

**Airbus technical magazine**

January 2015

#55

# FAST

Flight Airworthiness Support Technology



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# Airbus technical magazine

# #55

# FAST

Flight Airworthiness Support Technology



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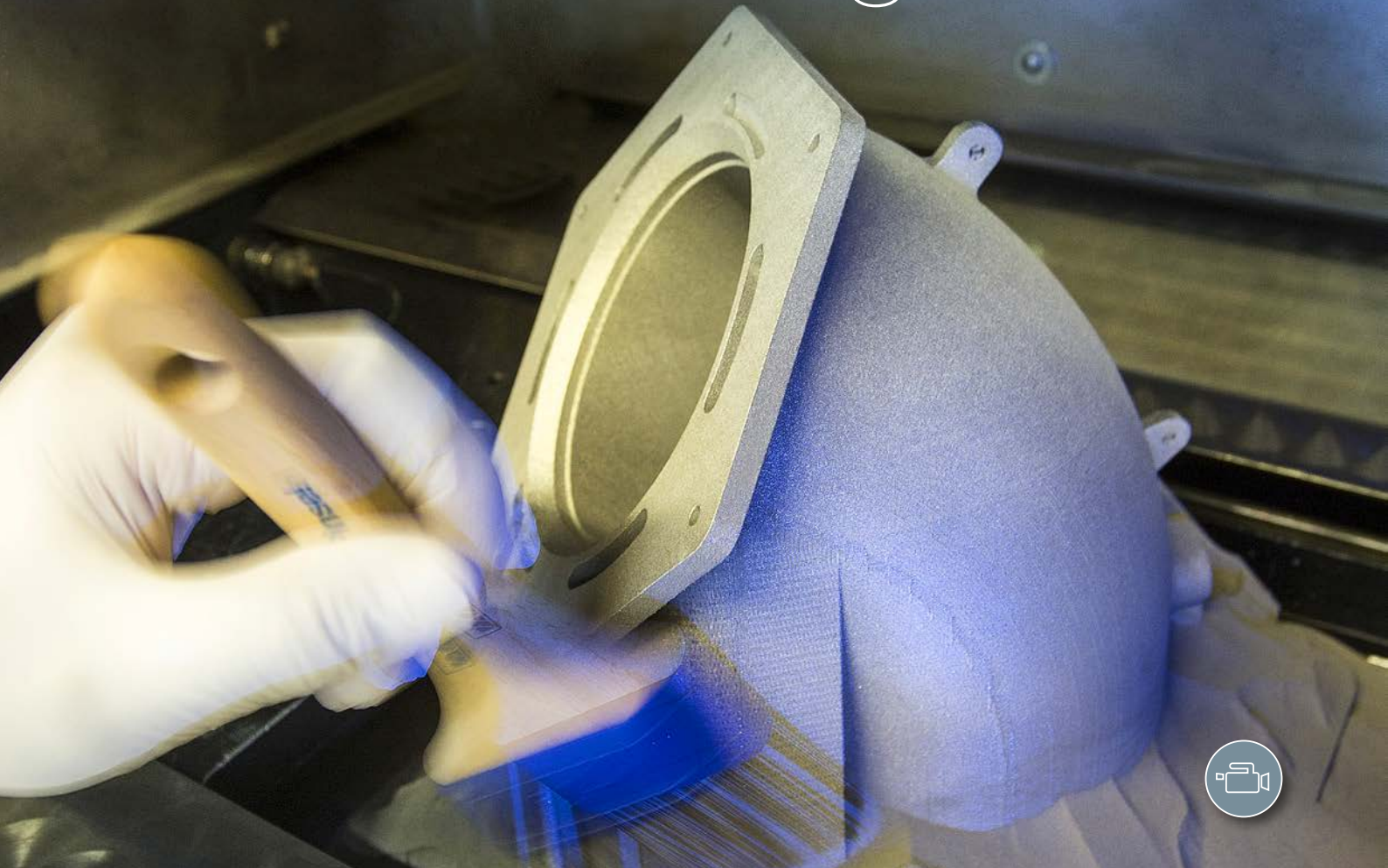
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Where you see these icons, videos or slide shows are available on the iPad & Android app versions of FAST magazine.

Printing the future with revolutionary

# Additive Layer Manufacturing



Article by

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Emerging Technologies & Concepts

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## An innovative technology shaping the future of aviation

Across the Airbus Group, numerous projects are speeding-up the development of Additive Layer Manufacturing (ALM), also known as 3D-printing, to produce prototypes and components, potentially delivering more cost-effective and lighter aircraft parts. 3D-printing technology can also improve production efficiency while avoiding shortages of components on assembly lines.

The first metal parts produced with this method (figures 1 & 2) are beginning to appear on a range of Airbus aircraft - from the latest A350 to the A300/A310 Family aircraft.

A quick overview about the 3D-printing technique indicates:

- Lighter parts due to structural, biomimetic redesign and the choice of materials used
- Shorter lead times – as production moulds and tooling are no longer needed due to the part's regeneration in a virtual 3D environment
- Less material used due to an additive production process (rather than subtractive)
- A significant reduction in the manufacturing process' environmental footprint

## The technology process

Instead of producing a part by milling a solid block of material, Additive Layer Manufacturing (ALM) “grows” parts and products using base materials such as aluminium, titanium, stainless steel and plastics.

Adding thin layers of material in incremental stages, generates parts, enabling complex components to be produced directly from Computer-Aided Design (CAD) information sent to the 3D-printer.

At the same time as the material layers are built-up, so is a layer of supporting material for the following layers (see building principles overleaf).

“This game-changing technology decreases the total energy used in production by up to 90 percent compared with traditional methods”.



Figure 1:  
Belt panel on an A310  
cabin crew seat

## Materials of interest

The range of materials used encompasses high performance plastics such as Polyetherimide (PEI), PEAK/PEK (polymer), FullCure (acrylic-based photopolymer), Polyamide, Accura and Greystone, to high performance metallic alloys including Titanium (Ti), Aluminium (Al), Maraging steel as well as graded materials. In industries outside aviation, materials used to make free-form shapes can include concrete and glass, and even edible ingredients such as chocolate.

For the A350 aircraft, Airbus has produced and incorporated a variety of 3D-printed plastic and metal brackets, whose material and structural properties have been tested and duly certified.

Figure 2:  
The flight crew rest compartment bracket installed on A350



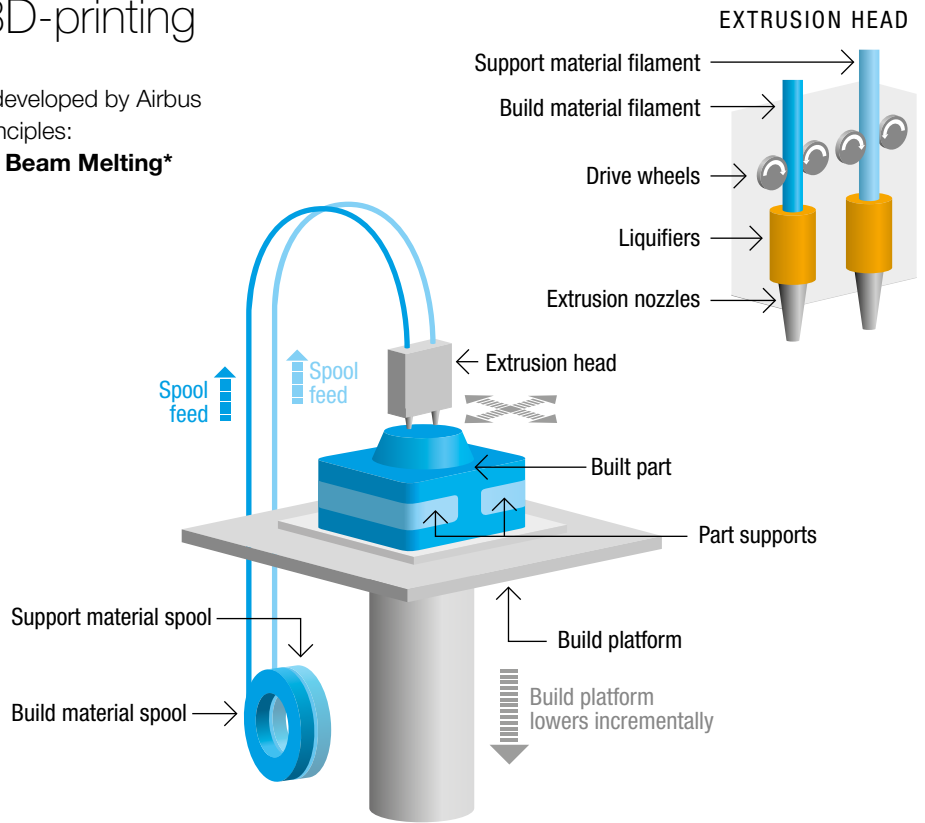
# Building principles of 3D-printing

The 3D-printing currently being used and developed by Airbus uses variations of two different building principles:

## Fused Deposition Modelling and Laser Beam Melting\*

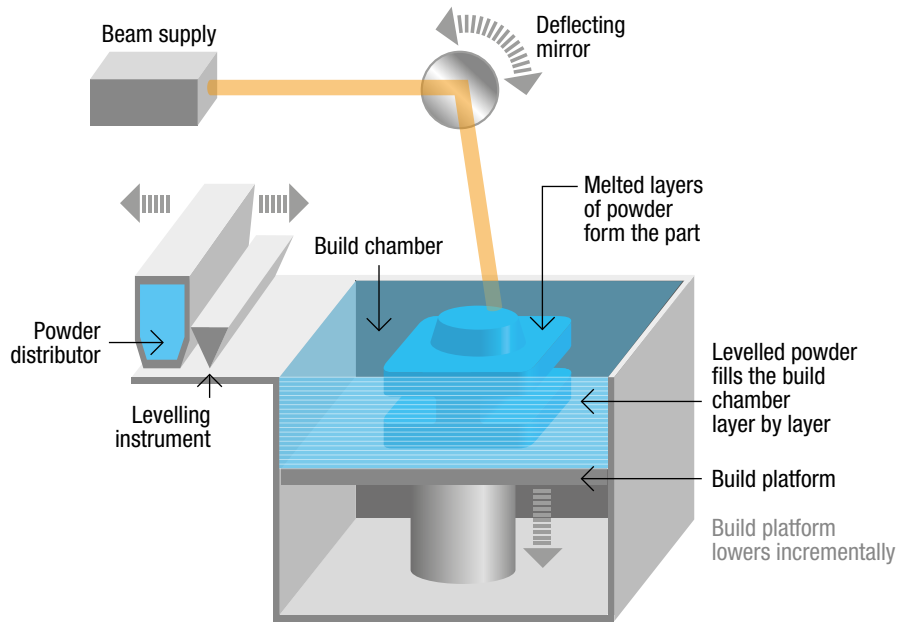
### Fused Deposition Modelling (FDM)

FDM is used to generate plastic parts. 3D objects are built by printing fine layers of liquefied building material filament onto a building platform that fuse with the layer beneath. At the same time a support material is printed in order to allow printing of the building material further up the object of features that hang from the main structure. The build platform moves down incrementally to print the following layer. Once finished the printed support parts are removed.



### Laser Beam (Powder Bed) Melting

Airbus uses variations of powder bed melting for metallic materials such as titanium alloys. 3D objects are built by having a fine layer of powdered building material levelled over the building platform, which is then exposed to a (laser or electron) beam which welds part of the powder, melting and joining it to the preceding layer to become the final 'printed' 3D part. The powder that is not melted remains in place to become a support for features further up the object that hang from the main structure. The build platform moves down incrementally to 'print' the following layer. Once finished the remaining unmelted powder is removed and recycled.



### \*Laser Beam Melting

Laser Beam Melting (LBM) is an additive manufacturing process that uses 3D CAD data as a digital information source and energy in the form of a high powered laser beam (usually an ytterbium fiber laser) to create three-dimensional metal parts by fusing fine metallic powders together. The industry standard term, chosen by the ASTM F42 standards committee, is laser sintering, although this is acknowledged as a misnomer because the process fully melts the metal into a solid homogeneous mass. The process is also sometimes referred to by the trade names DMLS or LaserCUSING. A similar process is Electron Beam Melting (EBM), which as the name suggests, uses an electron beam as the energy source.

# New opportunities for optimisation driven design

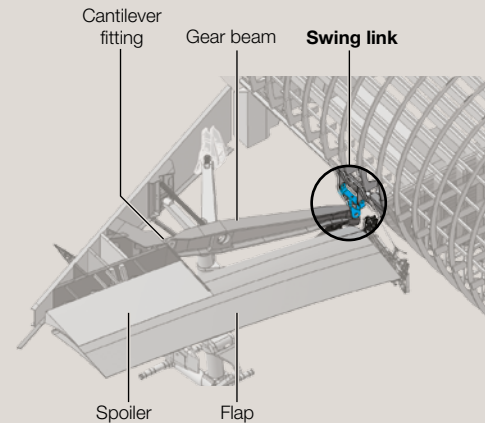
The flexibility of 3D-printing widens the potential of what can be formed, building parts in exactly the right shape and proportion to take stress only where it is needed.

