

Presented by

**Burkhard DOMKE**

Head of Engineering Intelligence  
Future Projects Office

# Boeing 787 Lessons Learnt October 2008

787 Lessons Learnt 2.0  
20. October 2008  
46 pages

# Acknowledgements

Felix Lutsch, EIXG – 787 Overall Aircraft Design, Weight, and Performance Analysis

Iain Morgan, EIXV – Long Range Sector Manager

Peter Brink, EIXDI – Detailed Analysis of 787 Structural Design, Manufacturing and Supplier Facilities

Matthias Heimerl, YDI – Supplier Business Intelligence

Louis Nobre and Norio Yamanouchi, Airbus Japan – Local Supplier Information

Joanne Potter, PAWT1 / TWA – Production Status & Ramp-up Issues

# Overview

- Design Issues
- Weight Issues
- Engine Issues
- Certification Issues
- Production Issues
  - Travelled Work
  - Lay-up Rates
  - Ramp Up
- Schedule Issues

# Design Issues - Summary

- Wing
  - Center wing box static test failure
  - Lightning strike protection
  - Wiring definition
- Fuselage
  - Lightning strike protection
  - Body join across window concept
  - Mid body section join assembly
  - Aft body join assembly (including pressure bulkhead)
  - Aft body and APU tail cone join
  - MLG doors
  - Pi-Box seat rails
  - Hybrid sine-wave floor beams
  - Single-piece frames

# Design Issues - Summary

- HTP
  - Center splice
  - Additional spar
- Pylon
  - Common pylon/nacelle
- Systems
  - Power Electronics Cooling
  - Brake control software
  - Generators
- Cabin
  - Wireless IFE
  - 16g seats
- Engines
  - Fuel burn

# Design Issues - Wing

## Center Wing Box (Section 11)

- The center wing box failed assembly-level static testing. The Issue was attributed to an FEM calculation error and classified as minor by Boeing
- Boeing planned to implement a temporary fix for LN1 to LN6 and a permanent solution from LN7 onwards
- Japanese supplier sources deemed this a major issue with significant impact on production

## Outboard Wing (Section 12)

- Issues with wiring definition and design changes due to lightning strike protection
- Engineering changes were interrupted by the center wing box issue
- In April, Boeing announced a revised wing design incorporating significant weight savings from LN20\* onwards
- A customer presentation indicates a post-EIS increase in MTOW from 219 to 227 tonnes from LN20 onwards.
- A Boeing source dated August 2008 advertised a revised airframe supporting this weight increase. This includes strengthening of the outboard wing, the center wing box, the wing leading edges, the MLG wheel well, and the center fuselage as well as enhancing manoeuvre load alleviation.
- Delivery of LN21 in 4Q 2009 leaves a tight schedule to achieve such a redesign and its incorporation into early production.

# Design Issues – Wing Fasteners / Lightning Strike

- Fastener design changed to tapered sleeve bolt type late in design to prevent 'edge glow' within fuel tanks (1)
- At the time, production lead-time of fasteners was ~60 weeks
- This lead to a limited availability of tailored-length fasteners
- Stacks of washers conceived as a workaround created problems with incorrect assembly (2)
- Solution infringes a BAE patent owned by Airbus

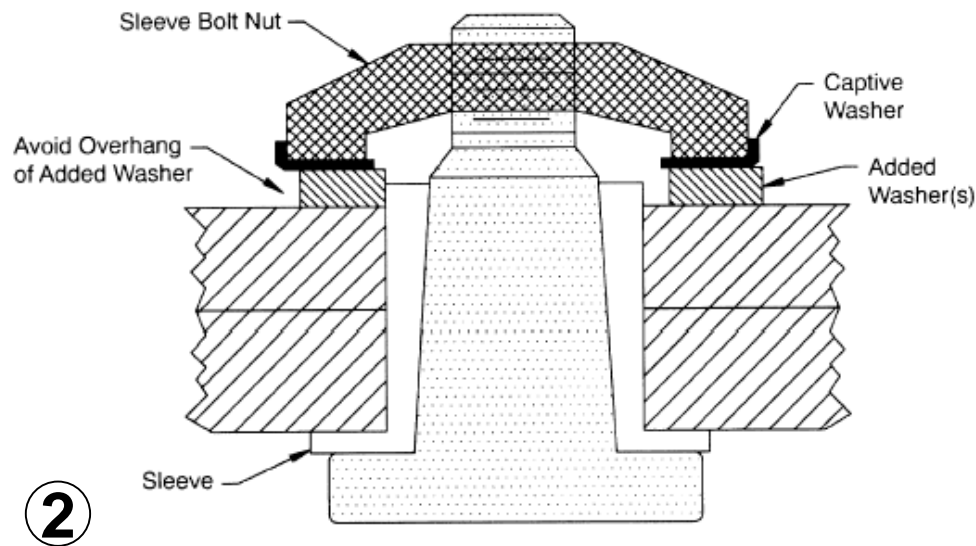
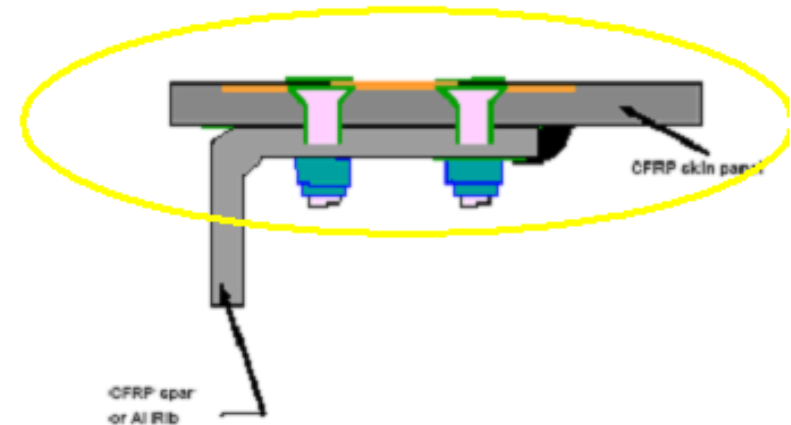


FIGURE 4 - AVOIDING WASHER OVERHANGS

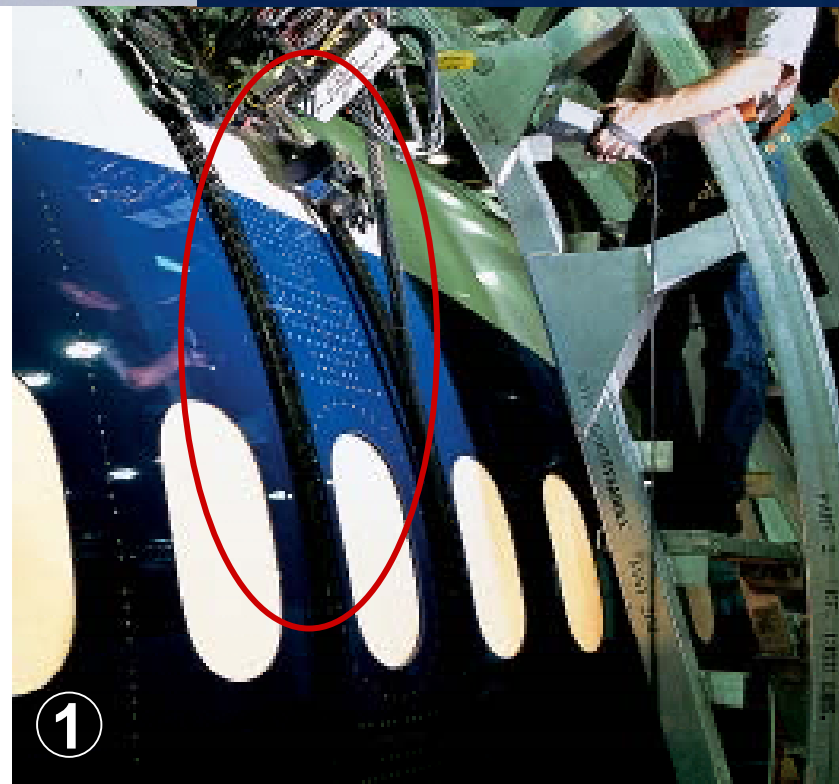


# Design Issues - Fuselage



Body join S41/S43 and S46/S47

- Initial concept ran the join right across the window (1)
- Concept altered after barrel mating demonstration
- Windows eliminated on LN1 (2)
- No mitigation observed, not even on later models like the 787-10 (3)
- Affected passengers may not be happy!



