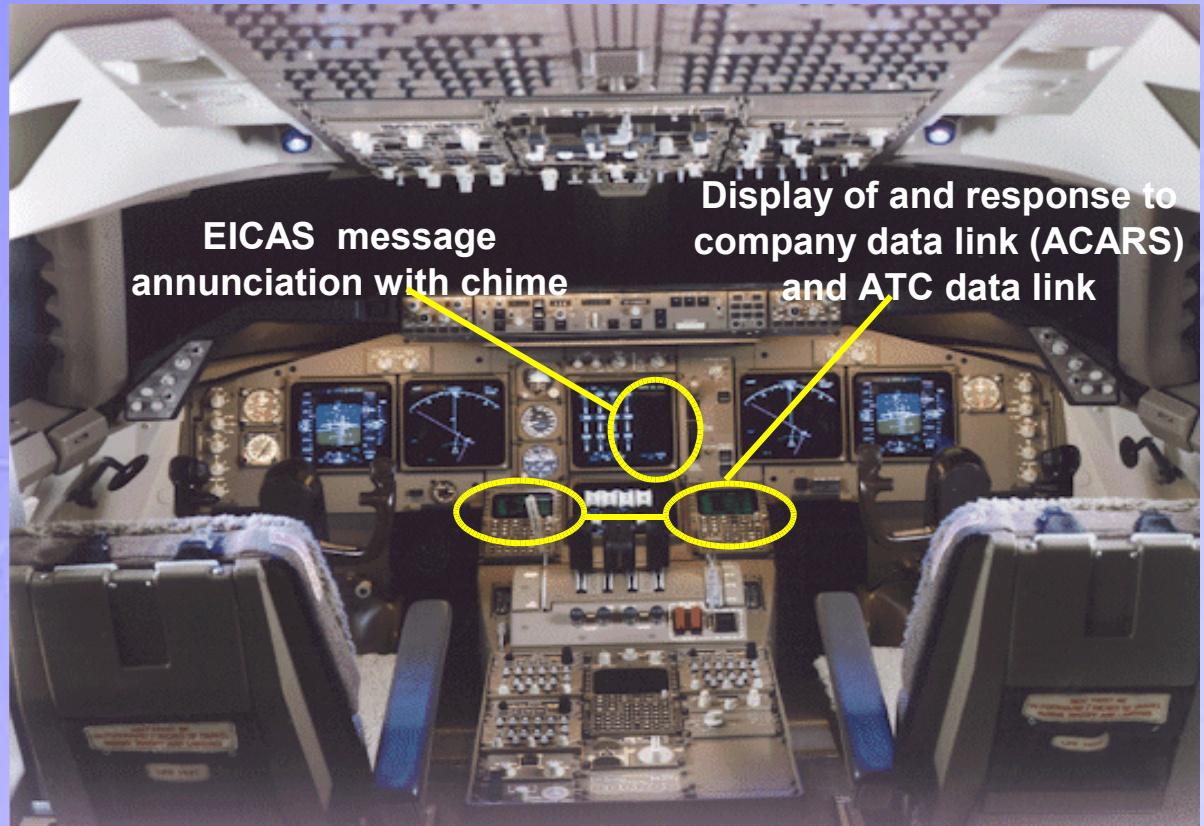
Datalink Recording

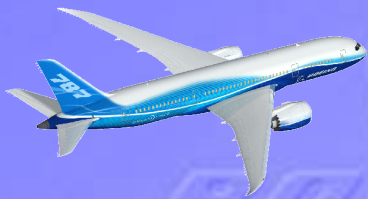
- **787 implements full ED-112 datalink recording**
 - **Dual recorders**
 - **Database drives which types of messages are recorded**
 - **Records as messages are transmitted and received**
 - **Records as messages are displayed, printed and loaded to FMC**
 - **ACARS applications can also route via CMF to the recorder**
 - **Allows them to record crew interactions**
 - **FMF does this for status changes**



