

JANUARY 2012  
FLIGHT  
AIRWORTHINESS  
SUPPORT  
TECHNOLOGY

# FAST<sup>49</sup>

A I R B U S T E C H N I C A L M A G A Z I N E



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A I R B U S  
T E C H N I C A L

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# Spare part commonality

## Ensuring A320neo series commonality with the existing A320 Family

Commonality is one of the key drivers of the A320neo development. The A320neo series, where neo stands for 'new engine option', has a target of over 95% spare parts commonality with the existing models, enabling the new aircraft to fit seamlessly into existing A320 Family fleets and customers' operations. This will help airlines to achieve significant savings in the areas of Initial Provisioning (IP) investment and maintenance training, compared to an all new aircraft series.

The A320neo series is a programme which uses innovative new engine and aero-structural technologies to provide a significant improvement in performance for the A319, A320 and A321 aircraft. Whilst striving to deliver this benefit to the operators, Airbus is also keen on minimizing the changes to a proven product. Changing only what is necessary to integrate the new engines, keeping the rest of the aircraft in harmony with the operators' existing economic and logistical models, can ensure the future operators a simpler, lower cost service entry.



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## Key drivers of the A320neo development

Spares' investment and services have a huge impact on the lifecycle cost of an aircraft. In recognition of this, Airbus has set clear targets for the A320neo development to drive cost factors such as spares' investment and commonality during the aircraft definition phase. This includes the specific objectives on both commonality and overall RSPL\* investment.

### OVERALL RSPL INVESTMENT

The overall RSPL investment was set at the same level for the A320neo series as for the standard A320 Family aircraft. It was then broken down to individual components, in order to ensure that both component reliabilities and contractual agreements with suppliers don't increase the overall quantity and cost of parts in the RSPL.



notes

#### RSPL (Recommended Spare Parts List)

Airbus provides customers with material provisioning data concerning spares' holdings for a given fleet based on customized parameters. This list gives recommendations for the unscheduled maintenance planning for the first year of operation.

### COMMONALITY STUDIES

The 95% commonality of parts defined in Airbus' objectives is not just a marketing figure. An initial verification exercise has been conducted to ensure that it is measurable, achievable and value adding. The following sections define how this was carried out.

Airbus has compared the standard engine variants, CFM (joint venture between General Electric and SNECMA) and IAE (International Aero Engines), with both 'neo' engine variants - 'CFM Leap X' and 'PW1100G', as shown in figure 2. The operators of both standard engine variants have expressed an interest in both new engine options, meaning all fleet combinations must be considered.

The technical scope of the assessment covers the whole airframe, including all systems impacted by the introduction of the new engines, but excluding the engines and nacelles themselves. The analysis does not consider structural parts.

### Generation of a Recommended Spare Parts List (RSPL)

To generate RSPLs as a basis of comparison, key assumptions were defined relating to the fleet size, aircraft utilisation, logistics and economics. The assumptions are based on experience with all Airbus operators and represent the average A320 Family mission.

Four RSPLs were generated based upon the defined assumptions and using the same methodology as a typical customized airline's RSPL for the following configurations:

- A320 CFM56-5B Variant,
- A320 IAE V2500 Variant,
- A321 CFM56-5B Variant,
- A321 IAE V2500 Variant.

### Recommended Spare Parts List: Short-listing

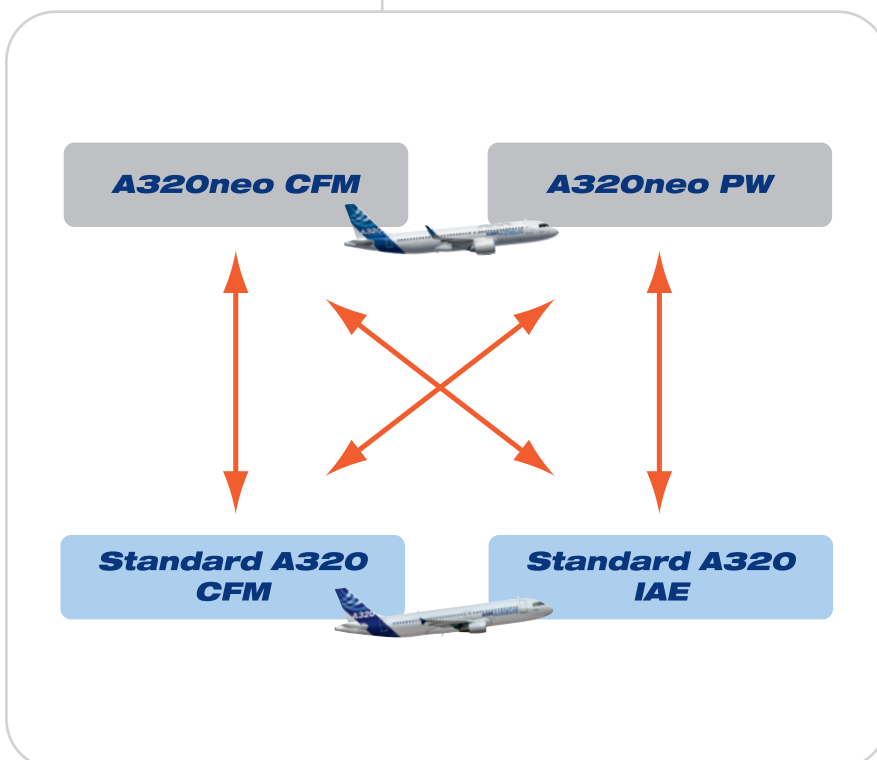
The Recommended Spare Parts List contains a huge range of different parts from large assemblies such as an APU (Auxiliary Power Unit) to small 'nuts and bolts'. It is critical to filter these parts to get a representative view of the commonality, as hundreds of small standard hardware part numbers with very small financial impact can falsify the results.

Airbus therefore considered the number of recommended parts, multiplied by the respective part number price, to determine the spares' financial impact of each part.

Through this exercise, standard simple items such as filters, light bulbs, placards, seals, switches and sensors with little financial impact, are removed from the calculation allowing the exercise to focus on the valuable and high impact items.

Airframe spare part commonality study considering A320 with different engine variants

Figure 2



## Parts' commonality identification

The commonality of each part on the short-listed RSPL has been determined for the A320neo series baseline designs for all engine variants. The determined commonalities have been graded using the following categories (see figure 3):

- 1. Fully common
- 2. Partially common - hardware only common\*
- 3. Partially common - interchangeable ('neo' to standard)
- 4. Non-common

The suitability of existing A320 Family parts for application on the 'neo' series is continuously being assessed to capitalize on the commonality opportunities.



notes

Software update is required. It allows the existing hardware to be embodied on both the pre and post 'neo' aircraft series.

Parts commonality identification

Figure 3





benefits

The principal benefits of the A320neo aircraft series are:

- Reduction in fuel burn of 15% versus the standard A320 Family aircraft.
- Minimum additional spares' investment required due to the synergy between A320 Family types.
- Minimal additional maintenance training required, owing to retention of existing components.
- Inter-operable with current A320 Family aircraft.
- Benchmark reliability.

## Commonality feasibility study results

The percentage of commonality between each pair of variants is visible in figure 4.

In order to clearly determine the commonality percentage, the results were classified into two categories, to reflect the required customer investment:

- Either, new hardware, including:
  - Parts which are completely different,
  - Parts which are new for the A320neo but can also be retrofitted on the standard A320 Family aircraft.
- Or, common hardware, including:
  - Parts which are completely the same,
  - Parts for which the hardware is the same (enabled by a software upgrade).

### SOME EXAMPLES

A320neo series' commonality can be seen on many of the control computers such as the FAC (Flight Augmentation Computer), ELAC (Elevator Aileron Computer) and the DMC (Display Management Computer), where the hardware will remain exactly the same, requiring only a software update to allow full compatibility with the new engine options. The new software will be such that once loaded onto the part, it can be installed on either the 'neo' or standard A320 Family aircraft, easing parts' management for a mixed fleet.

Furthermore, the Integrated Drive Generator (IDG) on the A320neo 'CFM LEAP-X' is currently common with the IDG on the standard A320 'IAE V2500'. An investigation was carried out on the feasibility of adding functionality to the IDG (see figure 5), which would have changed the part number. The change has since been rejected, retaining commonality of this exceptionally expensive item of the Initial Provisioning (IP).

Commonality feasibility study results

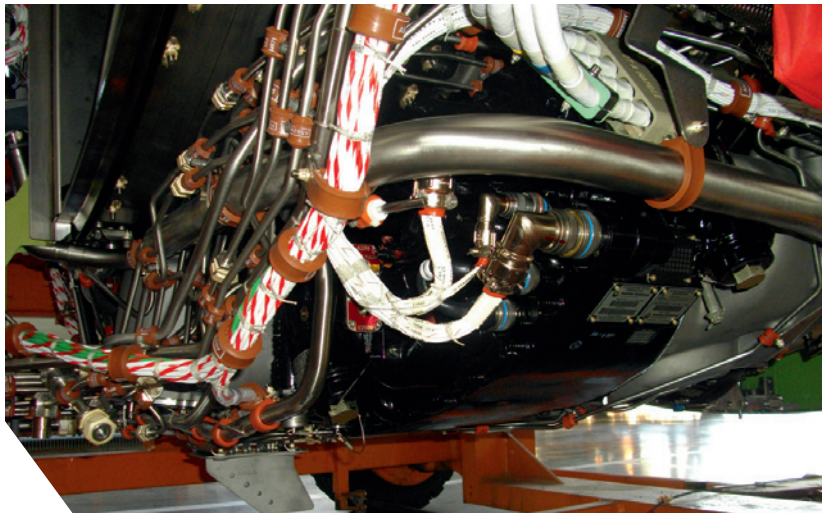
Figure 4

The A320neo series is currently under development and the detailed design is yet to be frozen, the commonality percentages will evolve as the design definition progresses.

Comparison	Common hardware (%*)	New hardware (%*)
A320 CFM56-5B and A320neo LEAP-X	95.6	4.4
A320 CFM56-5B and A320neo PW1100G	95.6	4.4
A320 IAE V2500 and A320neo LEAP-X	95.9	4.1
A320 IAE V2500 and A320neo PW1100G	95.5	4.5

\*Percentage calculated over the current A320 parts' baseline

This shows that Airbus can make informed decisions, based upon the overall fleet lifecycle costs for the customer, and obtain the best solution for the aircraft parts' commonality.



IDG example

Figure 5



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**Conclusion**

During the A320neo development, Airbus has set objectives for both the RSPL cost and the systems' commonality, and has accurately projected the spare parts' delta between the standard A320 Family and the A320neo series. It is clear that 95% commonality for airframe systems is a tough target, but the systematic and practical approach made possible by using spares provisioning data shows how this can be achieved. Innovation in Airbus does not stop with the introduction of new technologies.

The new engines for the A320neo series, sharklets and a continual aerodynamic optimisation allow reductions in fuel burn, and therefore significant savings. The implementation of this, whilst retaining system commonality, is a true demonstration of engineering excellence which is critical in today's competitive 'single aisle' market. Alongside the aircraft market leading performance, the success of the A320 Family is also a recognition of Airbus' constant strive to improve the product with the customer in mind.





# Biomimicry

## When aircraft designers learn from nature

Asked to design a flying object of about 1kg capable of a non-stop flight over more than 10,000km in less than 10 days, many engineers would cautiously answer that these requirements cannot be met with current technologies. Some others might even demonstrate that it is physically impossible to carry the required energy. But by simply raising eyes towards the sky, researchers have observed that migrating sea-birds, such as the bar-tailed godwit is achieving this outstanding performance, and even beyond, when crossing the

central pacific region from Alaska to New Zealand. This small but elegant migratory sea bird is indeed capable of an incredible efficient flight. This is just to illustrate that nature is constituted of biological solutions and behavioural strategies that are extremely efficient, such as energy saving in flight.

In this article, you will be convinced that nature inspires aircraft designers, engineers and manufacturers in many ways.



**Denis DARRACQ**  
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## Nature: A model for human creations

Natural selection has been happening ever since the first signs of life on Earth, more than three billion years ago. Charles Darwin explained that this key mechanism of evolution is driving the adaptation of species to their environment. This long process has yielded to remarkable achievements that arouse the admiration of those who are looking carefully at nature.

