SAE INTERNATIONAL
aero-online.org
December 2013

AEROSPACE ENGINEERING™

Embraer's Lineage 1000 Business Jet

Avionics for Position Integrity

Optimizing CFRP Assembly

Top Products

Waterjet-based micromachining

The MicroMAX JetMachining Center from OMAX provides the speed, versatility, and accuracy of abrasive waterjet technology to cut parts smaller than 300 µm from a range of materials, including exotic metals, advanced composites, polymer thermoplastics, and glass. The rigid machine has a table size of 2.3 × 2.3 ft. and an X-Y cutting travel of 2 × 2 ft. It uses high-precision linear encoders, innovative vibration isolation, and intuitive software control systems to achieve a position repeatability of 2.5 µm and a positioning accuracy of approximately 15 µm. Read more at ***http://articles.sae.org/12493***.

Absolute rotary encoder

Micronor's magnetic resonance imaging (MRI)-compatible fiber-optic absolute rotary encoder system features 13-bit (8192 count) resolution and 12-bit multiturn tracking. The all-optical, nonmetallic MR338 passive sensor provides precision absolute angular measurement from 0° to 360°. A duplex multimode fiber-optic link connects the passive MR338 sensor to the active MR330 controller module installed outside the MRI area. Read more at ***http://articles.sae.org/12497***.

Optical output illuminator

The OD-669-850 high-power, gallium aluminum arsenide, IR light-emitting diode illuminator from Opto Diode is suited for night vision illumination tasks. The illuminator features ultra-high optical output, from 800 (minimum) to 1250 mW (typical), and a peak emission wavelength of 850 nm. The device provides a highly uniform optical beam. The spectral bandwidth at 50% is typically 40 nm, and the half-intensity beam angle is 120°. Read more at ***http://articles.sae.org/12496***.

Leaky feeder antennas

W. L. Gore & Associates' leaky feeder antennas improve signal propagation and reduce dead spots without increasing the amount of hardware required on the plane, enabling passengers to connect easily to in-flight entertainment, Internet servers, and email accounts throughout the cabin. The antennas deliver proven performance in a range of aircraft — from small business jets to long-range commercial airliners. They reduce equipment costs by offering a single solution that provides connectivity for a variety of electronic devices. Read more at ***http://articles.sae.org/12495***.

Triaxial accelerometer

Meggitt Sensing Systems' Endevco model 7253D triaxial Isotron accelerometer is designed for applications requiring the measurement of shock and vibration simultaneously in three mutually perpendicular axes. Applications include testing of aircraft engines, industrial engines, missiles, aircraft/engine/weapons components, spacecraft components, flight testing, and industrial machinery. Available in sensitivities of 10 or 100 mV/g, the device is small and lightweight with a broad frequency response. Read more at ***http://articles.sae.org/12494***.

Top Articles

EADS aims to electrify the skies

The French company is pursuing electrification via so-called "E-aircraft" projects, which include an electric general-aviation training aircraft, a serial hybrid-electric motor glider, and a hybrid propulsion system for larger aircraft. Read more at ***http://articles.sae.org/12452***.

Technology being developed as part of the Distributed Electrical Aerospace Propulsion project by EADS, Rolls-Royce, and other participants is envisioned for deployment in about 2050.

Putting a tighter spin on engine component balancing

Vibration-induced shaking of a part wastes energy, increases noise, boosts stresses on associated components, and accelerates bearing wear. Eventually, vibration can degrade an entire machine and significantly raise maintenance and replacement costs. Read more at ***http://articles.sae.org/12407***.

The DEVILA is in the details of software integration for safety avionics

The decreasing relative cost of electronics and the pace of electronics development have significantly increased the need to adopt modern commercial off-the-shelf computing architectures in avionics. Read more at ***http://articles.sae.org/12366***.

Bombardier's sights set on sustainability at AeroTech Congress

Montréal, one of the world's leading aerospace centers, is the site of the SAE 2013 AeroTech Congress & Exhibition, with Bombardier serving as host company. Fassi Kafyeke, Director of Strategic Technology, Bombardier Aerospace, and AeroTech Co-Chair, discusses the event and emerging industry trends. Read more at ***http://articles.sae.org/12417***.

Aluminum in the air

Constellium provides a close focus on how waste material is recovered and reused through the supply-chain manufacturing process up to the time when the airframe is eventually dismantled after a lifetime of service use. Read more at ***http://articles.sae.org/12363***.

Altair

Innovation Intelligence®

Heavyweight simulation. Lightweight parts.

Achieving your program goals of lighter, stronger designs in less time just got a little easier. HyperWorks 12 has been enhanced with new capabilities created specifically for the aerospace industry, including more modeling control, greater analysis power and the optimization leadership you expect from Altair.

Learn how HyperWorks can improve your aerospace designs by visiting altairhyperworks.com/aero

HyperWorks is a division of Altair | altair.com

Clearing the air

Since the Wright brothers, aerospace engineers have essentially focused on safety, and that focus proved to be extremely successful — so much so that the focus has had to change.

The aerospace industry is acutely aware of the flying public's growing concerns with pollution, both the kind they hear and the kind they smell (not even to mention exactly what chemical reactions are occurring with those emissions at 36,000 feet), as well as the enormous leaps in the number of passengers projected to be flying in coming years, with some projecting that globally the annual figure will be about 1 billion passengers around 2020. And airlines need to address such concerns while both remaining profitable and replenishing their fleets.

The industry allows that it is responsible for 2% of manmade CO2 emissions. While that may not seem like much, in layman's terms, 2% of A LOT is still A LOT. The industry projects that aerospace CO2 amounts will increase to 3% by 2050. While that also may not seem much, 3% of a WHOLE LOT MORE is going to be QUITE A LOT.

Does the flying public really care? Put it this way: if only 2% of potential passengers decided not to fly due to the environmental impact of air travel, that is still A LOT of passengers, and A LOT of empty seats.

And, it's not just concerns about the environment that could potentially empty aircraft seats. There are also time concerns.

"There's not a person among us who likes interminable waits sitting on the runway prior to takeoff clearance," said Marion Blakey, President and CEO, Aerospace Industries Association, speaking in September at the NextGen Rally. "Nor is anyone enamored when flights are delayed by en route weather, [when] a slightly altered flight plan could get us home safely."

NextGen, formally the Next Generation Air Transportation System, is tasked to transform the air traffic control system from a ground-based radar system with extremely dated technology to a satellite-based system.

Ideally, the system will be implemented before the satellite-based system is also considered to have extremely dated technology, though there have been delays. The ultimate goal of the system is to reduce gridlock by optimizing routes and allowing aircraft to be closer to each other while in the air.

Blakey, a former FAA Administrator, has been on the NextGen bandwagon for over 10 years. "NextGen has rightly been called one of America's most impressive infrastructure projects," she said. "But it is also one of the most invisible public works projects we can imagine."

In her speech, Blakey made sure to point out some of the visible benefits of implementing NextGen. She cited an FAA-sponsored study that determined "domestic flight delays put a $33 billion dent into the U.S. economy, with about half the cost borne by passengers."

To address that concern, she cited a Deloitte study that "predicts that full implementation of NextGen — and I emphasize full — by 2035 will provide more than $281 billion in net benefits to the economy, and a decade sooner save 27 million hours in flight delays and reduce 216 metric tons of greenhouse gas emissions."

According to Blakely, that's the equivalent of annual greenhouse gas emissions from 45 million passenger vehicles, or the CO2 emissions from the electricity use of 30 million homes in one year.