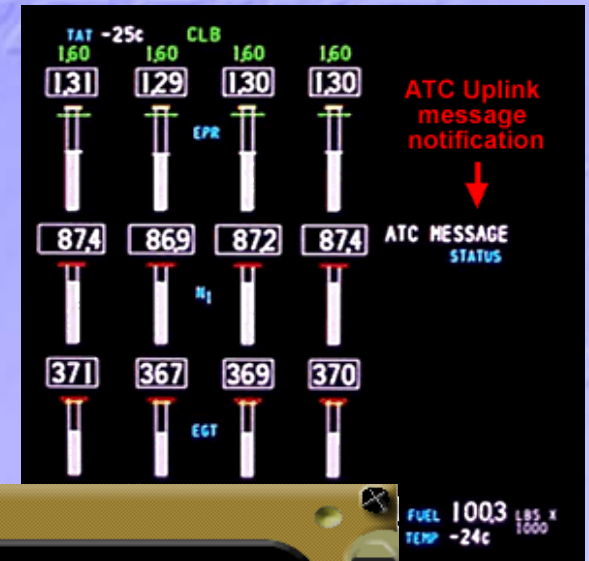
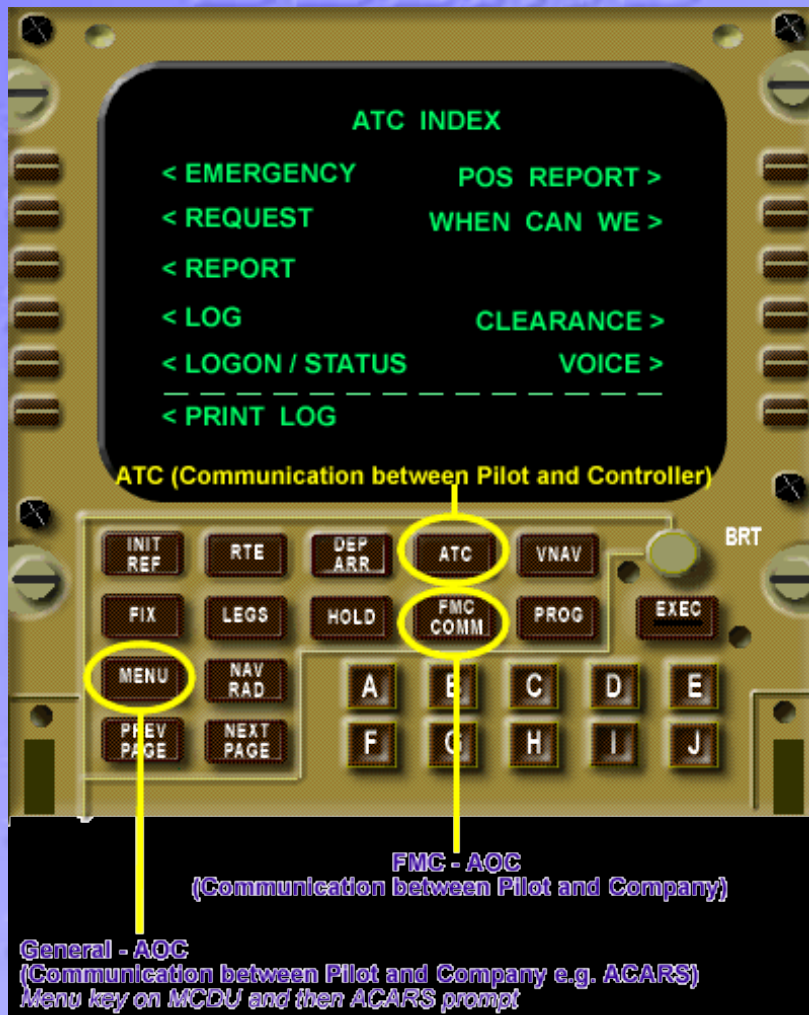
Boeing 747 Operation

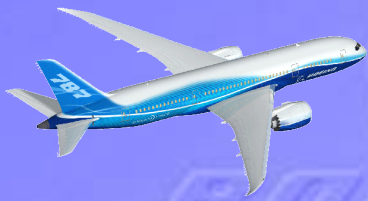
- Pilot interaction through MCDU
 - ATC key
- Alert on EICAS Chime