## EXAMPLE

### Optimisation of a swing link

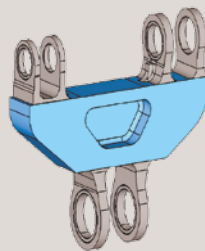
#### Step 1 - Analyse the baseline design

to evaluate exactly what functions the part has to perform such as volume needed, stiffness constraints.



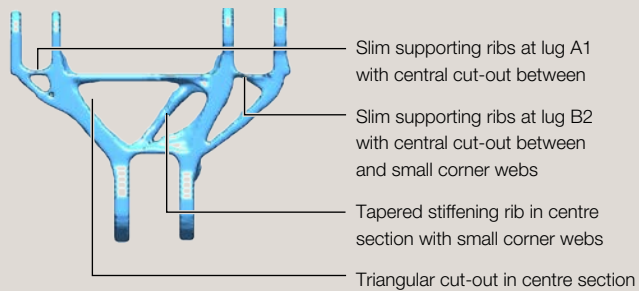
#### Step 2 - Design space allocation

The lugs are considered as optimally designed for their function and as such are not an important part of the re-design.



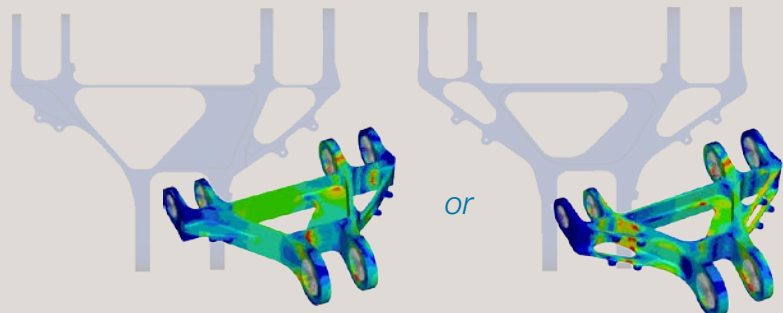
#### Step 3 - Topology optimisation

Revealing the load paths and formulate structural principles.



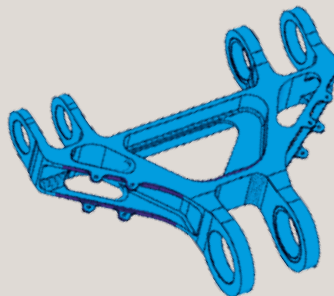
#### Step 4 - Rapid concept design

Interpretation following the topological load paths then validation of the tension carried for each interpretation.



#### Step 5 - Detailed sizing

Optimisation of the new design proposal, structurally perfecting each form.



#### Result:

The final swing link design carried out by the Airbus Optimisation Centre weighs less to fulfil exactly the same task.

## Biomimetic structure design, or... what nature teaches us

(see biomimicry article in FAST 49)

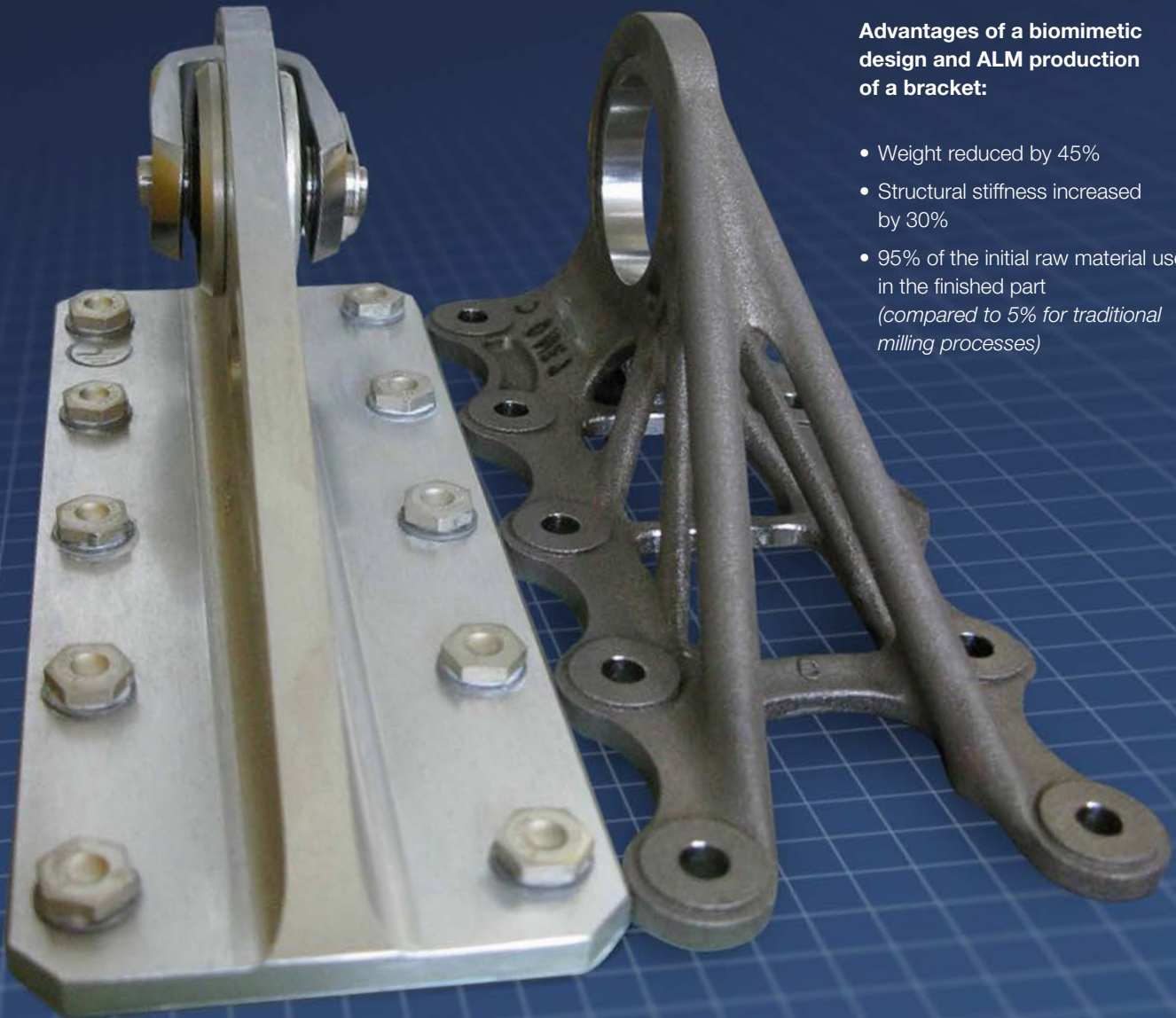
Biomimicry is the imitation of models, systems, and elements of nature for the purpose of solving complex human problems. Additive Layer Manufacturing represents a paradigm shift in structure design because it allows the reproduction of complex forms that nature has taken millions of years to evolve to the optimal structure for a particular task.

The lightness that biomimicry permits - for at least equal structural stiffness - will directly result in less fuel burn, and as a consequence reduce airlines' operational costs and environmental footprint.

“We are at the point of a step-change in weight reduction and efficiency - producing aircraft parts which weigh 30 to 55 percent less, while reducing raw material used by 90 percent is the next industrial revolution”.

### **Advantages of a biomimetic design and ALM production of a bracket:**

- Weight reduced by 45%
- Structural stiffness increased by 30%
- 95% of the initial raw material used in the finished part (compared to 5% for traditional milling processes)