"Put another way," said Blakey, "the industry's resolve to have carbon neutral growth by 2020 relies on NextGen moving ahead as planned."

Parts of NextGen, such as ADS-B, PBN, and RNP, are already functioning at some airports around the country and are already saving airlines and freight companies time and money. But there's still A LOT to do to get the full NextGen system up and running, and inherently clearing the air while simultaneously filling the skies with aircraft.

Jean L. Broge
Managing Editor

Are you leaving half your procurement value on the table?

Reducing procurement costs is one thing. Creating sustainable value from your procurement function is another. KPMG's Procurement Advisory practice combines thought leadership and global perspectives to help you transform the way you source and manage your supply base. So your procurement function can provide the value you expect. And the P&L results you need.

Download our latest research: *"High Impact Procurement Operating Models"* and *"FUTUREBUY: The Future of Procurement."* Visit **kpmg.com/us/procure13**

KPMG

cutting through complexity

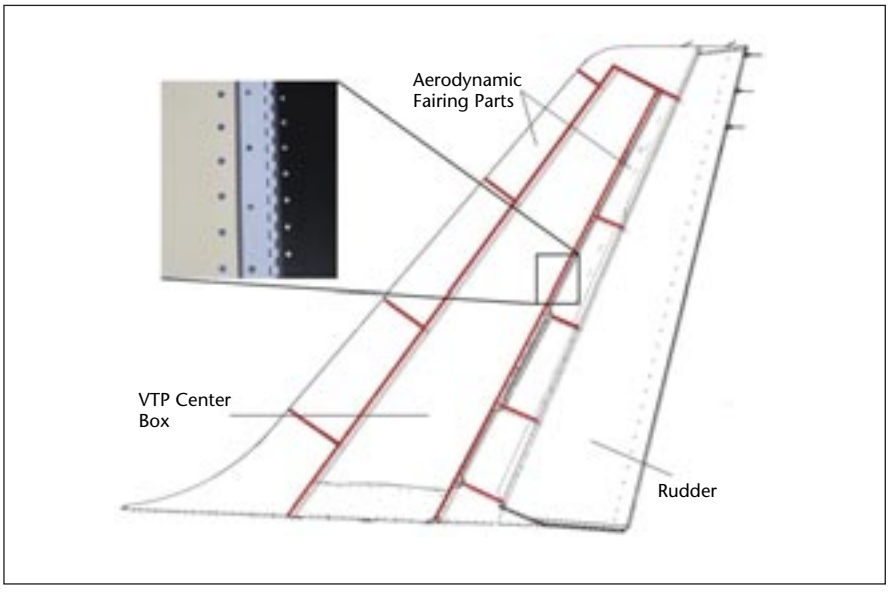
Heated Air Technology Helps Optimize CFRP Assembly

In today's assembly of large and complex carbon-fiber-reinforced plastic (CFRP) components such as passenger-aircraft vertical tail planes (VTPs), liquid resin-based materials are used for several applications. Commonly, these materials are used to close gaps between the CFRP single parts during assembly (shimming) or to smooth outer surfaces to fulfill aerodynamic requirements (aerodynamic sealing).

Depending on temperature and air humidity, these materials generally require curing times up to 12 hours. From an efficiency and cost optimization perspective in running aircraft production, such long curing times are definitively wasteful in terms of lead time (critical path).

By heating and/or air-conditioning these resin-based materials, the common curing time can be drastically reduced — to 2 hours. Due to the use of heated air — instead of, for example, heating lamps — the curing process can reliably be controlled, without any risk of overheating and destroying the sealant or shim material.

Researchers from Airbus Operations GmbH and Marcotodo GmbH describe two applications of heated air technology for the accelerated curing of resin-based shim and sealant materials. The first example is the aerodynamic sealing of a VTP; curing time of the aerodynamic sealant can be reduced by 8 to 10 hours using the newly developed heated air technology. The second example is the shimming of gaps between a VTP center box and metallic parts attached to the box.



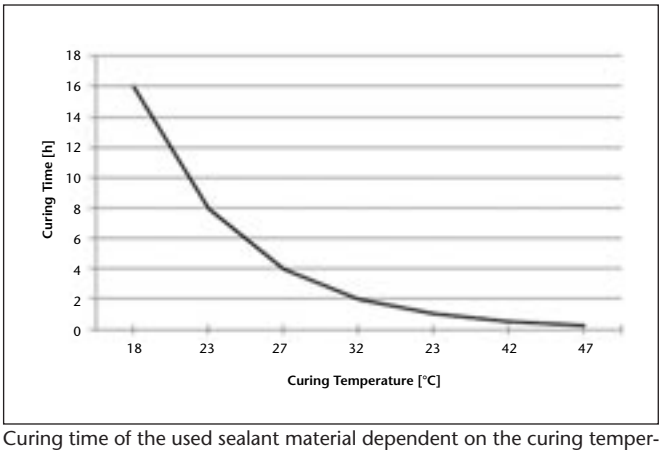
Vertical tail plane (VTP) of a single-aisle passenger aircraft showing gaps on the outer surface (in red) that have to be filled by aerodynamic sealing.

Tolerance Compensation Using Resin-Based Materials

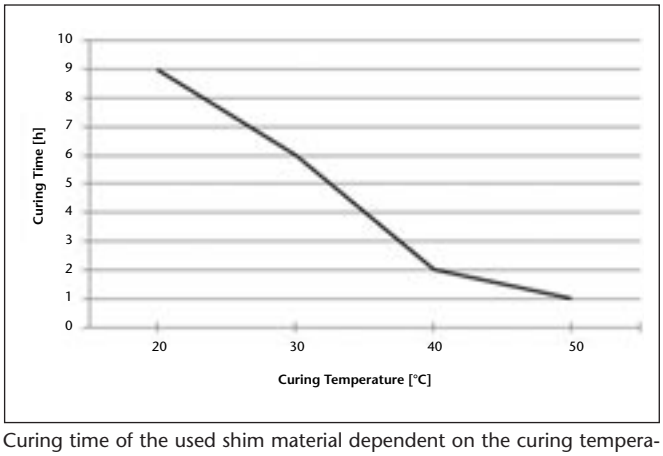
Large and complex parts made of CFRP commonly show larger tolerances regarding form and thickness accuracy compared to metal parts since higher accuracy would directly lead to exponentially higher costs of the single parts. Therefore, as a compromise, tolerance compensation has to be performed as part of the assembly process.

Shimming has to be performed between the single parts to close gaps that are caused by stack-up of thickness tolerances and to guarantee correct transfer of loads through the parts and the fastener elements. Closing gaps on the outer surface of assembled components, or aerodynamic sealing, has to be performed to smooth the surface.

The sealing material is a two-component polysulfide-based compound from



Curing time of the used sealant material dependent on the curing temperature.



Curing time of the used shim material dependent on the curing temperature.

CA | USA

2014

A Detailed Look Within the Aerospace and Defense Extended Manufacturing Enterprise. AeroDef Manufacturing 2014.

Join the elite of Aerospace and Defense manufacturing as they gather at AeroDef 2014 to usher in a new era of innovation, collaboration and community. In this time of great change, OEMs are looking for business partners who can bring value and quality to their programs. This is your opportunity to be a part of the discussion and get noticed.

