AUGUST 2011

FLIGHT

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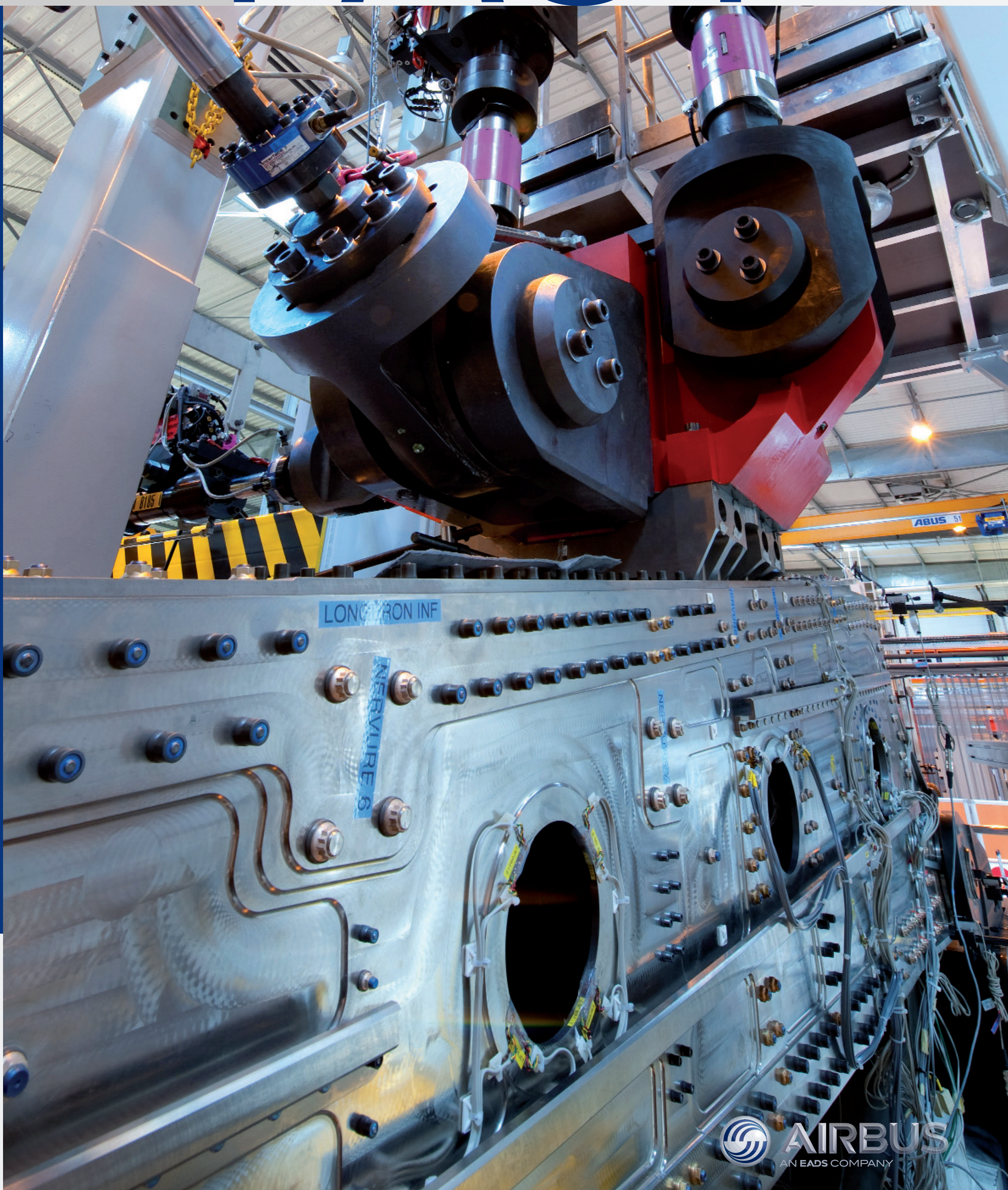
FAST 48

AIRBUS TECHNICAL MAGAZINE



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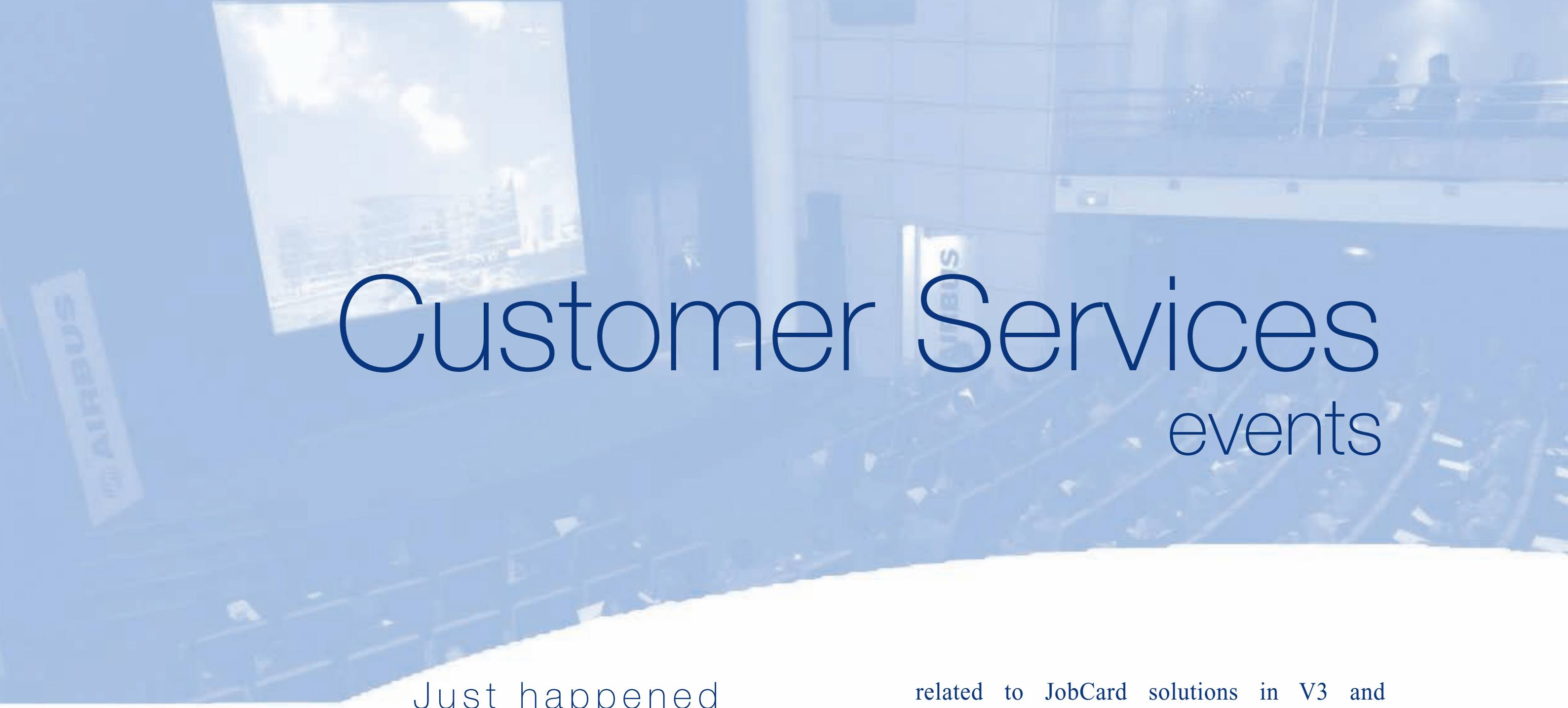

Customer Services
events

Just happened

A320 Family symposium in Toronto

The main aim of this symposium which was held last May was to provide the A320 Family operator's community with an opportunity to review the major issues and their associated initiatives with Airbus and its key suppliers. A caucus followed, highlighting a consolidated request for key areas of focus from the operators for a collaborative work.

In particular, the caucus revealed that the highly successful FAIR (Forum with Airlines for Interactive Resolution) Working Groups should be continued and developed, and that collaborative approaches also be developed for component obsolescence management and fuel saving initiatives.

The 17th Performance & Operations conference in Dubai

This conference gathered 270 attendees involved in flight operations including over 90 airlines, airworthiness authorities and suppliers. Nearly 80 presentations including the Going Digital project, Operational Landing Distances, or EFB (Electronic Flight Bag) have been presented by Airbus specialists, not to forget the participation of some of Airbus' customers.

Airbus introduced for the first time a new type of sessions called "Sharing experience roundtables". A pre-selected panel of three to five participants were on stage, debating on a list of topics and moderated by an Airbus specialist. The rest of the audience had the opportunity to express their points of view. This open exchange on the important Flight operations' topics has received a very warm welcome by all participants.

Record participation for the 5th AirN@v users club

The 85 customers from 49 airlines, MROs and leasing companies met last June in Toulouse, France, to share their experience and to discuss with Airbus AirN@v specialists.

The first day of the users club was dedicated to software and functionality enhancements that are available with the AirN@v V3 technology.

Workshops and feedback on V3 and training needs have been held, followed by presentations related to JobCard solutions in V3 and AirN@v/Engineering enhancements. The second day was dedicated to the advanced functionalities of the current AirN@v V2 modules and the benefits that have been achieved with Technical Data Upgrade's enhanced functionalities.

Airbus customers have appreciated the enhancements introduced with AirN@v V3.

Support Improvement meeting, Toulouse - France

Airbus has recently organized its second Support Improvement meeting in Europe hosting eight major suppliers and 11 key airlines from the European region. For the first time a co-chairman, Mr Eduardo Sebastião, M&E Strategic Purchasing Manager at Air Portugal has helped Airbus in preparing and driving this event. The main objective of this meeting was to focus on the suppliers' continued support improvement projects for customers. The suppliers highlighted their improvement plans and spent time in bilateral meetings to address specific concerns of the airlines.

The participants also had the opportunity to share their views during three workshops focusing on 'Supplier Improvement plans and tools enhancement', the 'Airbus Supplier Support Operation Team Scope' and on how to 'Improve Airbus cabin BFE Supplier Support rating'.

Coming soon

Leasing conference

The next Leasing conference will be held in Dublin, Ireland, on the 12th and 13th October 2011. The invitations and agenda will soon be sent out.

A300/A310 Family symposium

The next A300/A310 Family symposium will be held in Istanbul, Turkey, from 17th to 20th October 2011. The OIT (Operators Information Telex) with the agenda and invitations will soon be sent.

Airbus Family symposiums are held for each Airbus programme every two years, and target airline engineering and maintenance managers. The prime function of these meetings is to enable two-way communication, leading to an ever safer and more efficient fleet.

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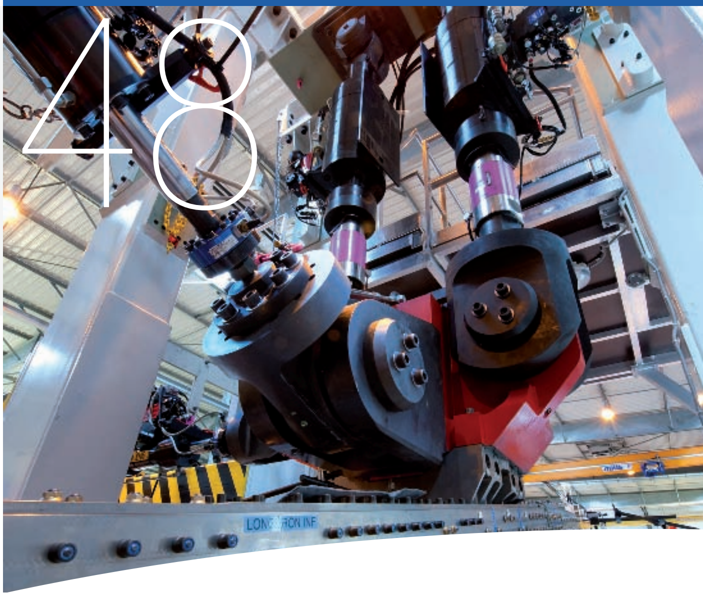

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Every little helps!

The Airbus High Tyre Pressure Test

A regulation change for new aircraft generation

When the International Civil Aviation Organisation (ICAO) initiated the Aircraft Classification Number/Pavement Classification Number (ACN/PCN) system in 1978, they included a simplified means for airports to categorize their pavement as either rigid (Portland cement concrete) or flexible (asphalt concrete) pavements, an index of subgrade (natural soil) categories that expresses the bearing strength of the soil on which the pavement rests, and an allowable tyre pressure. From the advent of this system, the tyre pressure element was only loosely defined, having no prescribed methodology. The dilemma that are facing both airports and aircraft manufacturers is that commercial aircraft tyre pressures have gradually increased across the categories described in the ACN/PCN system and yet few, if any pavement failures, have been identified as having been caused by higher tyre pressures. This article describes a full-scale test programme called "High Tyre Pressure Test" (HTPT) which was performed by Airbus for supporting a revision of the current tyre pressure limit code.

Cyril FABRE
Head of Airfield Pavement
Airport Operations
Airbus S.A.S.

Background

In 1978, the ICAO initiated the adoption of a single means for airports to express the load bearing capacity of airfield pavements and at the same time, created a means by which the aircraft manufacturers could indicate the pavement loading intensity of their aircraft. The method is now used worldwide and is referred to as the ACN/PCN system. There are five attributes to the ACN/PCN system (see figure and table 1). The methodology is, by now, used by 95% of the ICAO member states at all of their international class airports.

Why do aircraft tyre pressures tend to increase?

With the continuous increase in air traffic over the past three decades, combined with a demand for higher aircraft payloads, range capabilities, and at the same time recognizing the need to develop eco-efficient aircraft, the aircraft manufacturers have had to design their new aircraft to comply with these additional challenges. As a direct consequence, aircraft sizes and weights have gradually increased. Among many aspects, the landing gear is one of the most fundamental aspects of the aircraft design. This system and its integration process encompass multi-engineering disciplines, including cost and weight considerations. Landing gear weight can represent between 6 to 12% of the aircraft's empty weight. Aircraft manufacturers must comply with and anticipate the payload-range increases and at the same time, reduce cruise fuel consumption, CO_2, NOx and other gas emissions on the ground, while meeting required noise regulations. Aircraft pavement loading therefore is the result of an optimisation process, essentially driven by aircraft weight (which itself is driven by range), landing gear concepts and aircraft geometry which all serve to result in higher wheel loads (ACN) and tyre inflation pressures.

notes

More than 40% of the current long-range airports' network is limited to 1.5 megapascal (MPa) operations.