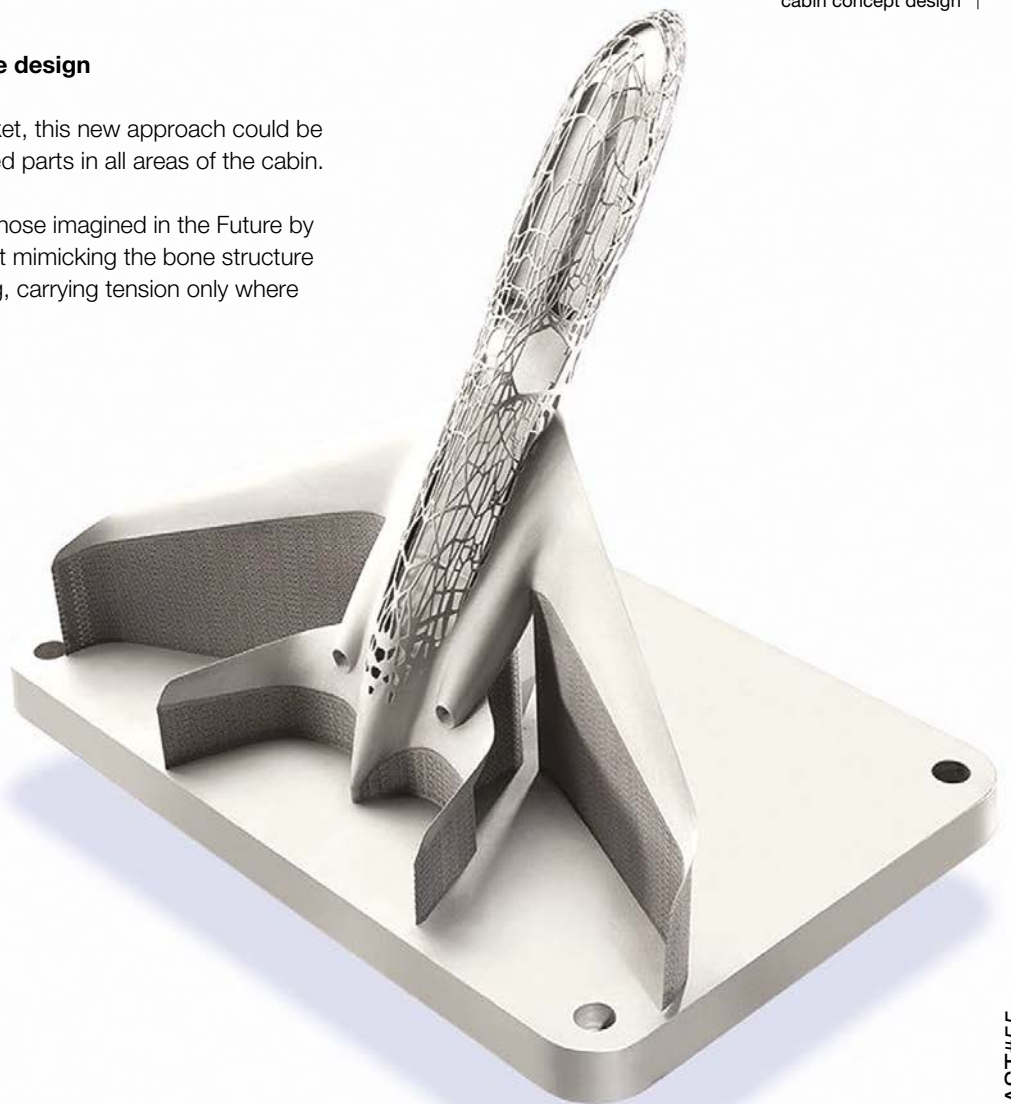
Future by Airbus  
cabin concept design

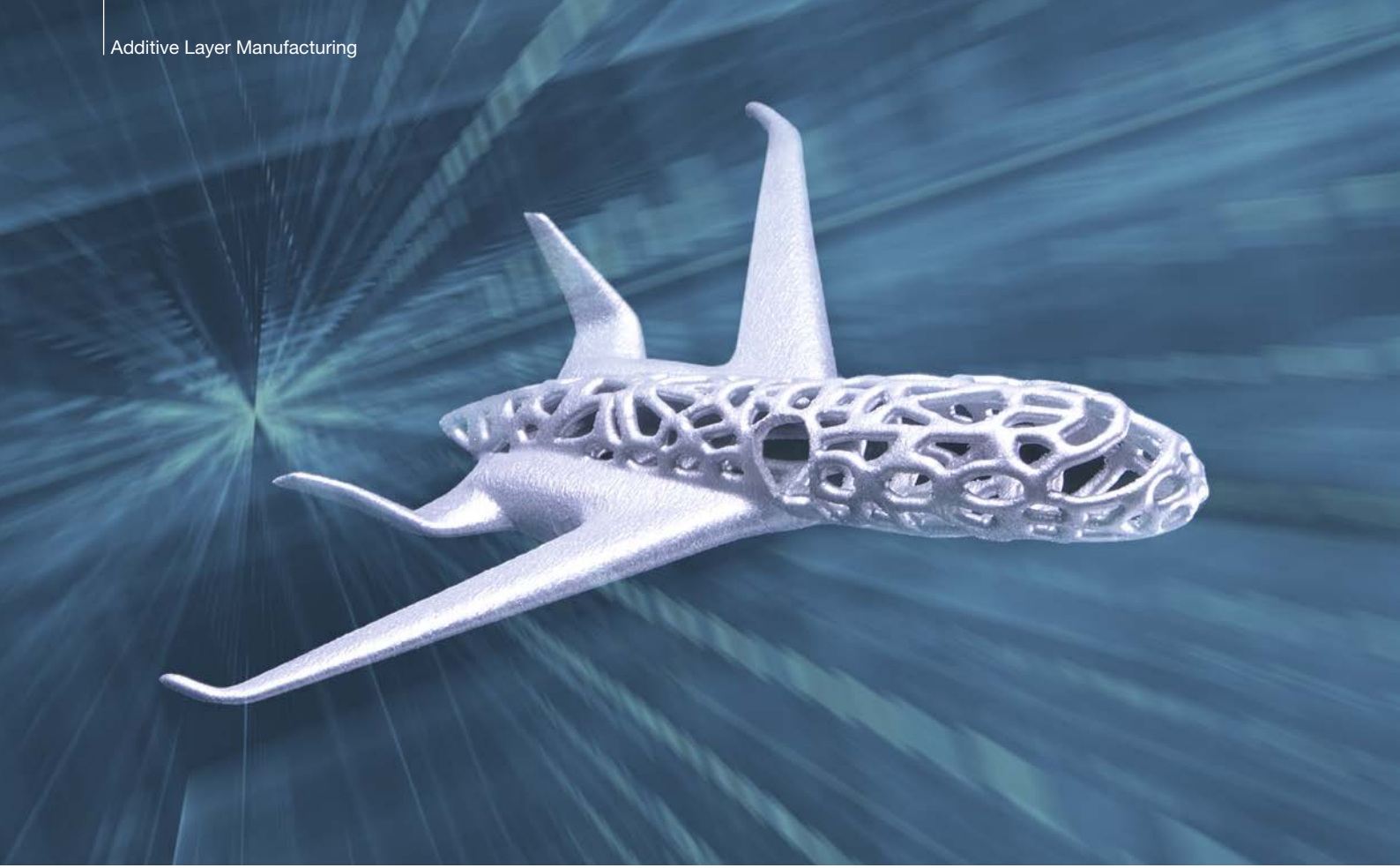
### The future of biomimetic structure design

As illustrated by the biomimetic bracket, this new approach could be very useful in the design of customized parts in all areas of the cabin.

In time, complete airframes such as those imagined in the Future by Airbus' concept design, could be built mimicking the bone structure of birds which is both light and strong, carrying tension only where necessary.

By using biomimetic structures, the fuselage will have the strength it needs, where it needs it, making it possible to add features like oversized doors for easier boarding and panoramic windows.





### Benefits of 3D-printing

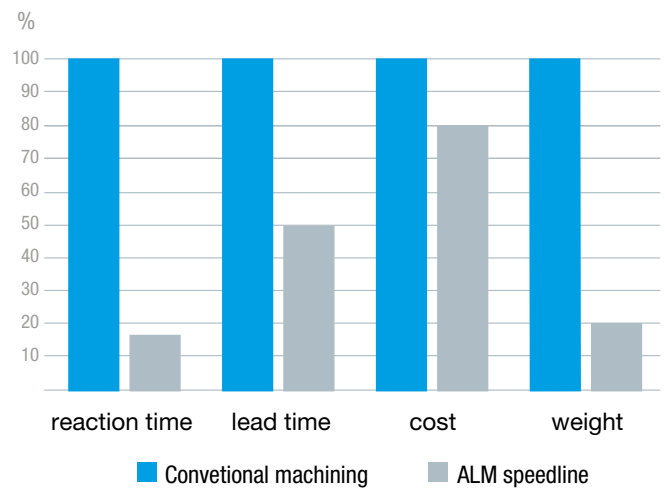
3D-printing makes it simpler to produce very complex shapes, therefore, parts designed for and manufactured by ALM can have a natural and topologically optimised shape, which would be impossible if producing them from a solid block of material. Such parts are significantly lighter, faster to produce and ultimately much less expensive than conventional ones.

- Weight reduction - up to 50%
- Non-recurring cost saving (no tooling) - up to 90%
- Green technology (less energy) - up to 90%
- Improved lead time delivery - up to 75%
- Functional integration (e.g. of cooling channels)
- Simplifying assemblies due to part reduction
- Shortened R&D time (one-shot testing)
- Lightweight design through biomimetic structures
- Customized products
- Highly complex geometries (e.g. hydraulic manifolds)
- Tool, jig and ground support equipment manufacture
- Ensure production for spare part shortages
- Replicate parts that are out of production
- Enabler for next generation airframe design

### ALM in the assembly line: print and go

Beyond its use to build parts that are already flying, Airbus Group is looking into using ALM technology to avoid shortages during the manufacturing process.

### Conventional machining compared with the ALM speedline





## 3D-printing spares

Airbus is actively working towards using 3D printing technology as a spare parts solution due to the ease and cost effectiveness of producing out-of-production spare parts on-demand. This year, the first “printed” component – a small plastic crew seat panel – flew on an A310 operated by Canada’s Air Transat. The lead time for such a part can be as little as one day, if the component is based on an existing design, while redesigned parts can be produced in less than two weeks.

## Eco-efficient manufacturing - minimising the environmental footprint

ALM represents a new alternative to production processes such as milling, melting, casting and precision forging, producing only 5% waste material instead of up to 95% from current machining. The high flexibility in part design, production and testing offers considerable benefits to the customer in terms of cost and time.

## The ramp-up phase

3D-printing is being progressively integrated into new design and manufacturing in the supply chain, starting small but steadfast in the fields of prototyping, tooling and on-demand production. Airbus has teamed up with major 3D-printing stakeholders to cover the process end-to-end, ensuring the production of certifiable structural components based on consistent tested material properties and meeting the requirements of a rigorous certification process.



Airbus Concept Plane

## Future candidates for 3D-printing

Airbus is looking at the entire aircraft: cabin, system and structural components, as well as manufacturing and tooling. It will also play a major role in the production of spare parts.

In the coming years 3D-printing could potentially account for thousands of aircraft and ground support equipment components.

Each day we are stepping closer to the “Future by Airbus”.

## CONCLUSION

Additive Layer Manufacturing (ALM), also called 3D-printing, is an innovative technology shaping the future of aircraft component manufacturing. Harnessing CAD software, ALM is being used to construct 3D objects by melting and building up a solid product layer by layer.

Components produced provide significant advantages in terms of reduced weight and production lead time compared to traditional manufacturing methods, while reducing waste and, as a consequence, the environmental impact.

3D-printed airworthiness certified parts are already appearing on Airbus aircraft, and the list of parts proposed as candidates for 3D-printing is constantly growing.

This new manufacturing method is not only being considered for aircraft parts but also for the production of jigs, tools, Ground Support Equipment as well as spare parts.

As technology develops we may one day see the first entire aircraft built using ALM. ■■■

An innovative Airbus  
risk management service

# Runway Overrun Prevention System (ROPS)



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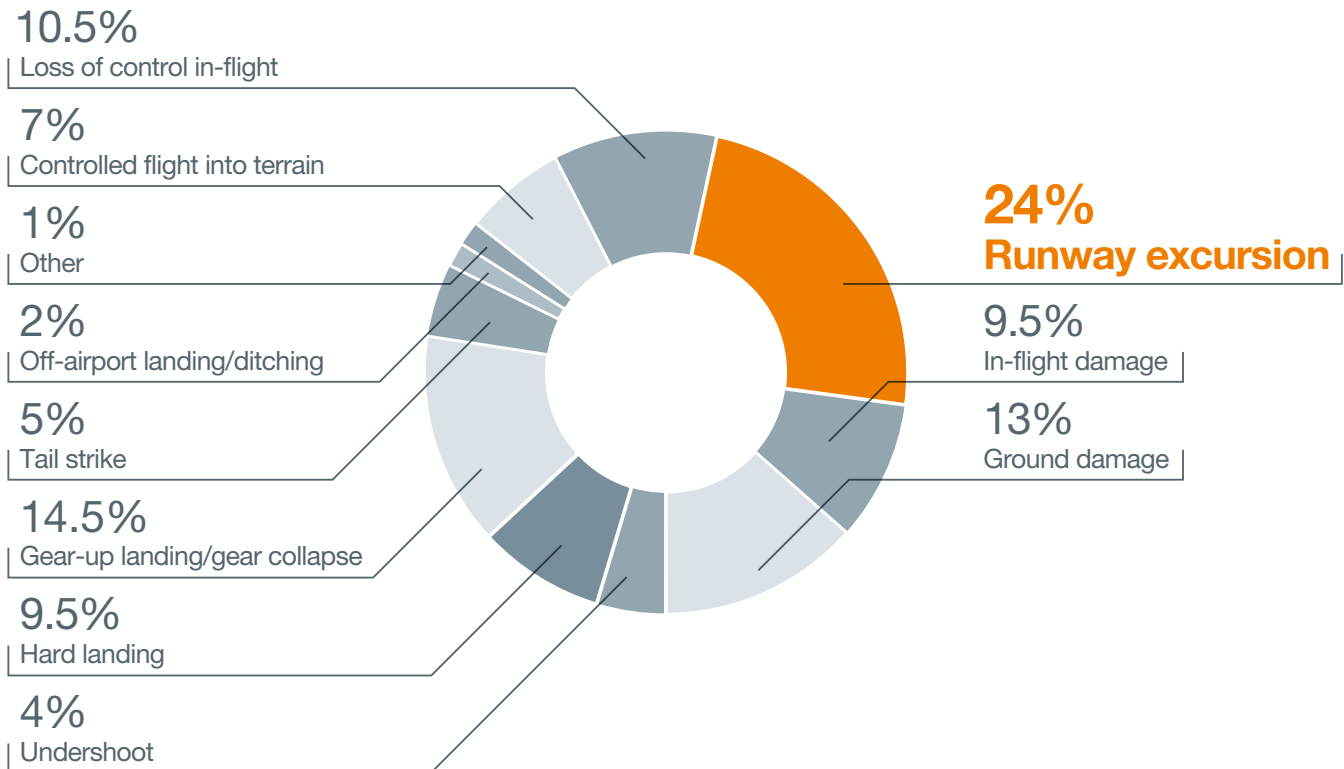
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**Airbus' Runway Overrun Prevention System (ROPS) is risk management technology that mitigates the n°1 source of accidents: runway excursions.**

Runway excursions at landing are the most common aviation accidents and a significant economic issue for the air transportation industry worldwide, costing US\$ 300 million per year (about 33% of all aviation segments' insurance claims). Studies demonstrate that the vast majority of these events could be avoided by providing flight crews with relevant information to make the right decision in a timely manner.

Fig 1: 2008 - 2012 aircraft accidents



### Reducing runway excursions is a n°1 priority

Initially developed between 2006 and 2009 as a smart automatic braking system named Brake-To-Vacate (BTV) for the A380 (read FAST magazine #44), it soon became apparent that elements of this system could be used to warn and protect against runway overrun risks, whatever the level of automation used for the braking system (pedal braking, classical Auto-Brake or BTV). This important safety system, named ROPS, has been in operation on A380 since October 2009 (nearly all operators) and on the A320 Family since November 2013. For A330 and A350 aircraft, ROPS approvals are expected over the next two years depending on engine types.