AERODEF MANUFACTURING

produced by sme

SUMMIT AND EXPOSITION | FEBRUARY 25–27, 2014 | LONG BEACH (CA) CONVENTION CENTER | AERODEFEVENT.COM

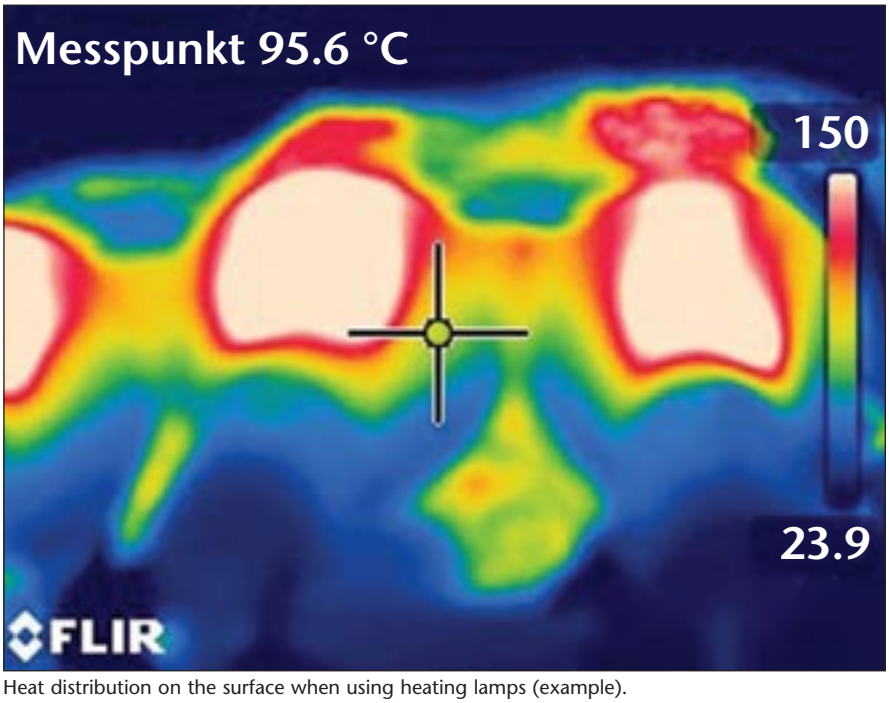
EXECUTIVE COMMITTEE

Bell Helicopter A Textron Company · BOEING · EADS NORTH AMERICA · LOCKHEED MARTIN · NCDMM NATIONAL CENTER FOR DEFENSE MANUFACTURING AND MACHINING · NORTHROP GRUMMAN · Raytheon

Chemetall. With the current product variant, the curing time is about 8 hours at 23 °C to achieve a hardness of Shore A ≥ 30 of the cured material. By increasing the temperature, the curing time can be reduced; a decreased temperature leads to longer curing times. Especially during winter (with shop-floor temperatures less than 20 °C), this could lead to curing times of up to 16 hours.

In addition, a minimum relative humidity is necessary for the initiation of the chemical curing reaction (vulcanization). Especially during winter, relative air humidity could be less than 10%, which leads to further extension of the curing time.

The shim material used is a two-component epoxy-based compound from Henkel. The curing time at 20±3 °C is 9 hours. By increasing the temperature, the curing time can be reduced to less than 2 hours.

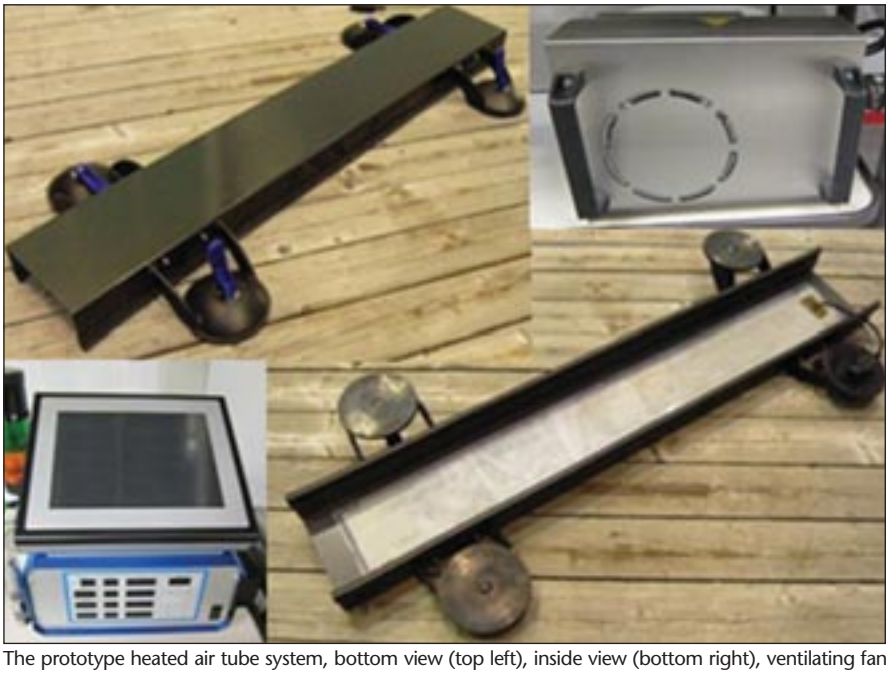


Heat distribution on the surface when using heating lamps (example).

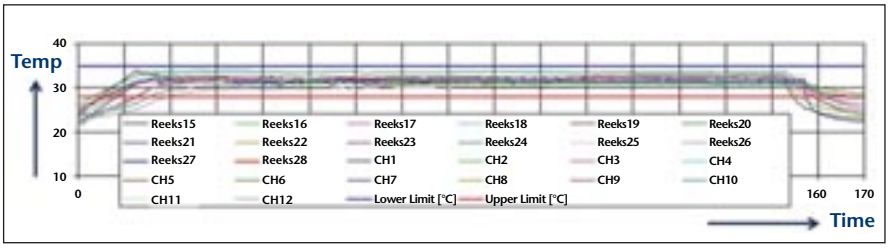
Improved Aerodynamic Sealing with Heated Air

Heating (IR) lamps have traditionally been used to heat the sealants; however, the heat distribution on the surface is very uneven, leading to uneven curing of the sealant. There also is a risk of overheating and damaging the sealant, or in the worst case, the CFRP material itself.

