Innovative cables and cabling solutions for next-generation Aerospace

Aerospace White Paper

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June 2015

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Synopsis

This report is intended to give a general overview of the global aerospace market and provide information about how Nexans is continuing to introduce new products, solutions and services to serve that market.

It opens with a broad description of the world Aerospace industry, explains some general trends for both commercial airlines and defense, introduces the major players and newcomers, and outlines the challenges in two widely differing areas.

Then the paper examines in detail a series of current trends that have a symbiotic relationship to cables and cable solutions. At times, these trends prompt innovation in cable development, design and processes; at other times, cable solutions empower the aerospace industry to meet its chosen strategic and commercial targets, always with the ultimate users, including flight crews and passengers, in mind. This section concludes with a list what is expected from a cable manufacturer.

The third section explains Nexans' integrated products and solutions for both the commercial and defense markets, focuses on several specific products and solutions to meet the trends outlined in section two, lists the current aviation standards being met, and explains Nexans dedicated aerospace services.

Finally, it concludes with a brief review of Nexans major aerospace achievements, and in the Appendix lists some headlines, milestones, projects and awards.

INTRODUCTION: INNOVATING WITHIN COST

"This industry is quite incredible. It is not just because there is something a bit magical about flying, it is also the fact that, contrary to all other great industries, and despite crises which shake it up periodically, it has still not fully integrated the simple principle of profitability."

Pierre Jeanniot,
President and CEO of Air Canada (1984-90)
Director General Emeritus of IATA

"During the past year, we are seeing something quite new. Our customers still demand quality, but they want design-to-cost and supply chain efficiency; and innovation has to pass via cost savings."

Dominique Dhenin
Key Account Manager for Airbus, Nexans

It is significant that the history of transportation reflects the symbolic table of the four elements: earth, water, air and fire.

In its primitive beginnings, mankind had to contend with and master both earth and water, and via a series of successive evolutions and technological innovations we went from foot, wheel, horse, cart, steam locomotive and automobile to their sophisticated contemporary counterparts: High Speed Rail (HSR), Formula-1 racing cars, and e-vehicles. Similarly, the raft, canoe, sailboat, steamboat, and ocean liner have evolved into mega-sized container ships, cruise liners, naval frigates and nuclear submarines.

Since the beginning of the 20th century, we are now definitely in the age of air and fire – the Age of Ariel – which accurately describes the aerospace industry, combining commercial aviation, cargo transport, humanitarian services, military might, and the future challenges of outer space.

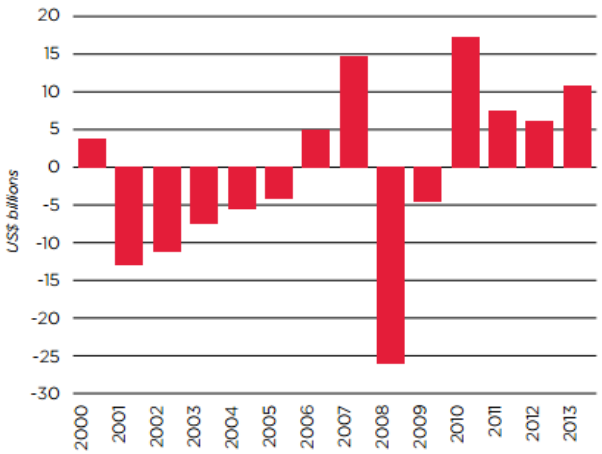
The overall global aerospace and defense (A&D) industry is now poised to grow by some 3% in 2015, largely due to the rising fortunes of the commercial aerospace sector.[1] Aerospace is not just another industry. Taken in all of its multiple facets, it is now the world's leading industry *par excellence*.

General trends: commercial aircraft

In the commercial airline sector, according to the International Air Transport Association's (IATA's) 2014 Annual Review, there are nearly 1,400 airlines worldwide operating a global fleet of over 25,000 aircraft, serving 4,000 international airports. Every day, 8.6 million passengers are carried, and 100,000 flights are made.[2]

[1] See: http://www2.deloitte.com/content/dam/Deloitte/global/Documents/Manufacturing/gx-mnfg-2015-global-a-and-d-outlook.pdf
[2] For these and following statistics, consult: http://www.iata.org/about/Documents/iata-annual-review-2014.pdf

Moreover, the wind has changed concerning profitability. After a disastrous period during the global recession that began in 2008-9, airlines are back in the black. Net post-tax profit for 2013 was $10.6 billion (€9.5 billion), which was the fourth successive year of profitability. This was largely achieved by increased demand, restructuring and lower fuel costs. Fuel continues to be the largest expense for airlines, accounting for some 31% of airline costs.