In front of a challenge to human intelligence, such as flying, these natural achievements have often been a direct source of imitation for pioneers as described by Otto Lilienthal in 1911 in "Birdflight as the basis of aviation". Sometimes with dramatic consequences, as experienced by first attempts of human take-offs.

Then the scientific knowledge has been acquired through a more rational approach of the problem. It has enabled a controlled powered flight yielding a few decades later to the emergence of the air transport industry which carries now more than two billion passengers per year across the world.

Continuous progress of technologies combined to the exploitation of more and more powerful computers has permitted to produce more efficient aircraft. As a consequence, the consumption and emissions of Airbus aircraft have been reduced by 70% and noise production by 75% over the last 40 years

But the performance obtained with standard technologies will begin to saturate soon. Moreover, it will not permit to deliver the radical step in aircraft efficiency that is required in a not so far away future, to meet air transport objectives in terms of fuel consumption and emissions. Nature is a source of inspiration for aircraft designers to improve performance.

Biomimicry should not be considered as a full scientific discipline, but more as a new approach in which biologists and engineers are working together, firstly by learning to share a common language. The basic idea is to understand the mechanisms of the living world, to adapt them and to apply them on human productions, such as on aircraft, for Airbus.

A380 in flight



Honeycombed-like structures are used for aircraft panels to save weight



We cannot copy precisely nature: An aircraft is not a bird and aeronautical engineers are not expected to transform themselves into butterfly hunters. Commercial aircraft are indeed operating in an extreme environment at transonic speeds, high pressures, very low temperatures and are much larger and heavier than any animal on Earth. For example, at these speeds, air compressibility is playing a major role on aerodynamic performance. Therefore the objective is not to simply “mimic” but to understand and to get inspiration from “technological” solutions and strategies of the nature.

The adaptation from the living world to aircraft production may require several years of research and development. At Airbus, we are following attentively all these potential sources of innovation for our future products.

But where to look? Assuming that a predator must be tougher and faster than its prey, it seems therefore sensible to look first at the creatures on top of the food chain, such as flying raptors and sharks.

But species adapted to extreme conditions or born to a strategy of long distance migrations have also developed some clever solutions that also should be looked at by engineers.

Denominations of recent and future technologies are a revealing indicator of this attraction of engineers for the models of nature. In aeronautics, we speak of “morphing” shape, “natural” laminarity, “health” monitoring, “self-healing” and “smart” materials, “memory” shape alloys, “genetic” algorithms, Airbus “sharklets”, etc. The purpose of this article is not to make an exhaustive list of innovations inspired from nature, but more to give a status and a perspective in the field of flight sciences.

## Flight control and flight performance

At the end of the 19<sup>th</sup> century, the Wright brothers observed that birds were manoeuvring and recovering from gust destabilisation by slightly twisting the tip of their wings.



They decided to implement a similar system of wing warping on the "Flyer" aircraft in 1903, to complete what is considered the first powered controlled flight. Less than ten years later, as wings were becoming more rigid, wing-warping was replaced by moveable surfaces located on the wing. The use of ailerons or spoilers for rolling is still the norm today on all modern aircraft. This is likely the first successful application in aeronautics of biomimicry, though the word did not exist at that time.

Globally, an efficient flight requires producing enough lift (force opposed to gravity) to go up while lowering drag (force opposed to speed) to move forward with the minimum energy.

Unfortunately, the production of lift is generating some drag called the lift-induced drag or induced drag. It can be the source of about one third of the total drag of an aircraft. Long narrow wings (characterized in aeronautical terms by aspect ratio: Wing chord over span) generate less induced drag for a given lift. Thanks to a higher wing span of any living bird, albatrosses (aspect ratio up to 15) are exploiting sea wind energy to glide in any direction effortlessly through dynamic soaring. Modern commercial aircraft have pushed the limits of aspect ratio up to about 9 to 10, as beyond the benefits from drag reduction are offset by other penalties, such as manoeuvrability on ground.

Very large wings are a handicap for bird manoeuvrability (as nicely described by Charles Baudelaire in "The albatross").

Therefore, in order to minimize the induced drag for a given wing span, nature has been extremely inventive. Some large birds, such as raptors and storks, are deploying impressive large feathers on wing tips.



These feathers are smoothing the mix of airflow near the tip that is responsible of creating wing tip vortices that generate induced drag. Similarly, the A380 whose wing span is limited to 80m to meet airport gate space requirements, is equipped with wing tip fences, aiming to improve its aerodynamic performance. The A320 Family will also soon benefit from innovative wing tip devices - the "sharklets" - that is expected to result in at least 3.5% reduced fuel burn (first test flight performed in December 2011).

To be safe and controlled, a landing must be completed at low speed. Additional lift and drag is required to lower the speed. To achieve low speed performance, the aircraft deploy flaps and increase the angle of attack. Hence aircraft and birds adopt similar strategies: But maybe the bird solution is the more advanced.

More astonishingly, some birds are deploying alula, a digit covered with feathers located on the front part of the wing, in order to create a slot on the leading edge. Current speculation is that this function is enabling birds to delay stall of the wing (i.e.: To produce more lift). It is exactly this concept that is used on commercial aircraft through the deployment of slats.

Some sea birds, evolving in areas of strong winds and turbulence have developed a passive control capability of the flow - passive because it does not require any energy from the bird. Some feathers located on the wing of skua birds are deployed by reverse flow, preventing a local separation from spreading across the whole wing. Large flow separation is responsible for stall. This passive concept is not applied on aircraft but wings are equipped with active moveable surfaces (e.g. spoilers) to control the flow on the wing.

Biomimicry is very promising in terms of new perspectives.

## Morphing concepts

A common characteristic of life is the flexibility of shapes that human industrial implementation struggle to reproduce. The rigidity of a robot, an aircraft or a submarine, is striking compared to a man, a bird or a fish. Birds are characterized by continuously varying the shape of their wings which guarantee optimum performances for various purposes: Landing, gliding, flapping, manoeuvring for hunting, diving, etc. In aeronautical terms, these are “multi-functional” wings.

On the contrary, commercial aircraft are based on a fixed-wing structure that is primarily designed for optimum cruise performance. The rest of the aircraft mission is achieved through dedicated add-on moving devices such as spoilers, flaps, slats, rudders and landing gears, that are generally retracted during almost all the flight duration.

Even though the deployment and the retraction of aircraft flaps and slats can be seen as “primary age” in morphing evolution, we know that we cannot go beyond with the current structural technologies, due to the impact on cost and weight. Nevertheless, novel technologies such as “smart” materials are raising the prospect to morphing aircraft concepts. Amongst various enabling technologies, shape memory alloys sustain large deformations and recover their initial form through temperature variations, and piezoelectric materials produce mechanical stress when submitted to a voltage. Therefore, suitably designed structures made from these materials can be accurately controlled to manage seamless deformation of the aircraft weight. This will revolutionize the aircraft performance and will make them definitively look like birds.



The first test flight with "sharklets" on an A320 took place in December 2011





## Formation flight

We have all observed the impressive 'V' formation flight of migratory birds. Scientific studies of pelicans in formation have concluded that follower birds are flying at a lower heart rate and are more often gliding than flapping, compared to a solitary flight. Actually, follower birds are exploiting very opportunely the lift (i.e.: The energy) produced by the outer wings of leading birds.

Studies confirmed that such formation flights (actually inverted 'V' flights) could be applied to air transport with a significant reduction of emissions on trans-continental routes, even though there would be a time penalty to organize the flight from various airports.

## Surfaces

Beyond all these macroscopic solutions captured from the observation of bird flights, we know that the marine animals and even the vegetal world, constitute a tremendous potential source of innovation for future aircraft. Particularly, materials and interfaces of species with their environment might inspire revolutionary capabilities for aircraft engineers. Shark skin is not smooth at all but on the contrary, is constituted of micro structures in

the shape of grooves: The dermal denticles. This was going against the belief of aerodynamicists - the smoother the surface, the lower the drag. Detailed investigations have indeed demonstrated that these groove structures are reducing significantly the skin friction, enhancing speed, and the energetic efficiency of sharks. Flight tests on the Airbus Beluga aircraft with shark skin-like surfaces called "riblets", have confirmed that such surfaces are reducing the fuel consumption and emissions. About 70% of the aircraft surface could be covered by these surfaces. The drag could be reduced by several units of percentage which represents a significant step of performance for an aircraft. Nevertheless, there are several challenges to address such as production, operational reliability (resistance to erosion) and maintenance.

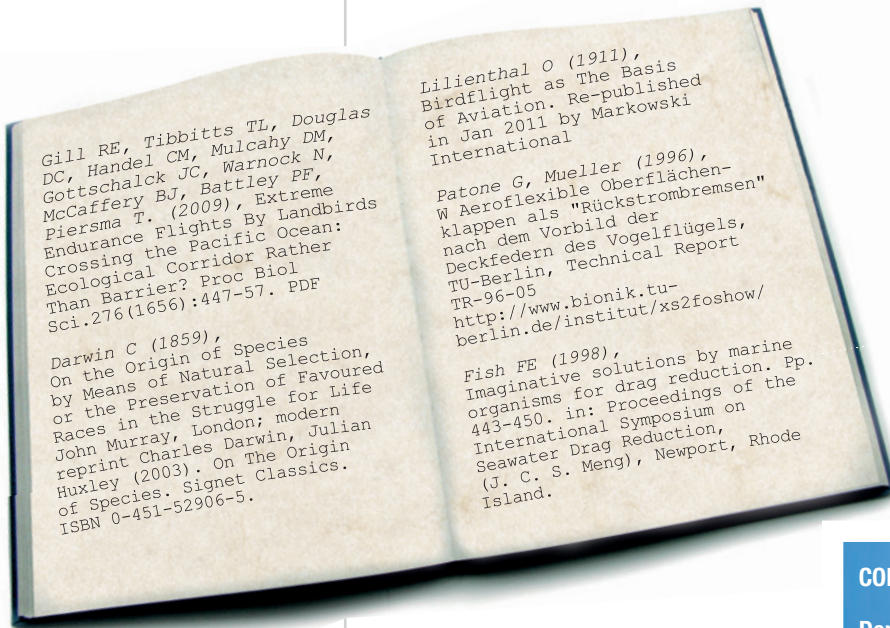
Lotus plants trigger engineers' curiosity as they present remarkable properties. They are always clean and dry in a dirty and wet environment. Micro structures on the surface of the leaves prevent water droplets spreading across. Droplets are slipping over the leaf clearing the surface from any particle of dirt. This self-cleaning property is set to equip coatings for aircraft cabin fittings, or could even be exploited to prevent ice accretion on wings.



This article is dedicated to our sadly missed colleague, Frédéric PICARD, who was a world class connoisseur of orchids. During his time in the Airbus Innovation Cell, he used to conceive biomimicry as one of the exciting levers for innovation.



Frédéric PICARD



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# Conclusion

Establishing historically the sources of progress of human flights is not an easy task. And if aircraft look like birds, it is sometimes impossible to distinguish whether a technology is really due to the observation of birds or to pure human abstraction. Actually, it does not really matter: The lesson is that human deterministic methodology and natural selection often converge to the same solutions.

But the bird flight is only the emerged part of the iceberg that has been captured so far. The rest of the living world, including plants, is a huge tank of potential innovations for aeronautical engineers, particularly to control and exploit the turbulence of flows,

to design innovative materials and advanced interfaces. The further exploration of nature in the perspective of drastically reducing air transport fuel burn is requiring a more direct collaboration between aeronautical engineers and experts of all disciplines of biology.

The extinction of any species caused by human activities - that is a tragedy in itself - represents a definitive loss of knowledge and therefore a potential loss of source of progress for humanity and for the protection of the environment. This is the reason why the preservation of biodiversity is a priority for industries that will face tremendous technological challenges in the future, such as Airbus.



# Radio Altimeter systems

## Correct maintenance practices

Incorrect maintenance of key aircraft systems can harm the continued safe operation of the aircraft. One key system, used during critical flight phases including landing, is the Radio Altimeter system. Several events have been reported where failures of this system have contributed to damage the aircraft during landing operations. What is little known, is that in many cases these events could have been prevented. The root cause investigation

often identified that the reason for the malfunction of the system was due to a degradation that could have been prevented by simple maintenance practices, such as the cleaning correctly being carried out. This article aims to explain why the application of best practice maintenance procedures on the Radio Altimeter system is key, and details the best practices to support the continued safe operation of Airbus aircraft.