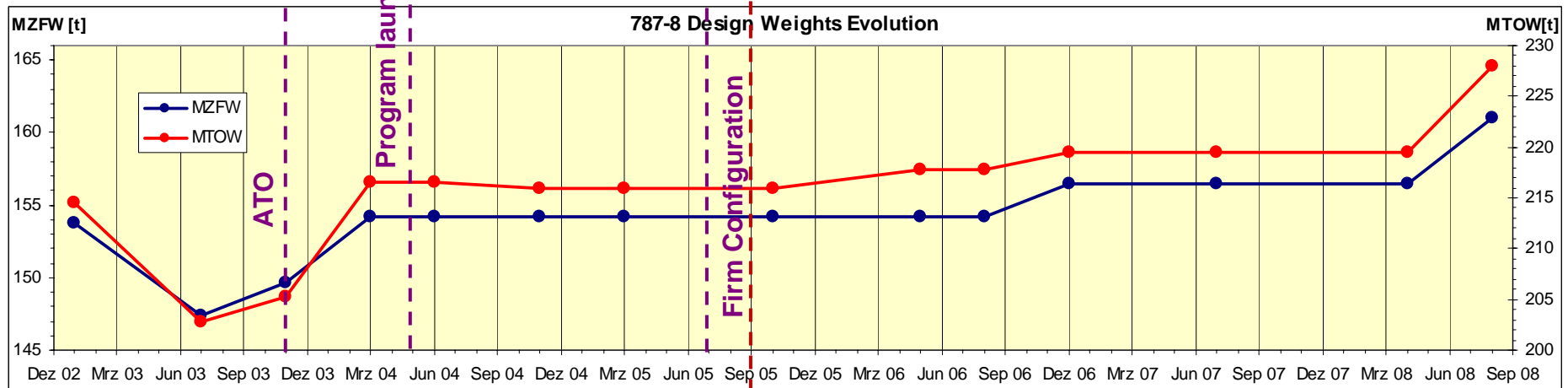
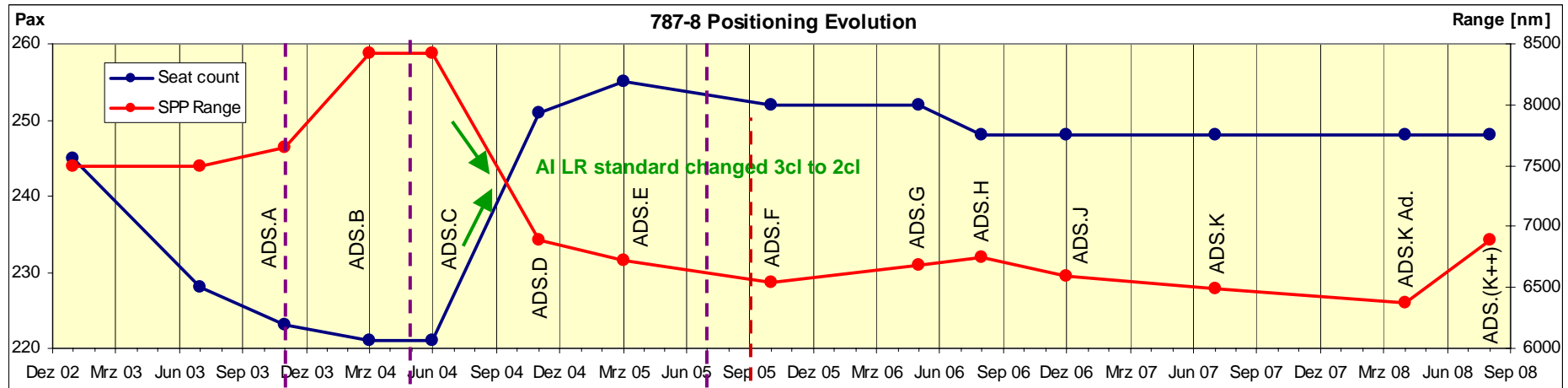


# Overview

- Design Issues
- **Weight Issues**
- Engine Issues
- Certification Issues
- Production Issues
  - Travelled Work
  - Lay-up Rates
  - Ramp Up
- Schedule Issues

# 787-8 Weight Evolution Charts

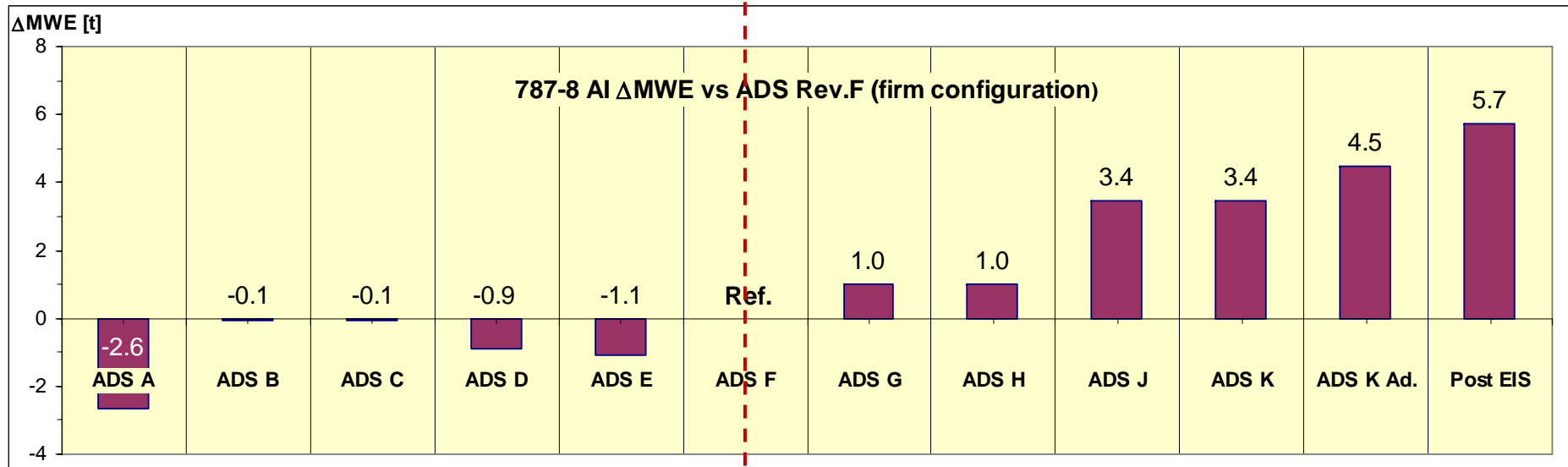
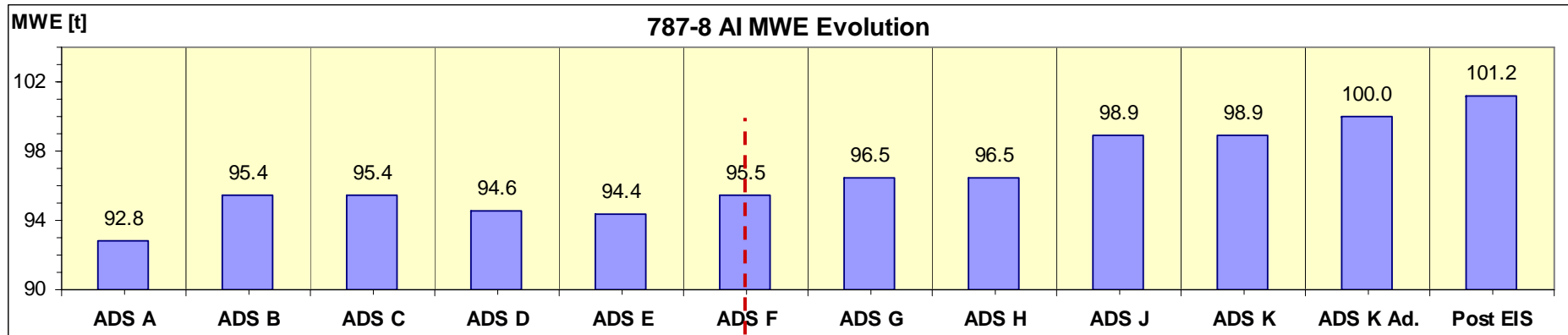
787\_Evol\_0908\_EIXUG\_PR0812577\_v2



September 2005  
Firm Configuration  
(3 month delay)

# 787-8 Weight Evolution Charts

787\_Evol\_0908\_EIXUG\_PR0812577\_v2



September 2005  
Firm Configuration

# Weight Evolution tables

787\_Evol\_0908\_EIXUG\_PR0812577\_v2

## 787-8

Design.	Key Date	Status	Pax	Standard	MTOW	MZFW	MWE	DMWE	Range	Comments
7E7-300	Jan 03		245	3cl LR	214.6	153.8	96.1	0.6	7490	initial configuration information
7E7 base	Jul 03		228	3cl LR	202.9	147.4	89.7	-5.7	7500	extensive compsites, more electric (no bleed), sakurai hili, cap.reduced
	Nov 03	ADS A	223	3cl LR	205.3	149.7	92.8	-2.6	7650	span increase, longer nose/tail, reduced LG-length, growth
7E7-8	Mrz 04	ADS B	221	3cl LR	216.6	154.2	95.4	-0.1	8420	revised TE, conv. hili multifunct, revised tail, growth
	Jun 04	ADS C	221	3cl LR	216.6	154.2	95.4	-0.1	8420	tracing skipped
	Nov 04	ADS D	251	2cl LR	215.9	154.2	94.6	-0.9	6884	span inc., changed nose/tail/HTP/VTP, D3 derated, AI rules changed
	Mrz 05	ADS E	255	2cl LR	215.9	154.2	94.4	-1.1	6723	inc. fuse/cabin length, inc. VTP, revised wing ref area
787-8	Okt 05	ADS F	252	2cl LR	215.9	154.2	95.5	0.0	6547	VTP increased, new aft galley arrangement
	Mai 06	ADS G	252	2cl LR	217.7	154.2	96.5	1.0	6680	untraceable MWE increase, recovery growth
	Aug 06	ADS H	248	2cl LR	217.7	154.2	96.5	1.0	6750	no changes
	Dez 06	ADS J	248	2cl LR	219.5	156.5	98.9	3.4	6590	untraceable MWE increase, partial recovery growth
	Jul 07	ADS K	248	2cl LR	219.5	156.5	98.9	3.4	6490	no weight changes, untraced performance reduction
	Apr 08	ADS K Ad.	248	2cl LR	219.5	156.5	100.0	4.5	6370	untraceable MWE increase
	Aug 08	Post EIS	248	2cl LR	227.9	161.0	101.2	5.7	6890	growth