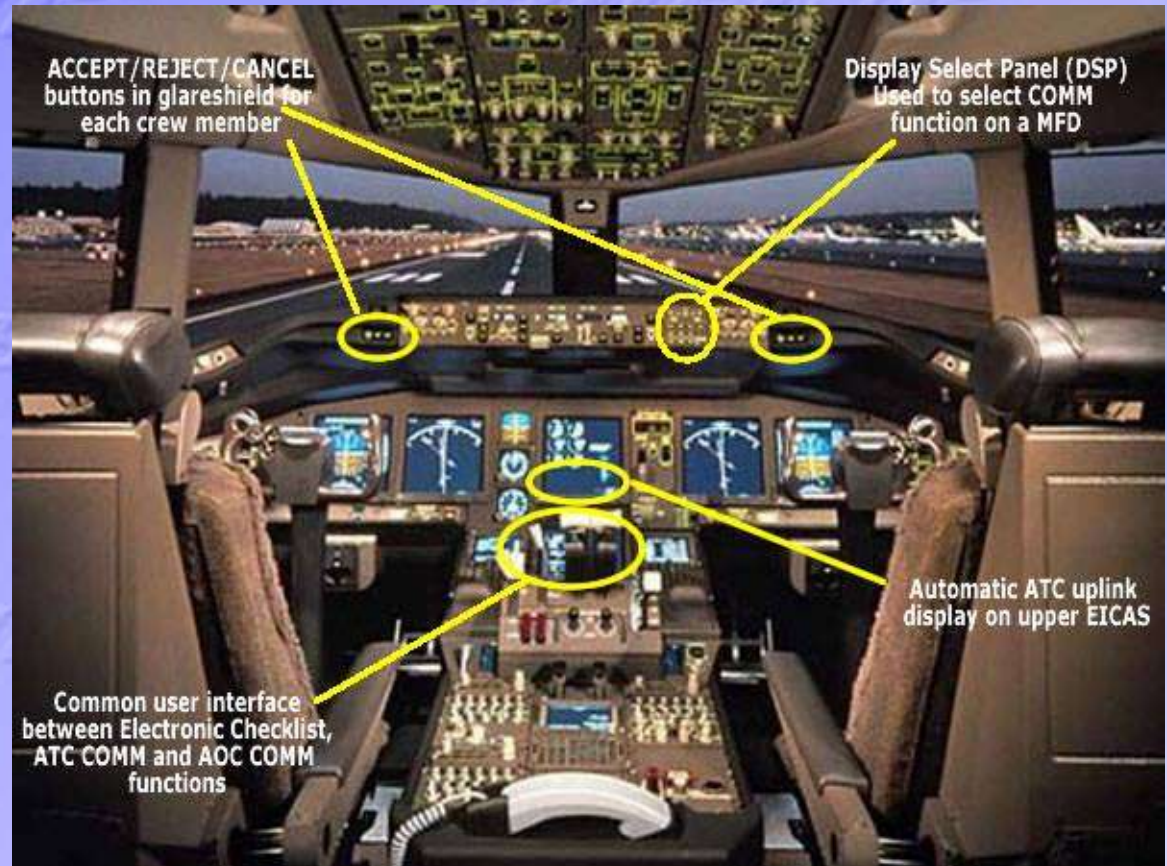
Boeing 747 Operation

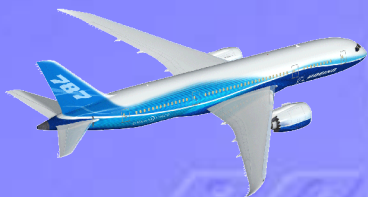




Boeing 777 Operation

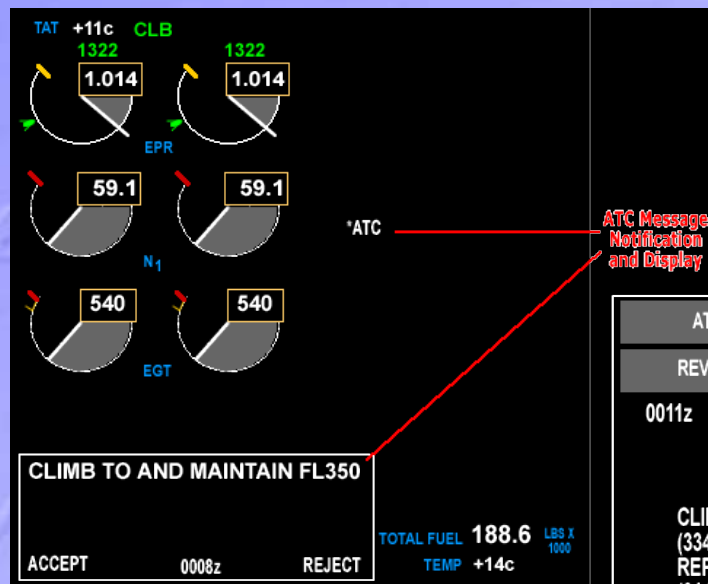
- Crew operation via MFD and cursor
 - Data entry on MCDU
- Data block on EICAS
- EICAS alert
- Chime
- Glareshield buttons
 - ACCEPT
 - CANCEL
 - REJECT
- Dial feedback on uplinks (e.g. MCP altitude for CLIMB TO AND MAINTAIN)