Realizing the global impact that ROPS-like technologies would have if applied on a worldwide scale, several safety bodies have already moved forward:

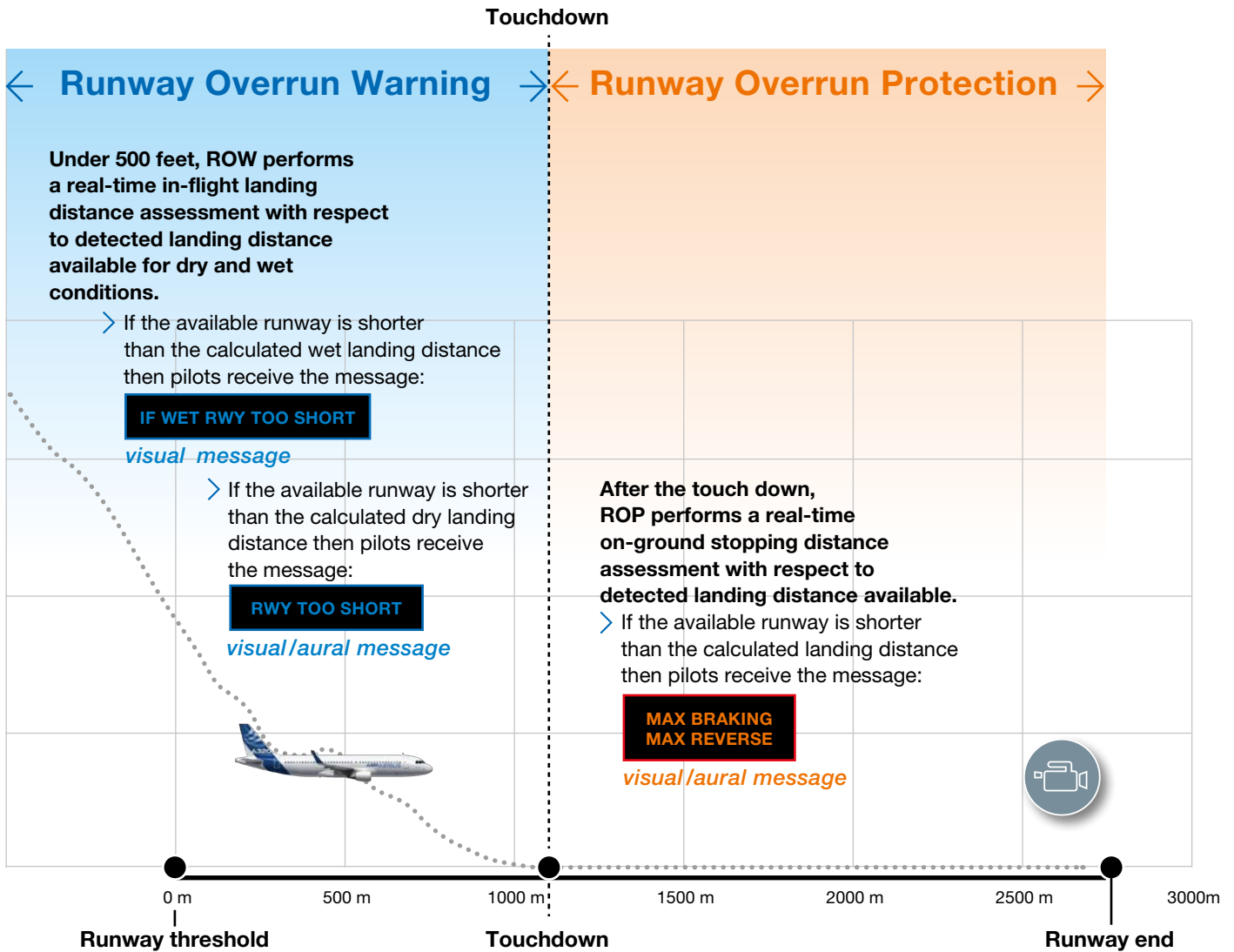
- In March 2011, the United States' NTSB recommended to the FAA to "actively pursue with aircraft and avionics' manufacturers the development of technologies to reduce or prevent runway excursions and, once it becomes available, require that the technology be installed (A-11-28)."
- The European Action Plan for the Prevention of Runway Excursions released recommendations to aircraft manufacturers and operators in January 2013 to respectively develop and install "onboard real-time performance monitoring and alerting systems that will assist the flight crew with landing/go-around decisions and warn when more deceleration force is needed".
- In mid-2013, EASA released a Notice Proposal of Amendment (NPA) regarding a possible mandatory installation of a "ROPS-like" system, generically called Runway Overrun Awareness Avoidance System (ROAAS) by 2017 for any new Type Certificate (TC) request, and by 2020 on any new delivered aircraft.

In a unique initiative to globally reduce runway excursions, Airbus announced at the May 2011 ICAO Global Runway Safety symposium, its decision to offer ROPS technology to all aircraft and integrated avionics equipment manufacturers.

# Airbus ROPS technology

From the aircraft approach up to the aircraft stop, ROPS is a turnkey technology designed to continuously monitor total energy and the aircraft's landing performance compared to the runway end. Its safety benefits have been demonstrated with reviews and replays of actual runway overruns, and about five years of in-service experience with overrun situations already avoided.

## Real-time assessment, in-flight and on-ground



## ROPS - the inaugural Airbus BizLab project

**ROPS was the first idea to be taken on board at Airbus' BizLab.**

Airbus' BizLab is an aerospace accelerator where start-ups and Airbus innovators can unleash their potential to accelerate the transformation of innovative ideas into valuable businesses within a collaborative environment.

This initiative from Airbus Corporate Innovation actively seeks opportunities to stimulate and develop ideas that can be of benefit to the aviation industry.

BizLab takes a hybrid approach that mixes internal and external participants to foster an innovative culture and promote an entrepreneurial mindset throughout Airbus.



The A350 is fitted as standard with ROPS

### **To effectively guide and assist the crew in the go-around decision-making process and the timely application of on-ground slowing down (reversers and braking), ROPS:**

- Automatically detects the upcoming landing runway using highly accurate runway information included in the terrain database (on A320 Family, A330 and A350) or the airport mapping database (A350 and A380).
- Performs a real-time in-flight landing distance assessment during the short final (last section of approach) taking into consideration the detected landing distance available. If the detected landing distance available is assessed too short, it triggers an alert to encourage the crew to go-around.
- Performs a real-time on-ground stopping distance assessment regarding the detected landing distance available. If the detected landing distance available is assessed too short, it triggers an alert to encourage the crew to apply and keep all available means of slowing-down.

## Real-time computation of realistic landing distance and remaining braking distance

In the air, the strength of ROPS is its ability to continuously monitor the aircraft's position and energy with regards to the remaining runway length. Consequently, any changes during the approach are immediately captured and the resulting distance required to stop is updated (e.g. changing winds affect the ground speed and thus the predicted touchdown speed, or flying above the normal glide-slope may affect the predicted threshold crossing point, or long flares which affect the predicted touchdown point).

The review of past incidents and accidents shows that seconds count (small delays have a large impact on the stopping distance), crews can be saturated with information and misjudgement concerning the amount of runway remaining is frequent. Moreover, acknowledging that ROPS cannot predict the future intention of the pilot, the system must protect against a pilot who is unknowingly approaching the runway end too fast while communicating that the current deceleration is not sufficient to stop the aircraft before the runway end. In addition, the system needs to protect against some unexpected degradation of aircraft braking performance (e.g. downward sloping runway end or runway end contamination by rubber).

# Creating a positive business case for operators with the ROPS risk management service

The wide adoption of safety-related technologies happens when a significant proportion of aircraft are equipped, which then creates a momentum within the industry. In the cases of the Terrain Awareness and Warning System (TAWS) and the Traffic Collision Avoidance System (TCAS) - two of the most important safety technological steps in aviation over the past 20 years (see FAST 45 and 52) - the installation took several years and was initially highly subsidized by governmental agencies.

In the case of ROPS, Airbus has looked for an innovative way to incentivize operators to adopt ROPS without relying on state subsidies but leveraging the value created by ROPS for the operators: less risk of runway excursions.

## The ROPS Risk Management Service

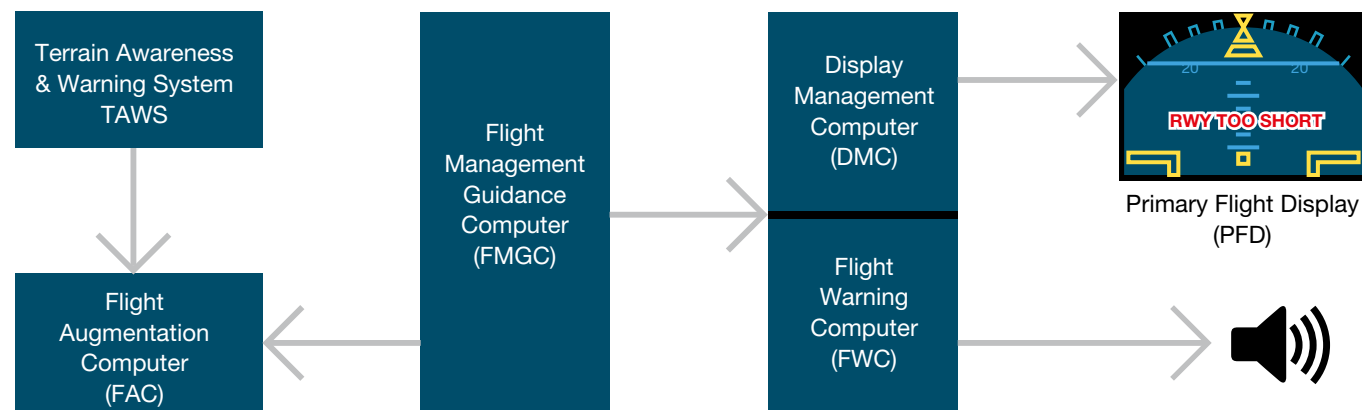
When one knows that runway excursions are the number one risk in terms of cost for insurances, it then becomes obvious that the reduction of this risk should translate into an insurance cost reduction for the operators installing ROPS on their aircraft.

Airbus has consequently entered into an innovative partnership with Willis Aerospace (insurance broker) and Allied World (insurance company) to develop the ROPS Risk Management Service which comprises:

- The installation kit for ROPS including all required software and operational documentation to activate and operate ROPS function,
- The supply of ROPS specific high quality and verified runway database updates,
- The supply and the management by Willis Aerospace of a dedicated Hull, primary and A rated insurance policy which would indemnify the operator against hull loss directly resulting from a runway overrun at landing for amounts up to US\$ 15,000,000 for a single-aisle aircraft or up to US\$ 25,000,000 for a long-range aircraft.

With the ROPS Risk Management Service, operators can negotiate on a case-by-case basis with their lead insurer or broker, a reduction of the insurance premium they pay as they are already insured against the risk of runway excursion and get a protection against the potential revision of their premium in case of overrun. This can create a positive business case for the installation of ROPS or at least alleviate significantly the cost of installation.

## An A320 ROPS architecture





## ROPS – Available for all Airbus families

### A320 Family and A330 Family status

- Implementation through software change mainly (retrofit can be done overnight)
- Certified for A320 Family by EASA and FAA in 2013
- Certification for A330/A340 Family expected in 2015

### A380

- Certified by EASA on October 15th 2009
- Selected on 77% of ordered/in-service A380s
- Implementation through software change only
- Coupled with Brake-To-Vacate (BTV)
- Proven: no runway overruns in seven years of operations

### A350

- Included in the basic entry-into-service configuration



## CONCLUSION

ROPS (Runway Overrun Prevention System) is an Airbus technological invention able to mitigate the n°1 source of accidents and insurance claims. This system is able to continuously monitor the aircraft's position and energy with regards to the remaining runway length and runway conditions, to effectively guide and assist the crew in the go-around decision-making process and the timely application of on-ground slowing down.

ROPS is available for linefit or retrofit on all Airbus aircraft and is being developed for non-Airbus aircraft. ■

# Airbus GSE & tools



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## New services to ease aircraft maintenance

Over recent years Airbus' Ground Support Equipment and Tools team has worked closely with airlines, transforming its "one-size-fits-all approach" into offering turnkey solutions, tailored to customers' specific requirements, and complete with customised technical data documentation.

In addition, Airbus GSE has worked with manufactures to test and approve alternative equipment, enabling new tools and equipment to be used for maintenance and repair with an approved procedure.

Now Airbus is bringing new materials and technologies to the tooling world to further improve aircraft maintenance.

## The GSE portfolio

Ground Support Equipment (GSE), as its name states, is the support equipment found at an airport or maintenance facility for servicing aircraft during turn-around or for maintenance and repair purposes, supporting the aircraft operations whilst on ground. The functions generally involve aircraft maintenance and repair, ground power operations, aircraft mobility and loading operations (for both cargo and passengers).