## 787-9

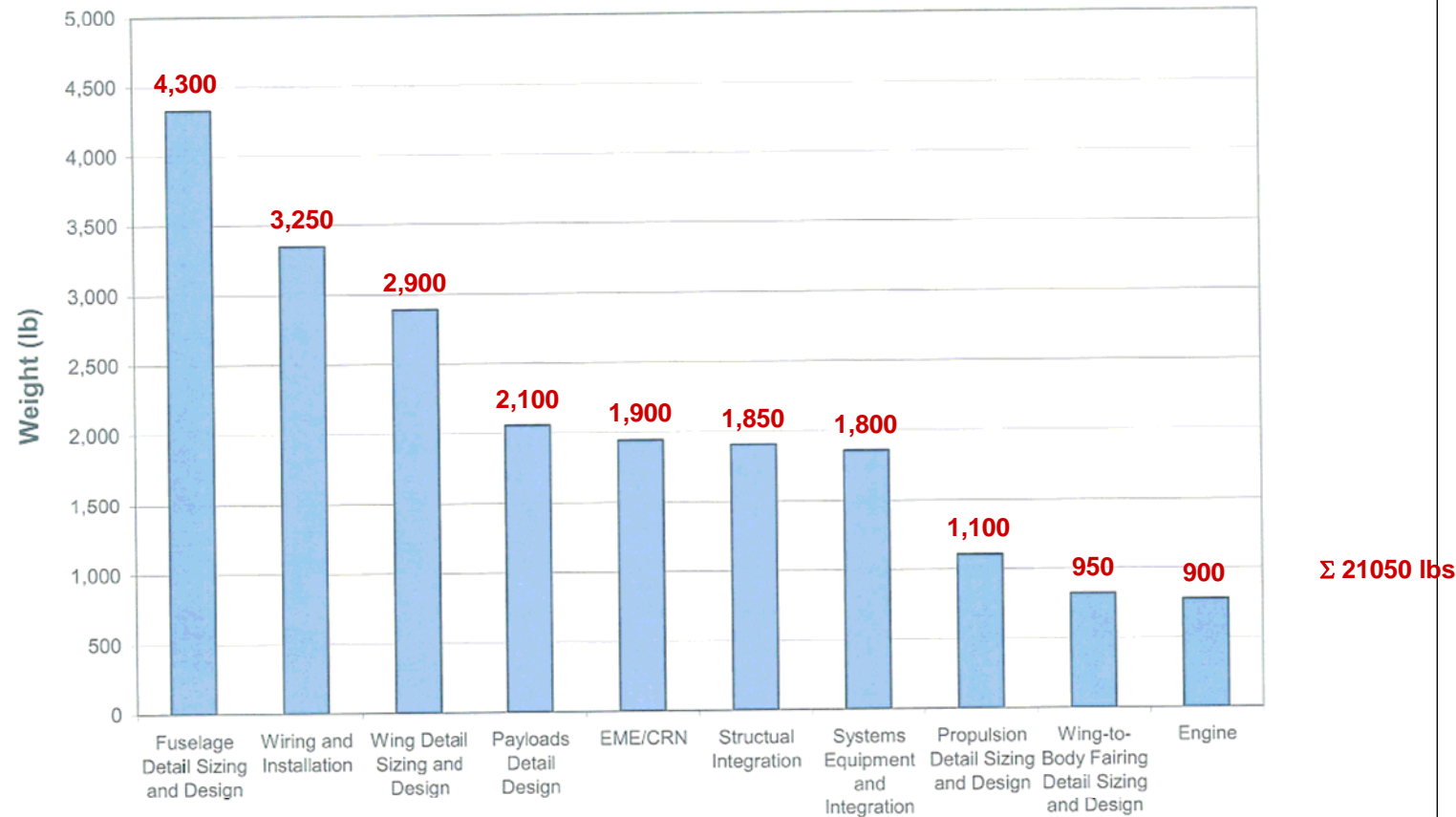
Design.	Key Date	Status	Pax	Standard	MTOW	MZFW	MWE	DMWE	Range	Comments
7E7-400	Jan 03		294	3cl LR	221.1	171.0	98.5	-4.4	6735	initial configuration information
7E7 stretch	Jul 03		277	3cl LR	219.8	163.8	93.8	-9.1	7500	extensive compsites, more electric (no bleed), sakurai hili, cap.reduced
	Nov 03	ADS A	276	3cl LR	230.0	167.8	98.5	-4.4	7950	span increase, longer nose/tail, reduced LG-length, growth
7E7-9	Mrz 04	ADS B	273	3cl LR	230.0	167.8	98.5	-4.4	7970	revised TE, conv. hili multifunct, revised tail
	Jun 04	ADS C	273	3cl LR	230.0	167.8	98.5	-4.4	7970	tracing skipped
	Nov 04	ADS D	286	2cl LR	230.7	169.6	98.8	-4.1	6727	span increase, changed nose/tail/HTP/VTP, AI rules changed
	Mrz 05	ADS E	290	2cl LR	230.7	170.6	99.3	-3.6	6494	inc. fuse/cabin length, inc. VTP, revised wing ref area
787-9	Okt 05	ADS F	286	2cl LR	244.9	174.2	102.9	0.0	7261	span inc., revised MLG, VTP increased, new aft galley arrangement, growth
	Mai 06	ADS G	286	2cl LR	244.9	176.9	103.9	1.0	7170	untraceable MWE increase
	Aug 06	ADS H	284	2cl LR	244.9	176.9	103.9	1.0	7200	no changes
	Dez 06	ADS J	284	2cl LR	244.9	179.2	106.4	3.5	6940	untraceable MWE increase
	Jul 07	ADS K	284	2cl LR	244.9	179.2	106.4	3.5	6870	no weight changes despite span increase!, untraced performance reduction
	Apr 08	ADS K Ad.	284	2cl LR	247.2	181.4	108.4	5.5	6810	traced ADS K span increase MWE impact, growth

# Weight Growth Areas

200804BCA\_787\_Program\_Update\_\_787-9\_weight\_Spec\_K+

787 DREAMLINER

## Line 1 Weight Growth Since Firm Configuration



BOEING PROPRIETARY COPYRIGHT © 2006 THE BOEING COMPANY

# Weight Saving Opportunities – April 2008

200804BCA\_787\_Program\_Update\_\_787-9\_weight\_Spec\_K+

## MEW Opportunities

787 DREAMLINER

Status	Opportunity	Potential Benefit
Committed	Pi Box Seat Tracks	-640
Committed	Replace Alum Spanner bars with composite	-60
Committed	Optimize skin padups adjacent to LCD	-15 (dash 9 only)
Approved <sup>1</sup>	Ti Floor Beams	-445
Approved	48/48 Pivot Bulkhead	-50
Approved	Bulk Cargo Net Support Optimization	-34
Approved	Delete Power Feeder Rails	-18
Approved	SAAB LCD Optimization	-18
Study	Lightweight Seats	-1500
Study	CFRP Ribs	-210
Study	Section 47/48 Join - K-Chord Redesign	-200
Study	Structural Fuel Vent Stringer	-155
Study	H-Stab	-145
Study	CMC Nozzle	-115
Study	Resin Infused Aft Fairing	-110
Study	Slat Optimization	-85
Study	PVDF Ducting	-53
Study	Stowbin Carbon Fiber Fittings	-40
Study	Non-Flyaway Cauls	-28

✓ Confirmed  
Boeing Source Aug 2008

✓  
✓

✓  
✓

✓

Σ 1690 lbs

Σ 3921 lbs

1. To be committed with Pi-Box

Includes items Committed thru CCB or other, Approved by TRB or Approved for Funding by TRB

BOEING PROPRIETARY

COPYRIGHT © 2008 THE BOEING COMPANY

# Overview

- Design Issues
- Weight Issues
- **Engine Issues**
- Certification Issues
- Production Issues
  - Travelled Work
  - Lay-up Rates
  - Ramp Up
- Schedule Issues

# Engine Issues

## General Electric GENx

- Achieved certification of GENx-1B in March 2008
- Rumoured to have missed SFC target by 2-3%
- Supplemental type certificate expected in March/April 2009, coinciding with estimate by FAA source that certification flight testing may start as late as March/April and another rumour that initial flight testing might switch to GENx engines

## Rolls-Royce Trent 1000

- Achieved certification in August 2007
- Rumoured to have missed book SFC by 3-4%
- Rumoured to need a revised LPT with broader chord blades, which would entail a redesign of the turbine casing. As the casing is a long lead item, the revised engine might not be available in time for certification flight testing
- Quick engine change
  - Original concept advertised an engine could be swapped in 1 hour. While this is technically feasible, the requirement remains a question.
  - Boeing now estimates the time for an engine swap to be 3.75 days, with the ultimate objective being 6 hours for a quick engine change (QEC)



# Certification Issues - Summary

- FAA Special Conditions
  - Interaction of Systems and Structures, Electronic Flight Control System-Control Surface Awareness, High Intensity Radiated Fields (HIRF) Protection, Limit Engine Torque Loads for Sudden Engine Stoppage, and Design Roll Maneuver Requirement (NM362 No. 25-354-SC)
  - Systems and Data Networks Security - Isolation or Protection From Unauthorized Passenger Domain Systems Access (NM364 25-356-SC)
  - Systems and Data Networks Security - Protection of Airplane Systems and Data Networks from Unauthorized External Access (NM365 25-357-SC)
  - Crashworthiness (NM368 25-362-SC)
  - Composite Wing and Fuel Tank Structure Fire Protection (NM366 25-348-SC)
  - Tire Debris Penetration of Fuel Tank Structure (NM367 25-363-SC)
  - Reinforced Flight Deck Bulkhead (NM372 25-355-SC)
  - Composite Fuselage In-flight Fire/Flammability Resistance (NM373 25-360-SC)
  - Lithium-Ion battery Installation (NM375 25-359-SC)
  - Operation Without Normal Electrical Power (NM378 No. 25-07-11-SC)
  - Seats With Non-traditional, Large, Non-Metallic Panels (NM384 25-370-SC)
- Other FAA reported concerns:
  - Compressed schedule and phased approach
  - Heat dissipation through composite skins