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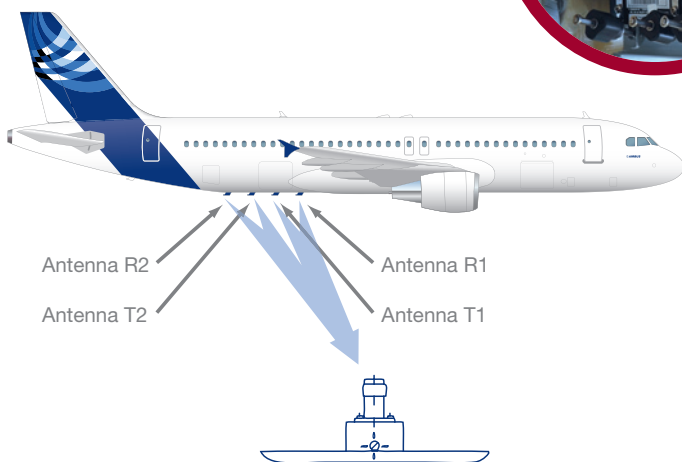
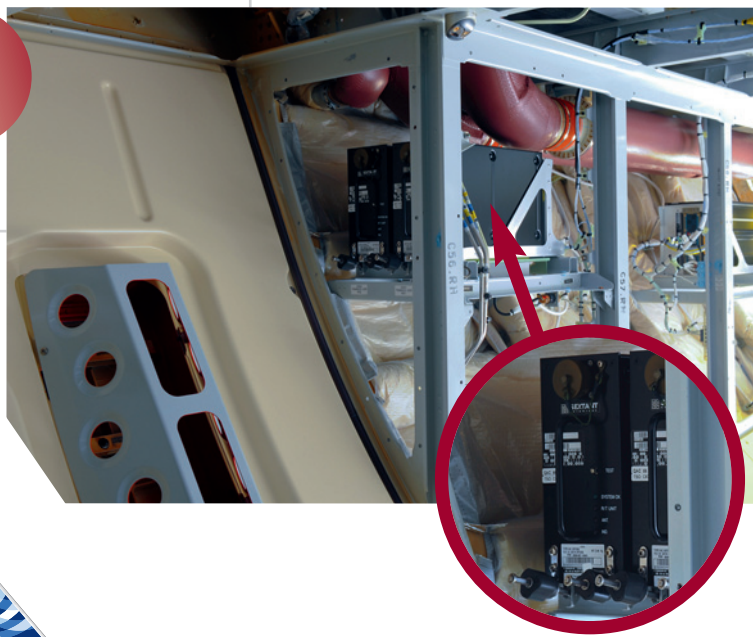
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## How does a Radio Altimeter function?

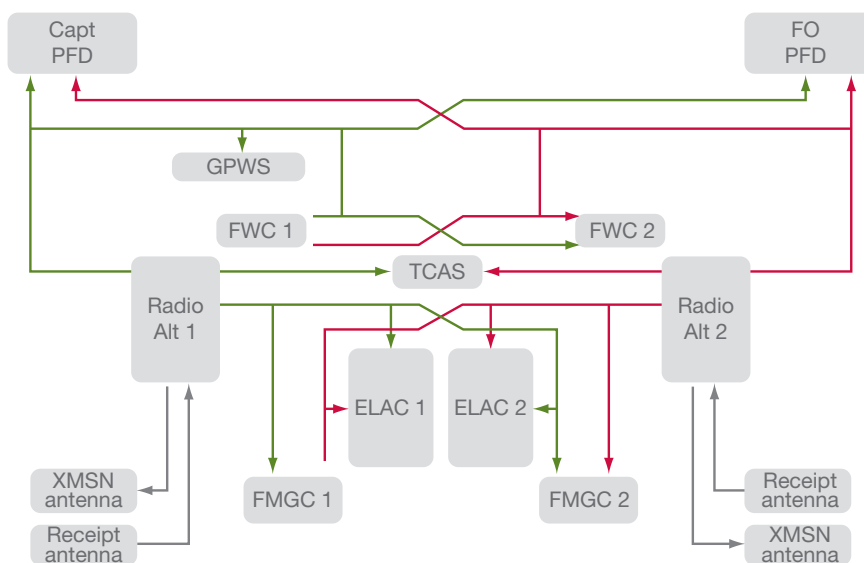
The barometric altitude, used during cruise phases to determine an aircraft's altitude, is by its nature imprecise due to the variation of the atmospheric pressure. Whilst this is not a problem in cruise, during the approach phases, it is however necessary to have a greater precision which is not possible using the barometric altitude. A Radio Altimeter is therefore used to provide an accurate height above ground level when the aircraft is between 0 and 2,500ft.

The Radio Altimeter functions by means of radio waves. It transmits towards the ground a radio wave, and measures the time taken to receive the reflected wave in return. The time between the emission and reception allows the calculation of the height of the aircraft above ground level. The Radio Altimeter system consists of two (three on the A380) independent systems, each system consisting of a transceiver, a transmission antenna and a reception antenna.



Interaction of the Radio Altimeter with aircraft systems (A320 used as example)

Figure 1



**Capt:** Captain - **ELAC:** Elevator Aileron Computer - **FO:** First Officer - **FMGC:** Flight Management and Guidance Computer - **FWC:** Flight Warning Computer  
**GPWS:** Ground Proximity Warning System - **PFD:** Primary Flight Display - **TCAS:** Traffic Alert and Collision Avoidance System - **XMSN:** Transmission

The radio height data is shown on the Primary Flight Display (PFD) and also provides feedback to a number of aircraft systems, to advise these on the height of the aircraft. In figure 1, you will find the typical interaction of the Radio Altimeter system with aircraft systems.

## What can go wrong?

Consequences of Radio Altimeter failures have been well documented, but before reviewing some case studies, let's review what feedback the Radio Altimeter (RA) provides. There are two common operating modes of the RA system:

- The first is coded Normal Operation (NO): In this case, the Radio Altimeter correctly transmits and receives the radio waves, and therefore provides an indication of the aircraft's height above the ground.
- The second is Non Computed Data (NCD): Above a certain altitude (more than 5, 000ft or during specific flight phases (i.e.: Roll > 30°)), the signal level received by the reception antenna does not allow the aircraft height to be computed. The height is therefore no longer transmitted and the RA output becomes NCD.

If an incorrect value is received, this can have a negative effect on the aircraft system:

- Too low value (erroneous), can lead to an early activation of flare which could lead to an increase in the aircraft angle of attack, which if not corrected, could lead to aircraft stall, hard landing or other operational effect.
- An incorrectly transmitted NCD value will lead the aircraft to believe that it is in cruise altitude. If this occurs when the aircraft is on the ground or in approach, this could lead to

the non-activation of the flare law, leading to a tail strike or multiple ECAM (Electronic Centralized Aircraft Monitoring) messages on ground.

## Does this occur in operation?

Damage to the Radio Altimeter system can occur from either wear and tear coming from normal daily operation of the aircraft, or following an incorrect or incomplete application of maintenance practices, all of which can lead to erroneous values. In such cases, these can lead to spurious cockpit indications or incidents which can result in the aircraft being out of service for a lengthy period. Three typical cases, with different causes are described in table 1.

### Consequences of Radio Altimeter failures

Table 1

Examples on aircraft	Symptoms	Observations	Corrective action
A319	Heavy landing in AUTOLAND and a continuous RETARD call out.	Radio Altimeter feedback frozen at -4ft. Moisture ingress observed in the RA installation.	Correct re-installation of the RA, including installation of waterproofing.
A320	Tail strike with multiple spurious ECAM warnings.	Both RA signals observed going NCD. Similar effects previously observed on same aircraft but had cleared at gate, so no trouble-shooting performed.	RA connectors not installed as per AMM (Aircraft Maintenance Manual), with lack of waterproofing and incorrect crimping on one antenna, suspected following an incorrect SB application. Antennas re-installed correctly.
A321	Untimely RETARD call out.	RETARD call transmitted at <22ft. RA antenna identified dirty.	Dirt impacted the transmission and receipt of the signal. Corrected by cleaning the RA antenna surface.



#### information

### Flare mode

This mode is automatically engaged when the Radio Altimeter indicates 100ft. above ground. At 50ft. the aircraft trims the nose slightly down. During the flare, Normal Law provides a high angle of attack protection and bank angle protection. The load factor is permitted to be from 2.5G to -1G, or 2G to 0G when the slats are extended. The pitch attitude is limited from +30 to -15° which is reduced to 25° as the aircraft slows down.

## Maintenance aspects

The operational consequences and what is observed when there is an erroneous Radio Altimeter reading has been covered in detail in Airbus' Safety First edition #11. However, as an essential and important piece of equipment, it is necessary to ensure that the maintenance actions and procedures are correctly applied.

### ACT NOW TO PREVENT LATER DELAYS

In the examples in table 1, whilst the root cause is different, a key message to extract is that the trouble-shooting and root cause identification only commenced after there was a significant operational interruption. Therefore, in the event that a Radio Altimeter failure is suspected, then trouble-shooting in accordance with the Trouble-Shooting Manual (TSM) should be performed.

New TSM procedures have been written to provide recommendations to cover:

- Erroneous Radio Altimeter height indications,
- Radio Altitude set to Not Computed Data (NCD).

## Prevention is better than cure with a correct maintenance application

Root cause analysis in the three case studies in table 1 show that the application of incorrect maintenance or installation procedures could drive to the RA misbehaviour so, prevention being better than cure, the following points detail the actions to take.



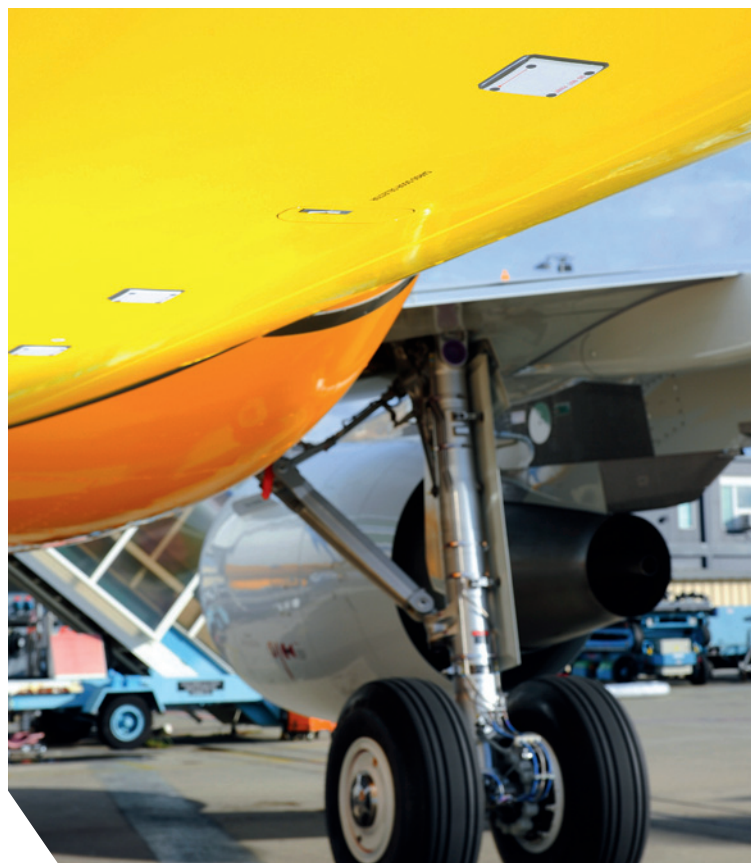
information

### Radio Altimeter cleaning requirements

- SIL 34-099 scheduled maintenance task recommendation for Radio Altimeter antennas' external surface cleaning
- 344200-0503-2 for the A300 MPD\*
- 34-42-02 for the A300-600ST OMP\*
- 344200-02-1 for the A300-600 and A310 MPD
- 344200-03-1 for the A318/A319/A320/A321 MPD
- 344200-04-1 for the A330 and A340 MPD
- 344000-00000-01 for the A380 MPD

\* MPD: Maintenance Programme Development

\* OMP: Operator Maintenance Programme



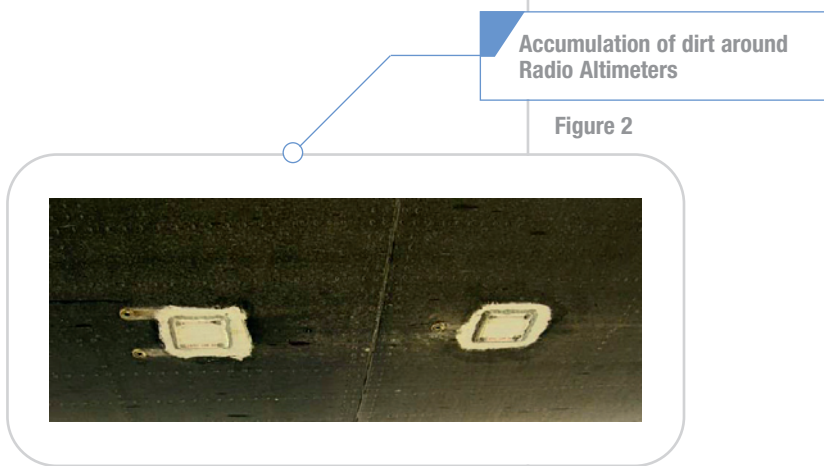
**CLEAN TO PREVENT ERRONEOUS DATA**

The first case is to ensure that the period of your maintenance task associated to the cleaning of the Radio Altimeter antennas is correctly suited to the aircraft operation. The RA antennas, located on the bottom of the aircraft behind the main landing gear (centre landing gear on the A340), are in the ideal position to get covered by dirt which accumulates in normal operation. In addition, they suffer from being stained by liquids discharged via the onboard galley drain. These materials can form a thick residue on the surface of the antenna and prevent them from functioning correctly.