The GSE services offered by Airbus GSE and Tools Engineering are the following:

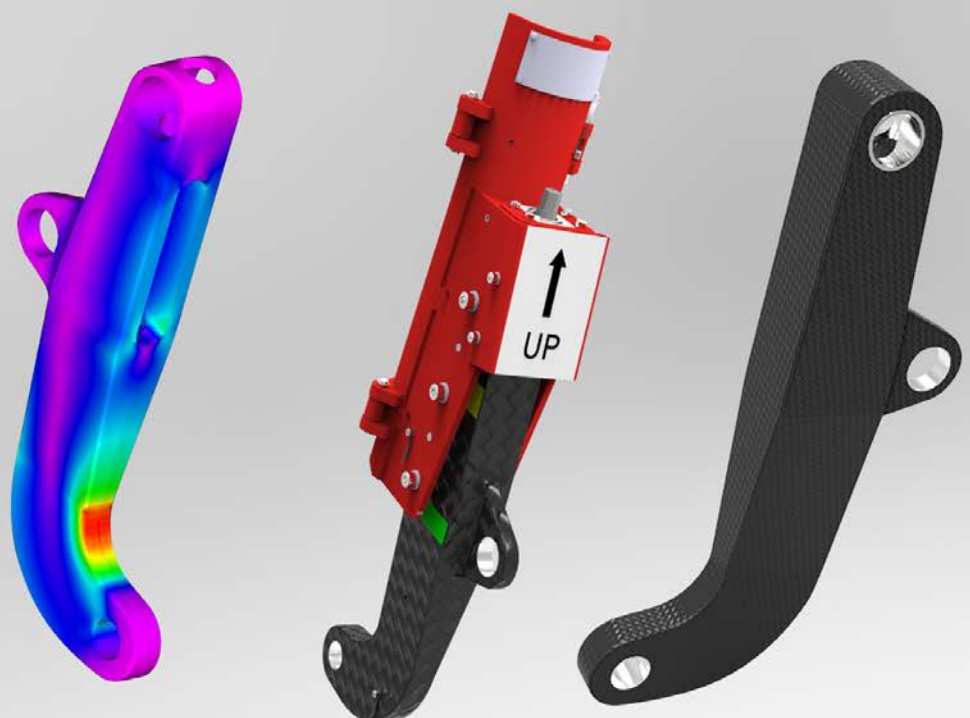
- Tailored tool service – the design, test, publication in Airbus technical documentation and supply of customised tools and equipment
- Alternative and standard tool validation service – the test, approval and publication in Airbus technical documentation of tools
- Tool recommendations – a recommendation list of required tooling based on the operator's needs

## Tailored tool designs

### Manufacturing heavy parts in carbon fibre

Traditionally, GSE and tools were made of heavy-duty materials as the main design criteria were cost of manufacturing and robustness. Nowadays, Airbus' customers are requesting cost effective tools, considering not only manufacturing costs, but the costs of using the tool during aircraft maintenance. Criteria such as cost efficiency, robustness with ergonomics, keeping safety in mind, are paramount. For example, the A380 body landing gear door safety collar has been manufactured for the first time in Carbon Fibre Reinforced Polymer (CFRP) reducing the tool weight from 25 kg to 9,4 kg. The proposed tool is now easier to use and reduces the number of mechanics needed to install it from five to one. In addition, with its much lighter weight, the potential for accidental damage to the aircraft is significantly reduced.

The new lighter A380 body landing gear door safety collar in CFRP





The "vortex killer"

## GSE tools developed by Airbus include:

- Electrical hoist kit for changing engines
- The Line Tool, a patented tool for Non-Destructive Testing (NDT) of composite materials for non-NDT specialists
- A380 Fuselage & Wing Protection Cover for use during slide/raft deployment test (MPD task 256200-00005).
- Fire Extinguisher System (FES) test box for A380 operational check of the firing circuit (AMM task 26-28-00-710-802A)
- Passenger door adjustment tool set for A380.

## Vortex killer for engine run-up

Following engine maintenance or during troubleshooting, it can be necessary to perform an engine run-up test on ground but, due to the close proximity of the ground to the engine, running an engine at high power can sometimes be a challenging task.

At high engine run-up speed, a ground vortex is formed leading into the engine air intake that can disturb the engine and cause it to stall. In addition, crosswinds can cause the ground vortex to fluctuate imposing wind speed and direction limitations when an aircraft is tested outside.

To solve this issue, Airbus has developed and patented a "vortex killer". It is commonly used in Airbus' Hamburg engine test facility for all A320 Family and A380 tests.

This "vortex killer" inhibits the negative effects from the ground vortex and enables a smoother engine run-up with less vibration. In addition, by using this GSE tool, the engine run-up tests can be performed in crosswind speeds up to 200% higher in comparison to normal testing.

At present, the "vortex killers" used in Airbus are sized specifically for each aircraft type meaning the A320 equipment can only be used on an A320. However, following a customer request, Airbus' GSE & Tools team started investigating the possibility of equipment suitable for several aircraft types, ranging from single-aisle to wide-body aircraft, in one single unit. By offering a single "vortex killer" customised to the operator's fleet, significant benefits with less equipment and investment can be envisaged.

## Alternative and standard tool validation

During the initial aircraft development, Airbus provides tool solutions for maintenance tasks. It may be equipment from a supplier that is approved and included in the technical data. Sometimes years later, an alternative solution can become available on the market or different solutions might exist locally to customers which are not included in the manuals, and not having an approved maintenance procedure can be a barrier to this new equipment being used.

Consequently, Airbus now offers a service to approve alternative tooling for which the tool and procedure are analysed, including completion of a test on aircraft. If successful, the tool is approved and the procedure is published with an update in the technical data. The benefits to tool suppliers are that the equipment can be sold with an approved procedure, such as in a format of an AMM (Aircraft Maintenance Manual) or SRM (Structure Repair Manual) task. This also benefits airlines by introducing new methods that can be faster or more efficient, while providing a greater choice of equipment. By updating the procedure in the technical data, it reduces the burden on airlines to internally approve and then prove to airworthiness authorities that the tool is technically equivalent, reducing cost and time when introducing alternative equipment.

For example, Airbus has recently worked with a supplier to approve new environmentally-friendly vacuum waste line cleaning equipment that uses biodegradable citric acid.

### Some examples of other alternative tool validations

- J. B. Roche (Manufacturing) Ltd: inflatable maintenance shelter for engines on large aircraft (see following article in this FAST magazine)
- Langa and Dédienne Aérospatiale: maintenance jacks
- Air New Zealand: A320 retraction actuator re-boring tool
- Teledyne and TechSAT: Portable Data Loaders (PDL)
- Cee-Bee, Celeste and Test-Fuchs: vacuum waste line system cleaning equipment
- AeroControlex: potable water system, disinfection with ozone

Torque multiplier tool

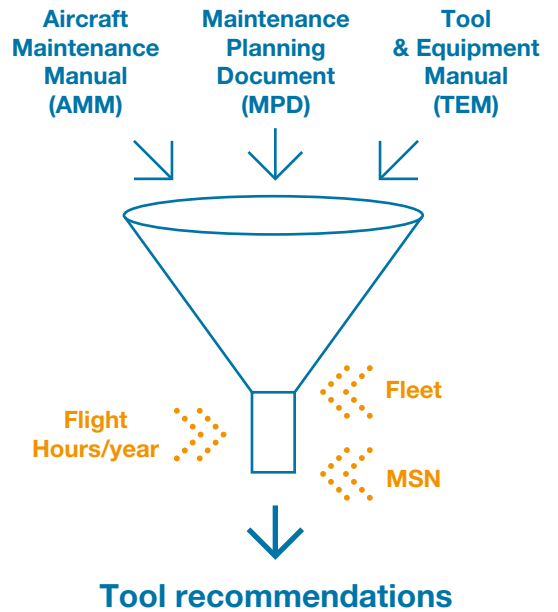


## Tool recommendations

Through the tool recommendations, Airbus advises what equipment is required based on a particular airline's fleet and/or specific needs.

The recommendation is a list of required tooling complying with Airbus' technical documentation, linking information together from the Aircraft Maintenance Manual (AMM), Maintenance Planning Document (MPD) and Tool & Equipment Manual (TEM) to identify all the tooling. From this list, Airbus can then filter, based on the airline's fleet, the aircraft utilisation, the airline's maintenance concept and purchase or lease policy, to advise what tooling is needed and when they will require it.

This has the benefit of ensuring that customers have the right tool at the right time, and to help customers prepare for specific maintenance events or the entry-into-service of new aircraft. This also has the added advantage of helping airlines to optimise their tool investment planning by purchasing the GSE at the right time, throughout the aircraft's life-cycle.



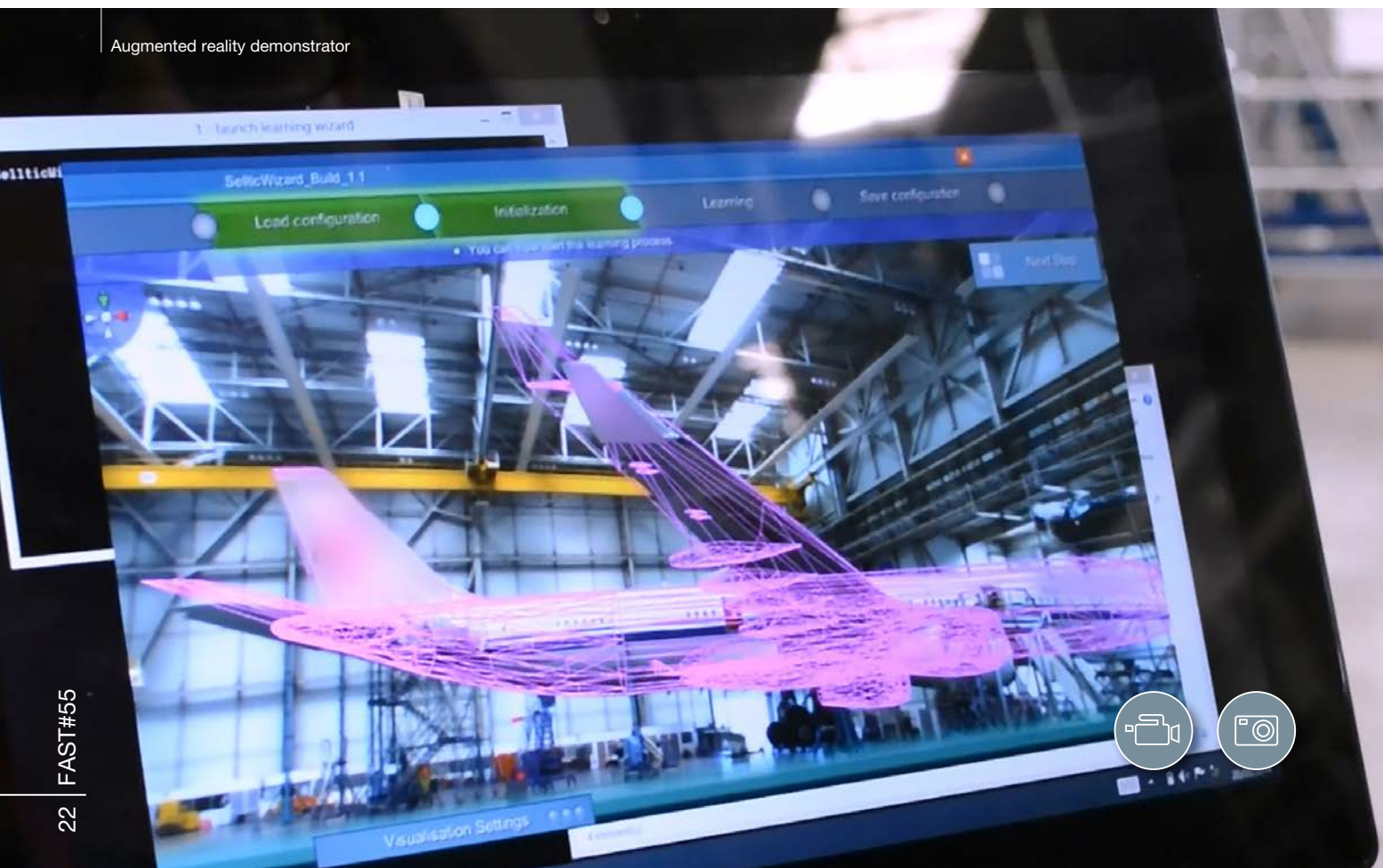
## New technology - augmented reality

Airbus has developed an augmented reality technology demonstrator for tablets that integrates high quality 3D data of the aircraft and tooling, 3D animations, the aircraft maintenance instructions and GSE guides.

The application is able to recognise the real working environment, without markers, and overlay an animation of the tooling installation to enable the maintenance teams to see where they are in the procedure, and verify the equipment is installed appropriately.

This will have the benefit of significantly reducing the time for interpreting and understanding the maintenance tasks. The augmented reality technology demonstrator is currently in its final development stage and the intention is to make this available, together with a cockpit dedicated to GSE, on the AirbusWorld portal in the near future.

Augmented reality demonstrator



The electrical hoist kit was developed by Airbus to ease engine changing.

The kit allows engines to be positioned with extreme precision and needs only three engineers as opposed to eight needed for traditional bootstrap systems (see article in FAST #52).

## CONCLUSION

Airbus GSE and Tools services have proven to help airlines optimise their maintenance and reduce direct maintenance costs.

By offering tailored tool services, Airbus can offer a complete tooling solution, tested on aircraft and provided with approved technical documentation for its use on aircraft.

With the services now offered to GSE manufactures, new equipment can be introduced and sold as validated on Airbus aircraft with an approved procedure in the Airbus technical documentation.