Pavement Classification Number (PCN) details

Figure 1

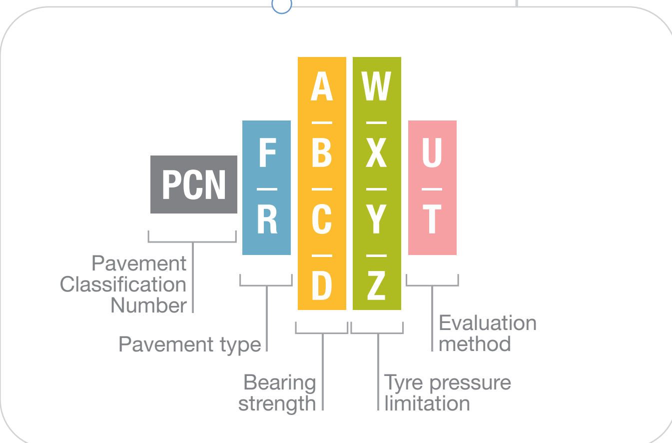
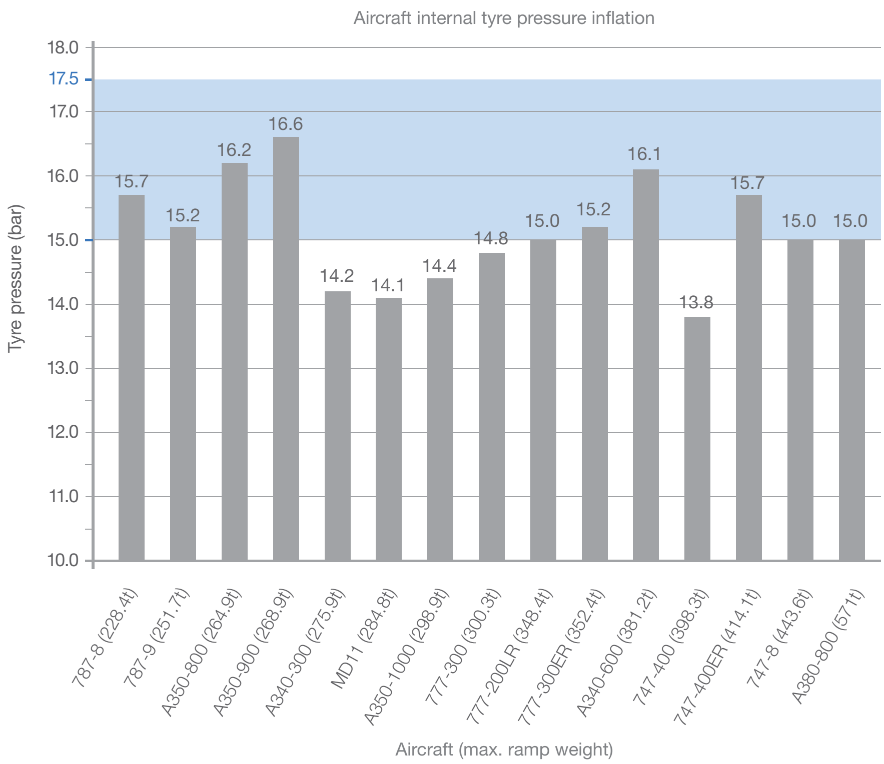


Table 1

The PCN with the highest permitted ACN at the appropriate sub-grade category.	The type of pavement		Pavement sub-grade category *CBR= Bearing capacity of a soil *K/PCI = Kilograms per cubic inch				Maximum tyre pressure authorized for the pavement			Pavement design / evaluation method	
				Category	Pavement CBR*	Pavement K/PCI*					
	F	Flexible	A	High	Over 13	Over 400	W	High	Unlimited	T	Technical design or evaluation
	R	Rigid	B	Medium	8-13	201-400	X	Medium	Limited to 217 psi	U	By historical data of aircraft using the pavement
			C	Low	4-8	100-200	Y	Low	Limited to 145 psi		
			D	Ultra low	0-4	Under 100	Z	Very low	Limited to 73 psi		

Aircraft tyre pressure summary

Figure 2



Consequences of adding wheels to bogies

The only other way to significantly improve pavement loading without increasing the tyre pressure is to distribute aircraft weight over additional wheels, which could have a major impact on payload and fuel tank capability. However, by adding four wheels to a typical aircraft equipped with a 4-wheel main landing gear (either by replacing a 4-wheel solution by a 6-wheel or adding a belly gear) would have detrimental impacts at several levels: The noise impact would increase in a range from +0.2 to +0.4dB (Effective Perceived Noise - EPN) depending on the gear geometry, and the drag during approach would also be increased. With the most optimistic hypothesis and using aircraft manufacturer design standards, the 4-wheel solution is 800kg to 1000kg lighter than an equivalent 6-wheel design, saving the average weight of 10 passengers with luggage.

Ground manoeuvring is improved with the 4-wheel solution as well, requiring less pavement width for U-turns and the ability to manoeuvre into tight gates or narrow taxi-lanes. Lastly, the overall direct value (the actual operating cost to the airline - factoring in the cost of the operational interruptions including the wheel and tyre maintenance) is about USD 1 million per aircraft life (100,000 flight hours).

High Tyre Pressure Test

1. TEST FACILITY

THE EXPERIMENTAL RUNWAY

A variety of seven typical flexible pavement test sections were designed in the Toulouse-Blagnac (France) airport with the intent of exhibiting whether the new proposed tyre pressure limit code (letter ‘X’) of 1.75MPa was a reasonable upper limit for typical pavements, as a replacement to the present value of 1.5MPa. As the tyre pressure effect is expected to be concentrated on top layers (namely surface and base courses), experimental pavements were designed by selecting a sub-base layer with a high bearing capacity, in order to limit structural damage which could occur in the deepest layers under high traffic levels and heavy wheel loads.

Parameters that varied from one section to another were the thickness of asphalt concrete surface layers (6, 8 and 12cm), its performance towards rutting (mixed composition) and the surface treatment (grooving). Test sections were instrumented to follow up both permanent and resilient deformation at different pavement depths (see figure 3).

Theoretically, the rut depth measurement at regular stops would have been sufficient to assess the real impact of tyre pressures on flexible-type pavements.

Figure 4

Vehicle simulator - the 'Turtle'

But overall pavement depth was instrumented to properly assess which layers are mainly influenced by the tyre pressure or by the wheel load itself, in order to verify the initial hypothesis and to understand the overall rutting mechanism which remains poorly defined in the literature.

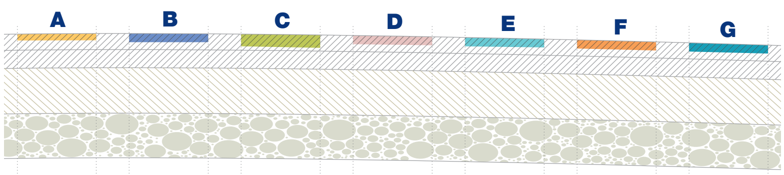
THE HEAVY TRAFFIC SIMULATOR: 'THE TURTLE'

The landing gear used for the tests had been developed by Airbus for the previous Pavement Experimental Programmes (PEP 1 & 2). The simulator was equipped with four dual wheel modules (see table 2). The distance between the two wheels of a given module and the distance between two different modules was chosen to be as large as possible, so that the wheels and gears interaction are minimized in the deepest layer of the pavement. This was done to study the influence of each module and each wheel on the pavement independently.

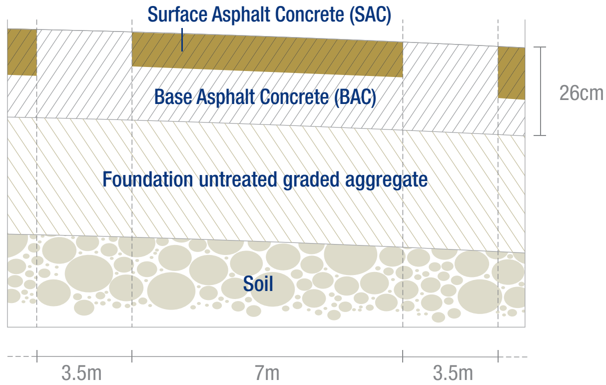
The High Tyre Pressure Test (HTPT) explored current and forecasted aircraft wheel loads and corresponding tyre pressures, from low to high temperature conditions. Four loading cases were selected to compare the wheel load (2 wheel-loads) and the tyre pressure effect (2 internal tyre pressure inflations) by combining both parameters.

Pavement test Item (longitudinal view)

Figure 3



	SAC (cm)	BAC (cm)
A	6	20
B	8	18
C	12	14
D	8	18
E	8	18
F	8	18
G	8	18



Vehicle simulator loading cases

Table 2

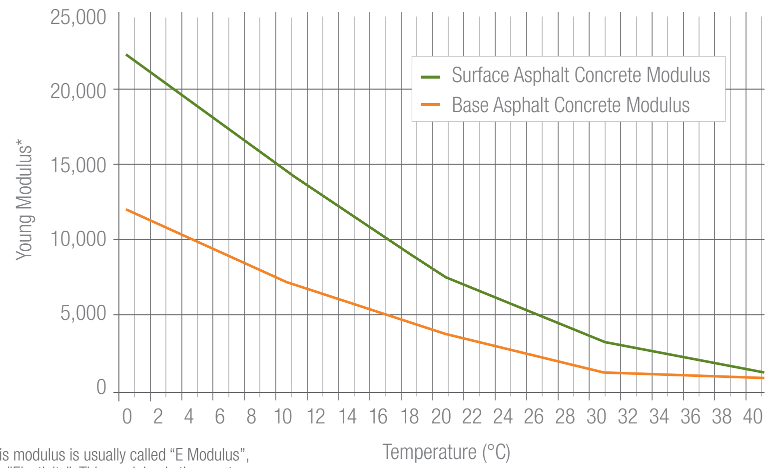
Module	Pnz		Load per wheel		Deflection	Gross contact area
	Bar	PSI	Tons	Lbs	mm	cm2
M1	17.5	254	28.7	63,270	99	1608
M2	15.0	218	33.2	73,200	125	2171
M3	17.5	254	33.2	73,200	112	1869
M4	15.0	218	28.7	63,270	112	1869

2. TEST CAMPAIGN

The tests consisted of a series of full-scale airfield pavements that were trafficked with full-scale aircraft tyres and wheel loads. The tests were designed to expose the wheel load and tyre pressure pavement behaviors across meaningful ranges of both attributes. Tyre pressures were set at 1.5MPa (the current 'X' limit) and 1.75MPa (proposed new 'X' limit), the wheel loads being set at the high end of typical commercial aircraft wheel loads of 28.7 and 33.2 tons (63,300 to 73,200 pounds). Traffic speeds were limited to 5km/h which was intended to be representative of the most damaging case and the tests were performed during a full year to benefit from year-round pavement temperatures, from lower throughout higher temperatures (August 2010 with a surface temperature exceeding 60°C). Tests were continuously monitored and the surface rutting measurement was made at regular intervals to follow rut depth development along the four loading cases. In addition, two temperature profiles were installed in the pavement because of asphalt concrete material sensitivity to temperature (figure 5).
A specific lateral wandering was applied to avoid the creation of gutters. The wander path was about 1.6m (63 inches) and space between two adjacent trajectories was 400mm (16 inches), corresponding to the tyre contact area width. Up to 11,000 passes of the simulator were applied from September 2009 to August 2010 (figure 6).

Temperature sensitivity on asphalt concrete layers

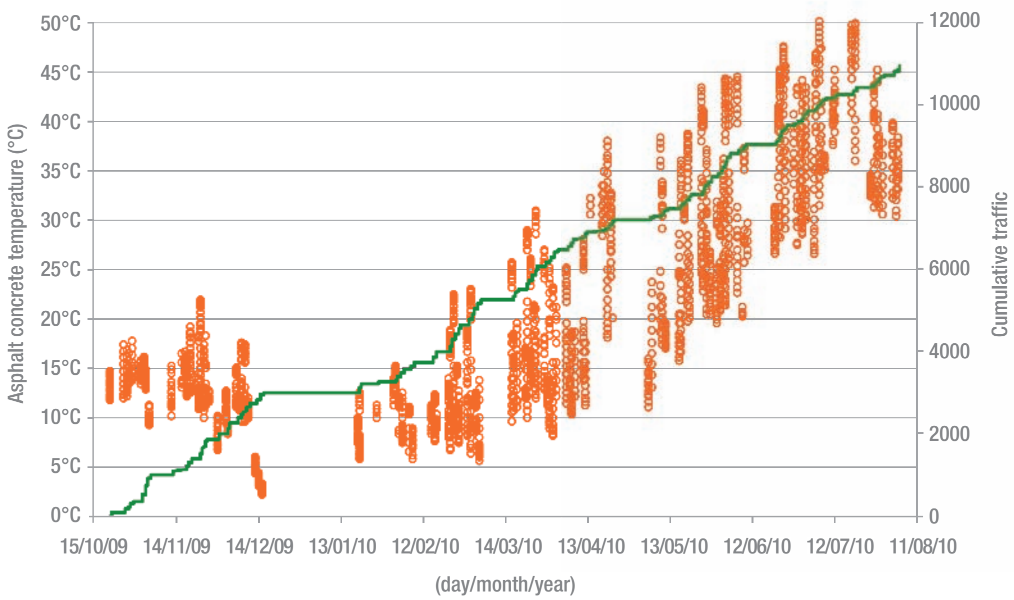
Figure 5



* This modulus is usually called "E Modulus", E for "Elasticity". This modulus is the most important material property which describes the ratio of stress to strain of a given material.

Evolution of the cumulative traffic and the temperature in asphalt concrete

Figure 6



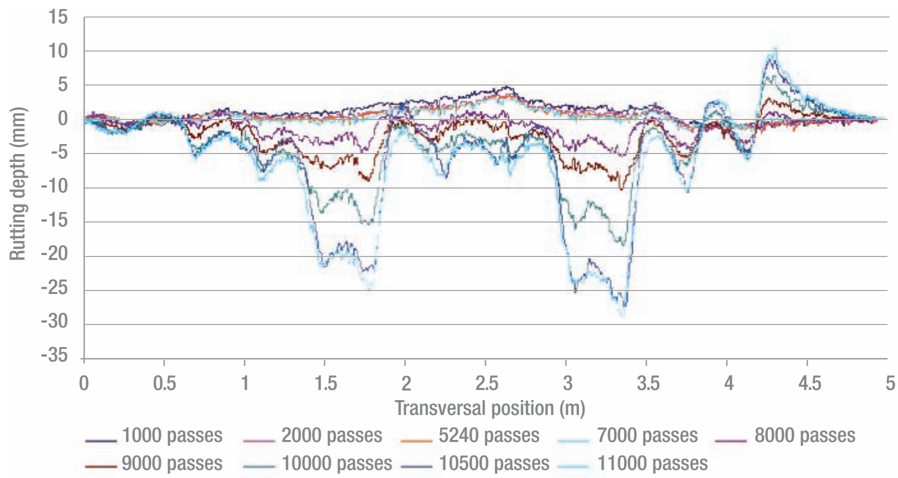
3. LESSONS LEARNT FROM THE TEST CAMPAIGN: TESTS ANALYSIS

Each rutting survey consisted of 84 transversal profiles' measurements, distributed over the seven structures and 4 twin-wheel modules. In figure 7, you will find an example of such transversal rutting profiles. For all sections (A to G), the rutting depth at 7,000 passes (mid April 2010) remained very low, due to the very moderate asphalt concrete temperature at that date. Then, the curves' evolution clearly exhibited a change in the slope, as a more and more significant percentage of the traffic was applied with the asphalt concrete temperatures exceeding 30°C. After more than 11,000 load applications, core samples were extracted from the experimental taxiway to evaluate the interface conditions between the surface and the Base Asphalt Concrete layers, exhibiting the contribution of rutting on each layer.