# Overview

- Design Issues
- Weight Issues
- Engine Issues
- Certification Issues
- **Production Issues**
  - Travelled Work
  - Lay-up Rates
  - Ramp Up
- Schedule Issues

# Production Issues - Summary

- Parts Shortages
- Fastener Shortage
- Travelled Work
- Conformity and Quality Assurance Issues
- Configuration Control
- Shop Floor Control
- Late Definition
- Engineering Changes
- Production Ramp-up Issues

# Production Issues – Travelled Work

- Parts shortages - Insufficient supply of frames, clips, brackets, and floor beams. Root cause are
  - NDI/QA cycle time not supporting production rate demand
  - Lack of qualified NDI/QA personnel and equipment at Tier-2 and -3 suppliers
  - Deferral of NDI testing from Tier-2 and -3 suppliers to Tier-1 partners to expedite pre-assembly
  - Further deferral of NDI and assembly work from Tier-1 to FAL to rush major assembly
  - Large number of defects detected at FAL level. Removal and replacement of defect parts incurring damage and repair
  - Repeated NDI/QA testing at FAL level due to all of the above
- Fastener shortages, primarily affecting but not limited to Mitsubishi. Root causes are
  - Late change to sleeved fastener design for lightning strike protection
  - Alcoa unable to meet demand in time
  - Unbalance in fastener inventory across supply chain
  - To tackle the parts shortages Boeing has now taken a consolidated approach to inventory management across the supply chain.

# Production Issues – Travelled Work

- Documentation
  - Production records on deferred work were found to be incomplete or lost in transfer resulting in a loss of configuration control
- Assembly work was found to be completed incorrectly only after assemblies reached the FAL. Root causes are
  - Oversight not adequate for the high level of outsourcing in assembly and integration
  - Qualification of low-wage, trained-on-the-job workers that had no previous aerospace experience
- Significant amount of change engineering work
  - Inadequate supplier capabilities in design, e.g. Vought had no engineering department when selected
  - Oversight not adequate for the high level of outsourcing in detailed design
  - Weight growth and subsequent weight saving changes
  - Producibility improvements
- Late Definition
  - Boeing admitted responsibility for a shortfall in wiring shipments
  - Late specification indicated by supplier as root cause

# Production Issues – LN1

- LN1 entered FAL 15<sup>th</sup> May 2007
  - Delivery to Everett rushed for 'Potemkin' roll-out on July 8<sup>th</sup>
  - Vought S47/S48 rear fuselage structure 16% complete, systems integration 0%
  - S41/S43 sagged out of shape in transit due incomplete frame and floor beam installation (no tolerance issues)
  - Aft body join S47/S48 could not be completed before delivery, redesign underway
  - Aft body join S48/S48 (APU cone) unknown issue, redesign underway
  - Center body joins S11/S44/S45/S46 redesign for improved producibility underway
  - Replacement of temporary fasteners hampered by lack of documentation
  - 35 part numbers still missing by July 2008
  - LN1 primary structure still not complete by end of August 2008 after 15 months in FAL
  - Completion now planned for October 6<sup>th</sup>

# Production Issues – LN2

- LN2 entered FAL 15<sup>th</sup> February 2008
  - LN2 structure arrived 50% more complete than LN1
  - Spirit S41 nose section structure 95% complete
  - Center fuselage assembled by Global Aeronautica contained partial wiring, flight test equipment, ducting, systems and insulation in the forward section S43 (Kawasaki) and center wing section S11 (Fuji), but significantly less in sections S44 and S46 (Alenia)
  - Vought aft body S47/S48 structure 93%, but devoid of systems and installations on delivery\*
  - MHI wings delivered with temporary fasteners and parts missing

\* Corroborating source believed to be Vought internal (Design News, 1<sup>st</sup> March 2008)

- “Ship 2 went to Seattle 2 months late from last schedule change”
- “Several 1000 parts short and no insulation, wrong hardware, no system components, full of FOD and unworked discrepancies generated by Vought”
- “Stringer wrinkles and delamination going undetected by Vought quality”
- “No inventory control oversight and accountability”
- “Inability to attract competent technicians to the facility”
- “Novice student inspectors, no competent management organization in-house”
- “Ships 3, 4, 5, and 6 all have more defects than the fatigue model”

# Production Issues - LN3

- LN3 entered FAL 2<sup>nd</sup> May 2008
  - Structure arrived 65% more complete than LN1
  - Spirit S41 structure completion level on delivery 98%
  - Systems completion level on delivery 37%
  - Structural work on fuselage mid-section continued through August



# Production Issues – LN4, LN5

- LN4 entered FAL 6<sup>th</sup> August 2008
  - Delivery delayed 5 weeks due to damage sustained in production at Global Aeronautica
    - Incorrectly installed fasteners, non-compliance by temp worker
    - Ad-hoc FAA inspection highlighted FOD issues and workers bringing in their own tools
  - Spirit S41 structure 100% complete
  - Center fuselage systems installation targeted to be 50% complete on delivery
  - Vought aft body section S47/S48 structure 98% complete, systems 87% complete, including THSA as well as potable and waste water tanks
- LN5 was to enter FAL 31<sup>st</sup> August 2008 – DELAYED
  - Center fuselage was undergoing assembly and systems integration at Global Aeronautica. Completion of the wiring approximately 30-40% with major structures fairly complete.
  - Center fuselage systems installation targeted to be 75% complete on delivery
  - Aft body section S47/S48 in the final systems installation at Vought. Due to arrive with 96% of systems installed.
  - Wing ship set delivered on 23<sup>rd</sup> August with high level of completion but still some wiring outstanding.
  - Alenia horizontal stabilizer and the first Spirit GEnx-compatible pylons delivered

# Production Issues – LN6...

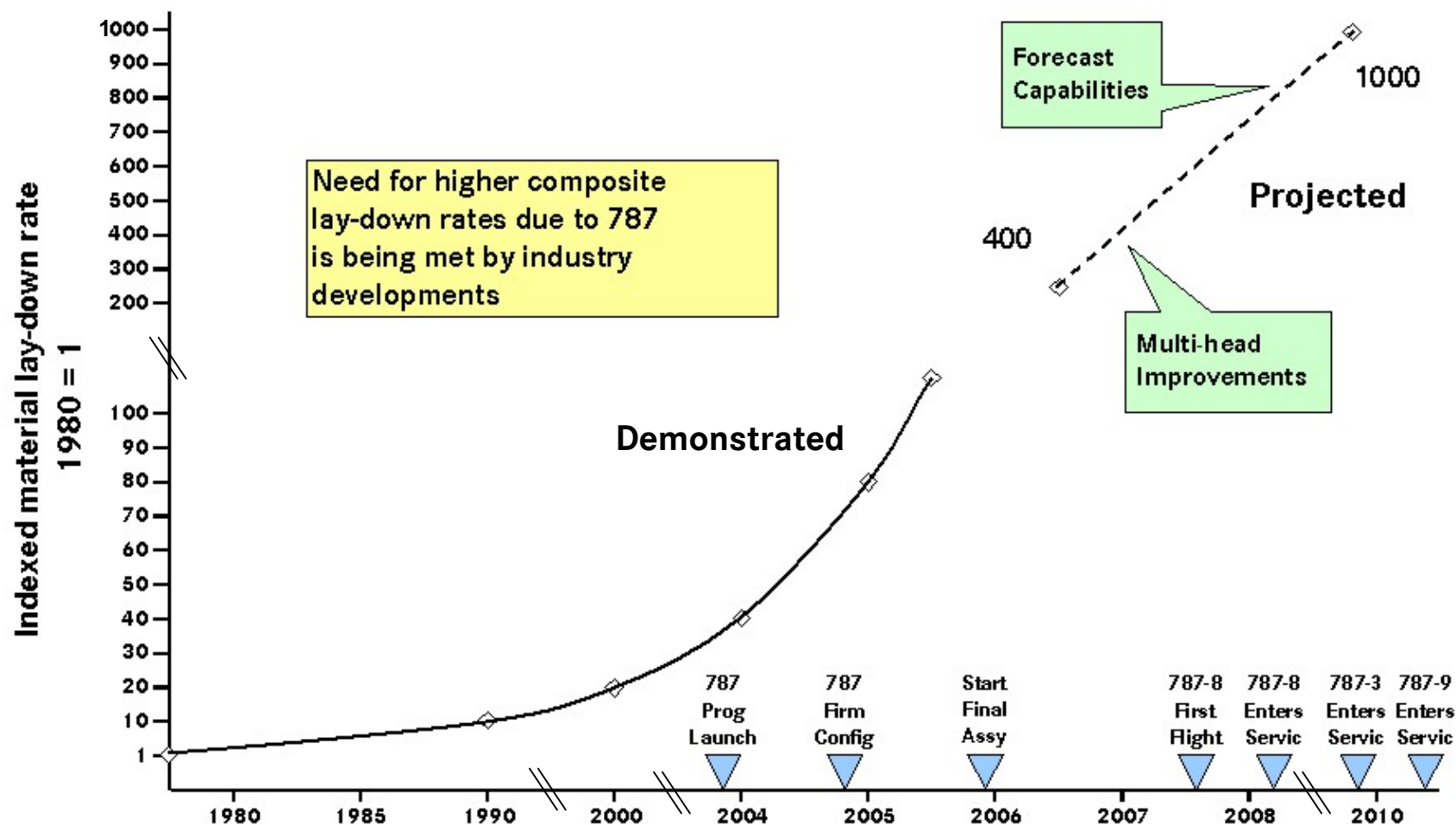
- LN8
  - LN8 mid fuselage to be first fully-stuffed assembly delivered by Global Aeronautica