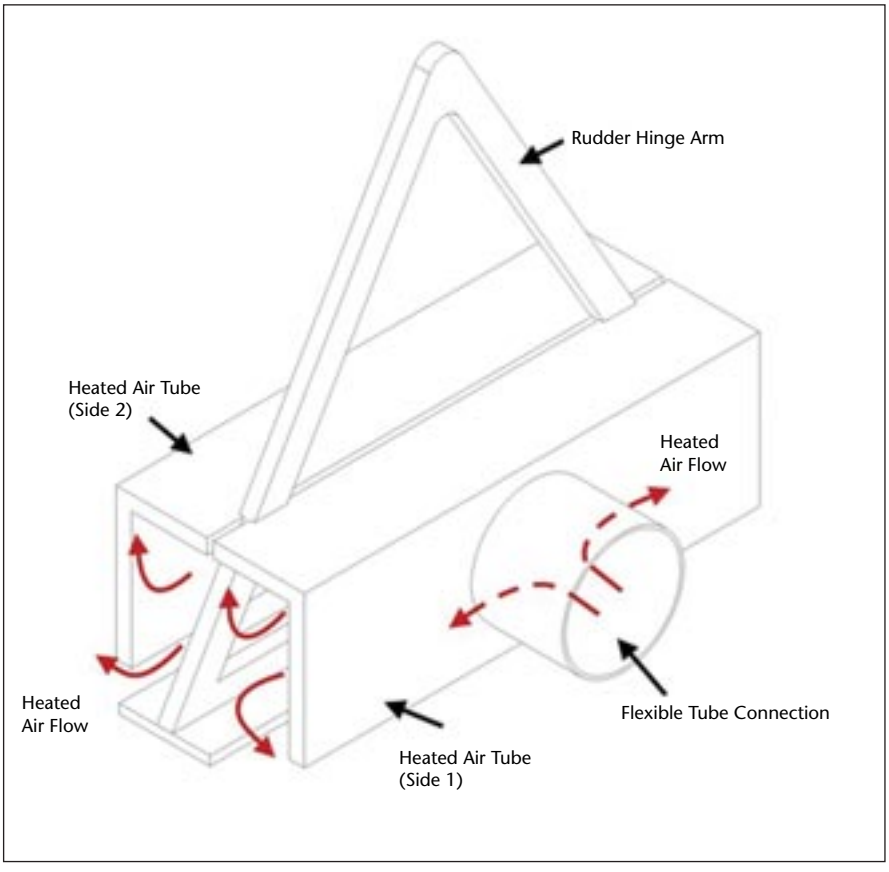
To overcome this risk, a new technology was introduced using heated air instead of lamps. By using heated air flowing slowly and continuously over the sealant material, a homogeneous heat distribution and curing process can be realized. The maximum temperature on the surface cannot be higher than the maximum air temperature independent of the position of the system. Therefore, the curing process can be reliably controlled, without any risk of overheating.


The prototype heated air tube system, bottom view (top left), inside view (bottom right), ventilating fan (top right), and control unit (bottom left).

Together with other specialized companies, including Oellerich and CFK-Valley Stade, dedicated tooling was developed and introduced. It consists of a U-shaped air tube made of CFRP. Vacuum cups are used for mounting the tooling onto the surface without damaging it. Rubber lips at the edges guarantee a closed canal for the heated and moisturized airflow. The air tube is connected to a dedicated fan heater via flexible hoses. Several air tubes can easily be connected to each other, depending on the length of the gap to be sealed. By means of a control unit, the air temperature and humidity can be adjusted, automatically controlled, and recorded. An additional electrical heating system and temperature sensors are installed inside the air tube.



Heat distribution inside heated air tube. The air temperature inside the system can be controlled very accurately, within a range of ±3 °C.



Schematic representation of the heated air system for accelerated curing of shim.

The air temperature inside the system can be controlled very accurately (by means of internal heating elements) within a range of ±3 °C, which meets the curing requirements for the sealant material.

To maintain a relative humidity between 10% and 90%, a humidity control unit can be added to the system.

In first trials using the prototype, the operational readiness of the heated air tube system could be demonstrated. A curing time of 2 hours was achieved including temperature ramp-up and installation time. The next step will be the introduction of serial heated air tubes.

Improved Tolerance Compensation with Heated Air

Heat can also be used to decrease the curing time of shim material. As risk mitigation, heating lamps are no longer used in the assembly of the VTPs. Another possibility to introduce heat is using flexible heating mats or metallic heating elements (e.g., beams) that are placed on the surface with the shim material underneath. In principle, this is only possible for less complex part geometries — e.g., flat or slightly curved surfaces. For complex surfaces, heated air again becomes an interesting option.

For joining the rudder with the VTP center box, aluminum hinge arms have to be assembled to the center box. Shim has to be used to fill the gaps between the rudder hinge arms and the rear spar of the center box to guarantee accurate positioning of the hinge arms and rudder hinge line. The heat introduction into the interface between hinge arms and the rear spar cannot be realized with a heating mat or other conventional heating elements due to the complex assembly situation. In particular, thermal expansion of the surrounding fittings has to be avoided. Therefore, a specifically adapted heated air tooling was developed that fits to the hinge arms.

In this case, the heated air system consists of two L-profiles that fit to the geometry of the dedicated hinge arm. Since the geometry of each hinge arm is different, individual systems have to be used per hinge arm. Rubber lips at the edges of the L-profiles ensure a closed inner room for the heated airflow. The profiles can easily be fixed at the part using conventional clamping devices. The heated air system is connected to a dedicated fan heater with flexible hoses and controlled by a control unit.

First trials at a test VTP were done using a prototype system. Again, a curing time of 2 hours was realized. Next steps will be the implementation of the heated air system in serial production.

Heated air technology enables the stabilization of the production process with regard to a clearly structured process and delivery planning since the curing time remains the same independent of the environmental conditions (temperature and air humidity) in the shop floor.

This article is based on SAE International technical paper 2013-01-2133 by Alexander Gessenharter and Bjorn Van Koppen of Airbus Operations GmbH, and Marc-Philipp Graf Bethusy-Huc of Marcotodo GmbH

Bizjets Wait for the Uplift

A look at how the global executive jet market is fighting back after a hard few years.

by Richard Gardner, European Editor

Embraer Lineage interior layout.

The past two decades saw the market for new business jets explode, with corporate customers discovering and embracing the value of a tool that could bypass the congestion and frustrations of airline travel, going more directly where they wanted to go, and allowing work to continue along the way. It seemed a perfect win-win situation for busy executives who could arrive at a destination refreshed and prepared for that important meeting, and for companies who could increase the productivity of their senior management at a competitive cost compared to using premium airfares on every trip.

Added to the rapid rise in company-owned business aircraft were a host of new "fly-as-you-go" air-taxi and fractional operators offering competitive rates for hired-out aircraft that came with crews, and all administrative and support functions taken care of.

These newcomers were soon ordering new business jets by the score, later by the hundred, and new products started to flood onto the market to meet the demand.

Although the powerhouse for bizjet growth was in North America, the attraction of executive jet air travel became global, especially in fast-growing emerging markets with very rich entrepreneurs developing a taste for personal jet travel.

But then the financial meltdown of 2008 hit North America and Europe, and the clear blue skies of the bizjet market suddenly became a tropical storm. Orders were cancelled or postponed, some manufacturers and suppliers became insolvent, and the sector's growth charts reversed their upward paths and started a decline.

While the first years of this decade have seen only a mild recovery in the return to growth in some parts of the sector, there are clear signs that aircraft manufacturers have used the downturn to their advantage by taking on more risks and developing a new generation of products that will, they believe, encourage a faster rate of growth to return sooner, rather than later.

Preparing for Takeoff

The business jet sector has more international trade shows than almost any other group within the aerospace industry, with major exhibitions on every continent. All the mainstream aircraft companies are usually represented at such events as the U.S.-based NBAA, EBACE in Europe, LA BACE in Latin America, and Jet Expo in Russia. Other up and coming shows are now gaining popularity in Asia and the Middle East, and China has become a big new market, with as yet few indigenous products to compete with Western aircraft.

There is now an optimistic attitude developing after a gloomy period of relative sales stagnation, but it is not expected that a full recovery to pre-2008 levels of spending, when annual sales exceeded 1,300 aircraft, will be possible for a few years yet.

The large backlog of deliveries that built up during the 2008 crisis period helped manufacturers to maintain production in most cases, even if at a slowed-down monthly rate. According to aerospace forecasters Zenith Jet consultants, deliveries of new business jets between 2013 and 2022 should be around 9,400 units worth an estimated $253 billion in revenues.

By any measure, this is a sector with huge future potential. Zenith concludes that deliveries will grow at a 17% rate through to 2017, before leveling off again.