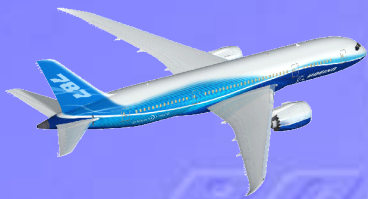


Boeing 777 Operation

ATC	FLIGHT INFORMATION	COMPANY
REVIEW	MANAGER	NEW MESSAGES
ATC		
ALTITUDE REQUEST	WHEN CAN WE EXPECT	EMERGENCY REPORT
ROUTE REQUEST	VOICE CONTACT REQUEST	ATC REQUESTED REPORTS...
SPEED REQUEST	LOGON/STATUS	POSITION REPORT
CLEARANCE REQUEST		FREE TEXT MESSAGE
		EXIT MENU

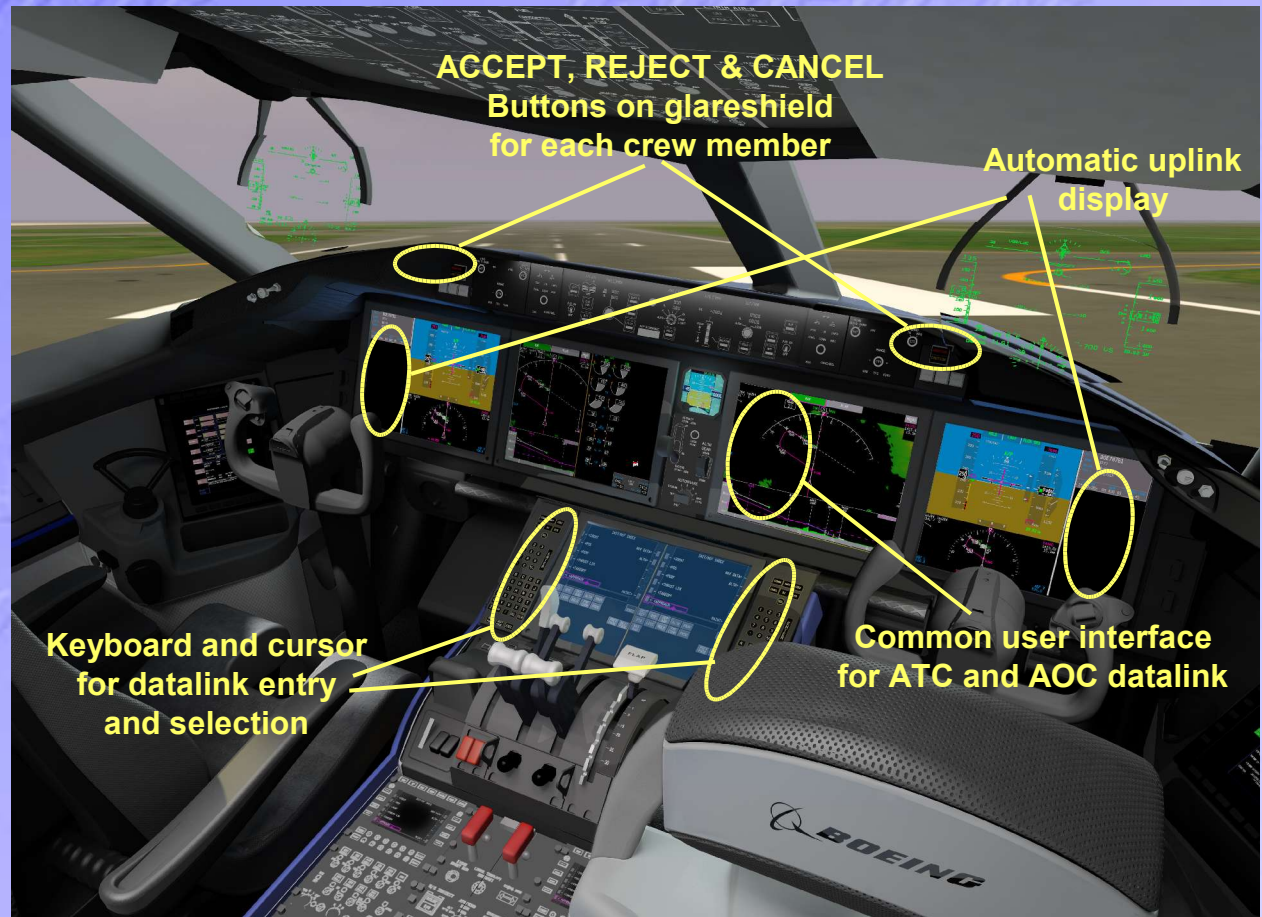


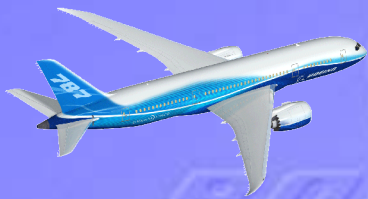
ATC	FLIGHT INFORMATION	COMPANY
REVIEW	MANAGER	NEW MESSAGES
0011z ATC UPLINK		
CLIMB TO AND MAINTAIN 10200M (33465FT), REPORT LEAVING 9600M (31496FT),		
DISPLAY REPORT	PRINT	CANCEL