The tyre pressure effects must be considered with an associated wheel load, both parameters being closely and intrinsically linked and cannot be described as isolated parameters. However, the contribution of each parameter to the rut depth development can be evaluated separately.
Both combined results from the rutting measurement and the core sampling allowed confirmation on known phenomenons, new lessons and advanced knowledge on the real impact of the tyre pressure on flexible-type runways (these representing approximately 70% of the worldwide runways).

Transversal rutting profiles measured on section B, profile P2, module M3

Figure 7



Synthesis of the rutting depths reached at the end of the tests

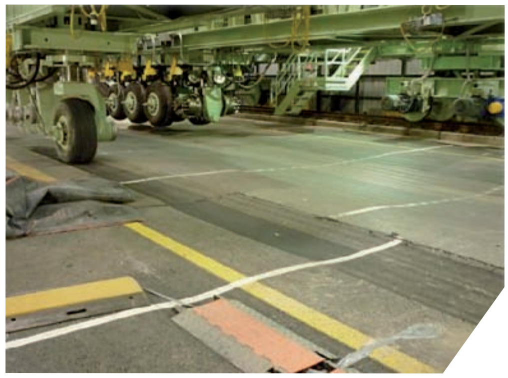
Table 3

Section	Module (mm)				Pressure effect (Δ in mm)		Wheel-load effect (Δ in mm)	
	M1	M2	M3	M4	M3 vs M2 @33.2t	M1 vs M4 @28.7t	M3 vs M1 @1.75MPa	M2 vs M4 @1.5MPa
A	24.9	22.9	27.9	21.8	5.0	3.1	3.0	1.1
B-E	22.9	22.4	27.5	20.7	5.1	2.2	4.6	1.7
C	24.2	22.6	25.4	21.8	2.8	2.4	1.2	0.8
D	20.9	20.2	21.9	17.5	1.7	3.5	1.0	2.7
F	19.7	21.1	22.6	17.8	1.5	1.9	2.9	3.3
G at 10,000 passes	23.2	22.0	26.9	20.9	4.9	2.3	3.7	1.1
G at 15,000 passes	34.1	33.5	44.7	32.5	11.2	1.6	10.6	1.0

EFFECT OF THE ASPHALT CONCRETE RUTTING PERFORMANCE

For section D (high rutting performance), material behaviour with regards to rutting is noticeably better than the other sections' behaviours, and tends to reduce the wheel load and tyre pressure effects.

As expected, the rut depth on section G (low rutting performance surface) is higher than on other test sections, and visco-plastic creeping at constant volume's strain-path is more significant.



National Airport Pavement Test Facility (Atlantic City, N.J., USA)

Figure 8

information

The proposed revision to the tyre pressure categories and designations has been positively endorsed by the ICAO Aerodrome Panel and the formal groups of the ANC (Air Navigation Commission). The ICAO state letter on the Annex 14 amendment (which includes the tyre pressure code limits' revision) was sent on May 30, 2011 to the ICAO state members. The applicability date for the revision implementation will be in November 2012, after ICAO's state members' comments.

Airbus is the International Coordinating Council of Aerospace Industries Associations (ICCAIA) representative at the ICAO-Aerodrome Operations and Services Working Group, Pavement Sub-Group (AOSWG-PSG).

EFFECT OF SURFACE TREATMENT

The grooving (section F) surprisingly appears to improve the rutting behaviour compared to B and E (which have the same structure) to a similar extent as section D, using a high rutting performance.

EFFECT OF SURFACE ASPHALT CONCRETE THICKNESS

Despite the three different thicknesses (6cm, 8cm and 12cm) of the same asphalt concrete standard surface used in sections A, B, C and E, their rutting behaviour is quite similar. This is due to surface rutting being caused by permanent deformation, not only of the surface asphalt concrete, but also the asphalt concrete base course - the sum of both layers being identical in sections A, B, C and E.

Rutting mechanism

THE INITIATION AND DEVELOPMENT OF PERMANENT DEFORMATIONS INCREASED WITH HIGH ASPHALT CONCRETE TEMPERATURES

The tests confirmed that the speed of the rutting evolution significantly increased as the asphalt concrete temperatures exceeded the range of 30-35°C, irrespective of the load, tyre pressure or traffic level. The prevailing rutting mechanism is the post-compaction of the pavement material by traffic on both, surface and the Base Asphalt Concrete. The visco-thermoplastic creeping of asphalt concrete material is secondary to the post compaction, except for the low rutting performance asphalt concrete material which combines equally both failure modes.

In addition, core samples showed that the permanent deformation not only affects the surface asphalt concrete layer as anticipated, but also the whole thickness of the asphalt concrete and the unbounded material. This permanent deformation of the bituminous base layer and the unbounded materials which was exacerbated by the very low moving speed of the simulator, confirmed the prevailing wheel load effect on the deepest layers and therefore, the relative low tyre pressure effect on asphalt concrete material.

WHEEL LOAD AND TYRE PRESSURE EFFECT

For a given wheel load applied on the pavement at a very low speed, the full-scale test campaign showed that rut depth differences ranged from 1.9mm (for the lowest wheel load of 28.7t) to 5.1mm (for the heaviest wheel load of 33.2t), showing that the contribution of the tyre pressure (that is isolated from the wheel load effect) to the rutting can be considered as very low.

The wheel load effect was identified as insignificant on the surface and Base Asphalt Concrete, although more confined in unbounded material, leading to the result that it was more related to the structural behaviour of the airfield pavement which is already considered in the ACN and the pavement thickness design method.

It should be observed that these major findings of the HTPT are in good concordance with the results of similar tests performed by the Federal Aviation Administration (FAA) and the Boeing Company at the Atlantic City, N.J. U.S.A., facility.

Current and proposed allowable tyre pressure categories

Table 4

Tire pressure category	Current ICAO limits MPa(psi), loaded	Proposed new ICAO limits MPa(psi), loaded
W	High	Unlimited
X	Medium: 1.50 (218)	High: 1.75 (254)
Y	Low: 1.0 (145)	Medium: 1.25 (181)
Z	Very low: .50 (73)	Low: .50 (73)

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Conclusion

In the light of the High Tyre Pressure Test campaign, it has been established and substantiated that an increase of tyre pressure from the current Code ‘X’ category limit of 1.5MPa of the ACN/PCN to an upper limit of 1.75MPa will not adversely affect either surface and Base Asphalt Concrete materials or the structural capacity of typical airfield pavements (i.e. pavement life duration will not be decreased as a consequence of increasing tyre pressure). The primary objective of this full-scale test campaign was to evaluate whether the new proposed tyre pressure upper limit of 1.75MPa was reasonable for typical flexible pavements. This objective was successfully achieved, and led to the main conclusion that this proposal is fully compliant with the test results.

The experiment, never done before allowed additional lessons which could be of interest for further investigations on this topic.

This intensive full-scale test programme, as for the A380 Pavement Experimental Programme (1997-2004), has brought value of experimental data, lighting up key elements for supporting the ICAO decision making process. This has contributed to replacing an empirical-based approach to a more rational methodology for the evaluation of the real effect of aircraft tyre pressures on flexible pavements.

This change will allow the ICAO tyre pressure limit codes to be formally and permanently changed to be more consistent with both, the performance of real world pavements and the new aircraft generation.

Damage tolerant composite fuselage sizing
Characterisation of accidental damage threat

The extensive use of composite parts in the design of the new generations of airframe, especially for the A350XWB programme and its full composite fuselage, has required some new studies on the tolerance to damage. Indeed, composite technologies are sensitive to impacts (also called accidental damages). A good knowledge of the impact threat to be considered for the composite sizing is key to ensure a robust design with equivalent maintainability, as for conventional metallic design. Its evaluation is based on an extensive collection and analysis of damages reported by airlines, supported by original impact calibration tests on large specimens representative of real aircraft.

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Head of Structures Test Operations France
Airbus Engineering

Emilie MORTEAU
Structure Analysis
Airbus Engineering

Composite structures and Fatigue & Damage Tolerance (F&DT)

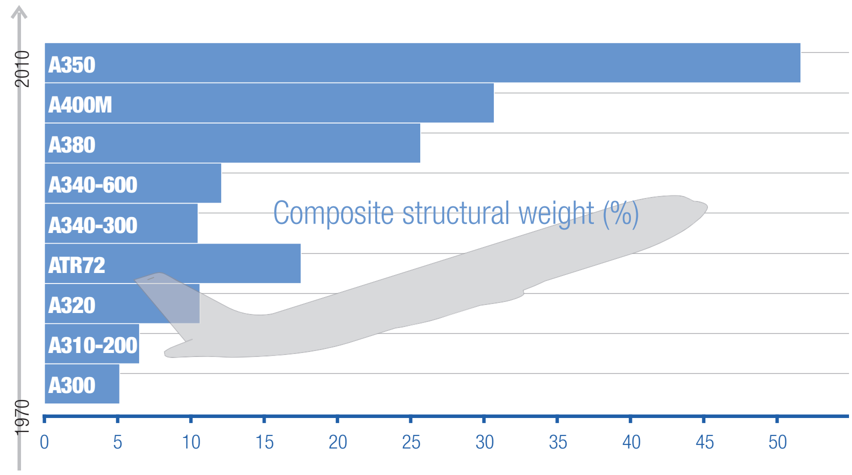
Airbus has more than 30 years of experience in the development and manufacturing of Carbon-Fibre-Reinforced Plastic (CFRP) components such as for the wing movables and the Vertical Tail Plan on A310, the Horizontal Tail Plan on A320, the Keel Beam on A340-600, the Centre Wing Box on A380 as well as its rear pressure bulkhead and rear fuselage section, and also with wing applications for Falcon 10, ATR 72 and A400M.
For the A350XWB programme, the use of CFRP material is much more important compared to previously certified aircraft with its composite wings, empennage and fuselage (see figure 1).

Composite and metallic materials behave differently when they are damaged. An impact on metallic structures creates a dent which can be detected. An impact on composite structures may create internal damages (delamination) not necessarily visually detectable.

The strength degradation due to damage is also different. On metallic structures, the damages (cracks) can propagate and the strength decrease progressively (slow crack growth behaviour). This is predicted by analysis supported by tests. For composite structures, the damage can lead to an immediate strength reduction and it will not evolve throughout the aircraft life. It is important to be able to characterize the damage for different impact levels and the resulting strength capacity.

Evolution of the proportion of composites used on Airbus fleets

Figure 1



notes

Airworthiness regulation (AMC25-571):
The damage tolerance evaluation of structure is intended to ensure that should serious fatigue, corrosion, or accidental damage occur within the operational life of the aeroplane, the remaining structure can withstand reasonable loads without failure or excessive structural deformation until the damage is detected.

information

Composite materials are not isotropic in behaviour. They are composed of fibre (carbon, glass or Kevlar, etc.) associated with resin (epoxy). Their inherent advantage is that the various fibre orientations can be tailored to suit various structural applications. Because of the low sensitivity to fatigue of composites (linked to Airbus' design principle) and their corrosion resistance, the accidental damage is at the forefront of the evaluation of damages for composite structures.

Areas of approach of ground vehicles near the aircraft

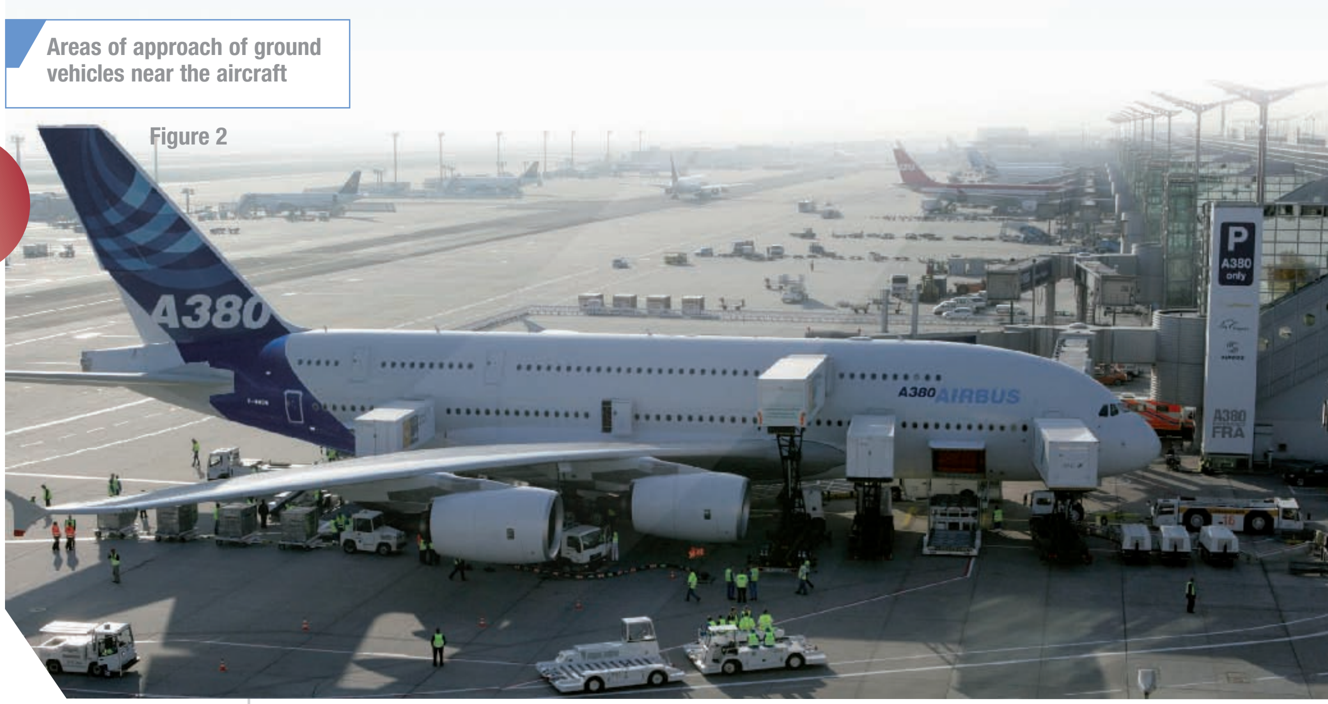


Figure 2

The fuselage is considered as one of the most prone parts to impact damages. Its structure can be damaged during manufacturing, shipping, airline operations and maintenance operations. Sources of impact damage are numerous, including: Falling tools and equipment during maintenance, runway debris, hail, small birds and collisions with ground vehicles or other aircraft on the taxiway (see figure 2). The introduction of composite in the A350XWB fuselage raised the need to refine the characterisation of the impact threat and to delimit it.

In-service history

The understanding of the fuselage impact threat cannot be based only on a theoretical analysis. A rigorous impact threat assessment involves a large in-service feedback on Airbus fleet (with metallic fuselage till now) and a litterature survey (Sikorsky data).

Airbus has collected, since many years, two types of damage reports from the airlines:

- Reports of damages which are outside the scope of the SRM (Structural Repair Manual). In that case, Airbus is systematically involved in the damage assessment and the repair definition, if needed.
- Reports of damages which are within the scope of the SRM, from airlines willing to provide this information. This input is precious as it allows growing knowledge on a more comprehensive range of damages (i.e.: Including small and/or frequent events).

To make the analysis successful, the required information for each damage is:

- The aircraft history (number of flight hours and flight cycles),
- The detailed description of the damage: Location, type of damage (dent, scratch, crack, etc.), dimensions (length, width, shape, depth, etc.), with relevant pictures,
- The source of the damage, although often unknown.