For general information please contact [maint.gsetools@airbus.com](mailto:maint.gsetools@airbus.com)

For further information on GSE & tools shown in this article:

- A380 body landing gear door safety collar,  
torque multiplier tool and electrical hoist kit  
Eric RIVIERE - [Eric.E.Riviere@airbus.com](mailto:Eric.E.Riviere@airbus.com)
- Vortex killer  
Daniel GYLLHEM - [Daniel.Gyllhem@airbus.com](mailto:Daniel.Gyllhem@airbus.com)
- Augmented reality  
José-Miguel VIZARRO-TORIBIO - [Jose.Vizarro\\_Toribio@airbus.com](mailto:Jose.Vizarro_Toribio@airbus.com)
- Tool recommendations  
Jean-Marc HERAL - [Jean-Marc.Heral@airbus.com](mailto:Jean-Marc.Heral@airbus.com)

Example of Airbus  
Ground Support  
Equipment (GSE)

# Inflatable tents for engine maintenance



Article by  
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GSE Designer  
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## Bringing apron maintenance indoors

Airbus Customer Services has recently noticed an increase in delays concerning unscheduled engine maintenance due to the lack of availability of hangar space.

Ideally engine maintenance tasks need to be performed in dry, temperate, comfortable conditions, and while they can sometimes be performed outside on the apron, customers that are located in regions with extreme weather often have to wait until hangar space is available.

Airbus GSE and Tools department was asked to find a quick, effective and low cost solution to perform fleet maintenance tasks when a hangar is not available and/or the aircraft is blocked outside.

Following an intense three months of collaborative work, Airbus has used its aircraft and tool manufacturer know-how to validate and offer a “ready-made” solution for their customers.



## The solution

The solution consists of an inflatable tent enabling “indoor” engine maintenance with optimal environmental conditions anywhere in the world.

The kit comprises an inflatable dome tent and an HVAC (heating, ventilating, and air conditioning) system that can be used on all Airbus aircraft engines. The tent is kept in place by placing ballast, such as water containers or sandbags, on the skirts provided for that purpose.

The system effectively allows maintenance teams to work anywhere, bringing the hangar to the aircraft, rather than the aircraft to the hangar.

The added value for the customer is that not only do they no longer have to wait for available hangar space - reducing Aircraft On Ground time - but can also avoid costly hangar fees.

### Features

Inflatable tents allow customers or Airbus work parties, to performing heavy maintenance activities whatever the environmental conditions reducing cost and saving time.

The main features are:

- Lightweight and manoeuvrable (it could even be stowed on the aircraft)
- Weatherproof
- Quick assembly, installation and removal
- Provision for anchorage, either mechanically or using ballast
- Oil, acid and hydraulic fluid resistant material
- A safe and comfortable working environment

The tents, which were initially validated for wide-body aircraft, are now available for all long-range Airbus aircraft (A330, A340, A350 and A380).

Airbus GSE & Tools department is investigating other sheltering systems that can be installed around landing gear, main fuselage and doors to offer a similar level of comfort for their maintenance.

“A comfortable and safe working environment, even in regions with extreme weather conditions”.





## Electrical hoist kit compatible

The opening end doors of the inflatable engine maintenance tent not only allow it to be pulled around the engine and above the pylon, but also allow the possibility of using the electrical hoist kit (see FAST 52) developed by Airbus to remove and install an entire engine.



# Inflatable tents for engine maintenance

## Main characteristics

- Operating temperature: -40°C to +60°C
- Installation time: 5 minutes (4 crew)
- Removal and stowing time: 10 minutes (4 crew)
- Shelter weight: 140 kg
- Blower weight: 22 kg
- Shelter dimensions (packed): 150 x 100 x 100 cm
- Blower dimensions: 50 x 40 x 60 cm
- Maximum wind speed: 30 knots (ballasted)



## CONCLUSION

To provide a quick, low cost solution to lack of hangar space for unscheduled engine maintenance, Airbus GSE & Tools department has developed, in collaboration with J.B.Roche (Manufacturing) Ltd, an inflatable maintenance tent.

This quick-to-install shelter is especially appreciated in regions of severe weather conditions where it provides a safe and comfortable working environment. Its ease and availability allow aircraft to not be grounded any longer than necessary.

For more information contact the Airbus GSE & Tools front desk: [maint.gsetools@airbus.com](mailto:maint.gsetools@airbus.com)

# Scheduled maintenance requirements

## Maintenance programmes and planning



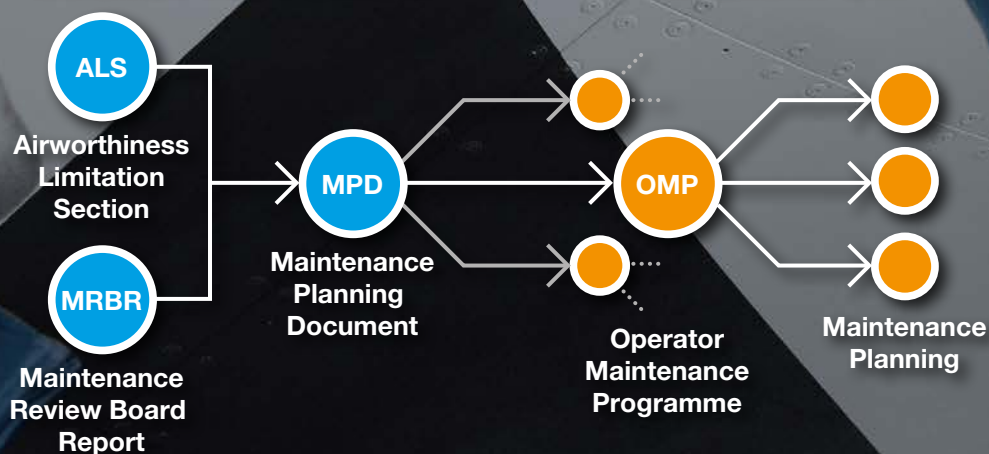
Article by  
**Christian DELMAS**  
Head of Maintenance Programmes Engineering  
AIRBUS  
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Maintenance programmes and planning activities aim at ensuring continued airworthiness while all the time maximising fleet availability and optimizing airlines' maintenance resources.

The purpose of this article is to clarify what maintenance programmes and planning are, who is responsible for setting them and by which factors they are influenced.

### MANUFACTURER

### OPERATOR



### GLOSSARY >>>

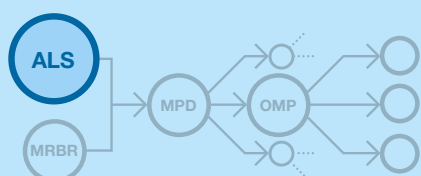
The definitions shown here use abbreviations and acronyms for smoother reading, and familiarity with basic maintenance terms is expected. A glossary of acronyms and terms can be found on page 37 to refresh your memory.



**First things first, let's start by reviewing what is developed and provided by the MANUFACTURER.**

## Manufacturer maintenance requirements

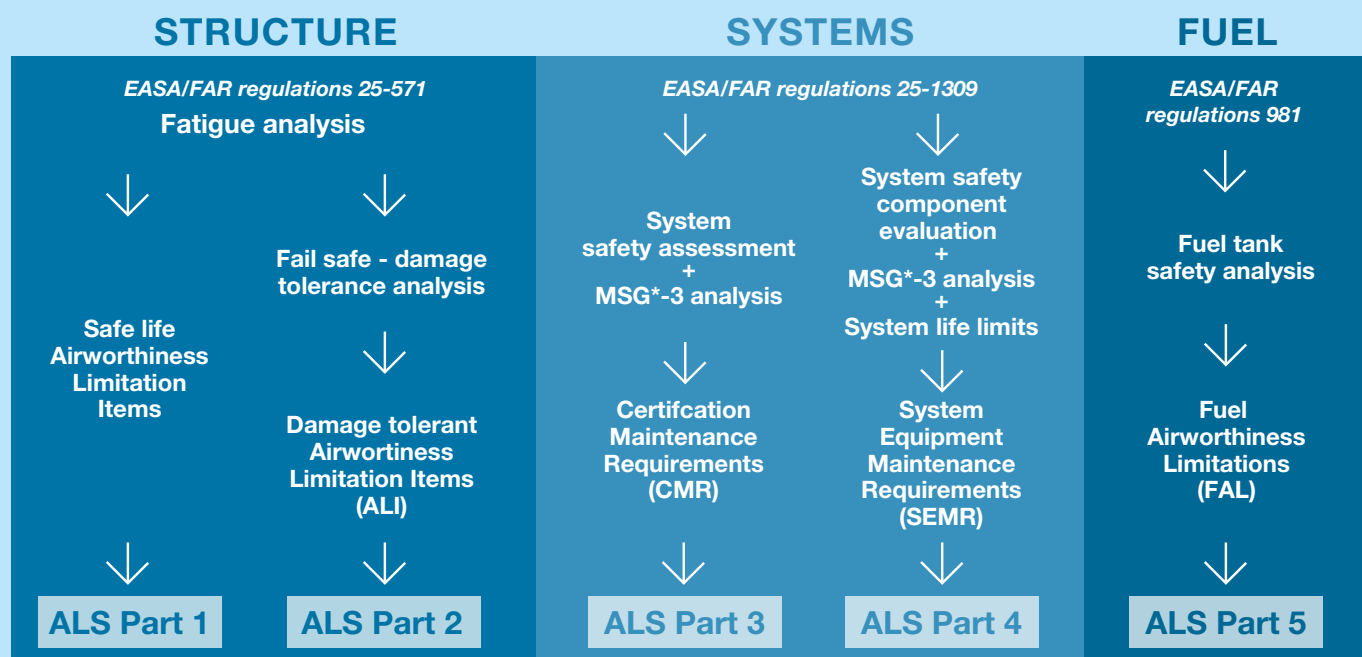
Scheduled maintenance requirements are developed by aircraft manufacturers to demonstrate compliance with regulatory requirements associated with “Instructions for Continued Airworthiness”. In practice, for a given aircraft programme (e.g. A300/A310 Family, A320 Family, A330, A340, A350 and A380) several documents are developed, the primary ones being the Airworthiness Limitation Section (ALS) and the Maintenance Review Board Report (MRBR).



## Airworthiness Limitation Section

The Airworthiness Limitation Section comprises standalone documents such as:

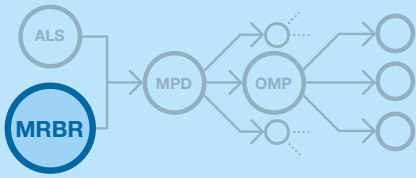
- ALS Part 1** Safe life Airworthiness Limitation Items (commonly referred to as Life Limited Parts (LLP))
- ALS Part 2** Fatigue & damage tolerant Airworthiness Limitation Items (commonly referred to as ALI)
- ALS Part 3** Certification Maintenance Requirements (commonly referred to as CMR)
- ALS Part 4** System Equipment Maintenance Requirements (SEMR)
- ALS Part 5** Fuel Airworthiness Limitations (FAL)



\*Maintenance Steering Group

The documents list, per ATA chapter, maintenance tasks and associated threshold and/or intervals expressed in the relevant usage parameter (Flight Hours (FH), Flight Cycles (FC) or calendar times (days, months or years)). The tasks and intervals come from quantitative analyses (e.g. fatigue and damage tolerance analysis, system safety assessment, etc.) developed in the frame of Type Certification (TC) activities.

These documents are not customized to a given fleet but provide envelope requirements for the worldwide fleet for a given aircraft programme. Quoted thresholds and intervals are not to be exceeded, unless otherwise specified. These documents are referenced in the Type Certificate Data Sheet and subsequent revisions are usually mandated by Airworthiness Directives.



# Maintenance Review Board Report

Unlike the ALS, the MRBR is developed according to a process which involves owners/operators, airworthiness authorities, the aircraft manufacturer and major suppliers or vendors; referred to as the MRB process.

The MRBR is complementary to the ALS because, unlike the ALS, it follows a qualitative assessment focusing not only on aircraft safety but also on aircraft availability and maintenance costs.

The MRB process is recognized and supported by the major airworthiness authorities.

This process relies on a method developed and maintained by the industry: MSG-3.

Aircraft manufacturers, airworthiness authorities and operators meet on a regular basis to adapt the process and the method to an evolving context: new regulations, new technologies, lessons learnt from implementation, in-service experience feedback, etc.

For a given project (e.g. A350), the Industry Steering Committee (ISC), chaired by an operator representative, develops and keeps the MRBR up-to-date. Representatives of the aircraft manufacturer (known as the Type Certificate Holder or MRB applicant), owners/operators, authorities and major vendors form the ISC.