To address this issue and as dirt accumulation on the RA is a common failure mode, the first action of the trouble-shooting for RA erroneous data is to clean its antenna. To prevent the aircraft from getting into a position where incorrect RA data is being transmitted due to dirt, a periodic cleaning is scheduled in the MPD (Maintenance Planning Document) with an interval of 6 months. In the event that dirt accumulation is observed to occur at a greater rate than that covered by the MPD task (for example if operating on slushy or contaminated runways, particularly in winter periods, etc.) then clean the RA antennas at a reduced interval. The advantages of this is to prevent the RA data becoming NCD or erroneous at landing, and reducing the chances of a tail strike or hard landing.

**MORE FORCE IS NOT NECESSARILY THE ANSWER**

On the A320 Family aircraft, when replacing the Radio Altimeter antenna, it is often observed that there may not be quite enough available cable length to comfortably disconnect/connect the antenna to the cable.



Accumulation of dirt around Radio Altimeters

Figure 2

A: Before MOD - B: With additional slack - C: Broken connectors

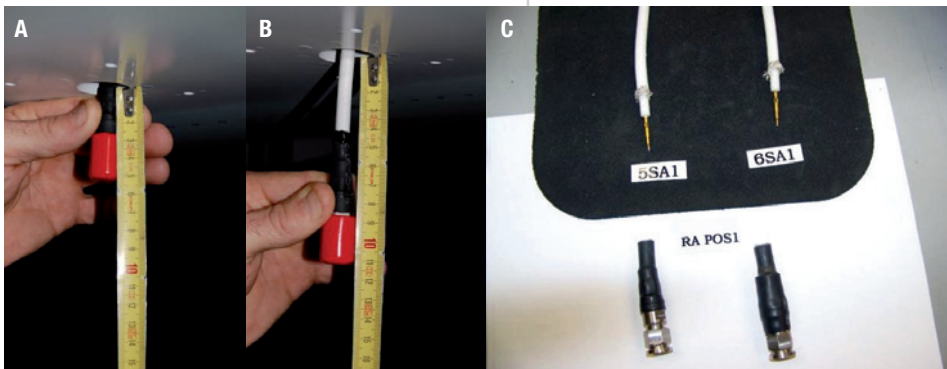


Figure 3

This tempts the mechanic to pull just that little bit harder, sometimes on the antenna, to give that little bit more slack. This extra force on the antenna harness weakens the connectors, and whilst it may look undamaged from the outside, several flight cycles after the antenna replacement the connectors may break (see figure 3). This can cause the disturbances of the RA signal which may transmit erroneous indications or switch to NCD, and lead to issues on approach and landing increasing the risk of an incident.

To counteract this difficult access to free the RA cable on the A320 Family aircraft, Airbus has certified a modification which re-routes the coaxial cable to provide additional free cable to ease the replacements of RA antennas. This can also be embodied on aircraft via a Service Bulletin.

**WATER ALWAYS FINDS ITS WAY TO THE WRONG PLACES**

One of the main causes for incorrect RA readings comes from water ingress and the contamination of the connectors. Water ingress can cause for example an erroneous -6ft value by direct coupling between the transmitting and receiving antenna. Also, NCD values may occur due to water causing corrosion of the cables or the antennas themselves. So what can be done about this? Water ingress can be tackled in two means:

- By ensuring that the correct installation procedures are followed, and
- By applying the latest installation recommendations and appropriate waterproof materials.

The evolution has taken various courses of action:

- Installation of additional shrink sleeves on the connector between the RA antennas and cables the introduction of which are covered by the issuance of appropriate modifications (see figure 4).
- The AMM (Aircraft Maintenance Manual) installation tasks have been updated, ensuring that the installation is correctly waterproofed.

To enhance the waterproof characteristics of the shrink sleeve installation, additional sealant at the top and bottom of the installation is added. This ensures that no water is able to ingress into the assembly; either from the top or bottom of the installation (refer to associated AMM procedures and SIL 34-087). When introducing the sealant, a key aspect is to make sure that the sealant has time to dry. Not drying the sealant may impact the waterproof abilities of the installation. The appropriate AMM tasks now reference this as a standard installation.

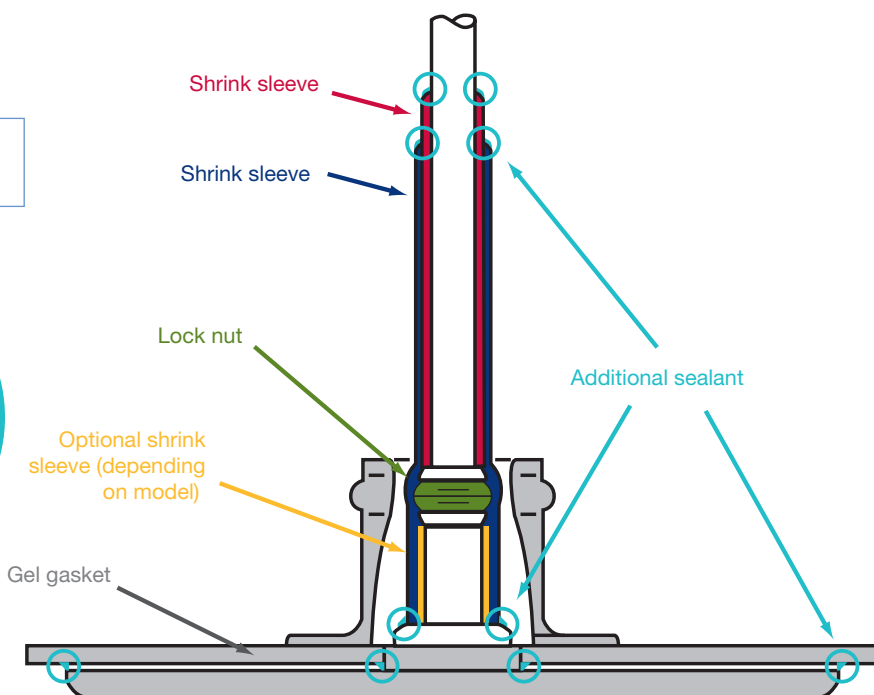
**Addition of shrink tubes to improve waterproofing of the RA installation**

Figure 4



**Enhancement of water proofing by the addition of sealant**

Figure 5



The figures 4 and 5 show the building up of the waterproof installation on the Radio Altimeter antenna. It is important to note that to get the full protection, all parts need to be correctly installed. If one of the parts is not correctly installed, then there is likely to be water ingress into the system with its consequential effects.

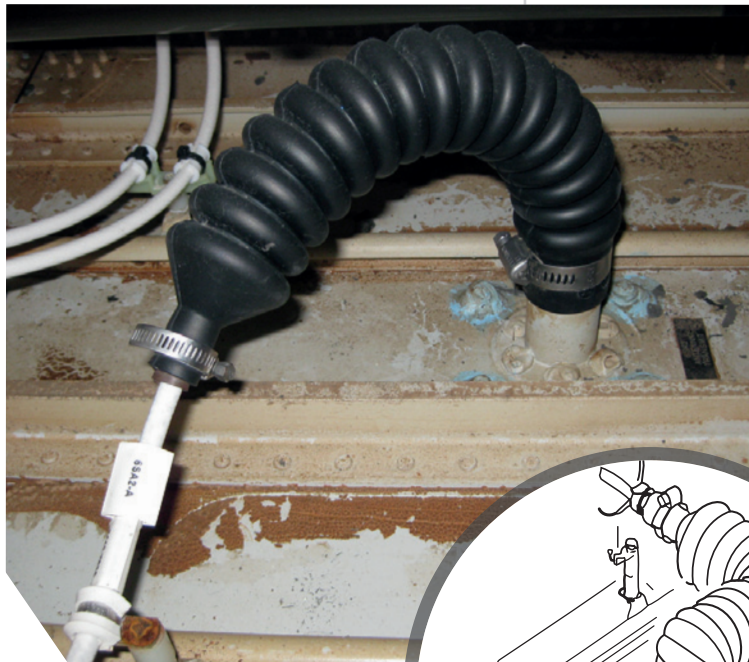
Further modifications have been introduced to prevent water ingress into the antenna cable and consist of:

- Adding sealant on the pipe.
- Replacement of the current polyamide protection pipe with a longer metal one which is less disposed to deformation and cracking caused by environmental conditions.
- Additional water proofing applied to the end of the protective boots, by putting additional tape and clamps at both ends to make sure that the entrances of the protective boots are sealed against eventual external water ingress (refer to figure 6).

- Introduction of a new gel gasket between the Radio Altimeter antenna and the aircraft structure to improve waterproofness of the installation (detailed in figures 5 and 7).

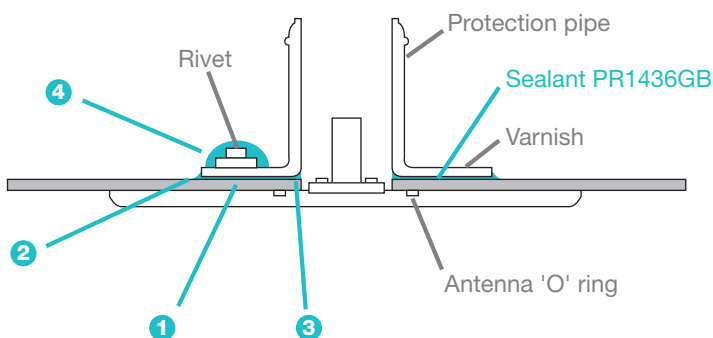
Protective boots

Figure 6



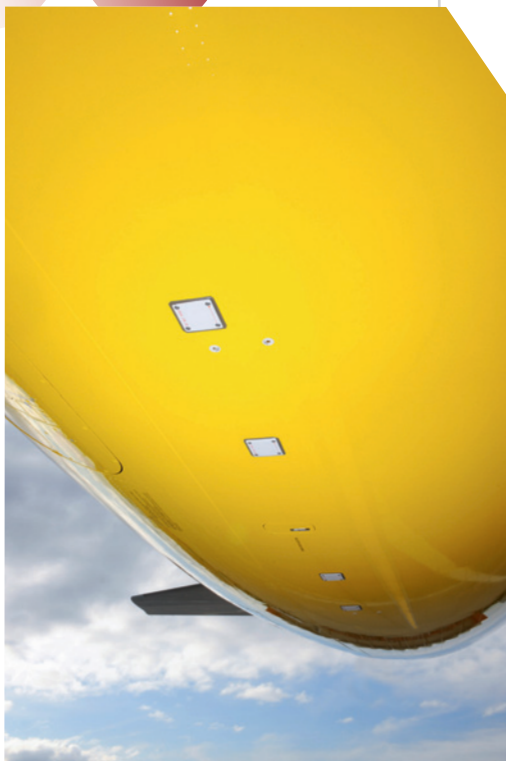
Steps for additional sealant between the Radio Altimeter antenna and the aircraft structure

Figure 7



- 1 Apply sealant between pipe and skin
- 2 Apply sealant around outer flange
- 3 Apply sealant in inner gap of pipe/skin
- 4 Apply sealant over the head of the rivets

Radio Altimeters located on the belly of the aircraft



## The replacement of cables - getting old gracefully

Like all equipment, after a life time of wear, tear and exposure to the environment, the Radio Altimeter antenna cables may become damaged, the water proofing may become less efficient and corrosion can set in. Water ingress that has occurred may have affected the shielding or the wiring, causing corrosion and thus perturb the signals. Water present in the RA cables may cause cross coupling and erroneous values occurring.