# Production Issues – Material Lay-down Rate

According to Spirit, composite material lay-down rates are far below projections

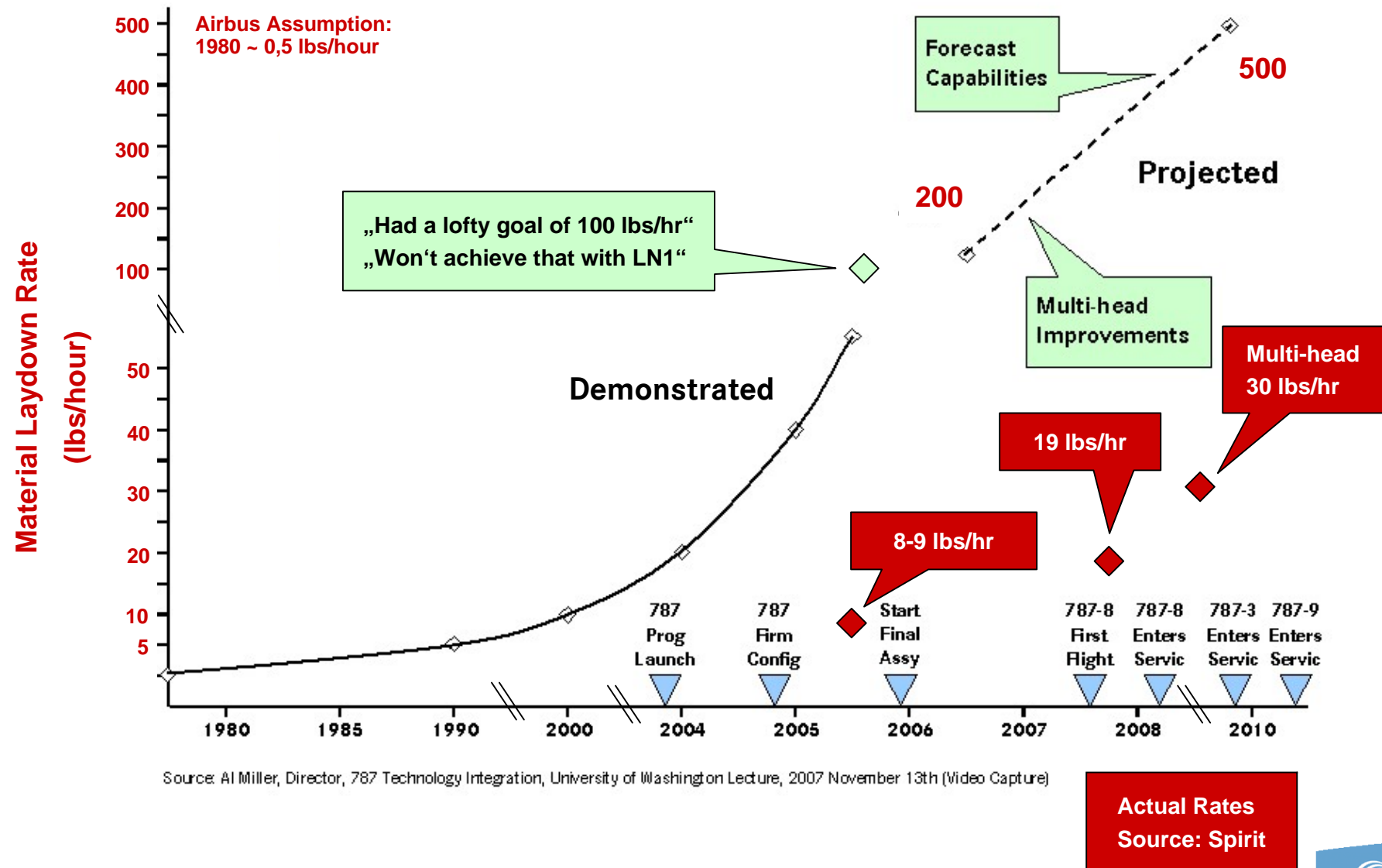
- The initial goal was 100 lbs/hr with a single-head machine
- Production started at 8-9 lbs/hour
- Efficiency gradually increased to 19 lbs/hour
- The rate is expected to increase to 30 lbs per hour once a new dual-head machine on order arrives.
- The rate of 100 lbs/hour now is a mid-term goal.
- The following chart has been reproduced from a video of a Boeing lecture held by Al Miller, Boeing Director ,787 Technology Integration, at the University of Washington in November 2007
- The Boeing chart is indexed to the 1980 technology level in material lay-down rates. It can be established that a rate of 0.5 lbs per hour was achieved by manual lay-down at that timeframe.
- Matching the result with the Spirit figures as above seems to indicate that the current production rate is less than a third of the targeted initial rate and almost one order of magnitude below the forecast for recurring production.
- This will have a significant impact on tooling and facility investment in order to support the targeted ramp-up in production figures

# 787 Material Lay-down Rates – Projected



Source: Al Miller, Director, 787 Technology Integration, University of Washington Lecture, 2007 November 13th (Video Capture)

# 787 Material Lay-down Rates - Actual



# Production – Ramp-up Schedule

- Original objective was a fast production ramp-up to achieve a rate of 10 aircraft per month in 2010
- In April 2008, the objective of rate 10 was pushed out by 2 years to 2012, with a more gradual ramp-up in deliveries in the first two years to mitigate the risk of having to rework early aircraft
- Boeing announced that due to the delay in first flight by 14 months and the slower ramp up deliveries would be “delayed by 20 month on average”
- One airline was advised by Boeing that the production ramp-up would be patterned after what was achieved with the 777 program. This would mean that only a rate of 7 would be achieved in 2012
- In fact, Boeing guidance implies that first delivery is delayed by 16 months, from May 2008 to September 2009. Moreover, announcements by various customers indicate accumulated delays of up to 36 months (JAL) with “the average in excess of 27 months” (ILFC). This matches the 777 ramp-up scenario.
- Despite this and the additional delays incurred since April 2008, launch customer ANA announced in September 2008 that they agreed with Boeing that first delivery is to happen in August 2009.

# Production – 787 Ramp-up Schedule

		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Boeing	May 03	1,6	2,9	5,8	7,0	7,0	7,0					Implicit Monthly Production Rate at 12 months
787 Production Guidance		8	35	69	84	84	84					Explicit BCA Communication
		8	43	112	196	280	364					Implicit Aggregate Output
Boeing	Oct 05	1,6	2,9	5,8	7,3	10,1	10,3					Implicit Monthly Production Rate at 12 months
787 Production Guidance		8	35	69	87	121	124					Explicit BCA Communication
		8	43	112	199	320	444					Implicit Aggregate Output
Boeing	Feb 07	1,6	2,9	5,9	10,2	10,3	10,3	10,3	10,3	10,3	10,3	Implicit Monthly Production Rate at 12 months
787 Production Guidance		8	35	71	122	124	124	124	124	124	124	Explicit BCA Communication
		8	43	114	236	360	484	608	732	856	980	Implicit Aggregate Output
Boeing	Apr 08			2,1	5,8	8,6	10,0	10,0				Implicit Monthly Production Rate at 12 months
787 Delivery Guidance				25	69	103	120	120				Explicit BCA Communication
				25	94	197	317	437				Implicit Aggregate Deliveries
EIXDI	Sep 08	0	2	3	5	7	8	9	10			Assumed Monthly Production Rate at 12 months
Production Estimate		0	24	36	60	84	96	108	120			Implicit Annual Production
			24	60	120	204	300	408	528			Implicit Aggregate Production
Supplier A)	3Q/08	0	1,8	3,3	4,8	8,3	9,4	10,7	10,9	11,4		Implicit Monthly Production Rate at 12 months
787 Production Rates		0	21	40	58	99	113	128	131	137		787 Production Rates
			21	61	119	218	331	459	590	727		Implicit Aggregate Production Output
Supplier B)	2Q/08	0,0	2,0	2,9	5,3	9,3	9,4	9,3	10,8			Implicit Monthly Delivery Rate at 12 months
787 Delivery Rate Study		0	23	35	63	112	113	111	129			Annual Deliveries to Airlines
			23	58	121	233	346	457	586			Implicit Aggregate Deliveries
Lehman Brothers	Jul 08			2,1	5,4	7,6	9,3	9,6				Implicit Monthly Production Rate at 12 months
787 Deliveries Estimate				25	65	91	111	115				Annual Production Rate
				25	90	181	292	407				Annual Production Rate

**Sales success driving  
ever more  
aggressive schedule**

Supplier A, B figures believed to be close to actual Boeing production plan

EIXDI estimate matching 777 ramp-up profile with further rate increase required to support current sales activities for 2020 slots

Key supplier has committed to a peak rate of 7 per month, but negotiations for a higher rate have failed.

# Production – Ramp-up Preparation Status

## Boeing

- Second FAL encouraged by customers, but real bottleneck is supply chain

## Alenia, Hawker de Havilland

- Investing in second autoclave and further equipment to support production ramp-up.

## Kawasaki

- Investing in new factory and production equipment

## Spirit, Vought, Global Aeronautica

- No investment in facilities or equipment, preparing for more gradual ramp-up
- Spirit unilaterally shut down the production of CFRP fuselage barrels in January 2008. Production was slated to restart in 3Q 2008



# Production – Ramp-up Preparation Status

## MHI

- Committed only to rate of 7 per month, facility sized for rate 10.
- Any plan to increase to rate 10 put on hold due to differences with Boeing over financing
- MHI did have preliminary order for additional tooling which was cancelled
- No intention to invest in production beyond rate 10
- MHI working on wing shipset LN7, no problems in process reported

## San Antonio

- First 20 aircraft to be refurbished and modified in San Antonio, TX
- Site is on seven year lease, what for?