Industry net profit (sources: IATA, ICAO)

In addition, demand for cargo and passenger services – measured in freight tonne kilometers (FTKs) and in revenue passenger kilometers (RPKs) – increased, in keeping with a rebounding global economy and trade. Aviation is still responsible for 35% of world trade by value, worth some $17.5 billion (€15.7 billion) every day.

Travel to and from emerging economies has even outperformed mature markets due to price drops in airline fares and increasing competition. Although passenger loads are up (at 80%), cargo load facts are still hovering around the 50% mark. All the same, according to the Air Transport Action Group (ATAG), "air transport supports $2.4 trillion (€2.1 trillion) in economic activity and 58 million jobs globally." An extraordinary achievement![3]

For commercial airlines, the top priority is still safety, especially after some dramatic and tragic "hull losses" in 2014-5, although commercial flight passengers have the lowest risk of death, with 0.1 fatalities per billion kilometers, compared to 0.15 for trains, and 0.45 for buses and coaches. In relation to this, automobile fatalities are astronomical, ranging from 3.3 (Norway) to 55.9 (Brazil).[4]

Other prime concerns for airlines are operating costs and sustainability. The industry is dedicated to improving fleet fuel efficiency 1.5% per year until 2020 (largely through new and improved engine designs and biofuels); and by 2050, it is committed to reducing its net carbon footprint by 50% (compared to 2005). Moreover, OEMs are also drastically cutting disruptive takeoff and landing noise levels through new engine and fuselage designs.

[3] For more details, see: https://www.iaa.ie/media/aviationbenefitsbeyondborde.pdf
[4] See: the Guardian newspaper at http://www.theguardian.com/news/datablog/2013/jul/25/how-safe-are-europe-railways in addition to WHO statistics in: http://en.wikipedia.org/wiki/List_of_countries_by_traffic-related_death_rate

Some key points to bear in mind concerning commercial airlines[5]:

- Emerging economies (India, China, the Middle East, and other Asia-Pacific countries) are driving leisure, business travel and freight
- Passenger travel is expected to increase 5% yearly
- By 2025, commercial aircraft annual production is set to increase by 20%
- New global OEMs are bound to upset the existing major duopoly (Boeing/Airbus) and their supply chains
- Innovation is focused on operational savings, fuel efficiency, maintenance, and passenger comfort
- Active OEMs will dramatically increase the rate of production of components, systems and services (and will expect very competitive pricing)

General trends: defense

Although the US spends by far the most on defense, with 39% of total global spend, overall defense spending is declining, due to wind-downs in certain asymmetrical battle zones. However, the UAE, Saudi Arabia, India, South Korea, Japan, China and Russia are continuing to acquire advanced military hardware. Nevertheless, a downward decline is anticipated for the world's top tier defense companies of some 1.3%.[6]

According to Strategy& (formerly Booz & Company):

> The outlook for defense contractors is clouded by many uncertainties: constrained military budgets, new and changing requirements, technology advances, and competition from nontraditional rivals. The US Department of Defense is retooling its war-fighting capabilities with an increasing focus on affordability. Consequently, defense firms need to alter their focus from exquisite systems to innovative equipment that grows out of existing product lines. New, asymmetric competitors are also putting pressure on legacy players to speed up development timelines and reduce costs. Consequently, for defense companies, success will depend on doing many things well, simultaneously.[7]

Major players and the newcomers

The major players are still Boeing and Airbus (the former largely supported by NASA and the latter supported by organizations like the European Aviation Safety Agency). As everyone knows, these giants build jumbo jets (wide bodied, double-aisle aircraft), but they also build a whole range of smaller aircraft, including single-aisle regional aircraft, business jets, and helicopters, etc.)

[5] Derived from the Deloitte 2015 Report mentioned in footnote 1.
[6] Ibid.
[7] From "Aerospace and Defense Trends" by Strategy& at:
http://www.strategyand.pwc.com/perspectives/2015-aerospace-defense-trends

They are followed by Brazil's Embraer and Canada's Bombardier, who are largely involved in single-aisle aircraft for regional or short-haul flights, business jets and serve other specialized market segments. However, they are occasionally competing with Boeing and Airbus when their passenger capacity exceeds 150 persons.

The Russian state-owned United Aircraft Corporation (once Tupolev, Irkut, and Sukhoi, etc.) and the Antonov State Company in Ukraine still remain a bit of a riddle wrapped in an enigma. However, UAC delivered 95 fixed-wing aircraft to customers in 2009 and has produced over 140 helicopters, while Antonov (traditionally a builder of large aircraft) produced the Antonov An-148/158, a new regional airliner with a twin-turbofan configuration; over 150 have been ordered since 2007.