The continued operation of the aircraft with old cables installed is not recommended. Therefore, as a precaution, Airbus has addressed this issue by including in the MPD a regular task to replace the cables and antennas. This is scheduled to take place every 144 months (12 years), during the heavy inspection for structural items (refer to SIL 34-097 for additional information). In addition, it ensures that the Radio Altimeter cables and antennas are installed to the most recent specification, with the latest standard of waterproofness, ensuring continued efficiency and accuracy of the Radio Altimeter system.



documentation

### Installation improvements for the Radio Altimeter:

- SIL 34-087 Radio Altimeter antennas, protection against water contamination
- SIL 34-097 Aircraft Scheduled Maintenance Task Recommendation relative to Radio Altimeter antennas' installation
- For the A320:  
AMM 34-42-11-400-001
- For A330/A340:  
AMM 34-42-11-400-801

### Service Bulletins:

- SBs for improvement of electrical installation for antennas (Issue 2 or subsequent):
  - A320-92-1030
  - A330-92-3044
  - A340-92-4054
  - A340-92-5005
- SBs for installation of gel gaskets:
  - A320-34-1476
  - A330-34-3218
  - A340-34-4222
  - A340-34-5064

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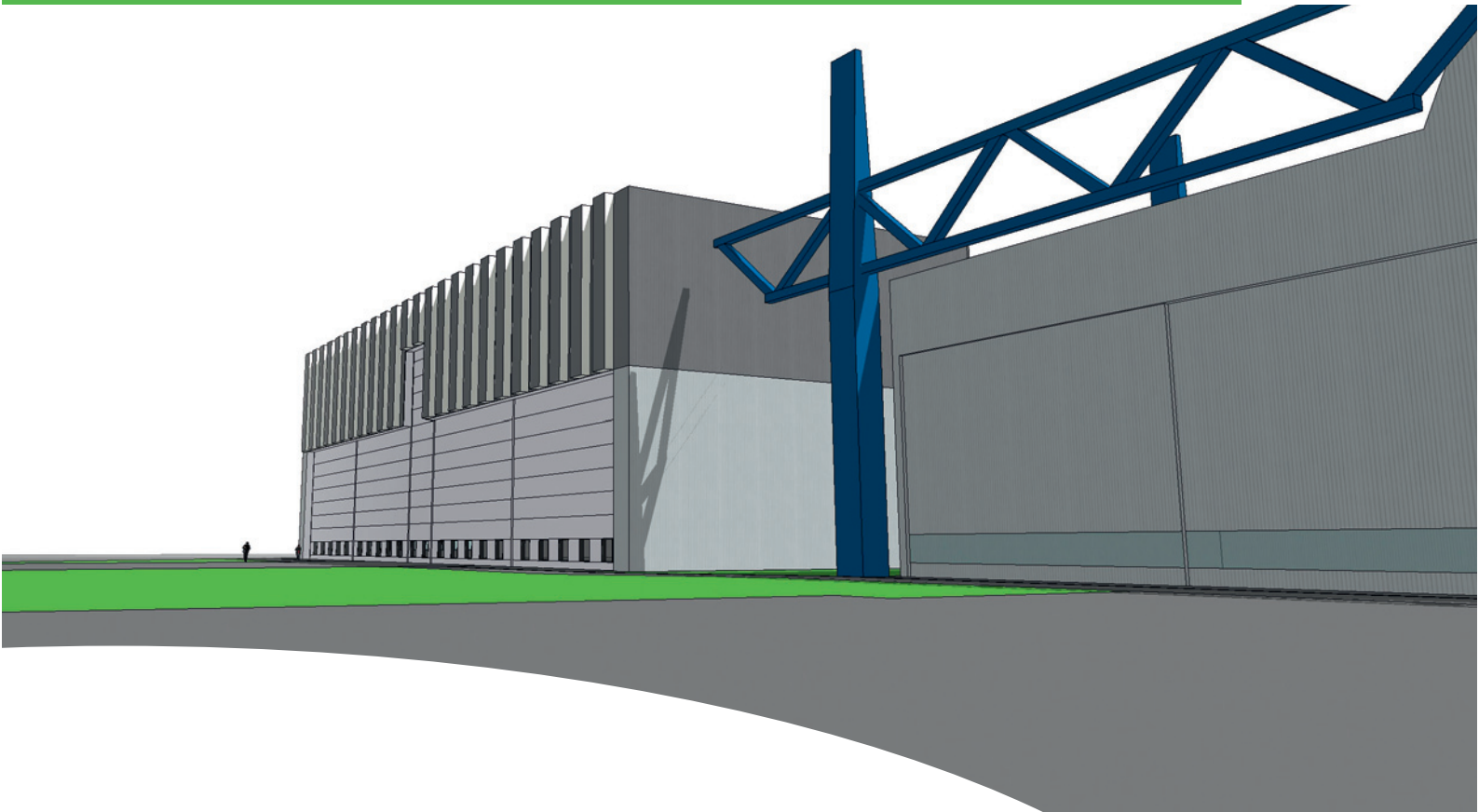
## Conclusion

To ensure that the Radio Altimeter system continues to provide accurate and correct information, it is necessary to recognize, report and trouble-shoot symptoms of the Radio Altimeter misbehaviours as soon as they appear.

The operators must adapt their maintenance regime to the environmental conditions and make sure that during the

installation of the Radio Altimeter, the instructions are fully followed (including respecting sealant cure times).

By following the points identified in this article and developed in the referenced Airbus documentation, the integrity of the Radio Altimeter system can be ensured and the continued safe operation of the aircraft supported.



# ELISE Consulting Services

## ILS advanced simulation technology

The Instrument Landing System (ILS) is a ground-based system at airports. It provides reliable guidance to aircraft approaching and landing at the airport, and is especially useful in reduced visibility conditions. The signal emitted by the ILS system can be sensitive to multipath disturbances caused by objects close to the runway, including other aircraft, buildings and cranes. Accurately predicting disturbances such as

these, ELISE (Exact Landing Interference Simulation Environment) enhances the safety of landing operations, can allow to increase runway capacity and allows the optimisation of airside land usage. This article describes the specialised consulting service which uses this advanced simulation software which predicts disturbances with an unequalled level of accuracy and reliability.



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Localizer and Glide Path antennas

Figure 1

## What is an ILS?

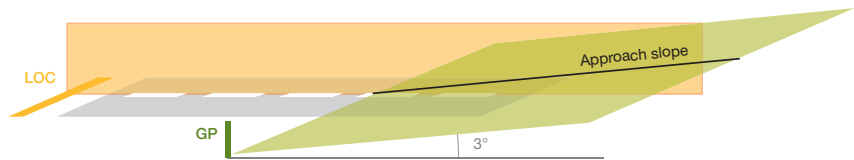
An Instrument Landing System (ILS) is a ground-based instrument approach system (see figure 1) that provides precision guidance to an aircraft approaching and landing on a runway. It uses a combination of radio signals to guide the aircraft during reduced visibility landings (Instrument Meteorological Conditions – IMC) such as for low cloud ceilings, fog, rain or snowy conditions. The ILS is composed of the Localizer (LOC) antenna which provides runway centre line guidance to aircraft, and the Glide Path (GP) antenna which provides the standard 3° slope guidance.

## ILS multipath interference

Any large reflecting objects at an airport can potentially cause multipath interference to the ILS signal. These disturbances can make the ILS signal deviate from its nominal position, which would cause a deviation of the aircraft in approach to the extent that it becomes unacceptable. Aircraft, cranes and large buildings can produce an ILS multipath interference that would exceed the required tolerances as set in ICAO's (International Civil Aviation Organisation) Annex 10 document.

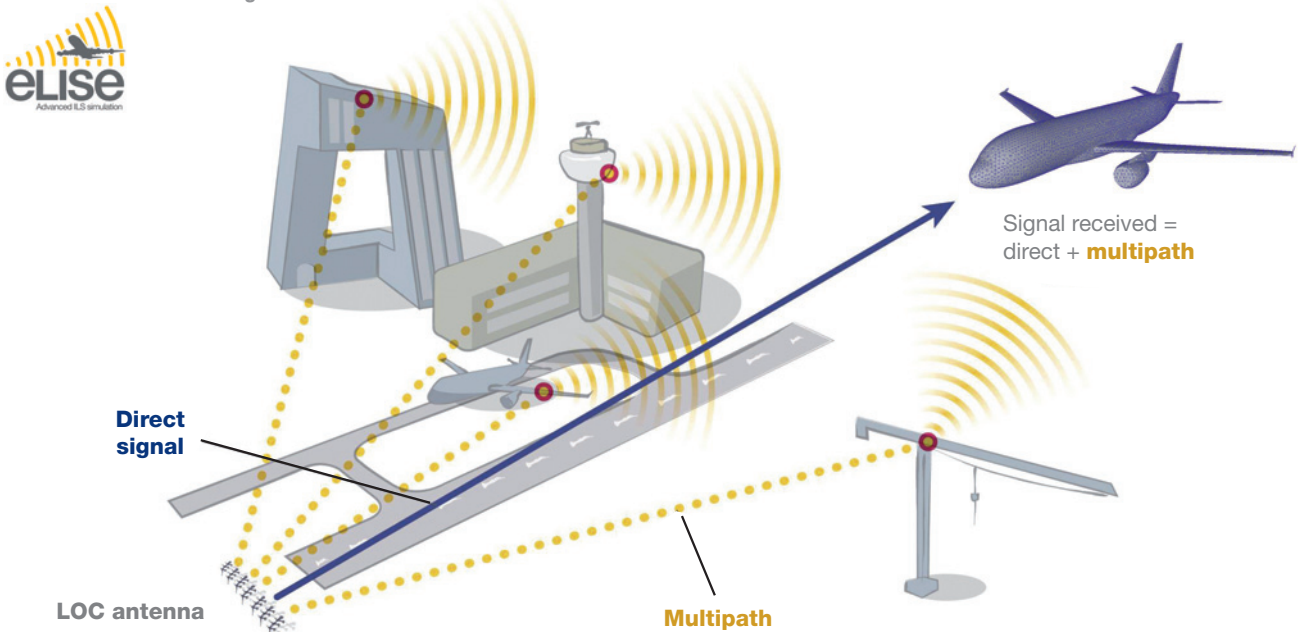
Approach slope: Intersection of Localizer (LOC) and Glide Path (GP) signals

Figure 2



Multipath disturbances of ILS signal caused by surrounding obstacles

Figure 3



However, ILS predicting software can be used to calculate the probable location, magnitude and duration of ILS disturbances caused by objects. A number of ILS disturbance prediction tools currently exist. These tools rely on the theory of physical optics applied to 2D flat rectangular plates. They have the advantage of providing very rapid simulation times but their validity for treating obstacles at grazing incidence is questionable. Generally, the more accurate the ILS predicting tool, the more computation power, memory and time is required. This is particularly true for the latest generation of tools like ELISE which models objects in 3D.

### The ELISE solution

Airbus in collaboration with EADS\* Innovation Works (EADS IW) and the ENAC\* has developed

a consulting service using advanced simulation software for ILS disturbances called ELISE (Exact Landing Interference Simulation Environment). ENAC is a renowned French civil aviation university and centre of excellence in ILS antenna expertise. EADS IW operates the EADS corporate Research and Technology (R&T) laboratories and a global network of technical centres, including electromagnetism.