# Overview

- Design Issues
- Weight Issues
- Engine Issues
- Certification Issues
- Production Issues
  - Travelled Work
  - Lay-up Rates
  - Ramp Up
- **Schedule Issues**

# Production Schedule Issues

- Pre-planned product improvement
- Original 787-8 Block upgrades
  - LN7 – first customer airplane
  - LN100 – block entry point for family improvements as spin-off from 787-9 design
- Added complexity from engineering changes
  - LN7 block entry point for first block of weight saving items
  - LN7 block entry point for permanent center wing box fixes
  - LN20 block entry point for significant wing empty weight saving
  - LN20 block entry point for max takeoff weight increase and strengthened structure (might also conceal a major impact of the center wing issue)
- Added complexity from schedule slips
  - 787-9 design on hold pending availability of 787-8 ground and flight test data
    - Ground and flight loads data essential to calibrate FEM models
    - Aero and engine performance essential to determine need for additional weight savings
- Conundrum: Either wait for 787-9 design spin-offs to limit number of low-value “wave one aircraft” ... or ramp up fast to recover delay in deliveries to customers

# 787-9 Engineering Changes - April 2008

200804BCA\_787\_Program\_Update\_\_787-9\_weight\_Spec\_K+

## 787-9 Configuration Features (Major Changes from 787-8)

787 DREAMLINER

280 seats (tri-class, 9 abreast economy class)

- Longer raked wing tip (wing span increased to 207.9 ft)
- New outboard slat
- Wing tip structure revised
- Wing structure strengthened
- Revised high lift actuation
- Composite ribs (on selected ribs)
- Structural fuel vent stringers (on selected stringers)

- Fuselage structure strengthened
- Section 43 and 46 lengthened 5 frames (120 in.) each
- Wheel well pressure deck raised and architecture revised
- Section 47/48 join and Section 48/48 join re-designed
- Hybrid Ti-sine wave floor beams

Design Weights:

MTOW = 545,000 lb

MLW = 425,000 lb

MZFW = 400,000 lb

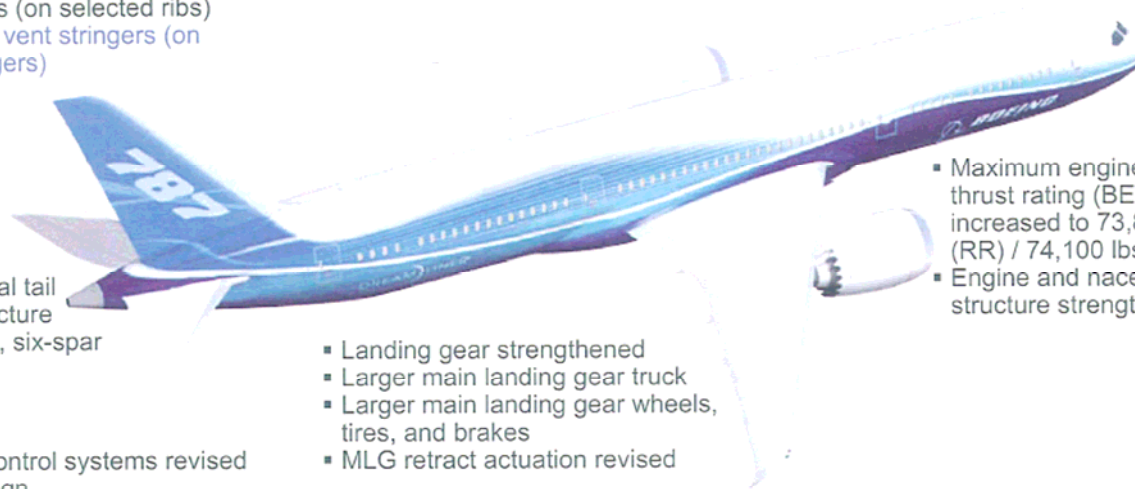
- Revised horizontal tail structural architecture (centerline splice, six-spar arrangement)

- Avionics/Flight Control systems revised due to 787-9 design
- Transport elements lengthened and revised over the wheel well
- Cargo ECS revised

- Landing gear strengthened
- Larger main landing gear truck
- Larger main landing gear wheels, tires, and brakes
- MLG retract actuation revised

- Maximum engine takeoff thrust rating (BET) increased to 73,800 lbs (RR) / 74,100 lbs (GE)
- Engine and nacelle support structure strengthened

- Cargo capacity increased to (6) pallets or (20) LD-3 forward; (5) pallets or (16) LD-3 containers aft



BOEING PROPRIETARY

COPYRIGHT © 2006 THE BOEING COMPANY

# 787-9 Engineering Changes - August 2008

## 787-9 Configuration Features (Major Changes from 787-8)

**Fuselage**

- Section 43 and 46 lengthened 5 frames (120 in., 3.1m) each
- Strengthened structure
- Aft body join re-designed
- Pi-box seat tracks
- Hybrid Ti-sine wave floor beams
- One-piece frame architecture

**Wing**

- Longer raked wing tip (wing span increased to 207.9 ft, 63.3m)
- Strengthened structure
- Composite wing ribs
- Vent stringers

**Design Weights:**

MTOW = 545,000 lb (247.2t)  
MLW = 425,000 lb (192.8t)  
MZFW = 400,000 lb (181.4t)

Black – 787-9 specific changes  
Blue – 787 Family improvements

**Horizontal tail**

- Revised structural architecture (centerline splice, six-spar arrangement)

**Systems**

- Hybrid air/vapor cycle cabin air conditioning system architecture
- Increased power generation to APU starter/generators (250 KVA)
- Cargo ECS revised

**Landing gear**

- Wheel well pressure deck raised and architecture revised
- Larger main landing gear truck
- Larger main landing gear wheels, tires, and brakes


**Engine thrust**

- Maximum engine takeoff thrust rating (BET) increased to 73,800 lbs (RR) / 74,100 lbs (GE)

**Cargo capacity increased**

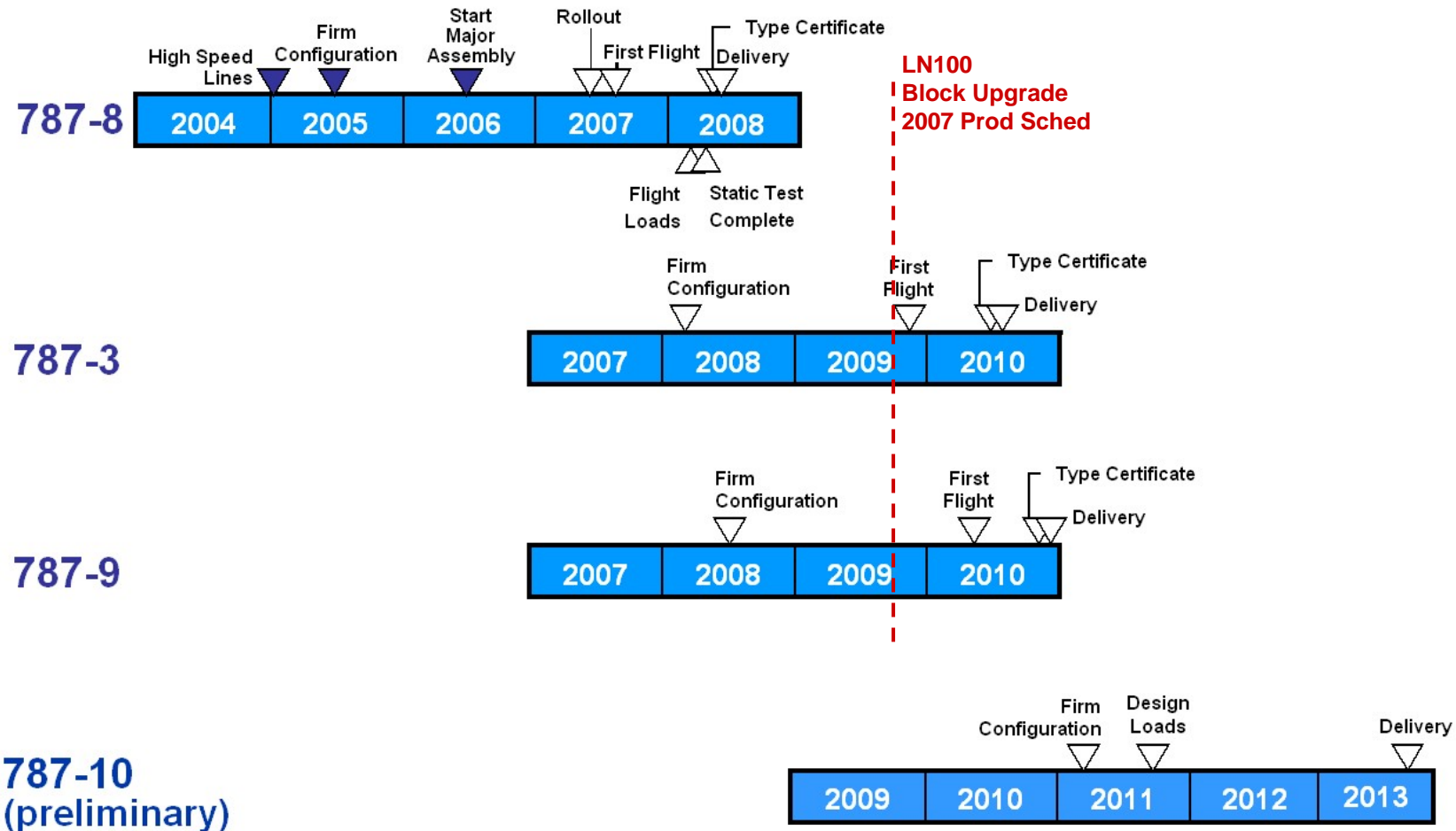
- (6) pallets or (20) LD-3 forward
- (5) pallets or (16) LD-3 aft