The collected damages represent the history of a fleet cumulating more than 30 millions of flight hours and constitute today the cornerstone of the analysis.

The most frequently damaged zones (i.e.: Damage prone areas) of the fuselage have been identified on the passenger and cargo door surrounds and also on the maintenance access doors (see figure 3).

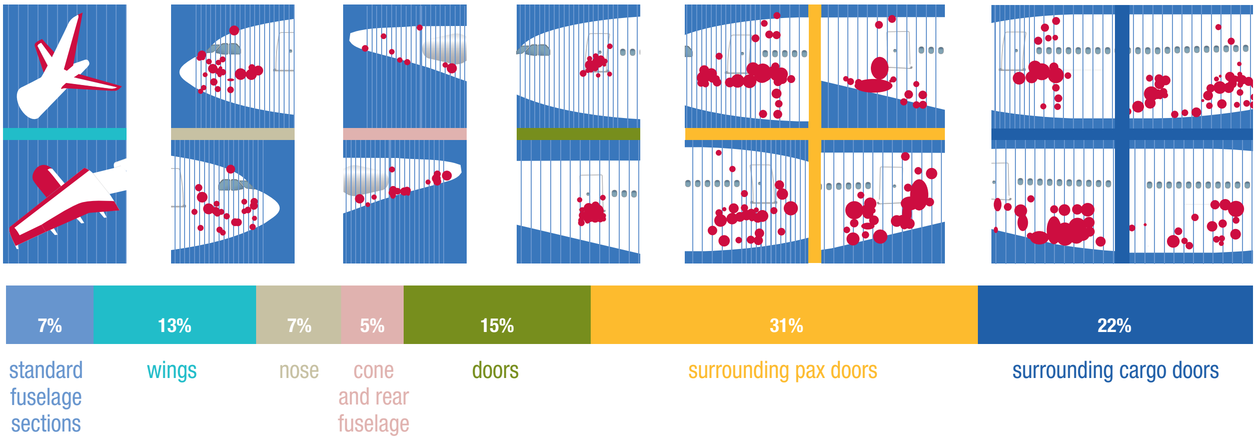
information

The impact threat on a given aircraft area is the mathematical description of the probability of impact occurrence versus its level of energy/force.

Global percentage of impacts by zones on the aircraft

Figure 3

Example on A320 Family



Impact calibration on representative specimens

Since the impact source is generally unknown, the in-service impact damage cannot be precisely linked to a particular impact energy/force. Therefore, an empirical approach was chosen.

A large impact test campaign on a metallic fuselage section was done to reproduce the in-service damages found from the metallic survey. The tests aim at identifying the energy/force which were causing these damages. As the in-service data collected by Airbus is mainly on the A320 Family, the representative fuselage section chosen was a metallic A320 fuselage from a certification static test campaign.

Specific impact test means were developed to be able to reproduce the range of reported damages (from low to high energy, quasi static and low velocity), with an adjustable impactor head at numerous locations and along several angles of impact incidence.

The objective was to standardize impact means to simulate the two main impact families:

- Family 1: Accidental damages from ground operations - Medium to significant level of energy (from 35Joule (J) to more than 150J) at a low velocity or in a quasi-static mode. This last mode consists in a configuration where the impacting and the impacted parts are already in contact (no shock) with one pushing the other.
- Family 2: Runway debris and tool drop - Light projectiles (maximum 4kg) impact the structure with a relative velocity from 2m/s (metre per second) to 15m/s.

The first family of impacts is done by the way of an innovative testing system, called GUISMOT (Generic Unmanned Impacting System for Maintenance and Operations Threats). GUISMOT was especially developed by the Airbus Structures Test Domain for this A320 impact calibration campaign.

Figure 4 shows the GUISMOT strapped on the A320 fuselage section. The interface with the fuselage is ensured through four adjustable pads so that GUISMOT can fit to different sections of the fuselage. The damage is introduced with a moveable part inside an impact arm whose movements can be controlled by a computer.

Pictures of GUISMOT impact device

Figure 4

Example of projectile/actuator ends (bumper and steel hemispherical)

Figure 5

The impact location is adjusted, precisely within a frame of 800x600mm², thanks to a bi-directional motorized system assisted by a camera.

Depending on the expected configuration, the moveable part consists of:

- A heavy projectile (40kg) at low velocity (below 5m/s) to represent an accidental collision with a ground vehicle,
- An actuator (load capacity of eight tons) to perform quasi-static dents, representative of a vehicle in operation (e.g. cargo loader).

The end of the projectile/actuator can be adapted to simulate different impact sources (hemispherical steel parts, sharp steel parts, rubber interfaces, etc., as shown in figure 5). As an example, the rubber parts are strictly representative of some GSE (Ground Service Equipment) protection (procured from the supplier of GSE).

GUISMOT is fully equipped with a set of sensors to characterize the impact (velocity, angle of incidence, etc.) and its effect on the fuselage (dent size). For quasi-static dents, the introduced load as well as the 3D deformation of the structure during the test can also be recorded.

The deformation measurement is based on an optical method (image correlation) which uses high resolution cameras.

The second family of impact test means used for tool dropping, runway impact simulations, etc., is called the “Gasgun” (see figure 6). It has been especially developed for Airbus according to a technical specification from its engineers. It has been set as the Airbus standard for damage introduction in all Airbus Structures Test centres.
The impact is generated by a mass projected by using pressurized air. The device is calibrated so that the level of air pressure in the Gasgun chamber gives the required level of impact energy.
A displacement sensor measures the mass translation into the Gasgun shaft, in order to determine the real velocity at the impact and then to deduce the energy.
A hemispherical steel head of various diameters can be assembled to the projectile.
The impact calibration campaign has been performed in the brand-new Airbus Test Centre of Materials and Structures, located in Toulouse, France, close to the design and stress analysts’ offices for the A350XWB programme. Hundreds of impacts and dents have been introduced with the GUISMOT and the Gasgun onto the A320 test specimen.

Gasgun impact device

Figure 6

Impact threat characterisation

The characterisation of impact threat is addressed in two steps. First the energy/force level is calculated for each in-service damage and then the data are statically analysed for each aircraft zone.

CALCULATION OF ENERGY/FORCE LEVEL

Test points from this large impact calibration campaign were interpolated by mathematical laws allowing a reliable estimation of the impact energy/force associated to each damage reported by the airlines. Those laws include functions to account the skin thickness or the impact location (see figure 7).

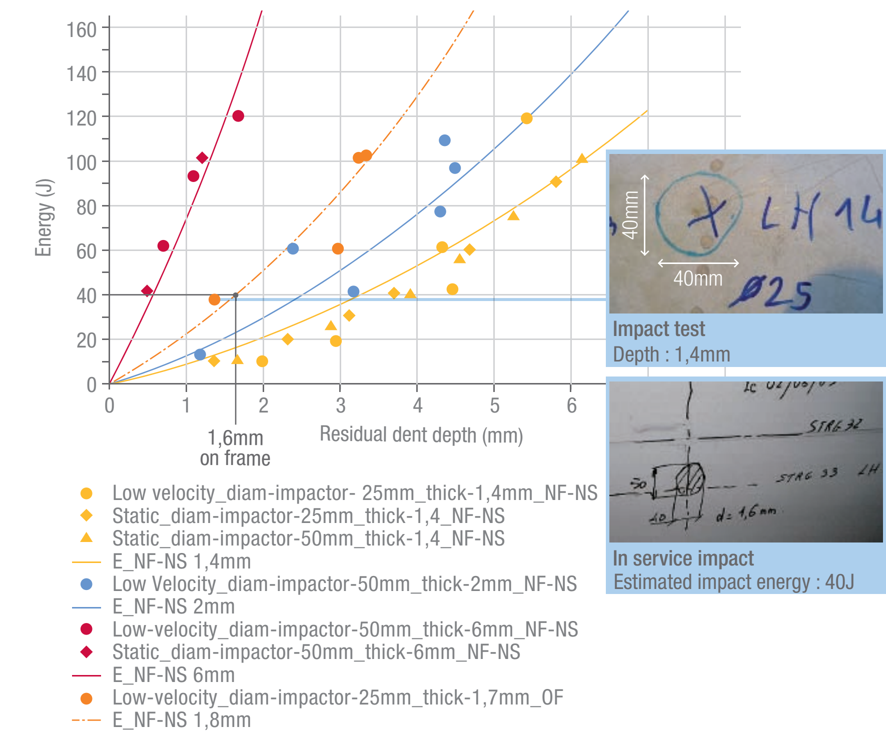
It is therefore possible to plot for a given fleet survey, not only on the exact location of the impact, but also its associated energy/force. Damage prone areas are then clearly identified accordingly (see figure 8).

EVALUATION OF IMPACT THREAT ON EACH ZONE

A dedicated statistical analysis is done for each aircraft zone (typical fuselage areas, areas around passenger or cargo doors, etc.). The outcome is the impact threat that is the mathematical description of the probability of occurrence of an event, at a given level of impact energy/force.

Calibration test results analysis examples

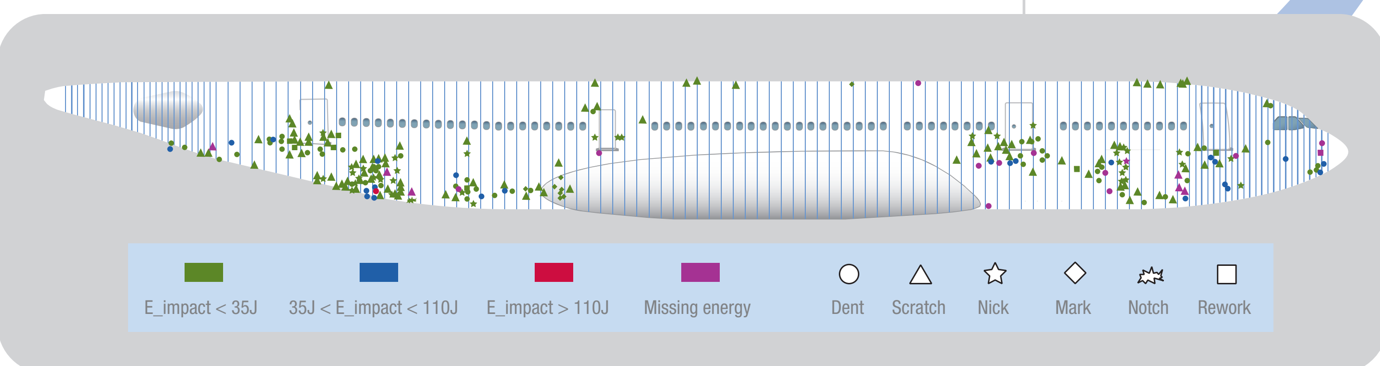
Figure 7



Impact close to stiffening element (frame or stringer) for different skin thicknesses

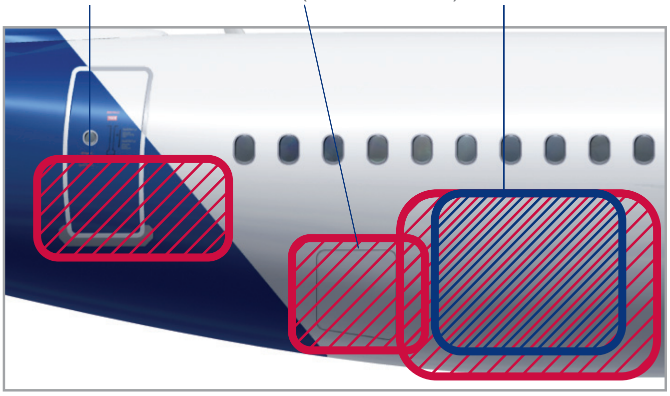
Mapping of impacts (location and level of energies) for one survey highlighting damage prone areas

Figure 8



Example of threat level used for composite fuselage sizing

Figure 9



For each zone, the energy/force level corresponding to the most critical event (maximum energy /force that can occur during one aircraft life) is then identified and taken into account within the composite structures' design rules (see figure 9).

Impacts at these energy levels are introduced on composite test specimens at different levels of the test pyramid (coupon, detail, element, sub-component and component levels) to understand the damage mechanism, check the damage visual detectability and assess the associated residual strength. This empirical approach validates the calculation methods to size damage tolerant composite structures.

Impact threat characterisation - a living process

Figure 10

notes

Design directives are set within Airbus for composite structures' design, so that:

- Realistic impact events that would stay undetectable by a visual inspection, will not reduce the strength capacity below ultimate design loads (Regulation ref. CS.25),
- Robustness is at least equivalent to metallic structures' design.

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Conclusion

Impact threat characterisation is a key parameter for the composite structure damage tolerance sizing. To guarantee the robustness of Airbus composite structures, Airbus Engineering has refined the impact threat evaluation for A350 XWB composite fuselage. This was possible combining the extensive in-service damage surveys with impact calibration tests, involving innovative test means. This analysis has a solid foundation thanks to the strong contribution of the airlines. New in-service data are still key to further expand the database and will consolidate more and more the accidental damage threat characterisation.

AIRBUS

Flight Data Recovery
Time for evolutions

Since their invention, the so called 'Black Boxes' have brought a worthwhile contribution to aviation safety. Past accidents have shown some limits of the flight data retrieval when the accidents have led to the aircraft sinking in deep water. Although the Flight Data Recorders (FDR) and Cockpit Voice Recorders (CVR) are extremely robust, they are not completely indestructible and are sometimes difficult to locate, especially after accidents over maritime or remote areas.

Data recovery can be tricky and turn into a sensitive exercise, especially when the recorders have laid for months in saline solutions under a strong water pressure. To meet new objectives, time has come to look for additional innovations in this highly regulation-driven system. The idea is not to incriminate the traditional recorders, but rather to think of complementary solutions or potential evolutions of current systems, continuously improving reliability and safety.


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Recorders story... for memory

Early attempts to develop flight data recorders are going back to the 1940s. In the early 1950s, a series of accidents where the causes could not be explained led to the grounding of the entire De Havilland Comet fleet for an investigation and put a doubt in the public's mind concerning the safety of passenger jets. Without witnesses nor survivors, only debris of the aircraft were available for the accident investigation. The unavailability of information made it very difficult to determine the root causes of the accident. Triggered by this, David WARREN of the Aeronautical Research Laboratories developed the idea of recording flight crew's conversations and flight data to assist the investigation of the causes of accidents. In the following years, he developed a FDR (Flight Data Recorder) prototype which was able to record some basic flight conditions of the aircraft like its altitude, direction and the crew communication. This data and sound recorder was encapsulated in metal and fire resistant material to be protected in case of an accident. The FDRs became mandatory in the early 1960s. With the early first generation FDRs, only five analogical parameters (heading, airspeed, altitude, vertical acceleration and time) were recorded on a metal foil, and increased from the original acceleration specification of a 100G (G-force) impact to 1000G in 1965. At that time the second generation Cockpit Voice Recorders (CVR) which recorded 30 minutes of flight crew communication and cockpit environment noise, using magnetic audio recording type tape, became also mandatory in commercial aircraft. Over the last 50 years, the flight recorder capabilities have improved significantly driven by new regulations.