### How does ELISE work?

ELISE uses advanced technologies in:

- Object modelling: ELISE is capable to model the objects in 3 dimensions, whereas the previous generation of classic ILS predicting tools uses 2D flat plates (see figures 3 & 4).



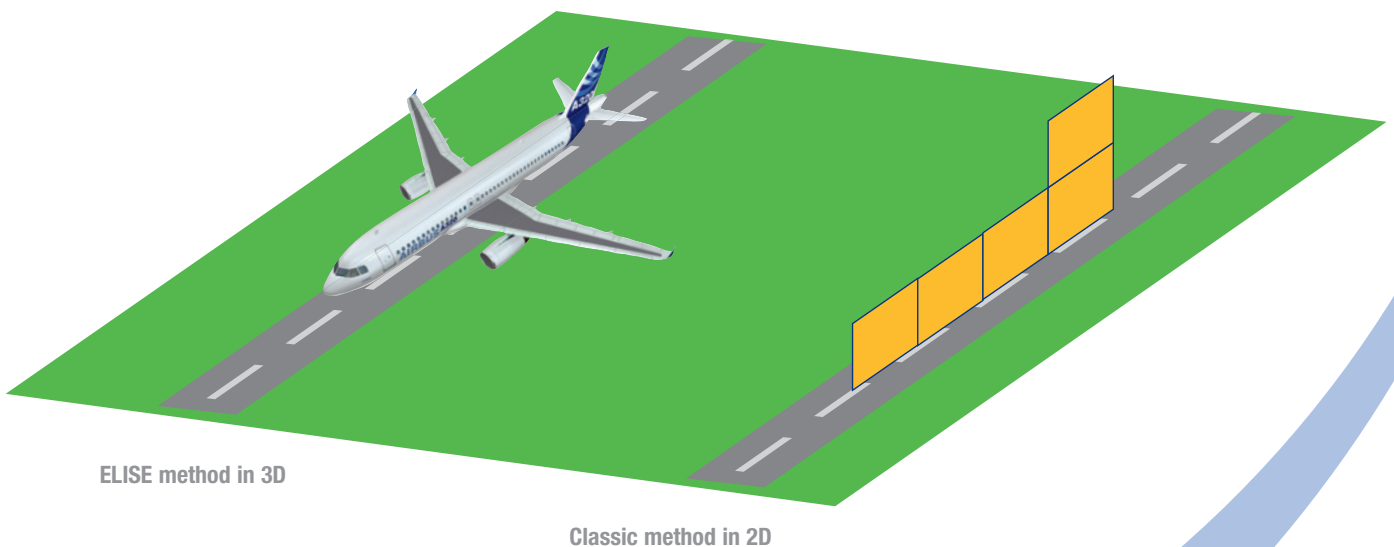
notes

**EADS:** European Aeronautical Defense and Space company

**ENAC:** Ecole Nationale de l'Aviation Civil

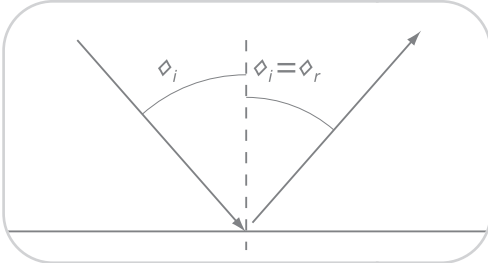
#### Methods of object modeling

Figure 4



**Methods of resolution of ILS propagation equations**

Figure 5



Simplified classic method

$$\begin{aligned} \operatorname{div} \vec{E} &= \frac{\rho}{\epsilon_0} \\ \operatorname{div} \vec{B} &= 0 \\ \operatorname{rot} \vec{E} &= -\frac{\partial \vec{B}}{\partial t} \\ \operatorname{rot} \vec{B} &= \mu_0 \vec{J} + \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t} \end{aligned}$$

Exact ELISE method

- Core computing: ELISE uses an exact method of resolution (Method of Moments) for the radio signal propagation equations (Maxwell's equations), whereas previous classical methods are based only on approximations (physical optics) of the Maxwell's equations. The 'Method of Moments' is the most advanced and accurate method to model the behaviour of ILS signals.

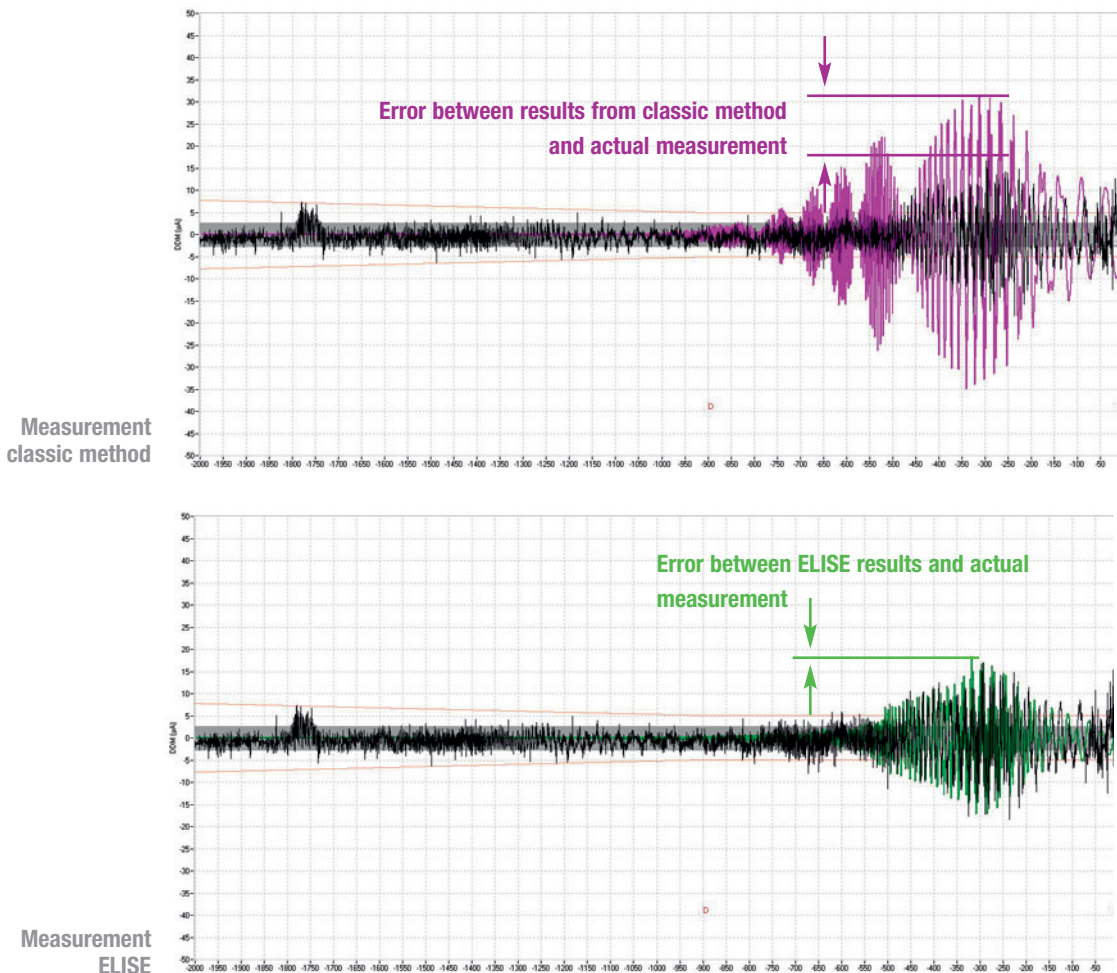
Based on those two advanced technologies, ELISE consulting services offer a step change in accuracy and reliability on ILS signal predictions compared to the existing classic ILS predicting tools.

The advanced levels of accuracy and reliability of the ELISE software have been validated by more than a hundred ground and flight measurements performed at several airports (see figure 6), in coordination with the reference of European Air Navigation Service Providers - ANSP (DTI in France, DFS in Germany, NATS in the UK and SkyGuide in Switzerland).

These measurement campaigns have demonstrated that ELISE simulations deliver a better correlation with these measurements, which translate into direct operational and tangible benefits to ELISE users.

**Better correlation between results from the actual measurements and ELISE**

Figure 6



## ELISE benefits

ELISE delivers direct operational and financial benefits to the target customers (i.e.: Air Navigation Service Providers, airport operators and consultants) described in the three following points.

### 1. TO IMPROVE SAFETY BY REDUCING THE RISK OF UNPREDICTABLE ILS FLUCTUATION

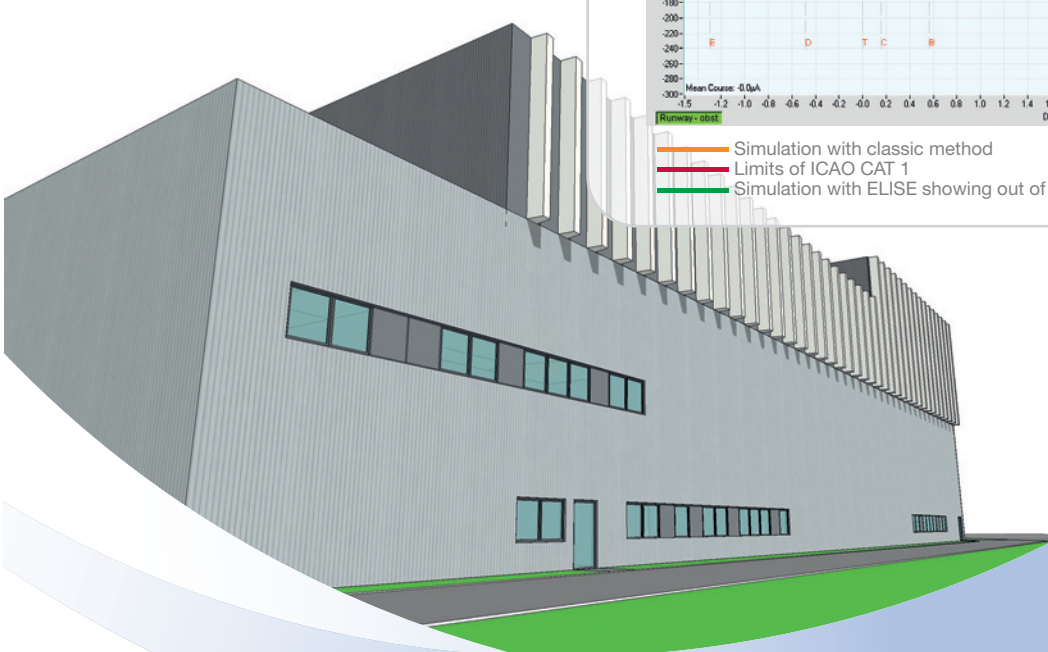
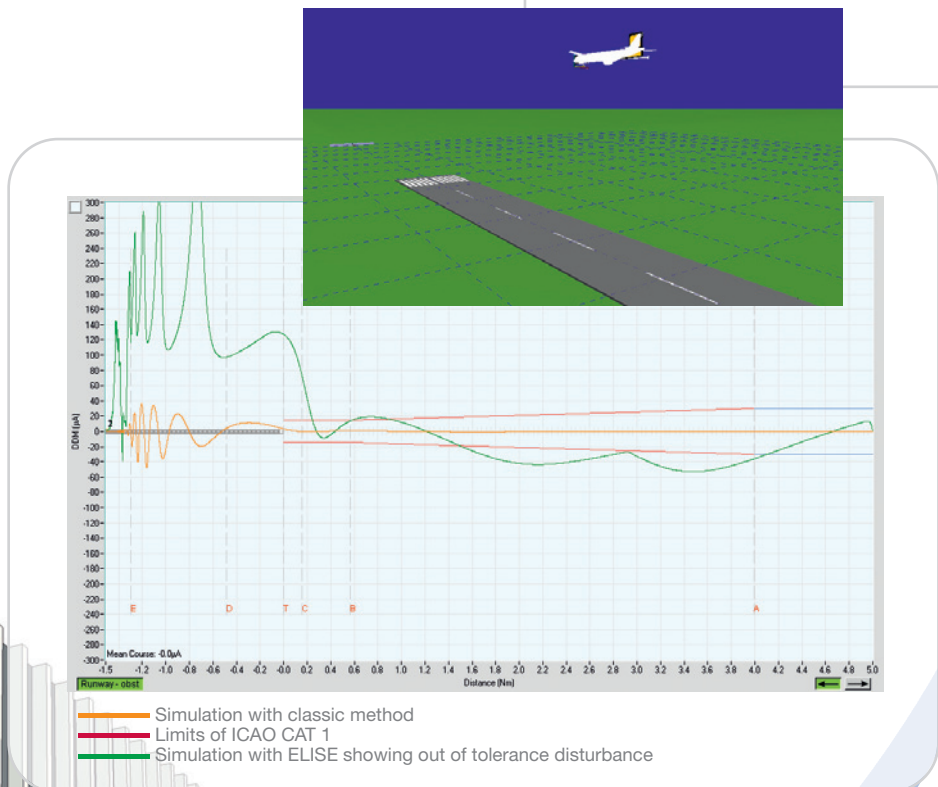
When an aircraft takes-off it can generate fluctuations in the Localizer signal used by any aircraft on approach. These fluctuations can cause lateral deviations to the aircraft on approach or during landing to the point where the landing aircraft could veer off the runway surface. By modelling the aircraft in 2D only, classic tools cannot predict those fluctuations, which is a concern for safety. ELISE modelling in 3D is accurate and can predict all situations delivering reliable simulations.