The new products offer improved economics, more environmentally friendly characteristics, greater comfort features, greater runway flexibility and accessibility, and extended range, al-

lowing more long-distance, nonstop journeys.

These advances create less noise and emissions pollution for a given number of aircraft movements and are more fuel efficient, so these gains are now demonstrating that the industry's environmental credentials are living up to the hopes expressed by the manufacturers in recent times.

Technology improvements are thus delivering results that refute the claims of more extreme voices that suggest business aviation is selfish, favors only the super-rich, and is destroying the planet. The reality is that today's newest business jets are amongst the least polluting means of transport in any domain, and have become an integral part of the wider economic infrastructure contributing to global wealth creation, not endangering it.

An interior view of the Embraer Lineage.

Embraer Legacy 500 cockpit with side-stick fly-by-wire controls, head-up display, and advanced touchscreen displays.

Robust Top-End Demand

The top end of the market sector is currently the area where most new program activity is taking place. It is forecast that over the next decade, 1,577 aircraft in this category of ultra-long-range business transports will be sold, worth a disproportionately high total of $95.8 billion.

Just under half the total will be destined for customers in North America, but the fastest growth rates will be coming from expanding customer demands from the Middle East, Asia, China, and Russia, where there are currently few suitable home-grown products to select. New civil aircraft such as the Sukhoi Superjet and Comac ARJ21, which have both suffered severe setbacks coming to market, are emerging in Russia and China as new transports. But although VIP government versions might be sold in small quantities, these aircraft are hardly competitive in open markets with Western long-range executive jet models such as the Boeing BBJ (based on the 737) and Airbus ACJ (based on the A318), or the expanding range of new aircraft from Gulfstream, Bombardier, and Embraer.

Bombardier is the market leader with new-model executive jets ranging from the super-light Learjet 70 and 75 nine-passenger aircraft, through the well-established Challenger mid-size family, including the new super-midsize Challenger 350, launched in May, and the recently launched top-of-the-range Global 6000, 7000, and 8000.

Each of these new aircraft features the very latest cockpit designs with advanced avionics suites including, in some models, adaptive LCD displays and synthetic vision systems. The Learjet 75 has a new Vision flight deck featuring Garmin 5000 cockpit displays, while the Challenger 350 has the Rockwell Collins Pro Line 21 advanced avionics suite with most of the previous features, plus a dual inertial reference system.

Powered by two Honeywell HTF7350 of 7,323 lb thrust, the 350 can fly eight passengers for 3,200 miles at a cruise height of 43,000 feet. The paperless cockpit and multiscan weather radar is aimed at both increasing situational awareness and reducing the pilot work-

Bombardier's Global 7000 interior.

Embraer's Phenom 100 in flight.

load. The Learjet 85, due for service next year, is in the mid-size category.

The new Challenger 350 follows on from the earlier 300 model, which has become a leader in its size range with over 400 aircraft sold. Fractional owner Netjets gave the new aircraft a big boost by ordering 75 as part of a larger 275 aircraft shopping spree with Bombardier worth $7.3 billion.

The Bombardier Global Series, now expanded from the original 5000 model to the 7000 and 8000 models, reflecting the ultra-long-range capabilities, offers high speed with generous cabin space and smooth operations at a cruising height of up to 50,000 feet. With lower operating costs than the adapted BBJ and ACJ corporate jets, the Global 7000 and 8000 have an identifiable segment of the top-end market almost to themselves, though for extra cabin volume, the Embraer Legacy family also now extends up to the corporate Lineage version of the EMB-70 aircraft, just one tier down from the BBJ and ACJ.

The Global's most direct competitor comes from Gulfstream in the form of the new G650, which is the largest member of the family. Gulfstream has been improving and refining its family of large executive jets over many years to remain competitive against the growing family of newer designs from Bombardier and Embraer.

Boeing is still pondering how best to adapt its new re-engined 737 Max commercial jetliner products to compete with the long-range Gulfstream G650 and Bombardier Global 7000. The new CFM Leap-1B high-efficiency engines on the Max will cut fuel costs and increase range, but the BBJ versions of Boeing's best-seller still come in at the heavy end of the executive market, and may get even heavier if modifications have to be made to extract a 7,000 nautical mile range capability. This might not be a problem for government customers wishing to use the aircraft as a VIP transport for state leaders and high-ranking officials, but it could struggle to match the economics of the purpose-built Gulfstream and Bombardier bizjets.

Exit and Entry

One of the most active manufacturers of medium-size bizjets was Hawker Beechcraft, but the company had to shed its business jet product line as a result of restructuring after a period in bankruptcy protection. The new Beechcraft is to concentrate on its popular twin-turboprop King Air and piston twin Baron aircraft. But there is no shortage of new business jets ready and waiting to step into the market gap left by Hawker's demise.

Embraer's new eight-seat Legacy 500 fills the mid-size role perfectly and is now engaged in certification flying prior to entering service in 2014. This will be followed by the Legacy 450, which is a super-light bizjet, with many common features and a very high-specification avionics system. This is due to enter service in 2015.

Cessna's highly successful Citation family comes in the mid-size and super-mid-size categories and the latest model, the Longitude, is due in 2017. The smaller Latitude is due to enter service in 2015. Before these two new-

comers, the company is about to introduce into service the Citation Soverign and Citation-X, both offering upgraded performance and interiors.

This year marked the 50th anniversary of France's Dassault Falcon family of business jets. The first of the breed was known originally as the Mystere 20. It used the wing and tail of the Dassault Mystere fighter, with a new ten-seat passenger cabin. The close affinity between Dassault's family of supersonic fighter jets and its Falcon family of business jets has resulted in the marque earning a reputation for high quality and advanced performance. This combination, along with highly innovative design features including digital controls, hi-tech cockpit displays, and advanced low-drag aerodynamics, has helped the company to deliver over 2,000 aircraft over the years, and they still represent sector leaders in terms of applied high technology.

The ground-breaking three-engine Falcon 7X model was not only the first major civil aircraft to be completely designed in a virtual environment using all-digital design tools and virtual modeling, but introduced fly-by-wire and side-stick controls to the executive aircraft market.

Continuous product development has resulted in the current Falcon family, comprising the Falcon 2000LX, 2000S, 900LX, and 7X, offering all-weather performance with an ability to operate from short rural or city-center runways, but with a nonstop intercontinental range of between 3,300 and nearly 6,000 nautical miles. Cruising at up to Mach 0.9, the aircraft can carry up to 16 passengers with an ability to fly direct nonstop sectors with maximum operating flexibility, thanks to the relatively slow approach speeds and short-field performance.

The EASy flight deck, developed with Honeywell in 2000, has subsequently been further developed with synthetic vision enhancements, and head-up displays add to the measures introduced to aid situational awareness. It is expected that Dassault will announce its next all-new Falcon product this year, a medium-size design known so far as simply the SMS.

Air-to-air portrait of Dassault Falcons.

An Embraer Legacy at Sharjah in the Gulf, an area of great market growth. (Gama Aviation)

Dassault's desire to make its products more environmentally friendly goes hand-in-hand with technical innovation that aims to lighten aircraft structures; simplify manufacturing and maintenance processes and procedures; and maximize gains from developing laminar flow aerodynamics, reducing drag, and increasing range and payload. The in-house military pedigree has so far resulted in aircraft that are both robust and mission-flexible.