**Drag reduction**



BOEING PROPRIETARY COPYRIGHT © 2008 THE BOEING COMPANY

# 787 Program Schedule – August 2007

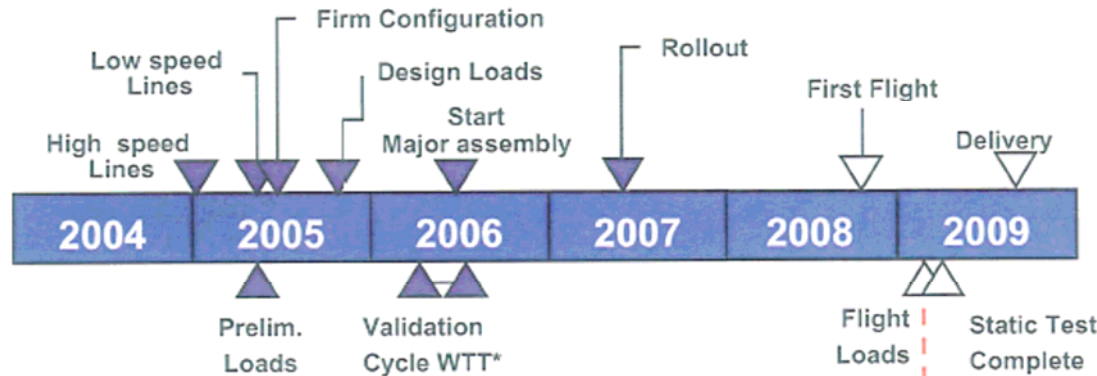


BOEING PROPRIETARY COPYRIGHT © 2005 THE BOEING COMPANY

# 787 Program Schedule – April 2008

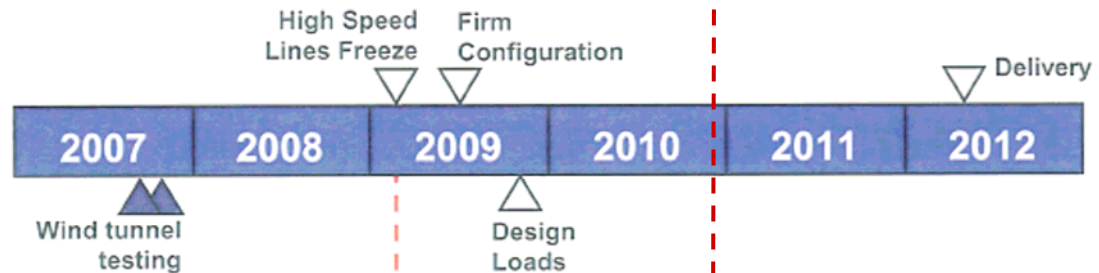
200804BCA\_787\_Program\_Update\_\_787-9\_weight\_Spec\_K+