Boeing 787 Operation

- Builds on 777 operation
- Same cursor operation
- Datablocks now located in primary view, dual, and larger
- MFD pages based on 777 but laid out for new larger displays
- Common operation





Common Logon Screen

- CM and AFN logon on same screen
- System determines whether to perform AFN or CM logon
 - Based on internal database
- Origin/destination from FMS flight plan

ATC	FLIGHT INFORMATION	COMPANY
REVIEW	MANAGER	NEW MESSAGES

1234z ATC LOGON/STATUS

LOGON TO:

FLIGHT NUMBER:

FILED DEPARTURE TIME: z

FILED DEPARTURE DATE:

ORIGIN: KLAX DESTINATION: RJAA

ATC CONNECTION: ESTABLISHED

ACTIVE CENTER: KZAK

NEXT CENTER: RJTG

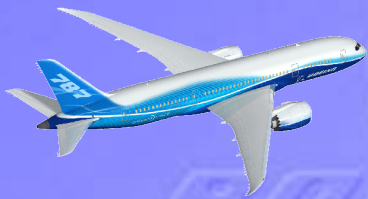
MAX UPLINK DELAY: SEC

ADS STATUS: ACTIVE

☒ ATC DATA LINK OFF ☐ CONFIRM OFF

SEND	ADS MANAGER	RETURN	EXIT
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SCRATCH PAD



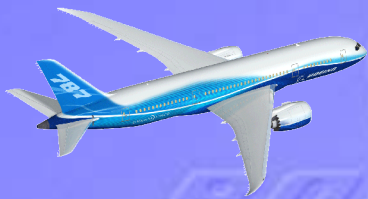
Common Downlink Pages

ATC	FLIGHT INFORMATION	COMPANY
REVIEW	MANAGER	NEW MESSAGES
1234z ALTITUDE REQUEST		
<input checked="" type="checkbox"/> ALTITUDE:	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	
<input type="checkbox"/> STEP AT:	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	
<input type="checkbox"/> BLOCK:	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	
TO:	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	
<input type="checkbox"/> REQUEST CRUISE CLIMB TO:	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> (REQUESTS MIN RATE CLIMB)	
<input type="checkbox"/> REQUEST VMC DESCENT		
<input checked="" type="checkbox"/> AT PILOTS DISCRETION		
<input type="checkbox"/> DUE TO WEATHER		
<input type="checkbox"/> DUE TO AIRCRAFT PERFORMANCE		
<input type="checkbox"/> MAINTAIN OWN SEPARATION AND VMC		
FREE TEXT: <input type="text"/> <input type="text"/> <input type="text"/>		
<input type="button" value="PRINT"/> <input type="button" value="RESET"/> <input type="button" value="RETURN"/> <input type="button" value="EXIT"/>		
SCRATCH PAD		

- FANS
- All options available

- ATN
- Baseline 1 options only available

ATC	FLIGHT INFORMATION	COMPANY
REVIEW	MANAGER	NEW MESSAGES
1234z ALTITUDE REQUEST		
<input checked="" type="checkbox"/> ALTITUDE:	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	
<input type="checkbox"/> STEP AT:	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	
<input type="checkbox"/> BLOCK:	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	
TO:	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	
<input type="checkbox"/> REQUEST CRUISE CLIMB TO:	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> (REQUESTS MIN RATE CLIMB)	
<input type="checkbox"/> REQUEST VMC DESCENT		
<input type="checkbox"/> AT PILOTS DISCRETION		
<input type="checkbox"/> DUE TO WEATHER		
<input type="checkbox"/> DUE TO AIRCRAFT PERFORMANCE		
<input type="checkbox"/> MAINTAIN OWN SEPARATION AND VMC		
FREE TEXT: <input type="text"/> <input type="text"/> <input type="text"/>		
<input type="button" value="PRINT"/> <input type="button" value="RESET"/> <input type="button" value="RETURN"/> <input type="button" value="EXIT"/>		
SCRATCH PAD		