Revival Due

The sector in the business jet market that has been hit hardest by the Western economic downturn has been that for very light jets (VLJs). Entry-level jets really began to take the market by storm around ten years ago as they introduced a whole new generation of operators to jet services, including individual owners who sought to upgrade from piston twins to something faster, but affordable.

Grumman Gulfstream family. (Richard Gardner)

A whole flock of startup companies entered the field, but many faded from view even before delivering the first production aircraft. Others are on hold awaiting an upturn in demand.

Embraer took a great risk by developing its all-new Phenom family, and although sales soon reached well into three-figure totals, the market crashed just as deliveries were running at a high level. Honda Aircraft also decided to go for the light end of the market for its first bizjet product, the Hondajet. In this case, however, it has been technical delays that have been the cause of a slowdown in the development and certification phases, and the aircraft is not now expected to enter service until late 2014 at the earliest, even though it is now undergoing flight test.

A light business jet that has a long established pedigree is the smallest in the Cessna Citation family. The original Citation CJ1 dates back to the 1980s, but the design has been steadily improved and evolved ever since. Under certification test flying at present is the latest iteration in the form of the Citation M2. This looks very similar from the outside, but its avionics suite is of a different order, being based around the latest Garmin G3000. This offers an integrated digital flight deck, with three 14" screens with multi-functionality, and touchscreen controllers. The advanced navigational capabilities greatly ease the pilot workload. Despite its compact size, the M2 can carry six passengers with a range of around 1,100 nautical miles.

Garmin and Honeywell dominate the avionics market for small, and not-so-small, business jets, but it can be claimed that the new electronic cockpit environment has contributed more than any other innovation in recent times to bringing the VLJ and light jet sector into the mainstream of commercial aviation, with clear and capable cockpit displays that considerably enhance air safety.

In the past, it is in the category of general aviation where more accidents have occurred than any other segment, and it is satisfying to know that the latest small jet and entry-level aircraft, thanks largely to their avionics systems, now offer a safer, not more hazardous, way of flying.

Managing Positioning Integrity

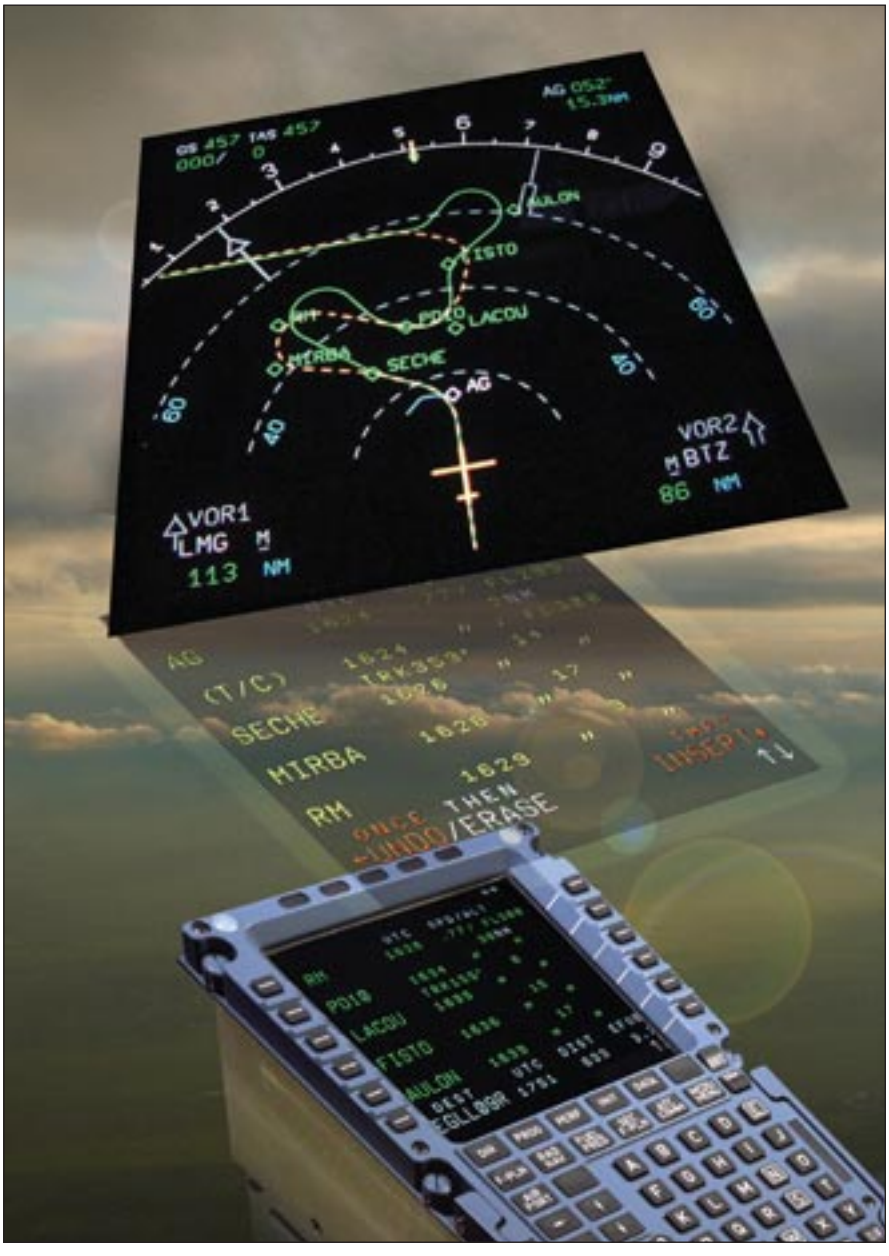
Thales has established a new reference system to comply with the most demanding RNP-AR navigation procedures.

In 2008, Thales launched the development of a new generation of inertial reference systems for civilian aircraft, TopFlight ADIRU (air data inertial reference unit). Thales embedded in the product its know-how relative to complex hybridization algorithms, its expertise in design and manufacturing of inertial sensors (gyrometers and accelerometers), and its ability to design and develop whole navigation systems.

TopFlight ADIRU is characterized by its RNP (required navigation performance) 0.075 100% worldwide availability and, therefore, contributes to significant increases of operational aircraft capabilities up to RNP 0.1 (kerosene consumption saving, optimal traffic management, and capability to access specific airports with low decision heights).

This operational capability is based on Thales' patented TIGHT algorithm, ensuring accuracy and integrity levels required to reach RNP 0.075 performance, as well as high-performance inertial sensors based on ring laser gyro technology and micromechanical accelerometers. TopFlight ADIRU is at the heart of RNP-AR (authorization required) performance, a highly demanding aeronautical navigation procedure. Thanks to its sophisticated multifilter hybridizations, it allows crews to maintain 100% availability and 100% worldwide RNP 0.1 capability.

In addition, it was Thales' goal to support design objectives higher than the current standards. TopFlight ADIRU allows the detection of hardware failures of connected equipment such as GPS/multimode receivers (MMR) or other ADIRUs, and to consequently reconfigure its hybridizations and position solutions. Futhermore, when integrated in a navigation system based on three TopFlight ADIRU and MMRs, a consolidated single position is provided for the entire aircraft systems.