The real current newcomer is China, with the commercial COMAC program, which is mobilizing resources to produce a single-aisle jetliner called the C919. It is still relatively new and inexperienced in a complex and mature high-tech industry. However, a country with an incredibly high GDP and with passenger traffic growing by 11% per year is well-positioned to make some important breakthroughs.

Commercial air challenges in an expanding market

- Enhance the "soft product" to create a positive customer experience
- Process and analyze mega-billions of data bits provided by high-resolution optics, communication sensing and other multispectral sensors
- Lower fuel costs and increase operational efficiency
- Innovate intelligently and cost-effectively
- Reduce downtime and improve overall airline performance
- Transmit key parameters to maintenance while in the air
- Decrease production costs through automation, robotics and computer-assisted design, and lower life cycle costs

Defense air challenges in a budget-constrained declining market

- Implement next-generation Intelligence, Surveillance and Reconnaissance systems (ISR)
- Promote faster product development and leaner production
- Partner more closely with customers and suppliers
- Overcome asymmetrical and unconventional threats
- Meet competition from non-traditional defense manufacturers
- Eliminate inferior and counterfeit products from the supply chain
- Develop new unmanned platforms

CABLE-RELATED AEROSPACE TRENDS

As indicated earlier, long-term forecasts for commercial aerospace predict yearly growth of 3 percent over the next years, driven by increasing demand in Asia, the Middle East and South America.

Even though fuel costs have fallen, the quest for profitability, the pressure from low-cost carriers, tougher regulations on noise and greenhouse gas emissions are forcing all operators to use lighter more energy-efficient aircraft, while improving In-Flight Entertainment (IFE) systems to enrich the air travel experience.

Aircraft designers have also increasingly replaced mechanical and hydraulic systems with electrical systems (fly-by-wire) causing the amount of electrical power carried by the aircraft Electrical Wire & Interconnect System (EWIS) to almost double. And engines are undergoing significant upgrades which are generating revolutionary aerodynamic design changes.

Defense aerospace has seen a similar shift towards next-generation platforms: a move to all-electrical systems, full computerization (leading to a dramatic increase of the amount of data carried), and a transition to all-composite airframes requiring more shielded cables.

Now, let us explore some of these important trends in greater detail.

1. Lighter weight and fuel-efficiency

Since jet fuel continues to be the largest number in the airline debit column, accounting for some 30% of airline costs[8], it comes as no surprise to learn that for airlines weight is money. The heavier a plane is, the more fuel it takes to fly it, and the more it costs.

Profitability is thus based on a complex tradeoff between heavier-than-air weight, fuel-efficiency, engine efficiency, materials science and the latest improvements in aerodynamic performance. Moving away from using aluminum in airframes, wings, trailing edges and other flight surfaces is one reason that manufacturers are replacing it with lightweight carbon fiber composites on planes like Boeing's 787 Dreamliner and Airbus's A350. Composites also provide a smooth finish for components and thus less drag, and open the way to manufacturing techniques whereby multiple single parts can be molded together at the same time, saving manufacturing time and money.

Ironically, structural composites got their start in aerospace, but they are prevalent today in cars, buses, trams, and trains, driven by a demand for low costs and higher

[8] According to IATA Annual Review 2014.

production rates. However, increasingly, aircraft manufactures are taking a leaf out of the book of carmakers who have proven that composites can meet new design challenges in terms of aerodynamics, packaging, structural stiffness and crashworthiness.[9]

According to Colin Sirett, Head of Research at Airbus UK: "Each kilogram cut means a saving of roughly $1 million (€900,000) in costs over the lifetime of an aircraft, and the use of such composites can reduce the weight of an aircraft by up to 20%."[10]

© AIRBUS S.A.S. 2011 photo by e.m. company/ H. Gousse

In addition, an EU-funded research effort has improved carbon nanotubes to create exceptionally strong, lightweight and cost-effective materials for aircraft parts, further reducing the fuel burn. According to Emmanuel Detaille of Coexpair in Belgium:

> Around 998 million passengers travelled by plane in 2010, compared to 262 million in 1989. In 2008, 25 million tonnes of kerosene were consumed for intra-European flights alone. We wanted to provide an effective answer to the issue of global energy by proposing technologies to decrease an airplane's total weight and thus fuel consumption.[11]

Another positive is that a great advantage of using carbon fiber instead of traditional aluminum is that it allows designers to find the ideal "equation" to resolve the demands of aerodynamic efficiency, fuel savings and reducing engine noise (which we will see below has ramifications for travel sustainability and long-term environmental concerns).