Today, all new Airbus produced aircraft are using third generation recorders using solid-state memory as a recording media, storing up to 1024 12-bit words per second, over a 25 hours period and two hours of cockpit voice. These recorders are able to withstand impact forces of 3400G for 6,5ms (milliseconds), a temperature of 1100°C for 60 minutes and a deep sea water pressure of 60MPa (megapascals), equivalent to a depth of 6,000 metres for a period of 30 days. In addition, the Data-Link traffic on CVR is recorded when FANS (Future Air Navigation Systems) is required (see FAST article on page 28).

Why are flight recorders called "Black Boxes"?

The origin of the term "Black Box" is not clear. One explanation is that at the time of the first generation of recorders, all aircraft electronics were housed in black rectangular boxes of standard size and shape. In 1965, it was required to paint the FDRs (Black Boxes) in bright red or orange so that they could be more easily spotted. Almost every airline in the world switched to orange recorder boxes keeping the recognized "Black Box" term.

How does a flight data recording system function?

The Flight Data Recording system gets attention if an airplane is involved in an accident. After the Search And Rescue (SAR), one of the first actions after an accident is to search for the Black Boxes, in order to try to define the cause of the accident. The national organisations responsible to investigate an accident (NTSB, BEA, AAIB, etc.) are using the data stored on the recorders to analyze the flight phases.

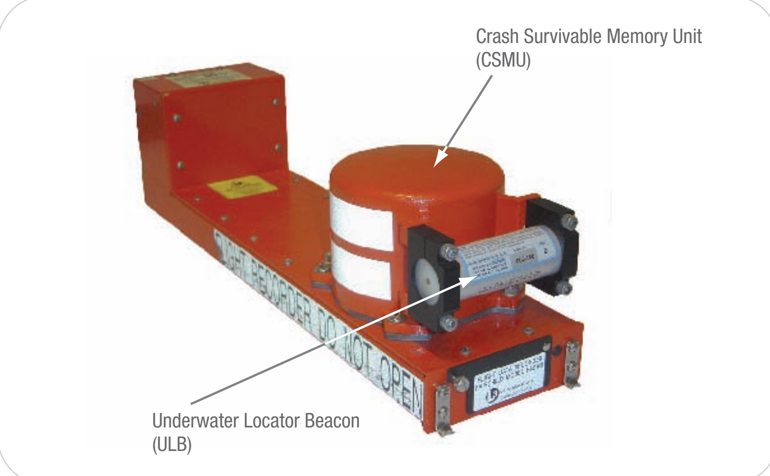
information

G-force:
A force acting on a body as a result of acceleration or gravity, informally described in units of acceleration equal to one 'G'. For example, a 12kg object undergoing a G-force of 2G experiences 24kg of force.

They then decide which measures should be taken to prevent similar accidents to happen again (shared objectives by all the contributors: Manufacturer, airworthiness authorities and the investigation bodies). The Flight Data Recording system collects mandatory parameters required by the airworthiness authorities and additional Airbus required parameters, to record these data on the Solid State Flight Data Recorder (SSFDR). A time signal is transmitted to the CVR for synchronisation purposes.
The sources of these parameters come from several aircraft systems which are connected to the Flight Data Recording system. Recorded data are for example engine data (e.g. EGT, EPR, N1, N2 and fuel), air data (e.g. temperature, altitude and speed), flight control data, navigation data, hydraulic data, etc. Around 1,000 different parameters are recorded and stored over the required period. To record the data during the whole flight profile, the recorder is switched on automatically as soon as one engine is running and it stops five minutes after the last engine is shut down.

Example of an FDR (A380)

Figure 1



Current aircraft definition

Figure 2

How is a Black Box retrieved today?

All Airbus aircraft are equipped with an Emergency Locator Transmitter (ELT). This radio-beacon with an external fixed antenna interfaces with a dedicated Search And Rescue non-geostationary satellite system (COSPAS-SARSAT). When activated, such beacons send out (50 seconds after activation) a worldwide monitored distress signal on 406MHz (formerly 121.5MHz), that either can be located by triangulation or by a GPS (Global Positioning System) signal, whenever equipped. The ELT, can be:

- Automatic Fixed: Rigidly mounted inside the fuselage of the aircraft and automatically triggered by the G-force sensing switch, or manually from the cockpit (it cannot send a signal to the satellite system when underwater),
- Portable Survival (as a complement of the automatic fixed): Generally carried in the cabin or packed into the escape slides/rafts of the aircraft. It floats and can be manually activated, water activated or both, depending on the model. The cabin crew would normally activate these beacons on evacuating the aircraft or requires a survivor to manually do so when the model is not water activated.

When the ELT signal is properly received, it indicates the accident occurrence and the on-ground localisation. As it doesn't work under water, the sunken wreckage can be located thanks to the Underwater Locator Beacon (ULB). The ULB is attached to the memory unit of each recorder and emits, upon immersion, an acoustic signal of 37,5kHz at an interval of one per second.

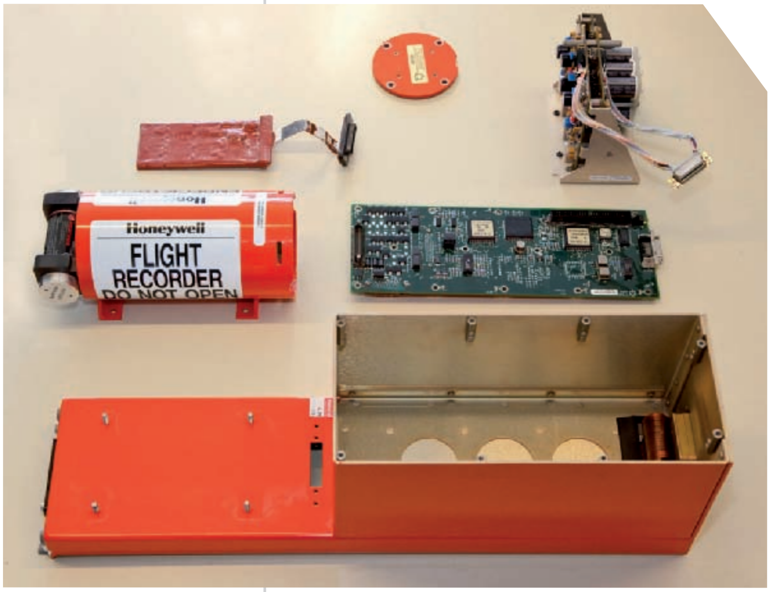
How is the data of the recorder processed?

After the recorder recovery, the Crash Survivable Memory Unit (CSMU) is extracted from its crash protection housing to proceed to the data recovery. The investigation is starting.

The FDR and CVR have brought a great contribution to safety by allowing experience feedback from accidents for improving designs of aircraft, air traffic management, improved operational procedures and trainings. However, there are still possibilities for improvement. Data and voice recordings sometimes do not completely allow the root cause analysis of an accident. Additional recordings are under study to enhance the investigation process. Beyond the technology readiness, a particular attention is paid on non-technical aspects (privacy, laws, unions, etc.) for the definition of future systems.

Picture series showing the crash protected memory module and the crash protection housing

Figure 3



1

When the data are retrieved by the incident investigation specialists, they are presented in a hexadecimal form (the so called raw data) as found in the memory of the recorder.

(see figure 4)

2

The next step is to decode the data in order to achieve a presentation of the data to the engineering units. A computer-based tool does this work by means of a calibration file which comprises all the definitions of the recorded data for the aircraft involved in this matter.

(see figure 5)

3

At the end, a computer-generated illustration based on the recorded data gives a picture of the image of the cockpit displays seen by the pilot, as well as the scenery with the aircraft's trajectory and attitude.

(see figure 6)

International Working Group recommendations to ICAO

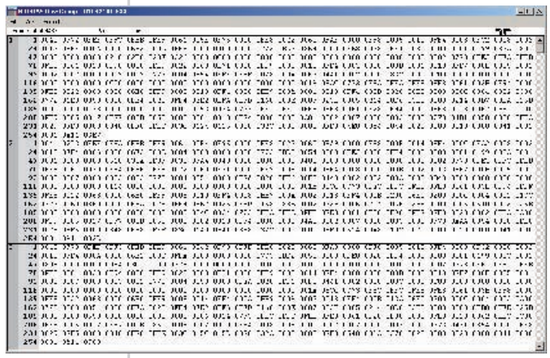
In October 2009, prompted by the difficulties experienced in recovering the FDRs during some sea operations, the French BEA (Bureau d'Enquêtes et d'Analyses - French civil aviation safety investigations and analysis bureau) decided to create an international working group called "Flight Data Recovery". This group, composed of 120 members from numerous countries, represents a wide range of actors like investigation bodies, regulatory authorities, airframe manufacturers, recorder manufacturers, underwater beacon manufacturers, satellite service providers, undersea searching companies and international associations (IATA and IFALPA). The aim of the team is to look into new technologies to safeguard flight data and/or to facilitate the localisation and recovery of on-board recorders. This working group has been investigating different areas such as flight data transmissions via satellite, as well as new flight recorders, but also evaluating emergency beacons and transmitters' technologies.

In an interim report published in December 2009, the BEA made the following recommendations (Rx) to the EASA and ICAO:

- R1: Extend as rapidly as possible to 90 days the regulatory transmission time for ULBs installed on flight recorders on aeroplanes performing public transport flights over maritime areas.
- R2: Make it mandatory, as rapidly as possible, for aeroplanes performing public transport flights over maritime areas to be equipped with an additional ULB, capable of transmitting on a frequency (for example between 8.5kHz and 9.5kHz) and for a duration adapted to the pre-localisation of the wreckage.
- R3: Study the possibility of making it mandatory for aeroplanes performing public transport flights to regularly transmit basic flight parameters (for example position, altitude, speed and heading).
- R4: Ask the FLIRECP (FLIght RECorder Panel) group to establish proposals on the conditions for implementing deployable recorders of the Eurocae ED-112 type for aeroplanes performing public transport flights.

Data image in a hexadecimal presentation

Figure 4



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EUROCAE ED-112

(Minimum Operational Performance Specification for Crash Protected Airborne Recorder Systems) defines the minimum specification to be met for all aircraft requiring flight recorders for recording of flight data, cockpit audio, images and CNS/ATM digital messages and used for investigations of accidents or incidents.

The BEA published the working group's report on its website. Airbus participated in it and supports its conclusions. The report can be downloaded at: http://www.bea.aero/en/enquetes/flight.af.447/triggered.transmission.of.flight.data.pdf

At the light of this working group, the FLIRECP will meet this summer and is planning to discuss the following items:

- Regular or triggered transmission of flight data,
- Deployable flight recorders,
- Class A airborne image recorders,
- Flight recorders to Unmanned Aircraft systems.

The ICAO FLIRECP met in June 2010 and proposed the following amendments of Annex 6 Part 1 and 3 from the International Standards and Recommended Practices for aeroplanes and helicopters:

- Alternate power source for CVR from 1 January 2018.
- Extension of the battery life of the ULB 37.5kHz from 30 days to 90 days at the earliest practicable date, but not later than 1 January 2018.
- Additional aircraft ULB at a frequency of 8.8kHz with a 30 days battery life for 1 January 2018.

A second working group led by the BEA concluded in March 2011 that it would be technically feasible to significantly reduce the search area for wreckage by:

- Triggering transmission of appropriate data via SATCOM prior to the impact, and/or,
- Automatically activating next generation ELTs prior to impact, and/or,
- Increasing the frequency of position reports.

Airbus internal Flight Data Recovery project

Airbus management has decided to launch an internal project aiming at assessing potential solutions to achieve the three following objectives:

OBJECTIVE 1: IMPROVE THE SEARCH AND RESCUE (SAR)

Search and rescue could be improved by two complementary means:

- An automatic send of alerting information regarding an aircraft accident.
- A second one providing the most accurate water accident localisation (R1 recommendation).

I. OBJECTIVE FULFILMENT

To fulfil this objective, Airbus decided to carry out studies regarding the improvement of the currently used emergency transmitters (ELT), but also a regular transmission of the aircraft positions' reporting parameters though a communication media.

The ELT is currently the main emergency alerting system providing accurate, timely and reliable distress alert and location when correctly activated. The major issue with current ELT definition is that only 25% of fixed ELTs operate correctly during an accident. In many accident cases, the ELT activation was highly unlikely for different reasons (no survivors for manual activation, destruction at impact, immersion when no water trigger, antenna cable cut or nadir* seeker orientation impossible due to debris or being upside down). Thus, ways of ELT improvement are currently under study and should improve considerably this important aircraft equipment. A possible evolution of this essential emergency beacon, amongst others, would be having an automatic free floating deployable ELT, attached to the external part of airframe, automatically deployed away from aircraft and activated either on impact, manually from the cockpit or by water detection.

2. AUTOMATIC POSITIONNING

The automatic position reporting by regular transmissions of some parameters remains also a viable solution, taking into consideration the easiness and facility of its implementation. Airbus' proposition is to send out six parameters (time/latitude/longitude/altitude/ground speed/heading) to the operator's ground segment every 15 minutes maximum during a 'normal flight', and this rate would accelerate to 30 seconds when triggered by an inconsistency between the expected aircraft position (waypoints, flight level, etc.) and the real one (GPS position/altitude). By receiving 30 seconds rhythmic aircraft positioning, the operators would then be in a position to get organized to react and check their aircraft situation. In case of voluntary deviations (evasive action, bad weather avoidance, air traffic control request, etc.) a particular protocol could be set to avoid spurious alarms and waiting for a trajectory recovery (back to a 15mn transmission rate). This solution can be a short term one as technologies are existing (e.g. live telemetry) and the activation is just a matter of software modifications for aircraft already equipped with communication means (SATCOM), representing more than 85% of the current concerned fleet. It remains essentially a recommendation to the operators, as aircraft in operation are under their proper responsibilities. Some operators have already implemented such solutions customized to their needs and capabilities.

3. AUTOMATIC SURVEILLANCE

The existing ADS (Automatic Dependent Surveillance) broadcast system could be a solution if the broadcast mode would work over seas (see FAST 47 – ADS-B article). Actually, the ADS-C (Contract) works over oceans but the dynamic agreement is initiated by the ground segments and is not monitored by the aircraft. Airbus is studying an alternative means using an aircraft-to-aircraft connection rather than by relayed satellite transmissions.

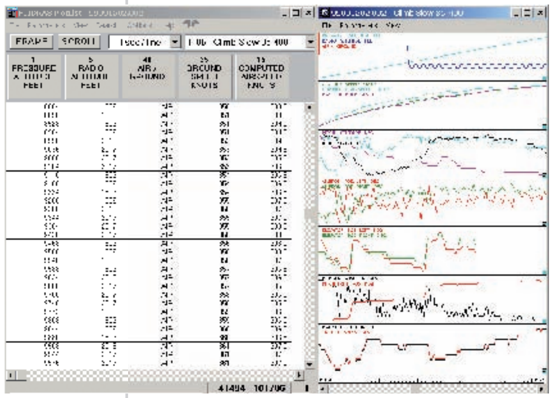
The three solutions have been assessed and associated recommendations will be made in the near future. In the meantime, Airbus is working on alternative solutions for aircraft not equipped with suitable communication means: The deployable ELT or a 'light' SATCOM are currently considered.

OBJECTIVE 2: LOCALIZE THE WRECKAGE IN DEEP WATER

The wreckage localisation is useful for the recovery of the debris and amongst them, the two recorders, all complementary for accident investigations.