RNP-AR Gains Ground

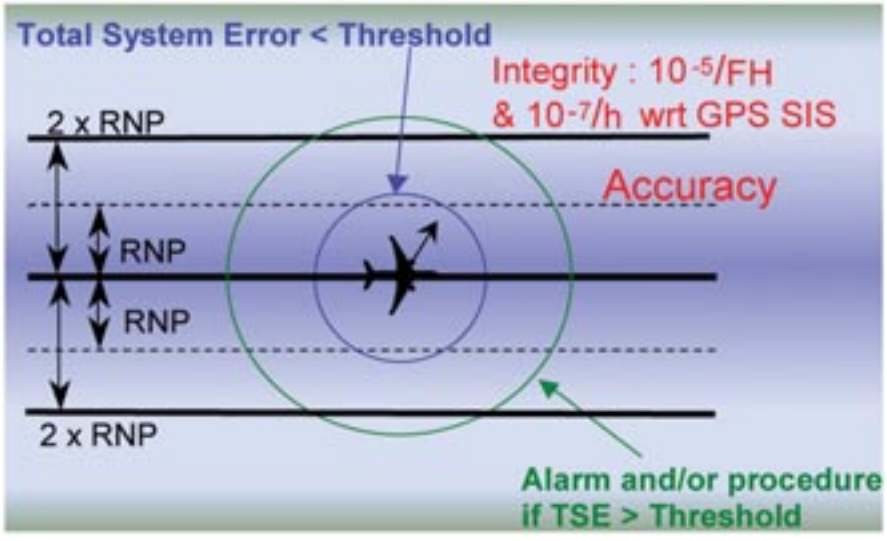
RNP-AR procedures were originally introduced by ICAO to allow aircraft to perform low-RNP approaches in bad weather conditions. This capability largely relies on the latest embedded civil aircraft navigation systems. Indeed, the use of satellite-based localization (GPS today, Galileo in the near future, hybridized with inertial data when the most stringent performance is required) allows the monitoring of aircraft positioning errors and the maintaining of position in a kind of tunnel, centered on a desired trajectory and bounded by limits that can be computed in a predictive manner as soon as trajectory, time, and day of flight are known.

Depending on considered operation and targeted decision height during approach, the tunnel may vary in width from ±0.3 nmi (RNP 0.3 operations) to ±0.1 nmi (RNP 0.1 operations).

To allow an aircraft to perform such an approach, it must be first guaranteed that the trajectory accuracy (95%) can be maintained within the tunnel limits.

It is also necessary to guarantee that the risk that aircraft position and guidance error exceeds twice the limit of the tunnel without any alarm can be raised (generally known as integrity limit) is lower than a rate generally fixed to values varying from 10-5/h to 10-7/h.

As mentioned earlier, RNP-AR operations were initially designed to allow aircraft to approach airports located in mountainous areas in bad weather conditions. They have generated significant economic benefits to companies by avoiding numerous flight cancellations.



A graphic representation of an RNP-AR procedure, which was originally introduced by ICAO to allow aircraft to perform low RNP approaches in bad weather conditions.

Furthermore, RNP-AR procedures allow optimizing approach trajectory to less demanding airports, thus generating significant reduction of fuel consumption and CO2 emissions. In some other cases, RNP-AR procedures allow for reduced noise nuisance in neighborhoods around airports. These last considerations are the key driver for current rapid development of new RNP-AR procedures.

As a consequence, to get RNP-AR capability, companies invest significant amounts of money to improve the avionics suite capability of already in-service aircraft. New generation aircraft include basic RNP-AR capability in their design.

Thales' TopFlight ADIRU (air data inertial reference unit), which allows crews to maintain 100% availability and 100% worldwide RNP 0.1 capability.

Global Technology Positioning

RNP-AR capability is not limited to the use of a satellite-based localization source. It globally generates constraints on cockpit display systems, flight management systems, localization systems, and autopilot. The answer to RNP-AR problems must be tightly coordinated between those different systems. Thales offers a global answer to RNP-AR problems in three key technical domains: avionics systems, air traffic management, and operational simulation.

Aircraft crews must be specifically trained to perform RNP approaches. The required level of training may be significantly reduced if the aircraft system is designed to be fail-op. In such a case, the system is designed to reconfigure automatically, without crew intervention, in case of failure. In that case, position for continuation or extraction of RNP procedure is automatically selected by aircraft systems.

In the RNP-AR context, embedded inside a redundant architecture, TopFlight ADIRU centralizes in unique equipment most major navigation functions previously split onboard aircraft. Due to this integration, TopFlight ADIRU contributes to increased safety and compactness.

In the objective to increase availability and safety, TopFlight ADIRU processing architecture is based on Thales' Core Software MACS2, derived from an integrated modular avionics solution, allowing full segregation (time and space) between operational functions. Applicative software and core software are developed in accordance with the RTCA-DO-178B Standard with Design Assurance Level (DAL) A. Hardware design is compliant with RTCA-DO254 DAL A.

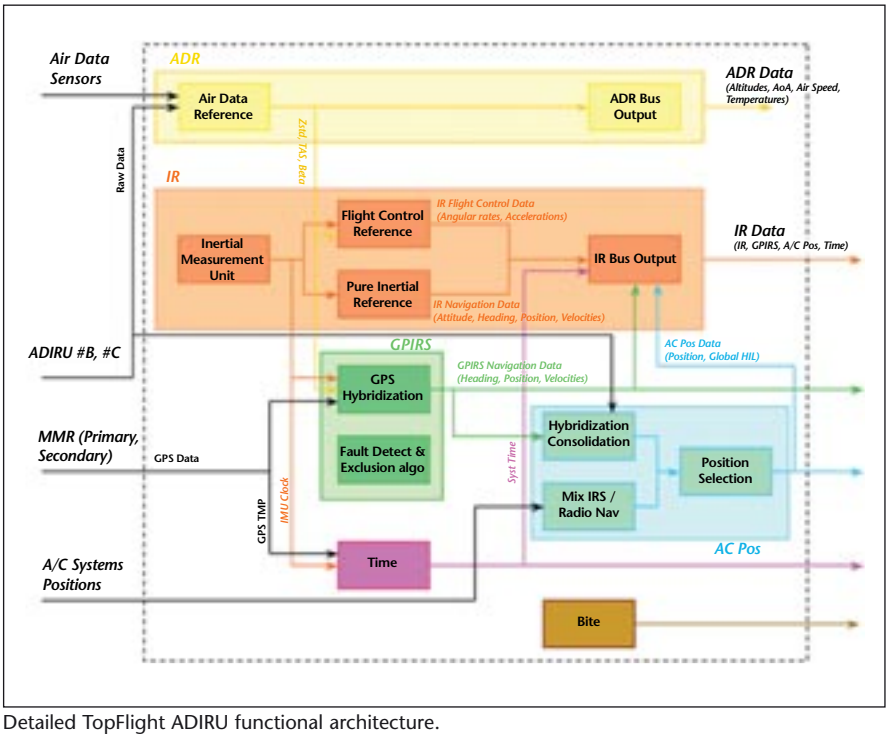
Air-data parameters (ARINC 706/738 standards: computed air speed, Mach, standard altitude, etc.) are computed from primary data provided to TopFlight ADIRU by various external probes installed on the aircraft fuselage.

TopFlight ADIRU provides an inertial primary reference and pure inertial localization solution (consistent with ARINC 738 standard: accelerations, angular rates, attitudes and true heading, position, velocity, baro-inertial altitude, etc.) from Thales inertial sensors embedded in the inertial measurement unit. Flight control data are computed through a dedicated channel, allowing very-high-frequency algorithms and therefore low latency, high noise reduction, and dedicated bandwidth.