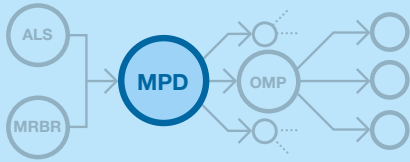
The ISC's objective is to develop and maintain an efficient MRBR and get it approved by the authorities.

## **The MRBR is a list of maintenance requirements (tasks) with associated intervals.**

In the past, a selection of maintenance programme intervals was highly influenced by planning considerations (and not only technical ones). Operators typically used block maintenance concepts which explains the reason why some intervals were harmonized in "letter intervals" such as checks A, C, etc.

For several years now, intervals have been developed according to an engineering assessment and are expressed with the most appropriate usage parameter (calendar time, Flight Hours (FH) or Flight Cycles (FC)) thus allowing greater flexibility in their planning. The usage parameter depends on the degradation mode of the analysed system/structure.





# Maintenance Planning Document

Unlike the ALS or the MRBR, the MPD is not imposed by regulations. The MPD is a non-approved document and a repository/consolidation of maintenance requirements coming from other documents (so called “sources”) such as the ALS or the MRBR.

The MPD, which is part of the manufacturer’s technical documentation, aims at helping operators in the preparation of their maintenance programme and planning. It establishes the link between the requirements and the maintenance procedures listed in the Aircraft Maintenance Manual (AMM).

The MPD also contains additional information to help operators in the organization of maintenance (e.g. access information, man-hours, elapsed time, required skills, etc.).

As the content of the MPD is not defined by an industry standard, there are different MPD concepts depending on the aircraft manufacturers. In the current Airbus MPD, all repetitive scheduled maintenance requirements are consolidated with the source documentation whereas other aircraft manufacturers may consider the MRBR only, or the MRBR and the ALS.

Special attention should thus be paid when comparing MPDs between aircraft from different manufacturers.

## Manufacturer maintenance requirements for revision/evolution

ALS and MRBR are developed in the frame of the initial Type Certification (TC). ALS and MRBR have to be kept up-to-date all along the programme life. There are actually three major triggers for a maintenance programme revision:

- Regulation changes
- Configuration changes (aircraft modifications)
- In-service experience feedback

Regarding the MRBR, initial intervals are often quite conservative. Consequently, from analysing in-service feedback, there is good potential to optimize intervals in a way that is beneficial to the operator. Most manufacturers have managed to optimize task intervals at several opportunities, rendering operator maintenance programmes more efficient.

Optimization of maintenance programme intervals essentially relies on scheduled and unscheduled data collected by the manufacturer from different operator environments, aircraft utilisation, aircraft configuration, aircraft age, etc.

Since 2007, authorities have imposed on manufacturers a rule for maintenance task optimization, which mainly relies on the volume and quality of collected data. The rule is known in the industry as IP44.

Without operators’ data, manufacturers do not have the means to optimize maintenance tasks.

## Manufacturer maintenance requirement summary

The manufacturer maintenance requirements are published in multiple documents (e.g. ALS parts, MRBR, etc.) and developed according to quantitative and qualitative analyses. The documents:

- Are developed to demonstrate compliance with instructions for continued airworthiness regulations and according to industry standards (e.g. MSG-3)
- Are approved by the certification authorities
- Envelope the entire fleet for a given programme and cover all possible configurations. They are not customized to a given Manufacturer Serial Number (MSN) or operator’s fleet
- Provide a list of maintenance requirements sorted by ATA chapter



**Now, let's see what happens on the side of the OPERATOR**



## Operator Maintenance Programme

OMP may also be referred to as Aircraft Maintenance Programme (AMP) or Continuous Airworthiness Maintenance Programme (CAMP). Within this document, the term “maintenance programme” may also be understood as “maintenance schedule”.

OMP development is under the responsibility of the operator and is developed according to National Airworthiness Authorities (NAA) continuing airworthiness requirements. OMP is a prerequisite for an operator to obtain an Air Operator Certificate (AOC) from its NAA.

The OMP shall list all requirements:

- Coming from the manufacturer's regulation compliance documentation (e.g. MRBR, ALS or specific procedures applicable to the operator's fleet).
- Coming from the manufacturer's recommendations (e.g. SB, SIL and OIT) provided the operator's engineering office considers them to be effective in the local operational environment.
- Coming from Airworthiness Directives (AD)

The MPD can be used as a source for all three groups but it must be ensured that requirements issued since its publication are not overlooked. It is essential to ensure that operators implement a thorough aircraft configuration management to only select tasks applicable to their fleet and, more importantly, not to miss any requirements that apply.

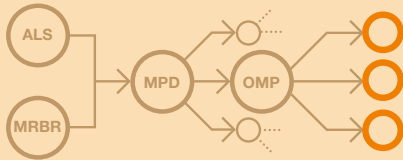
The OMP generally contains far fewer tasks than the MPD. For example, the A320 Family MPD lists about 3,000 maintenance requirements for all A318/A319/A320/A321 models, versions, configurations. Customized at aircraft level in an operator's maintenance programme, this number is reduced to approximately 1,000 tasks:

- Imposed by the operator's NAA and national laws
- Coming from the operator's in-service experience
- Coming from any aircraft Supplemental Type Certificate (STC)

Unless otherwise specified, operators cannot deviate from the ALS and AD requirements applicable to their fleet. However, regarding the MRBR, operators have the possibility to deviate from the published requirements according to procedures agreed with their NAA.

The Operator Maintenance Programme is approved by the operator's NAA. It is *'the'* reference for the maintenance of the aircraft.





## Planning the accomplishment of tasks

Considering that an aircraft generates value while flying and costs while on the ground, it is essential to ensure a maximum aircraft availability for operations. In addition, operators also have to ensure optimized utilization of available resources, whether internal or sub-contracted.

This is the reason why it is not relevant for an operator to perform each maintenance programme task (from the OMP) exactly at its quoted interval.

This would:

- Generate too many operational interruptions
- Require a surplus of means/resources for each task accomplishment
- Require availability of means/resources at different locations (main base and remote stations)

This is also the reason why operators have to organize/schedule their aircraft/fleet maintenance. To do so, they have to package the accomplishment of maintenance tasks into maintenance events, also referred to as maintenance checks.

Task packaging is a typical planning exercise which takes many different parameters into consideration:

- Aircraft utilization such as FH and FC per year
- Aircraft operational availability - some operators operate their aircraft in a similar way throughout the year during which very limited opportunity for maintenance exists. Conversely, others experience peak and low seasons. During the low seasons, aircraft utilization is reduced thus offering more opportunities for maintenance
- Manpower and hangar availability - some tasks can be performed “on the line” whereas some others (e.g. due to the need for ground support equipment - see article page 22 -, access, task duration, etc.) have to be performed in a hangar
- Means associated to the maintenance task accomplishment - some tasks (mainly structure inspections) may require heavy access
- Aircraft age - the more the aircraft ages the more tasks there are, associated with potential fatigue or corrosion degradation requiring heavier access
- Airline policy in terms of cabin refurbishing (which generates aircraft ground time during which maintenance tasks can be performed)
- Airline policy in terms of system or structure modifications (SB embodiment which may also impose aircraft ground time opportunities for maintenance)

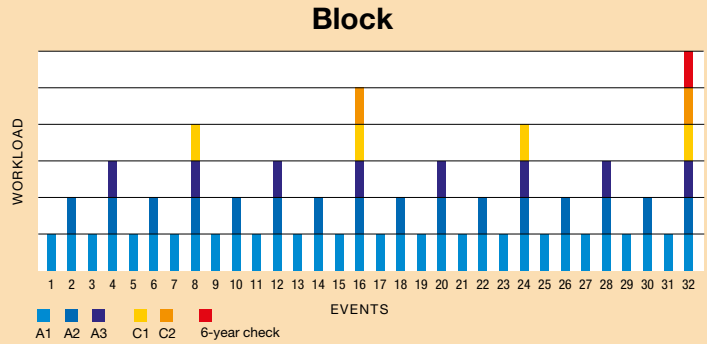
Consequently from the same maintenance programme, several maintenance planning options may exist. This also means it is not relevant to talk about maintenance check intervals at maintenance programme level: maintenance check is a pure planning exercise performed at operator level. It is even less relevant to talk about maintenance check intervals at manufacturer maintenance requirements level.



From the same maintenance programme, different operators may develop different maintenance planning scenarios:

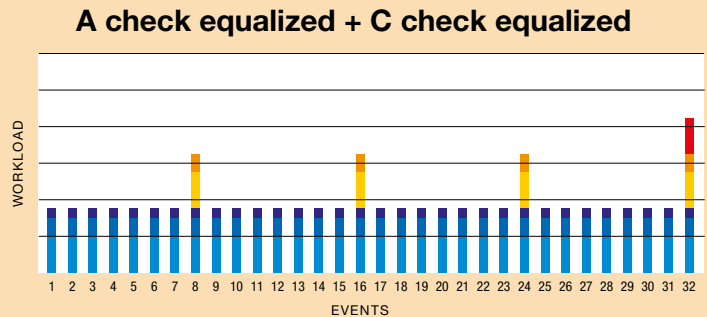
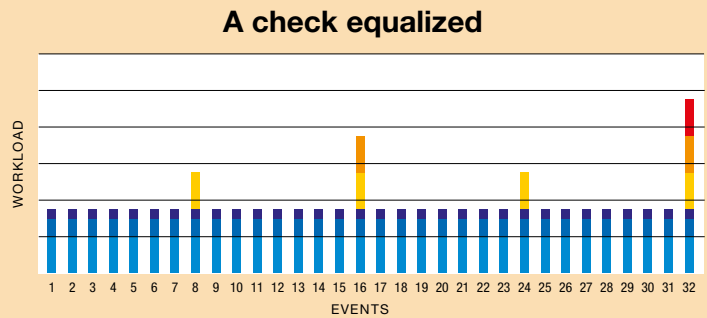
### Typical block check concept

Tasks are distributed in so called line checks, base checks (typically C check), intermediate checks (typically 6-year checks) and heavy maintenance checks (typically 12-year checks). Checks are distributed with the same interval but the content of each event may vary significantly, thus generating different workload or aircraft ground time (typically A1, A2, A3, etc., checks are different, as well as C1, C2, etc. checks).



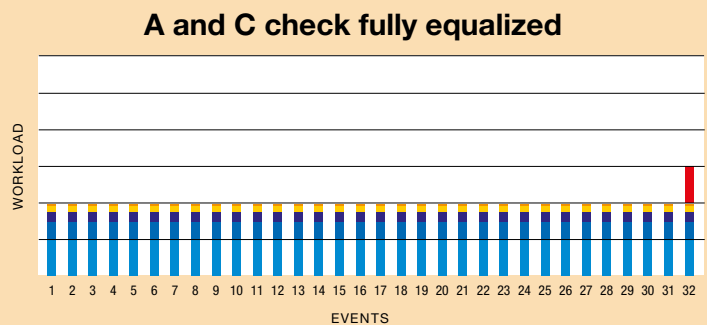
### Typical semi-equalized check concept

In order to better manage manpower and aircraft availability, some operators have managed to balance manpower needs and aircraft ground time between repetitive A checks or repetitive C checks.



### Typical fully equalized check concept

Extending the concept of the semi-equalized concept and looking for maximum aircraft availability and utilization of resources, some operators have also organized their maintenance in such a way that the tasks are performed during "light" events (that can be performed overnight) in between intermediate maintenance checks (typically checks with a six year interval).



Such a concept certainly generates a more intense maintenance planning exercise, may generate additional maintenance costs (same access opened more often), more logistics (spare parts and means available at line stations) but also generates more aircraft availability and subsequently potential revenues: aircraft can be operated on a daily basis without interruption in between six year interval checks. Maintenance checks are performed overnight when aircraft is available.

A stable fleet configuration, a thorough management of Minimum Equipment List (MEL) deferred items, a young fleet or intensive/regular aircraft operation throughout the year, are examples of conditions to be fulfilled to implement and get maximum benefit from such a maintenance planning concept.

Some A320 Family operators have implemented such maintenance planning concepts, as the A320 maintenance programme has demonstrated a high level of flexibility to adapt to any maintenance planning concept. In particular, for a fleet of young aircraft, with in-between six year checks there are no single tasks that impose aircraft ground time longer than an overnight stop. It is certain that if any single maintenance programme task imposes significant aircraft ground time or requires high manpower/important means (typically a structure inspection with heavy access), such a concept is not achievable.

From this experience, it could correctly be said that there is no “C” check on the A320! This would however apply only to those operators that have gone to a fully equalized concept.

The fact that such a concept is achievable is due to the flexibility of the maintenance programme. This implies that any other semi equalized or block check solution is also achievable if this is desired by the operator.