### 2. TO INCREASE GROUND CAPACITY BY REDUCING SIGNIFICANTLY THE ILS PROTECTION AREAS

The Localizer signal needs to be protected from multipath interference. One of the protection areas is near any parallel taxiways to the runway. On the taxiway, the aircraft is at a grazing angle to the Localizer signal. At grazing angles, classical prediction tools provide far more conservative results than ELISE.

Safety issue when results from classic methods under-estimate the real impact of obstacles

Figure 7



Unhelpfully and as shown in figure 8, classic tools can even predict out-of-tolerance disturbances (in red), which in reality, are well within the tolerance defined by the ICAO Annex 10 specifications (in green). By using classic tools, the ANSP could impose unnecessary operational constraints to the airport, even to the point of not allowing the use of a parallel taxiway which would adversely impact the runway's capacity. ELISE can significantly help an ANSP take decisions that optimize aircraft operations with sound and reliable predictions.

### 3. TO ALLOW THE CONSTRUCTION OF BUILDINGS CLOSER TO THE RUNWAY

The ICAO European guidelines for managing Building Restricted Areas (BRA) define a volume where buildings have the potential to cause unacceptable interference to the ILS signal. Within the BRA, it is necessary to demonstrate (using simulation or other means) that any proposed building for example will not cause disturbances in excess of the predefined limits.

ELISE advanced technologies have permitted the development of elegant “stealth” solutions for building facades to prevent the building from causing the loss of Category III operations at airport runways. The solution is based on diffraction gratings that redirect the incident wave back to its source rather than the specular direction. Diffraction grating has been extensively studied in the 1980s but has never been applied on buildings for the ILS problem. The shape of the diffraction grating is optimized for the specific position and orientation of the building toward the runway.

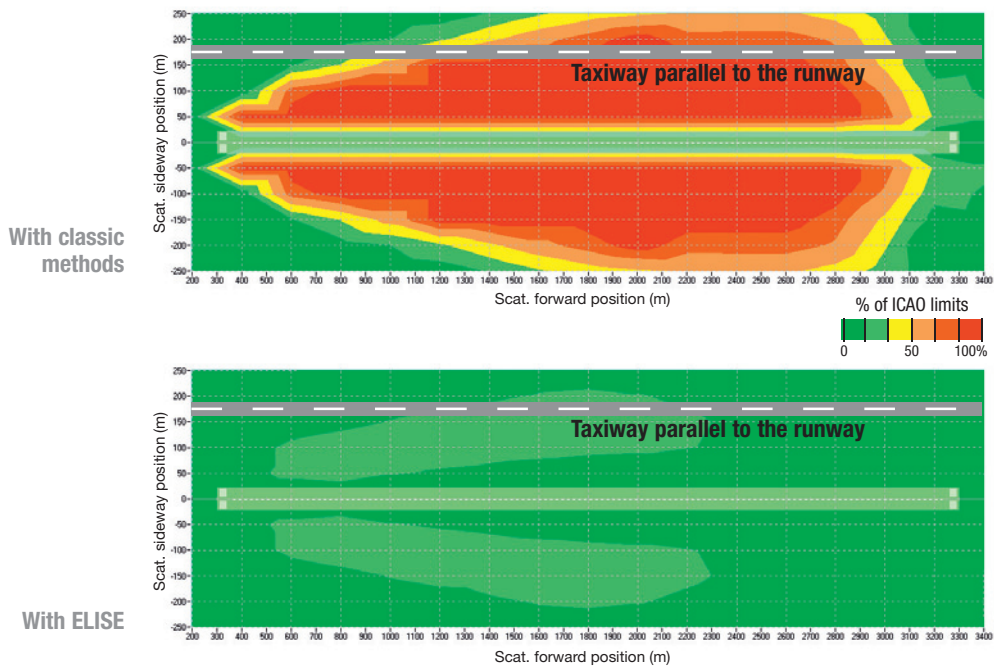
By using this stealth technology on buildings located within previously forbidden areas, land-constrained airports are now in a position to significantly increase their land income (up to 100 hectares can be saved).

### Way forward

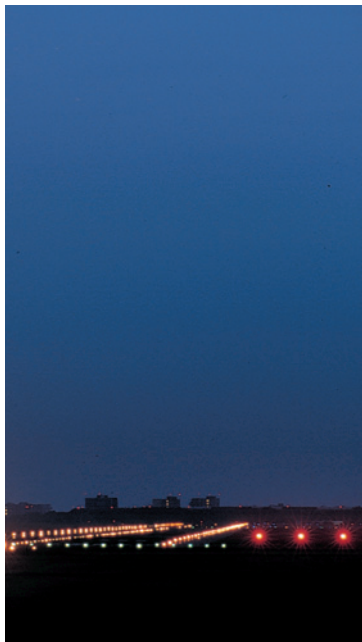
The ELISE software is being introduced in the ICAO Working Group in the Navigation Systems' Panel (NSP) in charge of updating the ILS Protections Areas in ICAO Annex 10.

ILS protection areas around runway optimized with ELISE

Figure 8



After almost one year of business tests, Airbus' ELISE Consulting Services receives very strong positive feedback from several airports and Air Navigation Service Providers. Since last quarter 2011, several studies have been already done for customers. Year 2012 is expected to see a confirmation of the interests of the huge capabilities of the ELISE software.



Supported by



## EADS IW and ENAC: Two core partners for ELISE

**EADS Innovation Works (IW)** gathers the EADS corporate Research and Technology (R&T) laboratories that guarantee the group's technical innovation potential with a focus on the long-term horizon. EADS IW has the mission to identify new value-creating technologies and to develop technological skills and resources. Gilles PERES (electromagnetic specialist) and Andrew THAIN (designer of stealth buildings) are part of the electromagnetic team that developed a complete range of software items including ASERIS which is at the heart of ELISE. These software support the studies of electromagnetic compatibility, antenna sitings, stealth, and more generally, the effects of the electromagnetic aggressions on those systems.

**The Ecole Nationale de l'Aviation Civile (ENAC)** is a French civil aviation university. Since 1 January 2011, it has become the biggest aeronautical university in Europe. The trainings provided at the ENAC involve each year an average of 2,000 students composed of engineers, air traffic controllers, electronic engineers, technicians, air transport pilots and flight dispatchers. Bertrand SPITZ (ILS instructor) is part of the electronic department that developed a worldwide expertise in ILS antenna knowledge. He has developed the ILS antenna modelling and the human interface display of the ELISE software.

EADS INNOVATION WORKS



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## Conclusion

Airbus is much more than the leading aircraft manufacturer. It delivers a large range of services not only to airlines, but also to Air Navigation Service Providers and airports. ELISE is one such service, with advanced simulation software that predicts ILS disturbances with a level of accuracy and reliability unequalled today.

The ELISE team can provide detailed analysis and expertise to airports which want to maximize their ground capacity, build new buildings closer to the runways or operate new aircraft. If you would like more details, please contact our specialists.



# The 'Clean Sky' initiative Setting the tone

Clean Sky brings together leading aviation companies and experts to form a truly European technology platform. Its key objective? To mature the most advanced green technologies in the fields of large commercial transport aircraft, regional aircraft, rotorcraft, aircraft engines and aircraft systems.

For Airbus, Clean Sky is one of the most important elements of aeronautical research in Europe; not only due to its budget of 1.6 billion euros, but also due to the fact that for the first time in history, the Clean Sky initiative has created a 7-year partnership on a European level,

to enable the validation of large-scale systems in real flight demonstrations.

Embedded in the 7<sup>th</sup> European Framework Programme, the Joint Technology Initiative (JTI) that is Clean Sky offers a key opportunity to accommodate Airbus Research and Technology priorities, with the view to preparing the next generation of ever more efficient aircraft.

The following article has been published in the Air and Space Academy Newsletter (#72) and demonstrates Clean Sky's active involvement in paving the way for an eco-efficient future.



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Clean Sky J.U.

An example of Airbus' role in Clean Sky is the coordination (jointly done with Saab Aero-systems) of the Smart Fixed Wing aircraft platform, which is one of the six mentioned integrated technology demonstrators in Clean Sky. Here Airbus is pursuing major activities to mature an all new low drag "Smart Wing" concept and the integration of the most promising innovative engine concept - the Contra Rotating Open Rotor (CROR) - to achieve a substantial improvement in fuel burn and noise reduction for the next generation large transport aircraft.

Airbus is also contributing to other integrated technology demonstrators, like systems for green operations, eco-design or the Technology Evaluator.

Clean Sky's article published in the Air and Space Academy Newsletter

"Clean Sky", a designation that clearly sets the tone. Whether green or blue, we know straight off that it will be a question of sky and environment. Let's be clear. The question here is not one of waging war on the (scant) smoke still escaping from our factory chimneys, nor even coping with the volcanic ash which grabbed the headlines in 2010. We are talking of aeronautical technologies designed to reduce the environmental footprint of future aircraft in terms of CO<sub>2</sub>, noise, NOx and life cycle effects.

Born out of the ACARE (Advisory Council for Aeronautics Research in Europe) Strategic Research Agenda, Clean Sky is a somewhat unusual initiative.

A "Joint Technological Initiative", it hinges on a public-private partnership associating the European Commission and just about the entire civil aircraft industry of Europe. In the course of a ten year period (2008-2017), it aims to deliver integrated demonstrators with a high TRL (Technology Readiness Level).

The total cost of the programme is 1.6 billion euros, making it one of two or three of the largest research programmes ever financed by the European Union in any field.

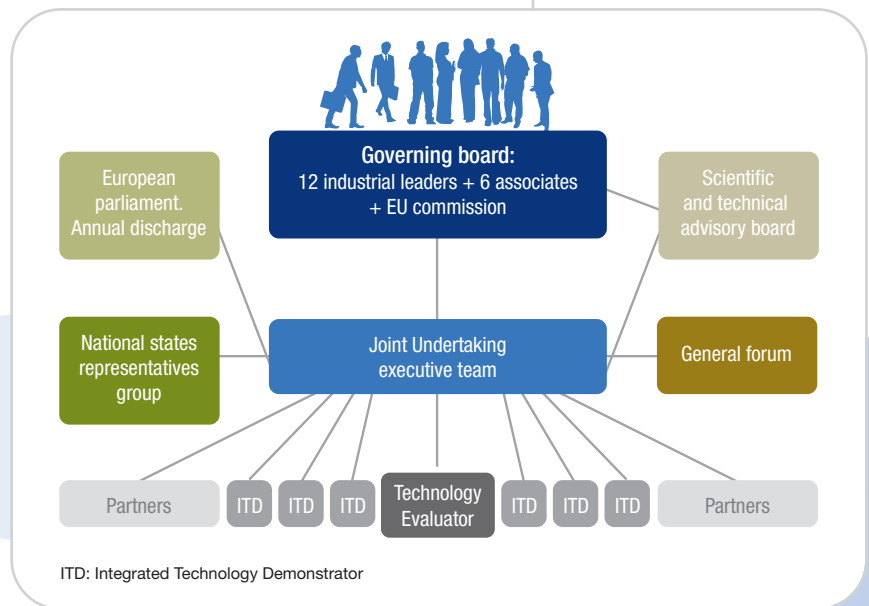
In addition to direct benefits to European citizens, the reduction of CO<sub>2</sub> emissions and noise also provides a federating objective on a technological level. Efforts will be made in the areas of aerodynamics, mass, propulsion efficiency, flight path optimisation, etc.