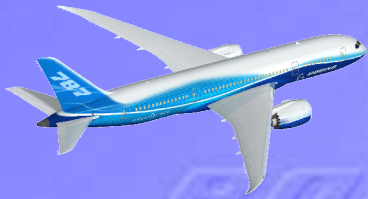
ATC Datablock Operation

- Dual identical datablocks outboard of PFD
- Displays ATC uplinks immediately
- Pilot response via glareshield switches (ACCEPT, CANCEL, REJECT) or on MFD

ATC UPLINK	
1234z	FROM KZAK
CLEARED ROUTE CLEARANCE	
DIRECT	OME
DIRECT	WENDY
DIRECT	N6225.3E16913.9
R220	NANAC
ACCEPT	REJECT

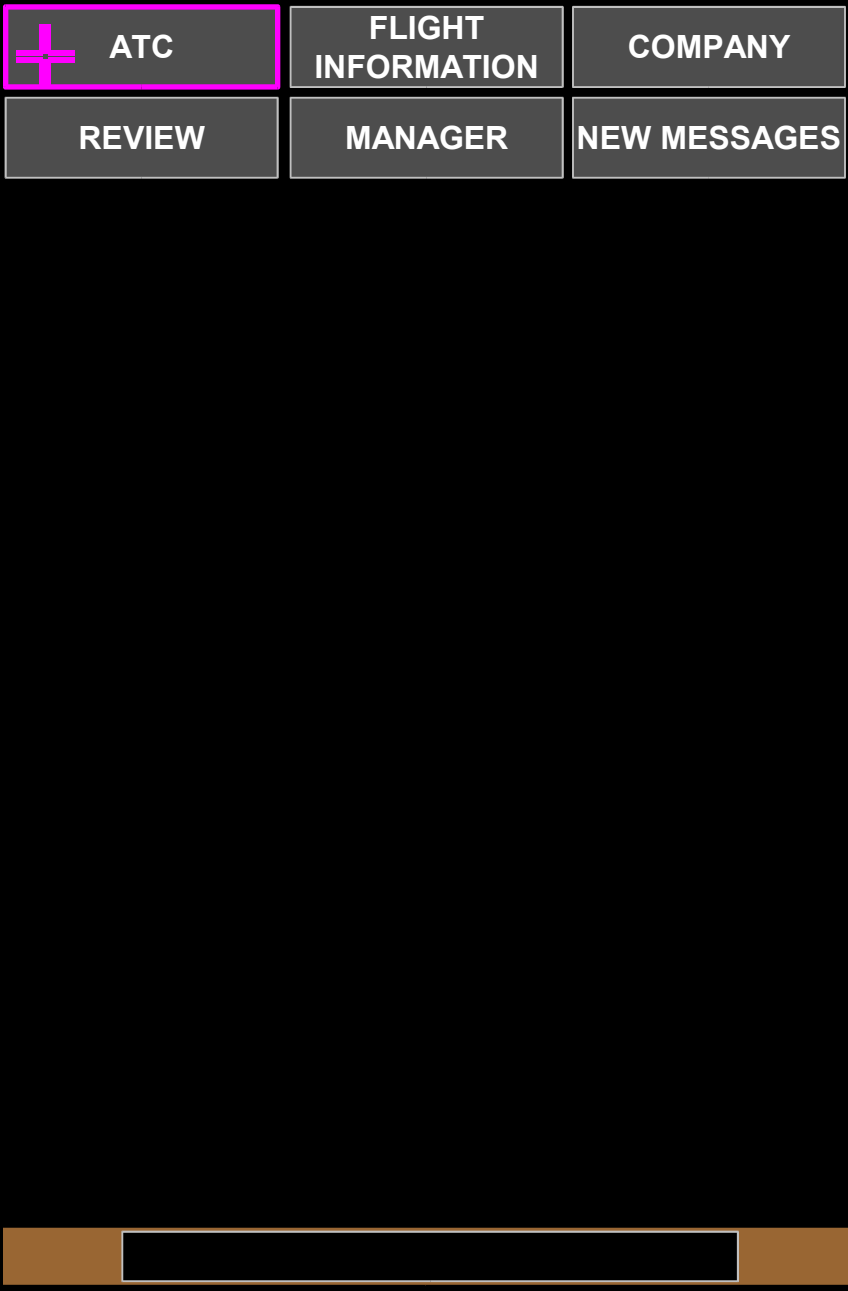
COMM SYSTEM MESSAGE	
LEVEL FL330	
SENT TO KZAK	
CANCEL	

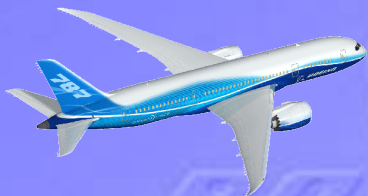
- Also used for COMM SYSTEM MESSAGES
- Common operation with 777