## 787-8



**LN100**  
**Block Upgrade**  
**April 2008 Prod Schedule**

## 787-9



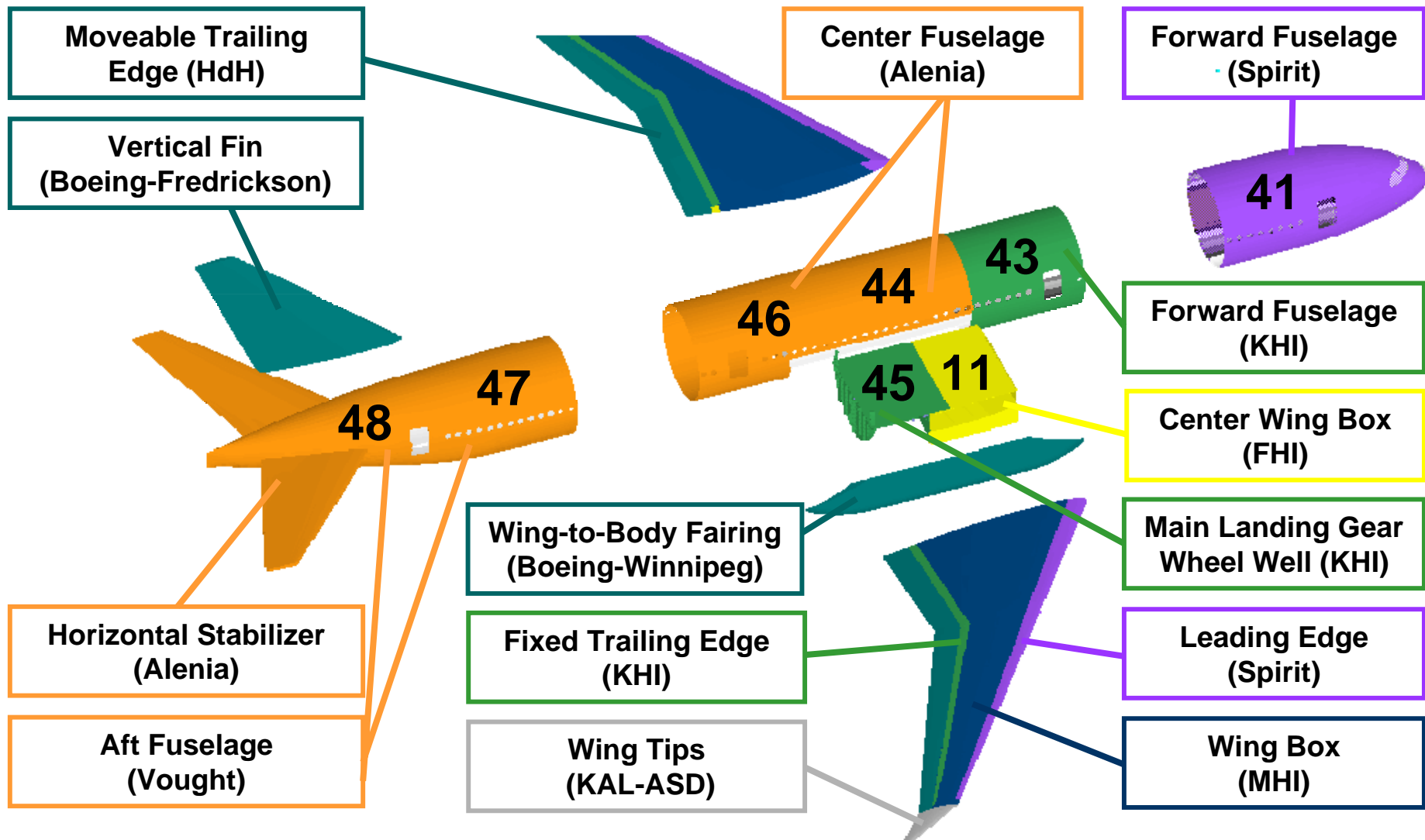




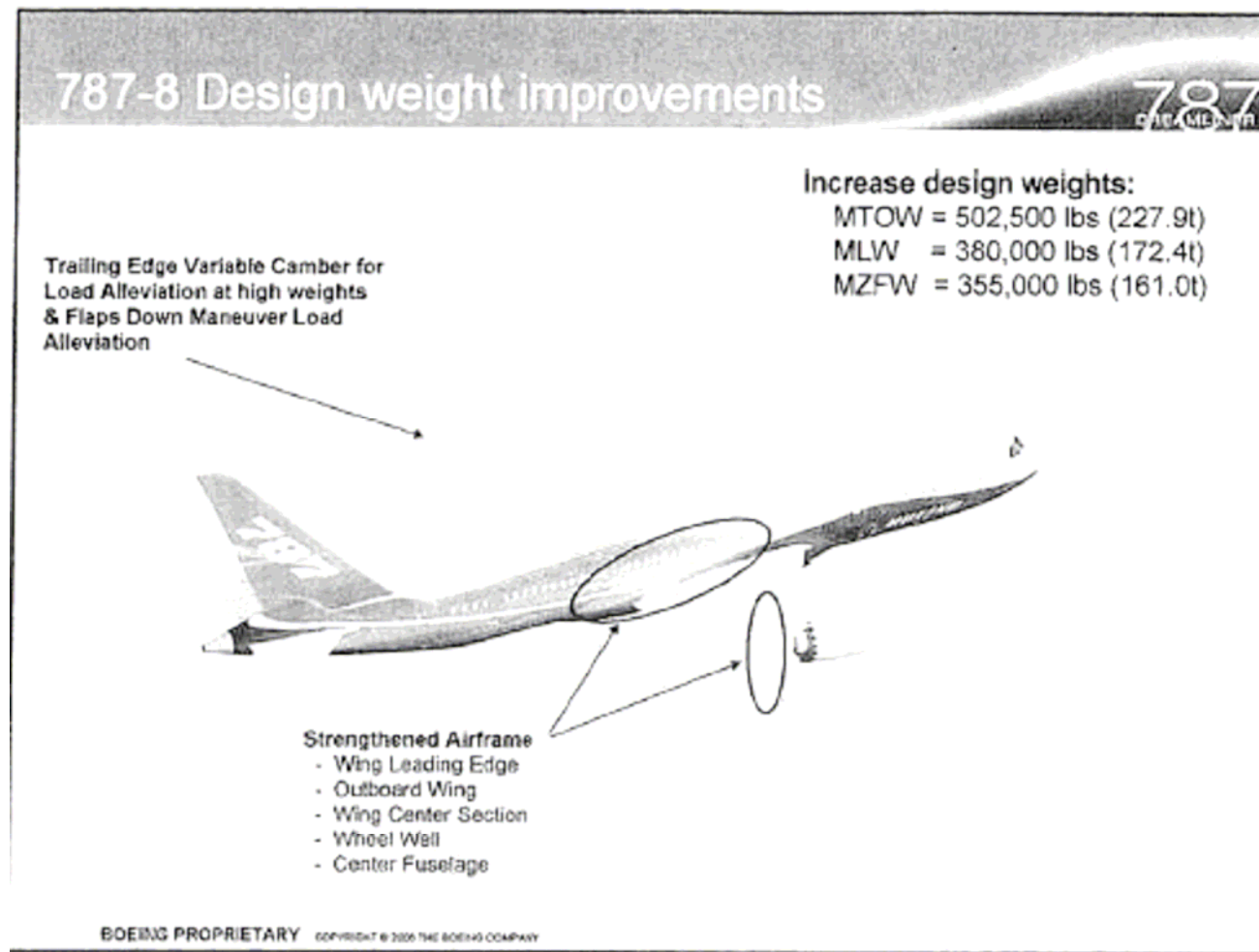


# Backup

# 787 Body Section Overview

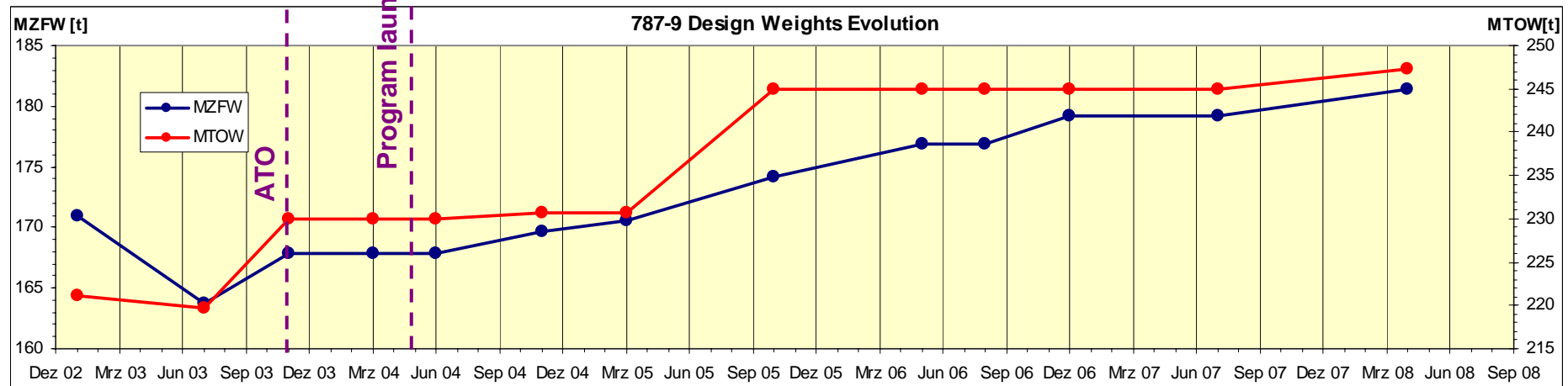
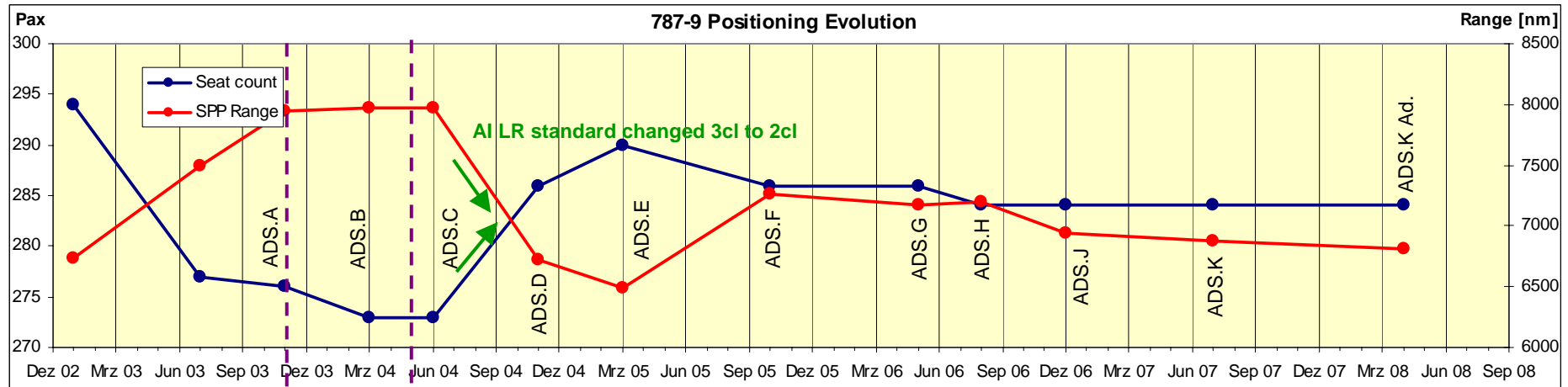


# 787-8 design weight improvements



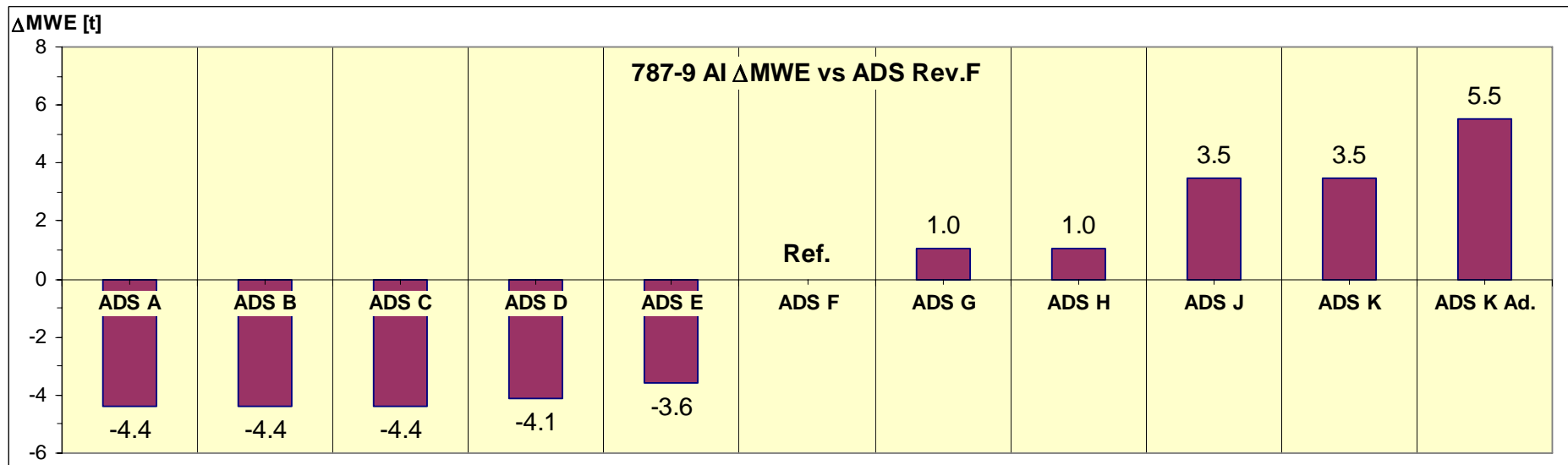
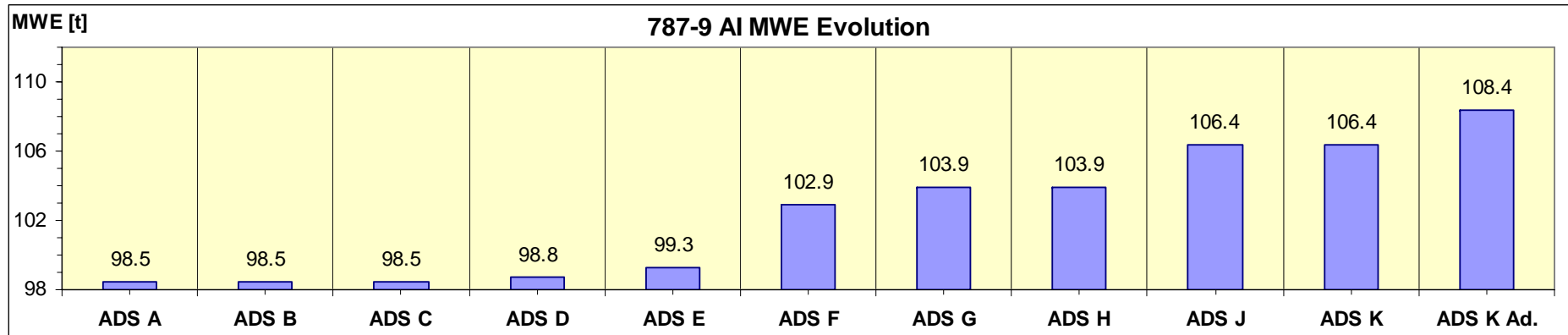
# 787-9 Evolution Charts

787\_Evol\_0908\_EIXUG\_PR0812577\_v2



# 787-9 Evolution Charts

787\_Evol\_0908\_EIXUG\_PR0812577\_v2



*This document and all information contained herein is the sole property of AIRBUS S.A.S. No intellectual property rights are granted by the delivery of this document or the disclosure of its content. This document shall not be reproduced or disclosed to a third party without the express written consent of AIRBUS S.A.S. This document and its content shall not be used for any purpose other than that for which it is supplied.*

*The statements made herein do not constitute an offer. They are based on the mentioned assumptions and are expressed in good faith. Where the supporting grounds for these statements are not shown, AIRBUS S.A.S. will be pleased to explain the basis thereof.*