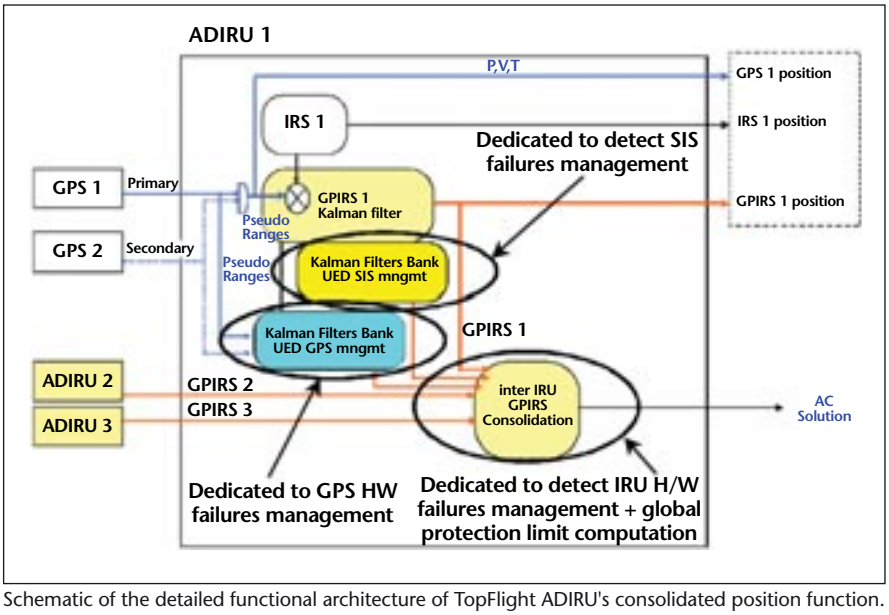
TopFlight computes a hybrid localization solution built from pure inertial data and GPS data. This solution (Thales-patented TIGHT algorithms) includes a protection limit that protects the solution vs. an undetected GPS signal-in-space failure with a high level of integrity. When satellite redundancy is sufficient, the FDE (fault detection and exclusion) algorithm excludes the faulty satellite measurement, if any.

When an aircraft is on the ground, complementary algorithms improve the accuracy and integrity of a hybrid localization solution through dedicated management of multipath impact on the GPS signals and, therefore, reinforce safety levels of aircraft navigation on the ground.

Another function consolidates positioning solutions provided by the different sensors onboard the aircraft, such as other ADIRUs or GPS functions (pro-



Detailed TopFlight ADIRU functional architecture.



Schematic of the detailed functional architecture of TopFlight ADIRU's consolidated position function.

vided by MMR on some aircraft systems). TopFlight introduces a significant step ahead regarding hybrid position (also known as GPIRS position) integrity management. Indeed, algorithms compute in real time a horizontal protection limit associated with an integrity level equal to 10-7/h that protects GPIRS position vs.:

- Signal-in-space undetected erroneous data (UED) effects (used in previous civilian inertial product generation), and
- Embedded hardware failures that could lead to UED. Protection is ensured regarding GPS receivers as well as TopFlight ADIRU (protection specifically added to increase safety level).

This last capability exploits the hardware redundancy (GPS receiver and TopFlight ADIRU) onboard the aircraft.

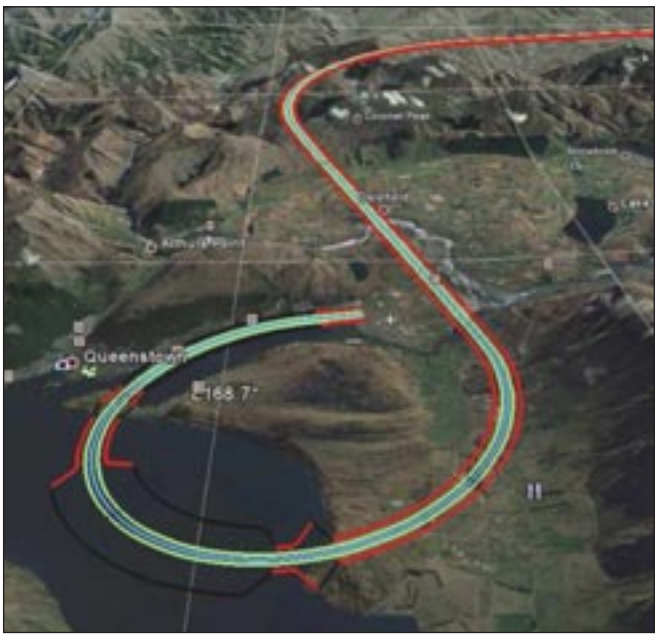
Designing Out Failure

Thales Topflight ADIRU guarantees 100% worldwide availability of RNP AR 0.1 at aircraft level with conditions defined in RTCA-DO-229D standard Appendix R (identical to RTCA-DO-316 Appendix R). In particular, demonstration takes into account the worst-case constellation; that is the Martinez constellation with no satellite masking during the approach, except the usual 5° angle masking.

In addition, if a failure is detected in real time, dedicated algorithms automatically (without crew intervention) perform exclusion of the failed component and reconfigure position on a safe solution. If the redundancy (signal-in-space or embedded hardware, depending on the type of failure that has been identified) is not sufficient to perform exclusion, the function automatically extracts a position with the required accuracy, including the effect of the failure. This can be used by the aircraft to perform a safe extraction from RNP-AR procedure.

TopFlight ADIRU provides aircraft with a time reference computed from GPS data received from MMR and its own internal clock. A built-in test function performs monitoring of TopFlight internal functions and of connected equipment data (MMR, probes) to reach a high level of safety through a low UED rate and high failure coverage.

With three decades of research and development efforts to its credit in this field, Thales claims to be the only company to have developed a high-performance, three-axis ring laser gyro solution combining into a single sensor with evident advantages in terms of compactness, reliability, and cost (minimizing the number of optical and mechanical parts). Originally developed for military and space applications (fighter, cargo, launcher), the PIXYZ-22 ring laser gyro has been upgraded to take into account constraints of civil applications (life du-



An example of RNP prediction is given for a Queenstown approach. In red, pure GPS HIL when available (GPS HIL < HAL); in black, pure GPS HIL when not available (HIL > HAL) due to terrain masking; in green, GPIRS HIL (always available); in blue, desired path. It is also possible to check the value of exclusion limit that is the maximum GPIRS position error before a potential UED can be excluded. This capability is particularly useful if full failed operational capability is required by the company.

ration, reliability, export control).

For full operational benefit of the RNP-AR capability, an aircraft operator needs to be certain of the availability at its arrival airport.

Thales' RNP performance prediction tool provides 100% availability of RNP-AR 0.1 in the worst GNSS constellation scenarios, but for some very specific airports, terrain masking needs to be taken into account.

If satellite terrain masking is forecast for a significant duration period, Thales has developed a ground-based tool able to predict the value of hybrid HIL (horizontal integrity limit) taking into account:

- Aircraft trajectory issued from the flight plan,
- YUMA (current constellation) or Martinez constellation (defined in RTCA-DO229-D Standard Appendix R), and
- Terrain database defining masking.

Because of this tool, it is possible to carefully check the availability of GPIRS position before performing the most demanding RNP-AR approach with severe terrain masking.

On the basis of technologies developed for TopFlight ADIRU, Thales is currently proposing new inertial products for military applications, characterized by very high pure inertial performance and dedicated operational functions such as stored heading alignment or in-flight alignment, along with the compliance to stringent certification standards.

This article is based on SAE technical paper 2013-01-2139 by Didier Portal, Jacques Coatantiec, and Pierre-Jerome Clemenceau, Thales Avionics.