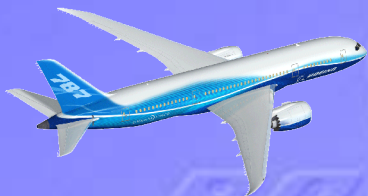
Operational Scenario

- Requesting and Receiving an Altitude Clearance

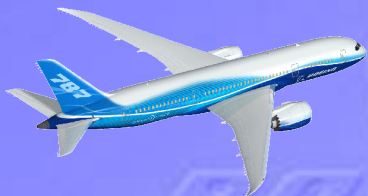




ATC	FLIGHT INFO	COMPANY
REVIEW	MANAGER	NEW MESSAGES
ATC		
ALTITUDE REQUEST	WHEN CAN WE EXPECT	EMERGENCY REPORT
ROUTE REQUEST	VOICE CONTACT REQUEST	REQUESTED REPORTS ...
SPEED REQUEST	FREE TEXT MESSAGE	CONDITIONAL CLEARANCES
CLEARANCE REQUEST	LOGON/STATUS	POSITION REPORT
		MONITORING REPORT
		EXIT MENU



ATC	FLIGHT INFORMATION	COMPANY
REVIEW	MANAGER	NEW MESSAGES
1234z ALTITUDE REQUEST		
<div>◇ ALTITUDE: <div><div></div><div></div><div></div><div></div><div></div></div></div>		
<div><div><input type="checkbox"/></div> STEP AT: <div><div></div><div></div><div></div><div></div><div></div></div></div>		
<div>◇ BLOCK: <div><div></div><div></div><div></div><div></div><div></div></div></div>		
<div>TO: <div><div></div><div></div><div></div><div></div><div></div></div></div>		
<div>◇ REQUEST CRUISE CLIMB TO: <div><div></div><div></div><div></div><div></div><div></div></div> (REQUESTS MIN RATE CLIMB)</div>		
<div>◇ REQUEST VMC DESCENT</div>		
<div><div><input type="checkbox"/></div> AT PILOTS DISCRETION</div>		
<div><div><input type="checkbox"/></div> DUE TO WEATHER</div>		
<div><div><input type="checkbox"/></div> DUE TO AIRCRAFT PERFORMANCE</div>		
<div><div><input type="checkbox"/></div> MAINTAIN OWN SEPARATION AND VMC</div>		
<div>FREE TEXT: <div><div></div><div></div><div></div></div></div>		
<div><div>PRINT</div><div>RESET</div><div>RETURN</div><div>EXIT</div></div>		
<div>350</div>		



ATC	FLIGHT INFORMATION	COMPANY
REVIEW	MANAGER	NEW MESSAGES

1234z ALTITUDE REQUEST

☒ ALTITUDE:

☐ STEP AT:

☐ BLOCK:

TO:

☐ REQUEST CRUISE CLIMB TO: (REQUESTS MIN RATE CLIMB)

☐ REQUEST VMC DESCENT

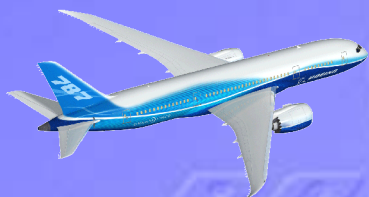
☐ AT PILOTS DISCRETION

☐ DUE TO WEATHER

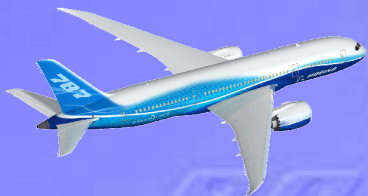
☐ DUE TO AIRCRAFT PERFORMANCE

☐ MAINTAIN OWN SEPARATION AND VMC

FREE TEXT:



ATC	FLIGHT INFORMATION	COMPANY
REVIEW	MANAGER	NEW MESSAGES
1234z ALTITUDE REQUEST		
<input checked="" type="checkbox"/> ALTITUDE:	<input type="text" value="FL350"/>	
<input type="checkbox"/> STEP AT:	<input type="text" value="-----"/>	
<input type="checkbox"/> BLOCK:	<input type="text" value="-----"/>	
TO:	<input type="text" value="-----"/>	
<input type="checkbox"/> REQUEST CRUISE CLIMB TO:	<input type="text" value="-----"/>	(REQUESTS MIN RATE CLIMB)
<input type="checkbox"/> REQUEST VMC DESCENT		
<input type="checkbox"/> AT PILOTS DISCRETION		
<input type="checkbox"/> DUE TO WEATHER		
<input type="checkbox"/> DUE TO AIRCRAFT PERFORMANCE		
<input type="checkbox"/> MAINTAIN OWN SEPARATION AND VMC		
FREE TEXT:	<input type="text" value="-----"/>	
	<input type="text" value="-----"/>	
	<input type="text" value="-----"/>	
<input type="button" value="SENT"/>		<input type="button" value="EXIT INFO"/>



 ATC	FLIGHT INFORMATION	COMPANY
REVIEW	MANAGER	NEW MESSAGES
<div></div>		

FLT # ANA123

TAIL # N7E701

DATE 20 JAN 08

UTC TIME 13:06:00z

ELAPSED TIME 00:00

ATC COMM

1307 z

FROM KZAK

CLIMB TO FL350.

ACCEPT

REJECT



FLT # ANA123

TAIL # N7E701

DATE 20 JAN 08

UTC TIME 13:06:00z

ELAPSED TIME 00:00

ATC COMM

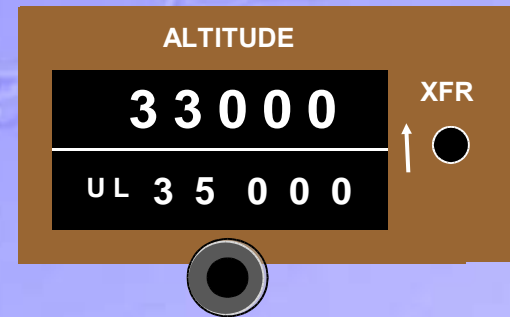
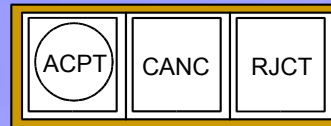
1307 z

FROM KZAK

CLIMB TO FL350.

ACCEPTED

CANCEL



FLT # ANA123

TAIL # N7E701

DATE 20 JAN 08

UTC TIME 13:06:00z

ELAPSED TIME 00:00

ATC COMM

1307 z

FROM KZAK

CLIMB TO FL350.

ACCEPTED

CANCEL

<input checked="" type="radio"/> ACPT	<input type="radio"/> CANC	<input type="radio"/> RJCT
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ALTITUDE	
35000	XFR <input type="radio"/>

FLT # ANA123

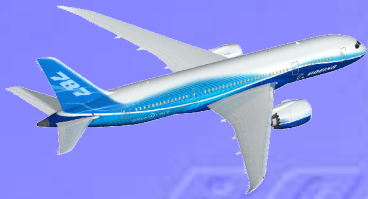
TAIL # N7E701

DATE 20 JAN 08

UTC TIME 13:06:00z

ELAPSED TIME 00:00





Conclusions

- 787 is a dual-stack airplane
 - Integrated ATN/FANS
- BUT,
 - Dual-stack fleet penetration will be slow
 - Ground needs to deal with large fleets of FANS-equipped airplanes and potentially CMU-based ATN airplanes
- Long-term goal has to be FANS/ATN convergence



Glossary

AAC	Airline Administrative Communication	FIS	Flight Information Service
ACARS	Aircraft Communication Addressing and Reporting System	FMC	Flight Management Computer
ACF	ACARS Convergence Function	FMF	Flight Management Function
ADS	Automatic Dependent Surveillance	FMS	Flight Management System
ADS-B	Automatic Dependent Surveillance - Broadcast	GLS	GPS Landing System
AFN	ATS Facilities Notification	GPS	Global Positioning System
AOA	ACARS Over AVLK	HF	High Frequency
AOC	Airline Operational Communication	MCP	Mode Control Panel
API	Application Programming Interface	IMA	Integrated Modular Avionics
ATC	Air Traffic Control	IP	Internet Protocol
ATN	Aeronautical Telecommunications Network	MCDU	Multipurpose Control & Display Unit
ATS	Air Traffic Services	MFD	Multi-Function Display
AVLC	Avionics VHF Link Control	SATCOM	Satellite Communication
CCS	Common Computing System	NM	Nautical Miles
CM	Context Management	TCP	Tuning Control Panel
CMF	Communication Management Function	UM	Uplink Message
CPDLC	Controller/Pilot Data Link Communication	US	United States
CRC	Cyclic Redundancy Check	VDL	VHF Digital Link
DM	Downlink Message	VHF	Very High Frequency
EU	European Union		