Data image in engineering units decimal presentation and concerned graphs

Figure 5



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*** Nadir:** The point of the celestial sphere that is directly opposite the zenith and vertically downward from the observer.

By reducing the search area (consequence of Objective 1), the wreckage localisation should be highly improved. Nevertheless, the relevance of the recommendations 'R1' and 'R2' are definitively to improve the current ULB's definition. For 26% of the accidents, but almost 2/3 of brand new recorders, ULBs are detached from the recorders during the accident and therefore, they do not fill their role to locate them. In some sea accident cases with high drifts, recorders have been found many days after the ULB beamed location. A better attachment is certainly a fair improvement.

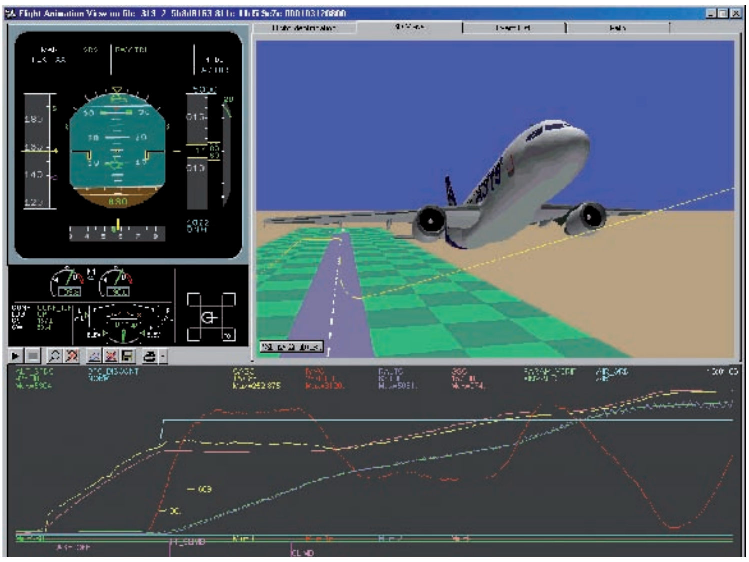
In the same way, the extension of a current battery life (ULB 37.5kHz) to 90 days is also a valuable modification for the recorder localisation. This will help to find the "needle in the haystack", given that the haystack be found. For that purpose, the additional 8.8kHz ULB with its lower frequency and thus, a farther detection, will undoubtedly help the wreckage localisation in deep water.
The deployable ELT as described in the previous paragraph, could also at stake, meet these objective requirements. An ELT, integrated in a deployable recorder (see Objective 2) will play the same role and therefore, will fully support the wreckage localisation, even in deep water as the deployment should be activated at the time the aircraft impacts the sea surface.

OBJECTIVE 3: RETRIEVE RECORDED FLIGHT DATA

The last stage after SAR and/or wreckage localisation is the flight data recovery. It remains mandatory to help explain the root cause of the accident, sometimes in complement to the debris analyses. Two solutions (with or without recorders) are currently being examined within Airbus:
- I. The transmission of flight data out of the aircraft.
- II. The new recorder technologies - combined, deployable and free-floating.

I. FLIGHT DATA TRANSMISSION

On a medium term timescale, the transmission of key parameters (around 40 items sent every 500ms) together with a five minutes DFDR buffer, could be triggered on detected loss of aircraft control, combined with defined systems' alerts (TCAS, EGPWS, etc.). Airbus has made various studies assessing this feasibility through different systems and protocols (ADS-C, ACMS2, mixed systems, etc.).



Computer simulation based on recorder flight data

Figure 6

A) Triggered by an identified aircraft loss of control

A list of emergency situations has been assessed (excessive pitch, excessive roll, stall, over speed, excessive acceleration, low speed, etc.) in order to ensure a proper interpretation of the flight situation.
Airbus is currently evaluating its feasibility with a list of flight databases aiming at validating our heuristic* on loss of control situations and ensuring a proper detection of genuine versus spurious catastrophic events.
The study allowed Airbus to evaluate the proposed criteria and to quantify the wrongly detected events.

B) A "tweeting" aircraft ?

The data flow must be confidential and secured, but the new communication technologies could allow automatic and triggered transmissions in a way to meet some of our objectives. Most of the current serial aircraft are communicating widely with ground segments (ATC, AOC, etc.) for many purposes like navigation, maintenance and information. Some aircraft operators are already using such communication means to transmit data with their own ground base.
The first results are promising but some limitations need to be solved. The aircraft attitude in such a situation might be so extreme that the satellite line-of-sight could be lost between the transmission and the reconnection delay (1 long minute). The power supply is also at stake, as the current SATCOM is not supplied by emergency power equipment that might be requested in case of lost of energy.

Bandwidth availability is a must that cannot be ensured anyway. Last but not least, non-repudiation of the data transmitted through "open" networks shall be ensured to meet the probative value, baseline of the enquiry and justice proceeding. Later on, CVR and videos could be included in the transmitted package, but they are not part of the current studies. Airliners become more and more connected through in-flight internet and data services, thus the aircraft permanent connectivity will be most likely one of the promising solutions in the near future as the cost and bandwidth are improving considerably.

II. NEW RECORDERS' TECHNOLOGIES

Airbus' plan to investigate the feasibility of Deployable Flight Recorders is motivated by a request of the ICAO High Level Safety Conference. Today's recorder technology is a hardened design concept where the crash protected memory housing is constructed to survive the severest crash scenarios, while fixed installed inside the aircraft.

information

* **Heuristic:** As a noun, a heuristic is a specific 'rule-of thumb' or argument derived from experience.

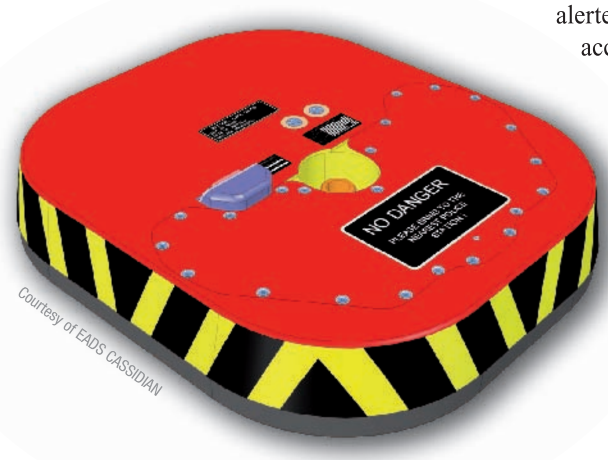
A combined free-floating deployable recorder

Figure 7

Courtesy of DRS Technologies Inc.

A combined free-floating deployable recorder

Figure 8



Courtesy of EADS CASSIDIAN

But even if the third generation recorders are nearly indestructible, it still can happen that the recorders are crushed into unreadable pieces, or located in deep water which makes recovery very difficult or even impossible.

An alternative survivability design approach is a deployable free-floating recorder. Such recorder combines a FDR, a CVR and an ELT, in one single deployable unit and deploys away from the aircraft during an accident, hence avoiding the crash forces. This allows a quick location and an economical recovery of the recorder, especially in accidents over seas. Thanks to the integrated ELT, Search And Rescue authorities are immediately alerted and the information of the accident location is provided to allow a quick recovery of the survivors.

Deployable recorders are used successfully on military aircraft and helicopters, however the technology has to be adapted to meet commercial aviation needs.

Airbus committed to be pro-active by implementing such requested improvements as early as possible, even though adequate regulation requirements will be established later.

The deployment logic is triggered according to the possible following situations:

- Accelerometers detect a crash (3-axis G-Vector Switch).
- Hydrostatic switches detect an immersion after ditching (no crash detected).
- Crash detection circuits detect an abnormal structure rupture.

The nominal sequence of the deployment in case of accident over water, could be as follows:

- Sensors detect the crash;
- Deployable Black Box is released from the aircraft structure and floats on the water;
- ELT transmits the location of the accident via a satellite constellation to the SAR authorities;
- Deployable recorder acts as a homing device for rescue crews;
- SAR personnel recover potential survivors.

g

glossary

AAIB: Air Accident Investigation Branch
ACMS: Aircraft Condition Monitoring System
ADS-C: Automatic Dependent Surveillance - Contract
AOC: Aeronautical Operational Control
ATC: Air Traffic Control
BEA: Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (French civil aviation safety investigations and analysis bureau)
CDAU: Centralized Data Acquisition Unit
CSMU: Crash Survivable Memory Unit
CVR: Cockpit Voice Recorder
EASA: European Aviation Safety Agency
ELT: Emergency Locator Transmitter
FAA: Federal Aviation Administration
FANS: Future Air Navigation System
(D) FDR: (Digital) Flight Data Recorder
FLIRECP: FLIght RECorder Panel
GPS: Global Positioning System
IATA: International Air Transport Association
ICAO: International Civil Aviation Organization
IFALPA: International Federation of Airline Pilots' Associations
NTSB: National Transportation Safety Board
SAR: Search And Rescue
SATCOM: SATellite COMmunications
SSFDR: Solid State Flight Data Recorder
TCAS: Traffic alert and Collision Avoidance System
ULB: Underwater Locator Beacon

Ensure a safe and efficient deployment

The Black Box deployment is one of the main concerns of the current studies. Depending of the final localisation on the aircraft, the deployable recorder trigger must be reliable. Currently, neither any airworthiness administrations have established rules for Deployable Flight Recorders for large civil aircraft. It remains a challenge to determine certification requirements for the installation of deployable recorders. There must be a good balance between the accepted benefits of deployable recorders (with integrated automatic ELT) and additional failure cases arising from the installation constraints, considering possible failures of the deployment mechanism. Such failure cases, like unintended deployment and loss of the recorder are not trivial and require specific assessments. During an initial meeting in April 2011, EASA agreed with Airbus on the basic principles to manage such certification issues.

The EASA counts on the assessment results and expects a more detailed proposal from Airbus before the end of 2011 (e.g. by a Certification Review Item - CRI).

In addition, Airbus accompanies future rulemaking activities. As noted above, ICAO has already suggested improvements and plans to issue new Standards And Recommended Practices (SARP) in a short time. Airbus will provide a proposal to ICAO via its participation in the ICAO-/FLIRECP (Flight Recorder Panel) in 2011. The Minimum Operational Performance Specifications (MOPS) for deployable recorders are already detailed in the Eurocae Document ED-112. An update of the ED-112 chapter 'Deployable Recorder' by the Eurocae WG-90 is foreseen with Airbus' contributions. The ED-112 is an accepted industrial implementation standard by almost all airworthiness administrations.

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Conclusion

Airbus has worked on complementary solutions to meet new objectives in order to improve the distress signal transmissions for triggering the SAR (Search And Rescue) and to recover the flight data for investigations.
Short term solutions will rely on the periodic transmission of key parameters through satellite broadcast systems triggered on defined events.
Future certification standards will certainly consider deployable recorders as a compliance means to demonstrate data recovery and localisation under all foreseeable situations.

Therefore, the deployable, combined and free-floating recorders including an ELT will shortly cross a series of tests to ensure its feasibility. On a longer term, the transmission every minute of a set of FDR parameters through appropriate communication means, together with five minutes of recorders' buffering would be a suitable solution. The current "Black Boxes" are not relic from the past; they are just evolving according to new technologies to serve the aviation safety, retrieving the flight data to investigate on the cause of an accident. Safety and efficiency are Airbus' priorities.

FANS for A320 and A330/A340 Families

Enhancing air traffic communications

In recent years, it has become clear that the usual voice communication means in the Air Traffic Control (ATC) environment are no longer sufficient to support the needs of pilots and Air Traffic Controllers. There is a need to exchange routine information in a flexible, reliable and secure manner. This is true in all operational contexts, whether in low traffic density, in oceanic or remote areas, or in high traffic density over continental areas. In 1983, the ICAO (International Civil Aviation Organization) began the development of a strategy which led to the selection of FANS (Future Air Navigation System) to overcome the difficulties linked to the global increase in air traffic.

FANS is basically a set of applications for ATC based on modern technologies such as Data-Link communication and satellite navigation. The main FANS application is the CPDLC (Controller-Pilot Data-Link Communication) that allows the pilots to communicate directly with controllers on ground, using Data-Link with a set of predefined text messages.

Today, the FANS function is acknowledged as a main pillar of the ATM (Air Traffic Management) development by the major ATM programme bodies such as the Single European Sky programme in Europe (SESAR) and the NextGen programme in the USA.

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The Airbus FANS packages

Since year 2000, Airbus has developed the FANS A package that was first certified on the A330/A340 Family. The Airbus FANS A has evolved into an enhanced package called FANS A+.
A new package called FANS B+ was developed to cope with areas of high traffic density and specific short range operational needs, mainly in Europe.
Selecting FANS A+ or FANS B+ is basically an operator's decision depending on their operational needs (Europe continental area or remote/oceanic areas), and obviously depending on the applicable/expected operational mandates.

FANS A/A+

The FANS A/A+ package has been developed for operating over remote and oceanic areas, making use of the ACARS (Aircraft Communication and Addressing Reporting System) network to support ATC Data-Link communication exchanges.

The FANS A/A+ function is integrated with the aircraft Flight Management System (FMS) which allows the exchange of flight information between ground ATC and the flight crew over ACARS. FANS A/A+ includes cockpit automation that provides support to the flight crew to automatically update flight plan based on up-linked data and provides flight data for flight information downlink.

g
glossary

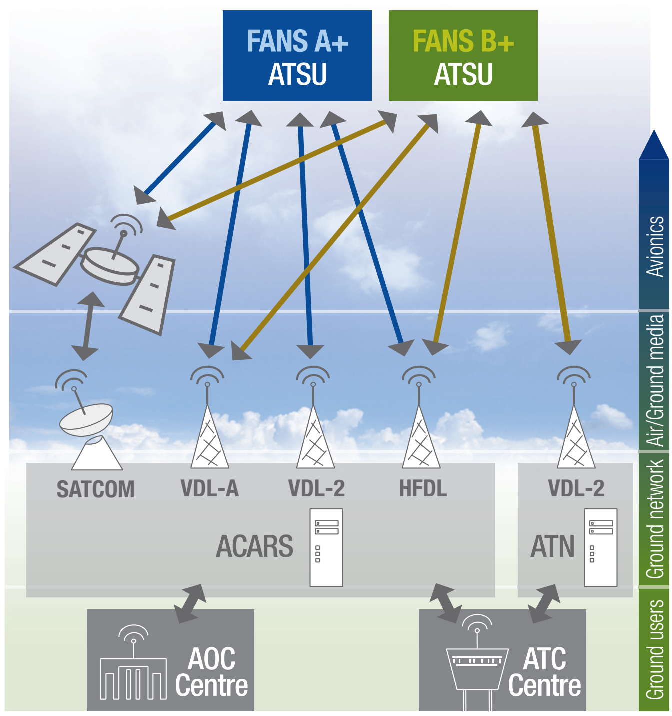
ACARS: Aircraft Communication Addressing and Reporting System
ADS-C: Automatic Dependent Surveillance - on Contract
AOC: Airline Operations Communications
ATC: Air Traffic Control
ATN: Aeronautical Telecommunication Network
ATSU: Air Traffic Services Unit
CPDLC: Controller-Pilot Data-Link Communication
HFDL: High Frequency Data-Link
SATCOM: Satellite Communications
VDL: Very high frequency Data-Link

FANS solutions

Operating environment with FANS A+ and FANS B+

Figure 1

	FANS A+ using ACARS over oceanic and remote areas		FANS B+ using ATN over continental areas
	Optional	Basic	Optional
Aircraft	A320	A330/A340	A320
FANS applications			
Communication: CPDLC	X	X	X
Surveillance: ADS-C	X	X	-
ATS 623 applications			using ACARS
Digital ATIS - D-ATIS	X	X	X
Departure Clearance - DCL	X	X	X
Oceanic Clearance - OCL	X	X	-
Medias			
SATCOM	Option	Basic	Option (AOC only)
VDL-Mode A	Basic	Basic	Basic (AOC only)
VDL-Mode 2	Option	Option	Basic
HFDL	Option	Option	Option (AOC only)



information

For information, Boeing uses the term FANS 1 to describe a similar solution to FANS A/A+ on their aircraft.