The programme is organized into six Integrated Technology Demonstrators (ITD), technological platforms grouping together coherent research areas and the interested players (see figure 1).



Clean Sky is steered by public and private stakeholders

Figure 1





Each one is directed by a tandem of industrialists. Three of them concern aircraft directly:

- Smart Fixed-Winged aircraft, for commercial aircraft (Airbus and Saab)
- Green Regional Aircraft (Alenia and EADS' Spanish arm)
- Green Rotorcraft (Eurocopter and AgustaWestland)

with three further transverse topics:

- Sustainable and Green Engines (Rolls-Royce and Safran)
- Systems for Green Operations (mission and flight path management, energy management with Thales and Liebherr)
- Eco-Design (Dassault and Fraunhofer).

The whole is topped by a 'Technology Evaluator', a set of models intended to identify environmental benefits on a level of an individual mission, an airport or the entire world fleet. This Evaluator is directed by Thales and the DLR.

Around this circle of ITD leaders is a wider circle of associates: Over 70 other industrialists, research centres, SMEs (Small & Medium Enterprise) and universities, committed like the leaders for the whole duration of the programme. These include organisations as diverse as Zodiac, MTU, Onera, Ruag, the Universities of Milan and Cranfield or the Romanian INCAS.

Leaders, associates and the European Commission constitute the members of the Clean Sky Joint Undertaking, or J.U., a peculiar legal creature whose unique mission is to implement the Technological Initiative of the same name. They are represented by a governing board, which acts as both the management committee of the programme and the board of directors of the J.U. The essence of the public-private partnership lies in the joint taking of strategic decisions. Of course, shared decision making also implies shared funding. Funds are provided half by the Commission - from the FP7 (Framework Programme for research - Euro funding and industry co-funding) budget - and half by industry. (NB: The term "industry" is a simplification. It includes research centres and other public organisations sharing the same financing terms).

A third circle exists, of crucial technological and political importance: The "Partners". These are selected by means of regular (more or less quarterly) calls for proposals. They must meet precise technical specifications stemming from the requirements of the demonstrators. Today, after seven calls for proposals and the related evaluation processes which are carried out according to European Commission rules, it would appear that the SMEs are doing well, representing about 40% of a total of almost 300 identified partners (and rising): Clean Sky is gradually involving not only the major aeronautics players, but also a significant number of newcomers.



As regards governance, the highest authority is wielded by the governing board while the management of the programme is entrusted to the executive director of this Joint Undertaking and his twenty-member team. The J.U. issues contracts to members and partners and ensures proper execution of activities; the Director is directly responsible to the European Parliament.

It would be tedious to cite the hundred or so key technologies and 30 demonstrator projects included in the six ITDs. A few examples will suffice in order to make some general observations:

- Open Rotor (see figure 2) is the most weighty, to the extent that Clean Sky finances two parallel projects: One by Rolls-Royce, the other by Snecma, both with geared counter-rotating pusher propulsors. In terms of CO<sub>2</sub> benefit, Open Rotor is very promising with approximately 30% reduction in engine specific fuel consumption, a little less once installed because of weight penalties for example. Problems of noise, vibration and certification have to be resolved of course, but the latest information is encouraging. One of these demonstrators will be bench tested in 2015, and subsequently flight tested on an Airbus A340-600. This concept is in fact not entirely new, having already been tested in the United States during the 1980s' surge in fuel prices, more short-lived than today. It does though benefit from developments carried out in the past quarter of a century.

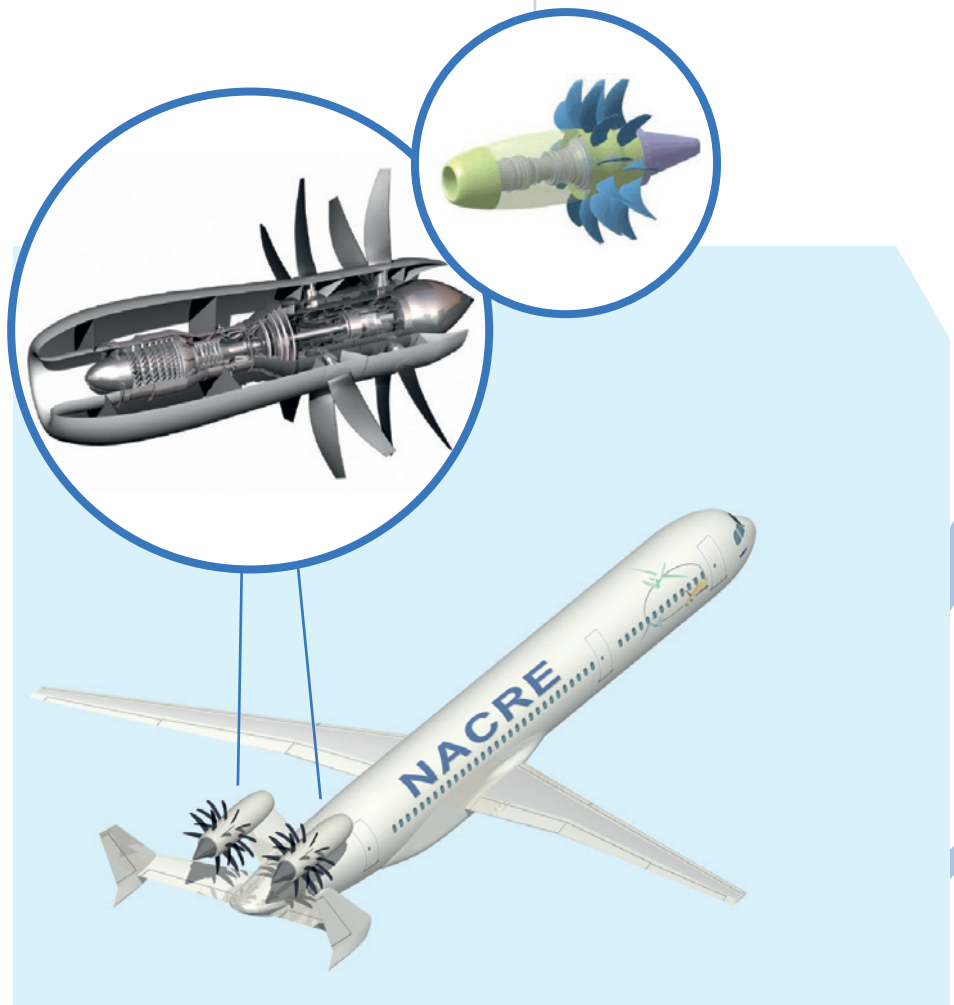
#### FIRST OBSERVATION

Clean Sky includes neither flying wings, rhomboidal wings, solar planes nor hydrogen propulsion, but rather aims for the shorter term, the very next generation of aircraft:

- Laminarity is another large-scale project, and a flight demonstration is also planned in 2015 on an A340, with the realisation and installation of an 8 metre-long wing element. For the moment it is a question of natural laminarity, which makes manufacturing aspects all the more essential, as well as the verification of the robustness of this laminarity, which must not be lost with the first mosquito strike! Like Open Rotor, laminarity is a very promising technology that will be relevant for future aircraft generations that could enter the market around the horizon 2025. Clean Sky provides the platform and timeframe, making the large required technological steps at the right time.

#### Contra-rotating Open Rotor

Figure 2



NACRE: New Aircraft Concepts Research

## SECOND OBSERVATION

Clean Sky, by definition, is related to industrial strategies. It aims to prepare, from the viewpoint of environmental technologies, future generations of planes and rotorcraft. This provides an essential guarantee - disregarding unforeseen factors which are always possible in research - that public expenditure will not be frittered away on superb but unapplicable technologies. It is also the objective of shared governance:

- Flight path optimisation is another effective means to reduce both CO<sub>2</sub> emissions and noise. In addition to the SESAR (Single European Sky ATM Research) programme, another J.U. comprising the technical side of the European Single Sky initiative, which will optimize air traffic and achieve environmental benefits by avoiding fuel waste, Clean Sky is also looking into

cockpit technologies which will enable real time optimisation of an individual mission.

## THIRD OBSERVATION

SESAR is interested in traffic, Clean Sky with the vehicle. Since the one cannot advance without the other, the two programmes are partially linked:

- Research concerning composite materials (and therefore weight) is carried out within the framework of regional aircraft. Some examples include carbon nanotubes in order to improve conductivity and shear strength, and multi-layer, multifunction materials. Admittedly, Clean Sky is far from being the only party involved in research activities on composites! For commercial aircraft, it is carried out in other contexts.

## FOURTH OBSERVATION

Clean Sky is not an island, on the contrary, it has many partners, many connections with the classic FP7 or national programmes; better still, Clean Sky aims to have some leverage on the latter. Let us note that in France, for example, the CORAC (COnseil pour la Recherche Aéronautique Civile) takes this necessary complementarity very seriously:

- Business aircraft, regional aircraft and helicopters coordinate part of their "all electric" activities since "all electric" or "almost all", is easier to achieve in these sectors (for reasons, in particular, of dissipated power) than for commercial aircraft, although the latter are not entirely absent. Corresponding architectures will all be tested on a "Copper Bird" belonging to the "eco-design" ITD.

## FIFTH OBSERVATION

Clean Sky is a coordinated programme, with many interactions between the different ITDs, and not a simple juxtaposition of interests.



This, together with the global nature of the technology evaluator, demands a “systems” approach which has not been a feature of European programmes until now.

Clean Sky being an aeronautical enterprise, one might say that it has now reached full cruising speed, after a delayed take-off. Initial hurdles have been overcome and the necessary budgetary flexibility and operational effectiveness achieved. Later, it will be up to the market to put these technologies into operation. The first intermediate achievements are emerging: Partial tests in flight, production of innovative parts, etc.

These parts of the puzzle will begin to be assembled towards 2013, when the largest demonstrators start to turn over.

In the meantime, the environmental benefits must be secured. Clean Sky has proven to be a very essential instrument in driving substantial technology advancement for the future of aeronautics.

*Article written by Eric DAUTRIAT  
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## Conclusion

Clean Sky has already proven itself to be an essential instrument in driving technology and innovation for the future of aviation. Given the ambitious targets set out in Europe's vision for aviation, "Flightpath 2050", it is essential that we keep our foot firmly on the accelerator. A commitment to delivering the most promising technologies in aviation - the fastest growing transport sector with >4,8%/a - at the earliest possible opportunity, – necessarily means maintaining technological leadership,

creating high skilled jobs, increasing transport efficiency, sustaining economical prosperity and driving environmental improvements worldwide. Indeed, a second generation J.U. will undoubtedly be required under the next Framework Programme if we are to maintain our current trajectory, whilst embracing ever-more ambitious objectives, such as using large-scale integrated demonstrators for new configurations.

# From barometric to radio

In 1928, Paul Kollsman invented a barometric altimeter making it possible for pilots to fly using only their gauges, such as in heavy fog or at night when visibility is limited. The aviator, James H. Doolittle, became the first pilot to take off, fly and land during the first all-instrument flight on a Consolidated N-Y-2 biplane, on September 24 1929.



“ What time is it?  
Well, I'm not quite sure.  
Can't you tell with your sophisticated  
watch showing time all over the world?  
No, Sir. This isn't a watch but one  
of the earliest barometric altimeters  
ever invented. ”



The history of the altimeter begins with the invention of the mercury barometer, the first device to measure air pressure. As early as in 1643, Italian physicist Evangelista Torricelli (a pupil of Galileo), filled a tube with mercury. One end of the tube was closed; the other open end was turned upside down and inserted in a cup of mercury. Because the air exerted pressure on the mercury in the cup, about thirty inches of mercury remained in the tube.

Nowadays, the Radio Altimeter sends out radio waves to a fixed point on the ground and then determines the altitude by the time it takes the wave to bounce back. Unlike the barometric altimeter, a Radio Altimeter won't be affected by the weather. However, a Radio Altimeter is usually only used when the aircraft descends below 2,500ft as detailed in this FAST magazine (Radio Altimeter systems - page 15), and regular maintenance practices are recommended.



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