### Out of phase tasks

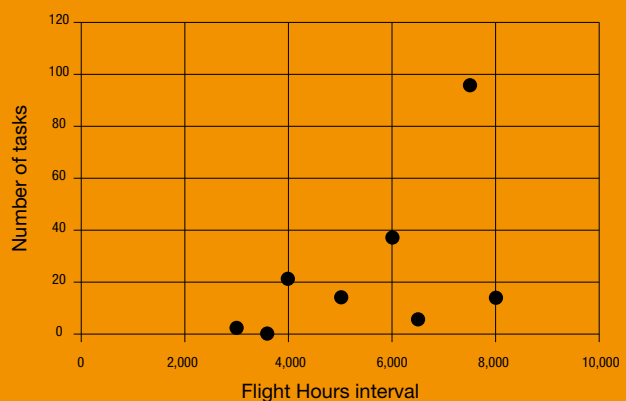
When developing the maintenance plan from the maintenance programme, operators are exposed to maintenance tasks whose intervals do not fit with the maintenance checks. They are referred to as “out of phase” or “drop-out” tasks and can be performed either in an earlier check package or managed individually as long as access, required means, etc., allow it.

As such, when comparing maintenance check intervals it is also important to understand the ratio of associated out of phase tasks.

### Examples of out of phase tasks

#### Reference programme

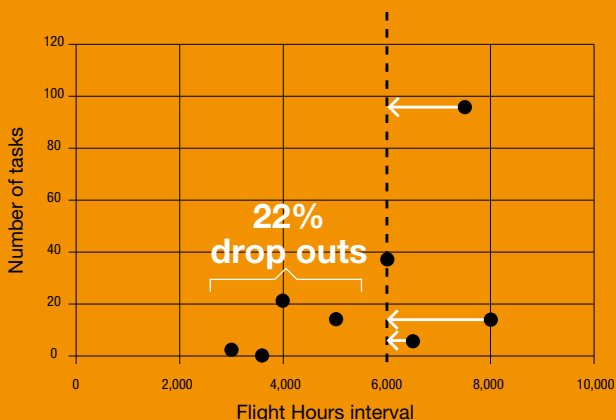
As an example, the chart to the right represents the number of maintenance programme tasks (typical C check candidates) as a function of the associated FH interval (fictitious programme).



#### Packaging of FH tasks

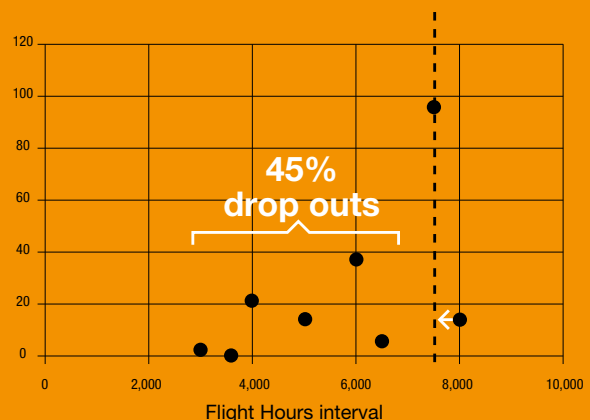
From the same programme, different operators can package FH tasks differently:

#### 6,000 Flight Hours maintenance check



compared to

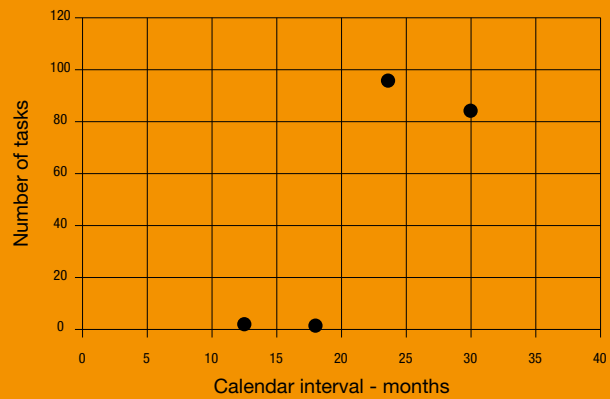
#### 7,500 Flight Hours maintenance check



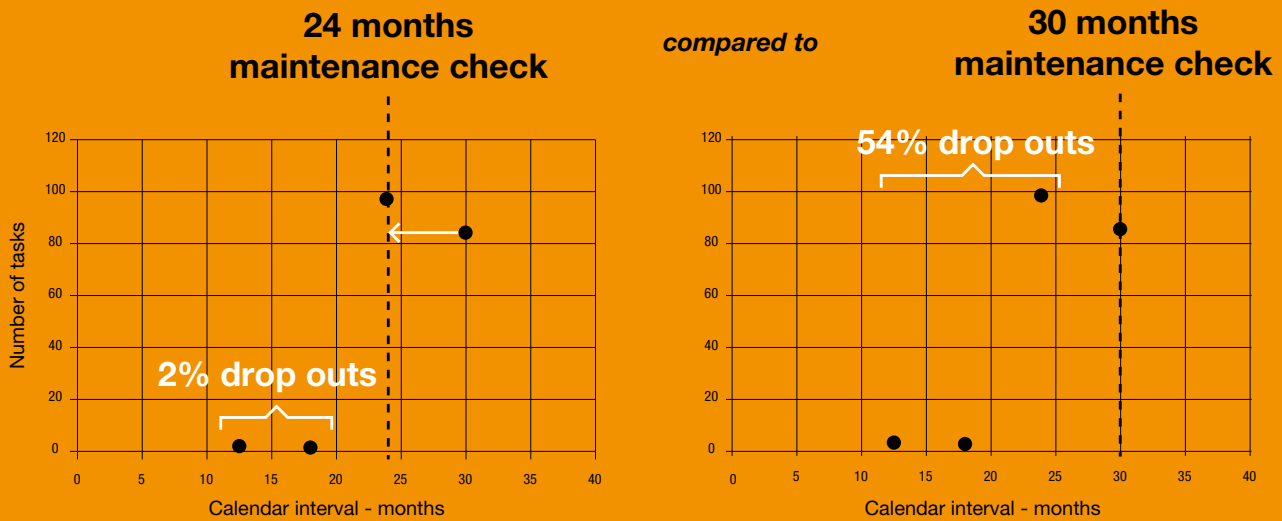
This demonstrates that from the same maintenance programme, the definition of the maintenance check interval can be communicated as “6,000 FH C check” or “7,500 FH C check”.

### Packaging of calendar tasks

Similarly, from the same initial maintenance programme, we can identify tasks whose interval is calendar:



From the same maintenance programme, different operators can package calendar tasks differently:



This also demonstrates that from the same maintenance programme, the definition of the maintenance check interval can be communicated as: 24 months C check or 30 months C check.

In his example, it is obvious to say that a 24-month C check is a more pragmatic proposition.

The same principle applies to the FC tasks.

### Global packaging

Additionally, in terms of planning it is essential to consider FH, FC and calendar related maintenance programme tasks. From the same programme (as per the two examples mentioned above) the planning exercise has to conciliate the FH, FC and calendar intervals. This means that for task packaging, the annual aircraft utilisation is a key parameter: a 6,000 FH task will be packaged with a 24 months task if the aircraft operates 3,000 FH/year. Higher aircraft utilisation will make that the 6,000 FH tasks become due before 24 months.

Consequently, from the above mentioned example, a “30 months C check” is only achievable if the aircraft flies no more than 3,000 FH/year (to permit packaging of the 7,500 FH tasks at 30 months) and information regarding the accomplishment requirements of the out of phase tasks (drop out) is understood, and also if there are no tasks at 6,000 FH or 24 months that impose a significant aircraft ground time.

Special attention should be paid when comparing aircraft scheduled maintenance information (task intervals, maintenance checks, etc.). The flexibility offered by the manufacturer maintenance requirements is a more appropriate comparison as it indicates which kind of planning solutions an operator could select to better adapt to their operations.

For example, the A320 Family maintenance requirements have demonstrated a high level of flexibility, allowing operators to develop a maintenance planning that best fits their operations.

## Glossary of maintenance vocabulary abbreviations

<b>AD</b>	Airworthiness Directive	<b>ISC</b>	Industry Steering Committee
<b>ALI</b>	Airworthiness Limitation Items	<b>LLP</b>	Life Limited Parts - <i>safe life ALI</i>
<b>ALS</b>	Airworthiness Limitation Section	<b>MPD</b>	Maintenance Planning Document
<b>AMP</b>	Aircraft Maintenance Programme	<b>MRBR</b>	Maintenance Review Board Report
<b>AOC</b>	Air Operator Certificate	<b>MSG</b>	Maintenance Steering Group
<b>CAMP</b>	Continuous Airworthiness Maintenance Programme	<b>NAA</b>	National Airworthiness Authority
<b>CMP</b>	Configuration Maintenance Procedures	<b>OIT</b>	Operator Information Transmission
<b>CMR</b>	Certification Maintenance Requirements	<b>OMP</b>	Operator Maintenance Programme
<b>DSG</b>	Design Service Goal	<b>SB</b>	Service Bulletin
<b>ETOPS</b>	Extended-range Twin-engine Operation Performance Standards - <i>now referred to as Extended Time Diversion Operation (ETDO)</i>	<b>SEMR</b>	System Equipment Maintenance Requirements
<b>FAL</b>	Fuel Airworthiness Limitations	<b>SIL</b>	Service Information Letter
<b>FC</b>	Flight Cycle	<b>STC</b>	Supplemental Type Certificate
<b>FH</b>	Flight Hour	<b>TC</b>	Type Certification
		<b>TCDS</b>	Type Certification Data Sheet

Previous FAST articles on maintenance programmes

[www.airbus.com/support/publications/](http://www.airbus.com/support/publications/)

FAST 10 (July 1990) Maintenance programme development

FAST 31 (December 2002): Less maintenance, less cost

FAST 38 (July 2006): The A380 maintenance programme is born

### Airbus support & assistance

For further information about Airbus scheduled maintenance contact [sched.maint@airbus.com](mailto:sched.maint@airbus.com)

Airbus also proposes Scheduled Maintenance Programme (SMP) seminars

(refer to Airbus Customer Services' e-Catalogue). For further information contact [sched-maint.seminar@airbus.com](mailto:sched-maint.seminar@airbus.com)

Airbus also offers the following scheduled maintenance services as part of its Airpl@n suite (refer to Airbus Customer Services' e-Catalogue):

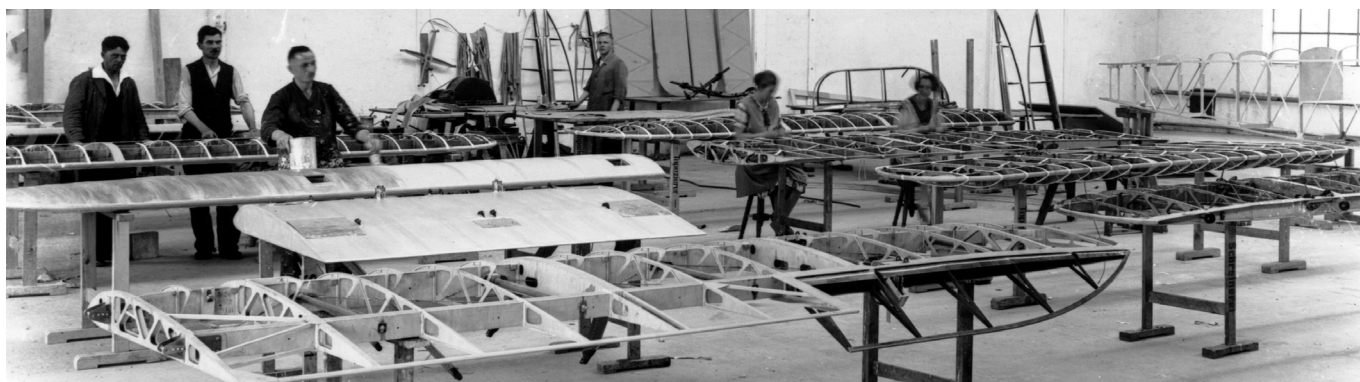
- Development, amendment and optimization of customized maintenance programme
- Initialization and optimization of corresponding maintenance planning
- Maintenance packages preparation through provision of task and job cards
- Provisioning list of material resources for the maintenance programme
- Assessment to bridge the aircraft maintenance programme and planning
- Clock resetting service maintenance programme customization, maintenance programme and optimization planning

For further information on AirPI@n services contact [airplan@airbus.com](mailto:airplan@airbus.com)

# FAST from the PAST

There wouldn't be any future without the experience of the past.

"Now let's see... this part goes here... it is assembled with that one, which is then attached to that one which goes underneath the upper part...". These engineers assembling the U 12 Flamingo in Augsburg (Germany) 1928, would never in their wildest assembly line dreams, imagine that in less than a century, 3D-printing (see FAST article page 4) would allow complex components to be built in one single part.



Photos courtesy of EADS Corporate Heritage

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