DCDU: The specificity of Airbus FANS solution

The FANS A+ package is now installed as standard on the A330/340 Family aircraft and can also be proposed as an option on the A320 Family (see figure 1).

Applications available in the FANS A/A+ package include:

- CPDLC (Controller-Pilot Data-Link Communication) that allows the pilots to communicate directly with ATC (ground) for routine communications, using Data-Link with a set of predefined text messages.
- ADS-C (Automatic Dependent Surveillance - on Contract) which operates independently of the flight crew and allows ATC to query the aircraft for specific information (i.e.: Flight Plan, aircraft position, weather information (WX info), etc.). The aircraft may be required to downlink the data once, at periodic rates (15 minutes), or at specific events (waypoints, altitudes).
- ATS 623 enhancement package (optional) with Digital Automatic Terminal Information Service (D-ATIS), Departure Clearance (DCL) and Oceanic Clearance (OCL).

FANS B+

The FANS B+ package (preceded by the FANS B package as part of the pioneer phase) has been developed for operations over the European continental area and utilizes the modern Aeronautical Telecommunication Network (ATN) to support the ATC Data-Link communication exchanges. The FANS B+ package is now proposed as an option on A320 Family, especially for those aircraft flying mainly over Europe.

The applications available in the FANS B+ package include :

- CPDLC
- ATS 623 enhancement package (optional and using ACARS network) with Digital Automatic Terminal Information Service (D-ATIS) and Departure Clearance (DCL).

No matter which version of FANS is deployed (A, A+, B or B+), the FANS function on the A320, A330/A340 Family aircraft relies on a main core system called the ATSU (Air Traffic Services Unit). The ATSU hosts the Data-Link communication router and the FANS applications and interfaces with the different avionics peripherals. The peripherals include the different Data-Link communication means available on-board to transmit and receive Data-Link messages. In the cockpit, two dedicated screens are installed on the main instrument panel called the DCDU (Data-Link Control and Display Units) to manage the transmission and reception of the CPDLC Data-Link messages (see figure 2).

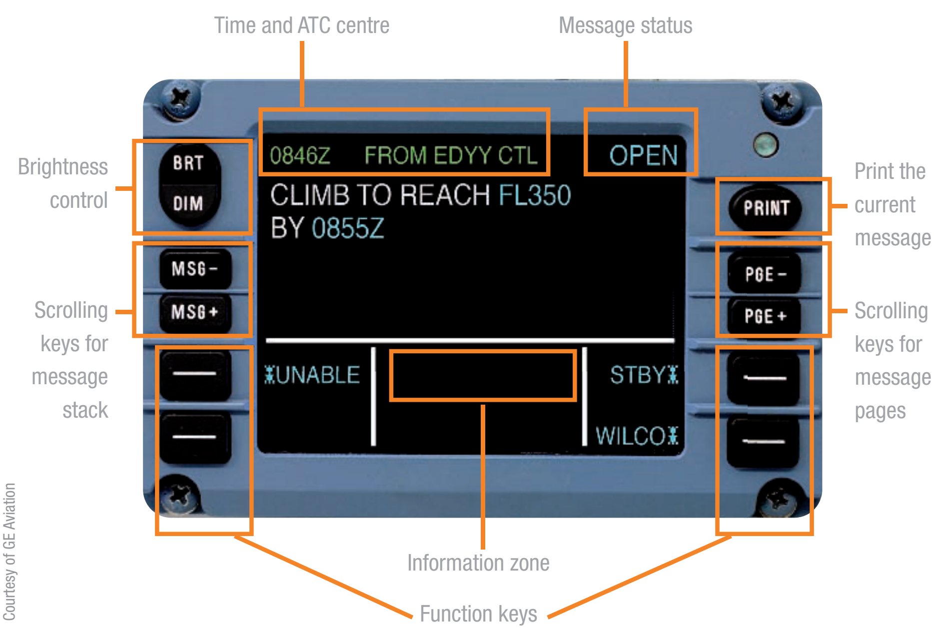


Figure 2

To send and receive CPDLC messages

Courtesy of GE Aviation

FANS global advantages

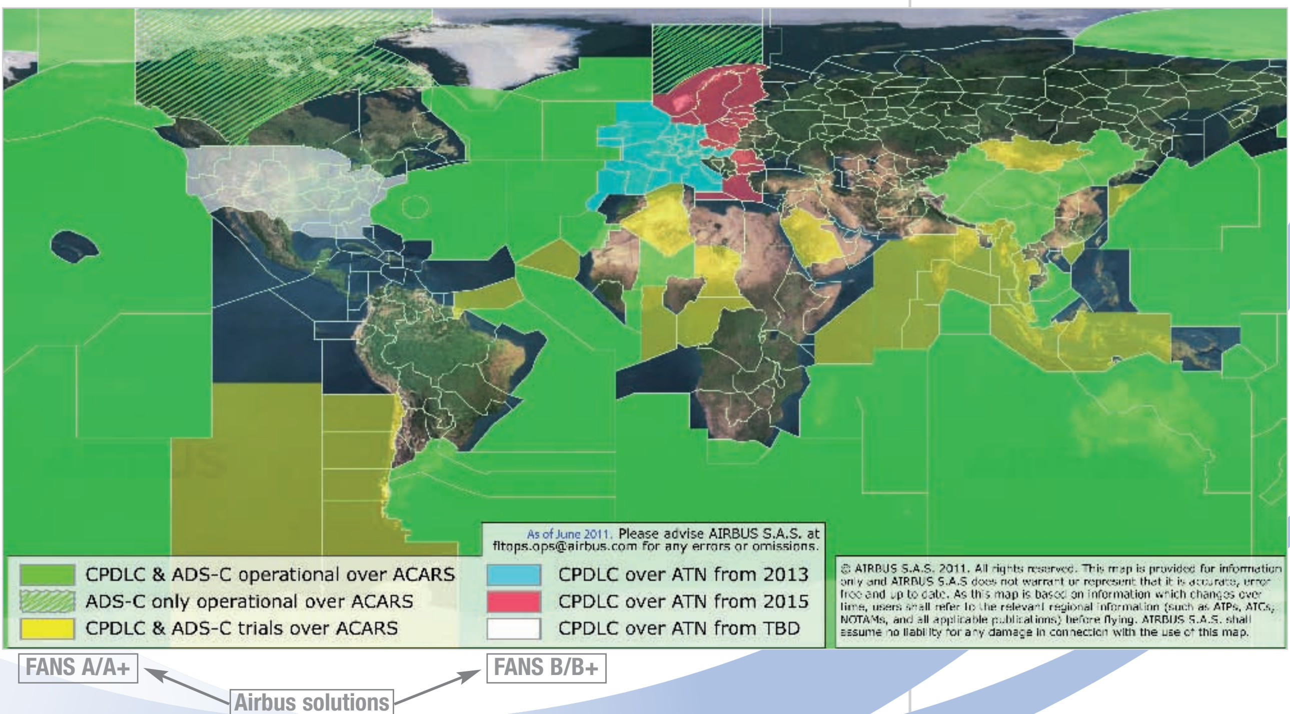
Clear FANS operational benefits can be identified for both pilots and controllers. As an example, when flying in oceanic airspace where there is no VHF (Very High Frequency) coverage, the pilot's traditional method of communicating with ATC is via HF (High Frequency) voice radio. The HF voice messages from the aircraft are transcribed by a radio operator and sent to the ATC centre. The HF voice frequencies are often congested making it difficult for pilots to communicate efficiently with ATC. Poor HF transmission conditions mean that messages may have to be re-transmitted or relayed by other aircraft. This consumes time and effort for pilots, radio operators and controllers, and increases the risks of errors. A routine request to change the flight level can take 20 minutes or more using such procedures.
On the other hand, FANS A routes have been created over those areas for aircraft equipped with FANS A Data-Link communication systems, where the pilots can request flight levels, speed or frequency changes and the controller can give clearance using CPDLC messages via Data-Link (ACARS VHF or SATCOM). Voice VHF (and/or HF radio) is reduced to backup or for non-routine communications.

More globally speaking, the risk of mishearing or misunderstanding is almost eliminated and thus, safety is enhanced. The CPDLC messages are delivered to ATC in near-real time and with higher reliability than achieved by the voice only.

FANS deployment in the world: Where and what?

OVERVIEW OF FANS OPERATIONS (SEE FIGURE 3):

Since the South Pacific regions introduced FANS Data-Link applications in the 1990s, the implementation has progressively grown to cover all oceanic/remote regions,



World map summarizing FANS operations

Figure 3

including Africa, the Middle East, the Far East, the Indian Ocean, the Central and North Pacific, and Atlantic Oceans. The global motivation for all areas are the significant operational benefits based on a separation minima reduction, allowing more efficiency and dynamics in route assignments. Most of the world's oceanic and remote areas now have FANS A capability.

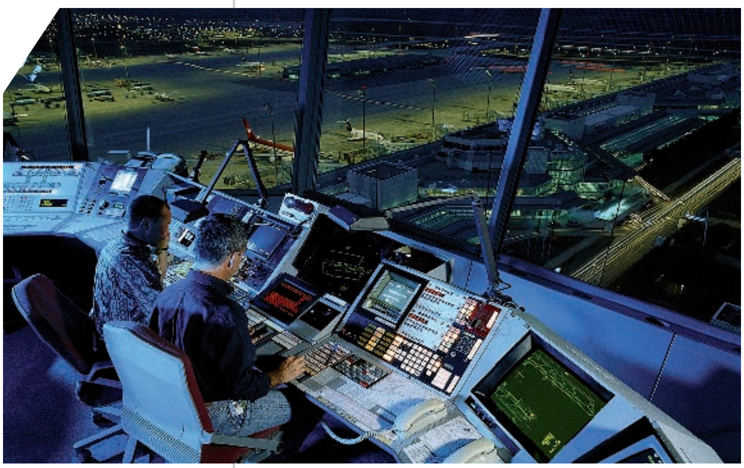
The FANS A exceptions

A) CONTINENTAL NORTH AMERICAN'S AIRSPACE

It is an obvious exception as not yet equipped. U.S. domestic ATS Data-Link capabilities will await the FAA (Federal Aviation Authority) NextGen data communications' programme implementation.

B) LINK 2000+ IN EUROPE

Continental European airspace has limited CPDLC/ADS-C operations and their focus is now mainly on full ATM/CNS (Air Traffic Management/Communication Navigation & Surveillance), using ATN protocols over ACARS VDL (VHF Data-Link) Mode 2 networks within the scope of SESAR and with deployment of the Link 2000+ Data-Link mandate, that has already begun as shown in figures 4 and 5.



It is likely that some European airspaces will continue to accommodate FANS A traffic in the near term, however focus in Europe is clearly on the Link 2000+ Data-Link programme.

Both European air traffic controllers and pilots are aware that voice communication has reached its limits in terms of air traffic capacity in Europe today.
The Link 2000+ Programme is addressing this problem by providing controllers and pilots with a second communication channel: Air/ground Data-Link through the implementation of Controller Pilot Data-Link Communication (CPDLC) in European en-route airspaces, based on Aeronautical Telecommunication Network (ATN) and the VDL 2 technology. The Link 2000+ operational concept is to use CPDLC as a supplementary means to voice exchanges and for non-time-critical communications.

LINK 2000+ MANDATE DEPLOYMENT

The draft Data-Link Services Implementing Rule (DLS IR) was delivered to the European Commission in early October 2007 and was adopted on 16 January 2009. The implementing rule is now legally binding and applies to both, ground implementation by Air Navigation Service Providers (ANSP) and to aircraft operators. The mandate targets airspace users operating above FL285 and ANSPs operating in the European region. The full text of the Data-Link Services Implementing Rule is available on the Air Transport portal of the European Commission (http://www.eurocontrol.int/link2000/public/subsite_homepage/homepage.html).

LINK 2000+ BENEFITS FOR ATC

- Enhanced safety,
- Increase of airspace capacity,
- Reduction of ATM delays and flight operating costs.

The industrial challenge for the FANS B+ retrofit on in-service A320 Family fleet related to the European mandate

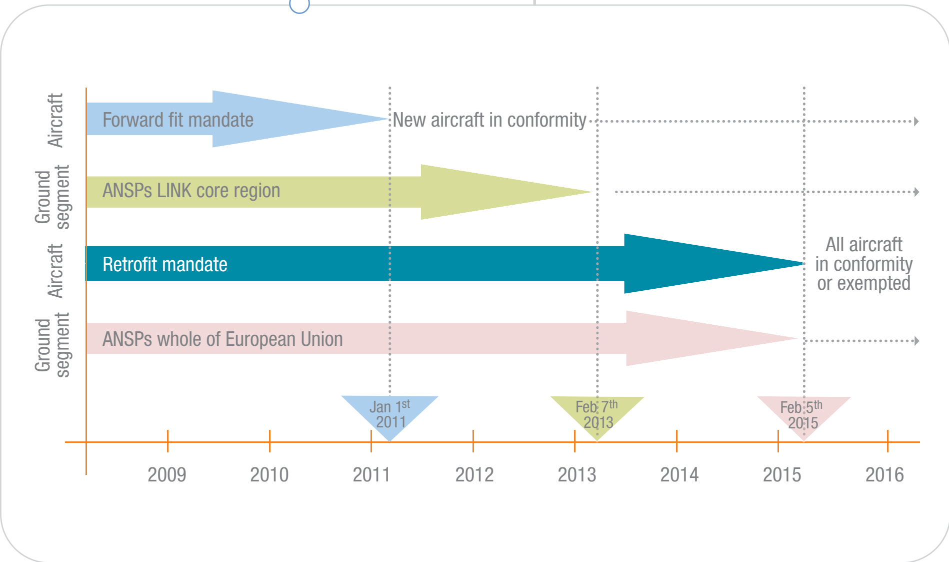
The Airbus solution for the Link 2000+ mandate is the FANS B+ package. Initial certification was achieved in early December 2010 and will be finalized by September this year for the A320 Family.

The FANS B+ remains an option on the A320 Family and is proposed to customers with main or partial European continental operations.

As per the Link 2000+ implementing dates for new aircraft, the FANS B+ installation is required as from 1 January 2011 and retrofit installations must be finalized by 5 February 2015.

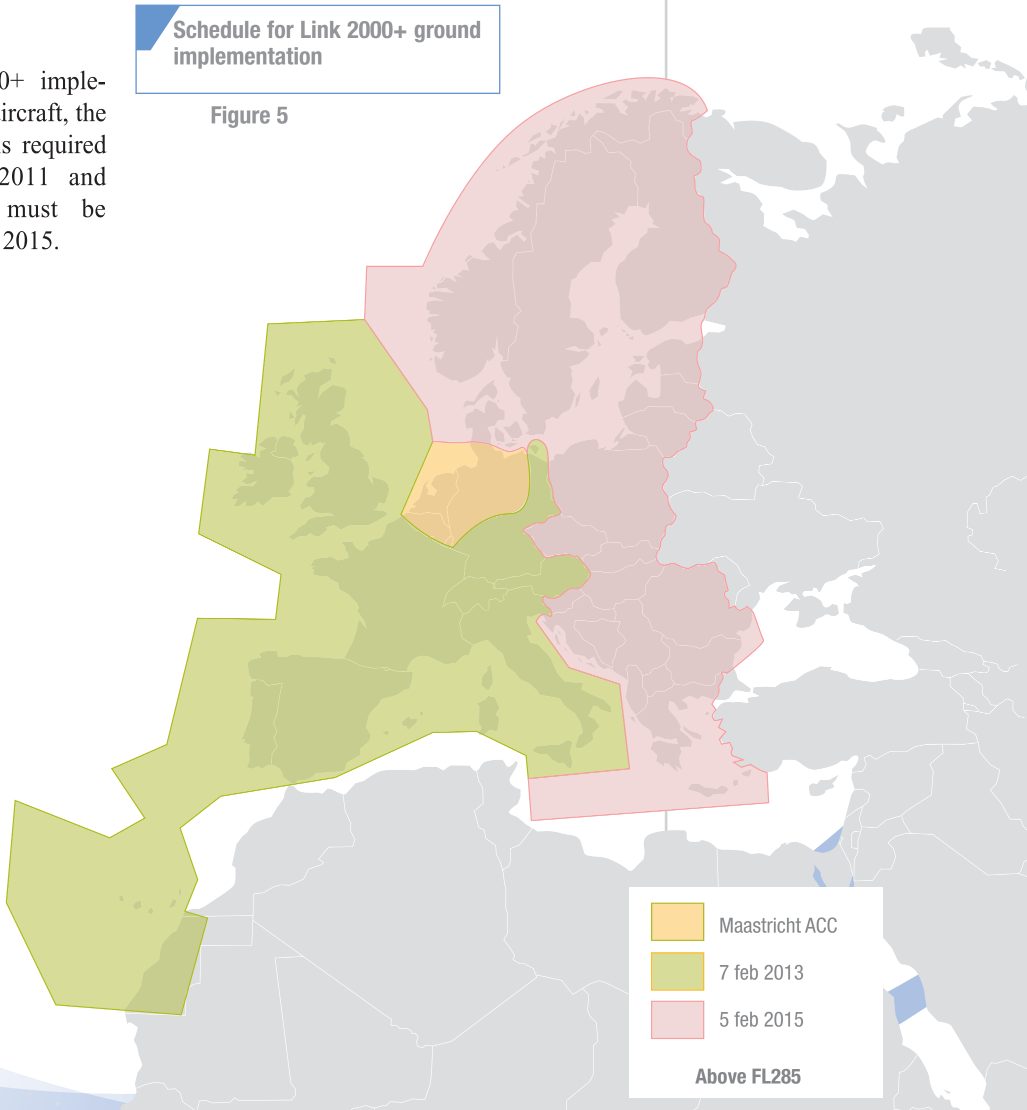
Link 2000+ implementing rule key dates

Figure 4



Schedule for Link 2000+ ground implementation

Figure 5



FANS crew interfaces

Figure 6

Retrofit needs on three typical A320 Family configurations in service

Figure 7

	Configuration A No ATSU and none or partial provisions	Configuration B Pre-FANS with ATSU & partial provisions installed	Configuration C FANS B
Equipment required	Full installation including provisions, ATSU, DCDUs, GPS synchronized clock, VDR capable of VDL Mode 2	Partial installation including ATSU upgrade, DCDUs, GPS synchronized clock, VDR capable of VDL Mode 2	ATSU software uploading (and additional wiring if necessary)
Man-hours required	Up to 350 C Check	20 to 50 A Check	3 to 6 Night stop
Approximate number of aircraft in fleet	950	3150	650

The automatic exemptions are for:

- Aircraft equipped with FANS A/A+ having received their first Certificate of Airworthiness (CoA) before 1 January 2014. Importantly this means that A330/A340 Family aircraft flying into European airspace already equipped are exempt (FANS B+ not available on A330/A340 Family aircraft).
- Aircraft with first CoA before 31 December 1997 and for which the end of operations in the European Union is planned before 31 December 2017.

Airbus estimates that around 2,000 A320 Family in service aircraft will be retrofitted with the FANS B+ solution by January 2015.

Aircraft architecture for the FANS B+ retrofit

Any in service A320 Family aircraft can be a candidate for the Airbus FANS B+ retrofit. The impact of the upgrade is dependent on the level of prerequisites already installed.

PREREQUISITES INCLUDE:

- 1 ATSU in Pre-FANS configuration.
- 3 VDL Mode 2 capable VHF data radios currently required. However, the possibility of VDL Mode 2 capability on one VHF data radio only, is under investigation for retrofit.
- Full FANS provisions.
- 1 synchronized GPS clock.
- GPS primary function activated.

FANS B+ RETROFIT WORKLOAD:

- Installation of 2 DCDUs in the cockpit.
- Activation of the 2 ATC MSG (Message) pushbuttons on the glareshield.
- ATSU hardware and software upgrade.
- Activation of VDL mode 2 function in the ATSU.
- Upload and activation of ATSU FANS B+ application software.

For more information, please link to Airbus e-Catalogue on AirbusWorld.

information

All FANS retrofit solutions are available today.

Summary of the FANS operations benefits

CPDLC:
- Reduced communication errors between pilot and controller
- Alleviated workload for ATC controller and flight crew
- Freeing up of voice communication channels
- Reduced clearance delivery time
- Allows the flight crew to print ATC messages
- Historical record of exchanged messages

ADS-C:
- Enables reduced separation between aircraft
- More efficient and direct routes
- Automatic downlink of position reports

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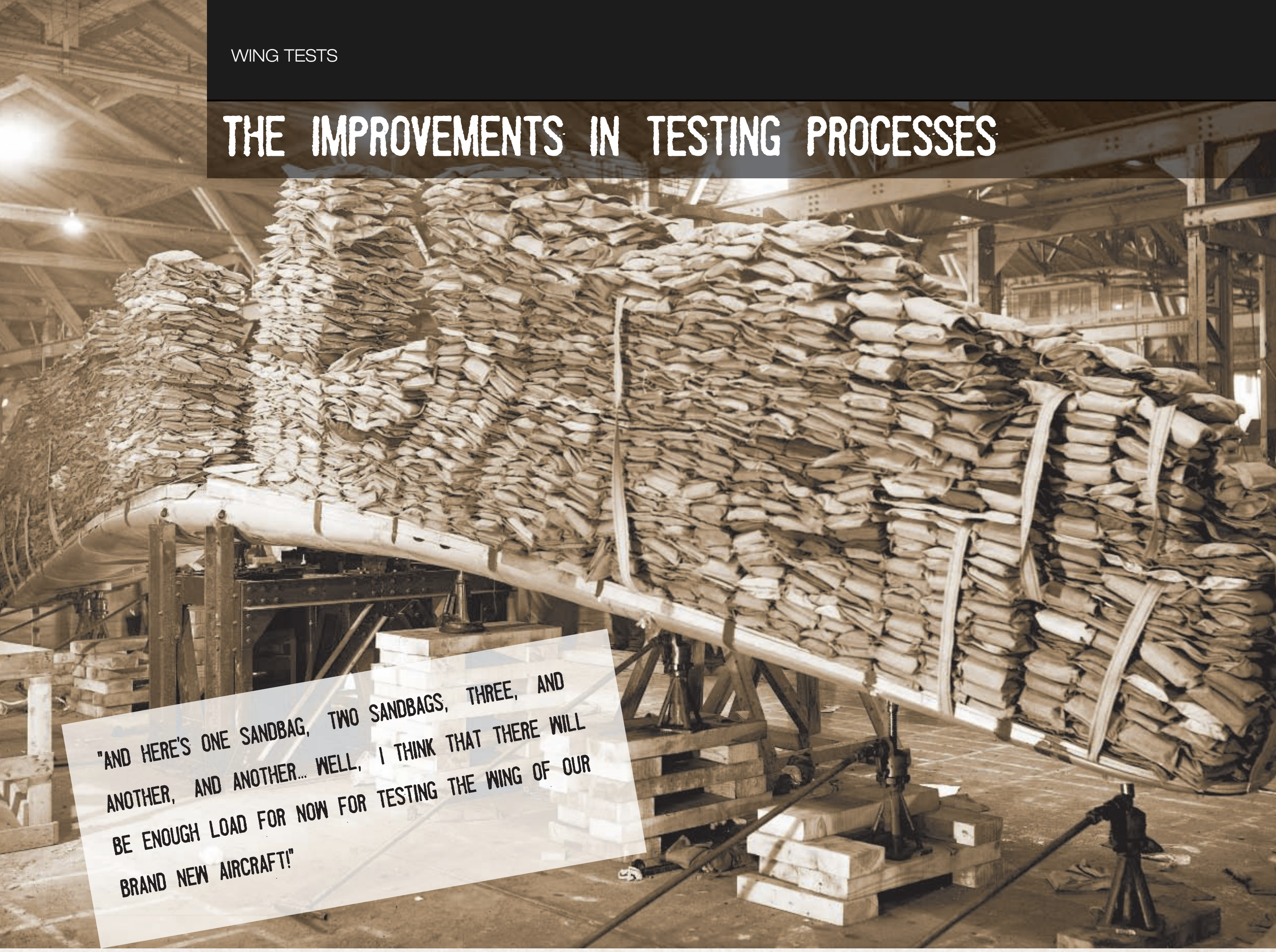
Conclusion

FANS is an integral part of the progress in the field of Air Traffic Management. FANS affects aircraft flying worldwide and requires the understanding and commitment of both Air Navigation Service Providers (ANSP) and operators. In order to prepare for the mandates already in place, it is paramount that all players take steps to prepare their in-service aircraft and schedule the timely introduction of the equipment concerned. The goal for all involved is the continued enhancement of safety and more efficient use of airspace leading to reduced fuel consumption and emissions.
We encourage operators not yet prepared for the coming mandate to contact their dedicated Airbus focal point for more information.

AIRBUS

THE IMPROVEMENTS IN TESTING PROCESSES



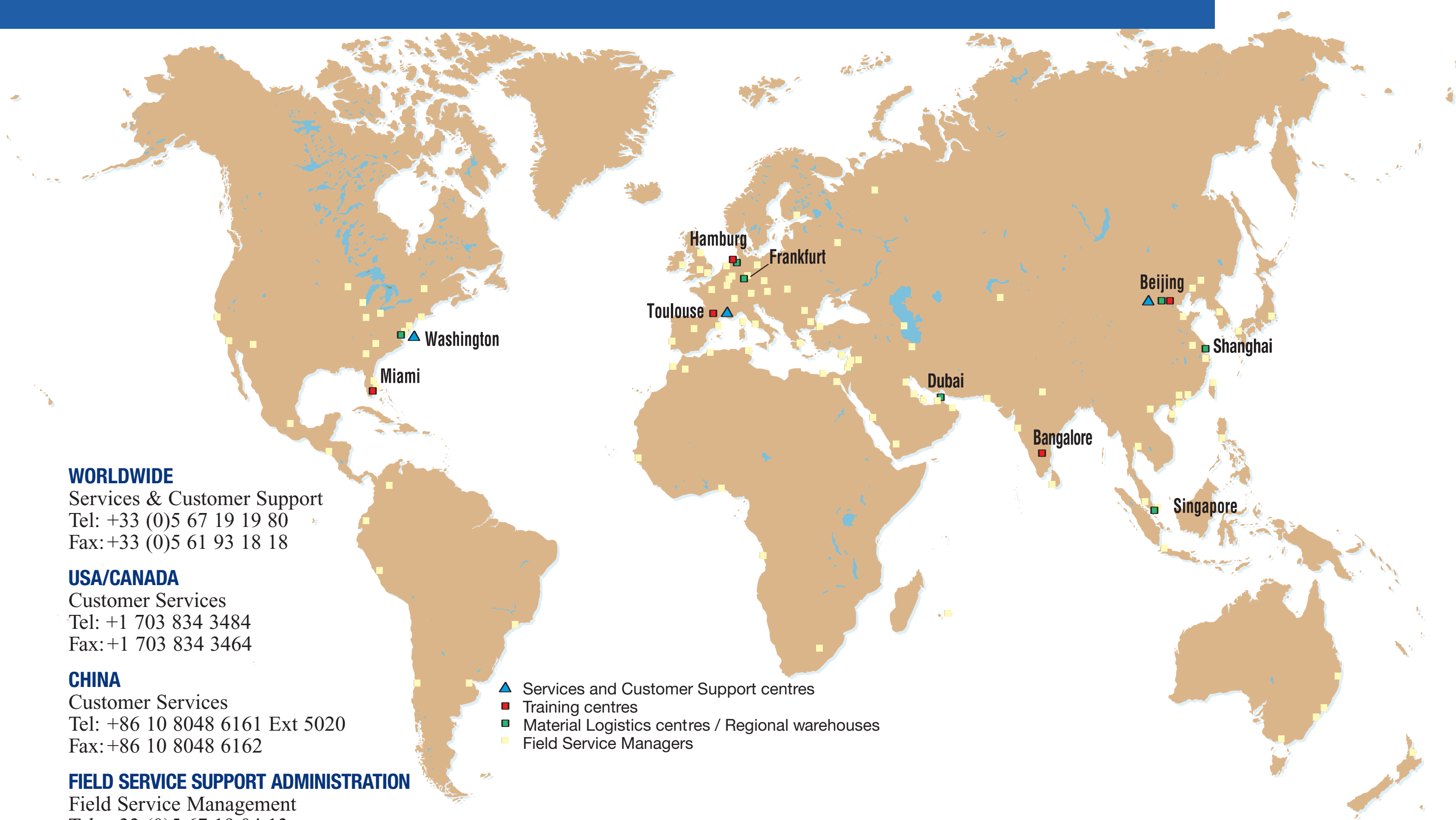
COURTESY OF AIRBUS FLIGHT TEST PHOTO LAB

You would have heard this in 1939 during the wing bending tests on the Dewoitine 520 aircraft. The workers back then would have found that today's GUISMOT tool for damage tolerant composite fuselage sizing (read FAST article page 10) would be pure science-fiction.

The Dewoitine 520 was a French fighter aircraft that entered service in early 1940. The ferry range was from 1,300 km (810 mi) to 1,500 km (930 mi) at 450 km/h (280 mph). The flight controls were well harmonized and the aircraft was easy to control at high speed. The maximum dive speed tested was 830 km/h (520 mph) with no buffeting and an excellent stability, both in the dive (depending on the fuel load) and as a gun platform.

DEWOITINE 520 AT THE MUSÉE DE L'AIR ET DE L'ESPACE, FRANCE

An all-metal structure was used, except for fabric-covered ailerons and tail surfaces. The wing, even if single-spar, was a solid and rigid unit with a secondary spar and many reinforced parts.



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