As with certain blended fuselage-wing designs in Stealth bombers, tomorrow's airliners will find ways to improve a plane's lift-to-drag ratio and reduce its overall weight, as it moves away from the current winged-tube design.

Already, new aircraft are 70% more fuel efficient than 40 years ago, and 20% better than 10 years ago; as clearly stated in the IATA Technology Roadmap:

LESS FUEL = LESS EMISSIONS[12]

Among other recent developments in weight reduction are a new titanium-making process that could reduce the multiple steps and high temperatures used in its production. Titanium powder (instead of ingots) could then be pressed into final aerodynamic forms with little machining. The lightweight, corrosion-resistant material

[9] Consult: http://aviationweek.com/technology/automotive-industry-embraces-composites-can-aerospace-benefit
[10] See BBC News' "Carbon fiber planes: Lighter and stronger by design" at http://www.bbc.com/news/business-25833264
[11] See: https://ec.europa.eu/programmes/horizon2020/en/news/lighter-and-stronger-materials-greener-aircraft
[12] For a brief sketch, see: http://www.iata.org/whatwedo/ops-infra/Pages/fuel-efficiency.aspx

is also ideal for certain engine parts, like fan blades, and seamlessly merges with carbon composites, unlike aluminum.[13]

Moreover, new research is being done on protecting wing leading edges from the laminar flow-destroying effect of residue left by insect strikes, as well as improving the performance of the tail through active flow control (AFC). By using "bug-phobic" coatings to increase natural laminar flow on an aircraft wing, fuel burn could be improved by as much as 15%, while AFC could lead to a 17% reduction in tail size, which would reduce drag and weight, cutting as much as 2% in fuel burn.[14]

All of the above efforts to lighten passenger aircraft draw on sophisticated engineering, process and materials science capabilities in at least a dozen different disciplines.

However, apart from these many initiatives to save weight on aircraft, one important component – largely metallic – is hidden out of sight: cables. According to model, size, passenger capacity and specifications, every airliner contains from 200 to 600 km of cables interconnecting vital equipment throughout the airplane.

They provide everything from power, data, sensor information, flight management control, avionics, and communications to overhead and emergency lighting and in-flight entertainment. The challenge is how to make lighter-weight cable designs to meet every airborne need, with no compromise on safety, performance and reliability.

2. Need to boost electrical power onboard

To understand the tremendous advances in onboard aircraft electrical power, one does not have to go back hundreds of years, but simply to the Wright Brothers and Kitty Hawk in 1903, just over a century ago. The only electrical components back then were used to start the small engine:

> The engine was started by priming each cylinder with a few drops of raw gas. The ignition was the make-and-break type. No spark plugs. The spark made by the opening was an ordinary single-throw knife switch bought at a hardware store. Dry batteries were used for starting the engine, and then we switched onto a magneto bought from the Dayton Electric Company. There was no battery on the plane.[15]

A single pilot flew in a forward direction for 260 meters in 59 seconds. Today's jetliners can carry over 300 passengers some 16,000 km, a third of the way around the Earth. The single spark for engine ignition has been transformed into a highly engineered electrical architecture with redundant systems that make modern air transportation possible.

As larger aircraft flew higher, farther, and faster, power supplies grew more complex for aircraft flight instruments and passenger services, including galley units, lighting systems, heating, and passenger services. Aircraft electrical components operate on many different voltages both AC and DC. However, most systems use 115 volts AC at

[13] Consult: http://www.technologyreview.com/news/535386/new-titanium-making-process-could-result-in-lighter-aircraft/
[14] See : http://aviationweek.com/technology/757-ecodemo-focuses-laminar-and-active-flow
[15] For a report on the electrical technicalities of the first powered flight, consult http://www.wright-brothers.org/Information_Desk/Just_the_Facts/Engines_&_Props/1903_Engine.htm

400 hertz or 28 volts DC. Running at 400z allows the use of smaller transformers, which is another important weight saver.

Traditionally, generators were driven by the engines to create electricity, and pneumatic systems "bled" air off the engines to power other systems, like hydraulics. However the latest airborne electronic systems use electricity directly to power hydraulics, engine start and wing ice protection. By using more generators on engines, and auxiliary power units (APUs) in the tail, recent designs can greatly reduce wiring. In the case of the Boeing 787 this led to 32 km less wiring, with significant weight savings.[16]

In power terms, hybrid battery-powered airplanes are already on the horizon. Boeing foresees a hybrid airplane the size of a 737 which could seat 150 passengers by 2030, while the Airbus Group has already developed a conceptual design for passenger airplanes that fly exclusively on electricity, although their range would be limited to relatively short regional hops.[17]

Meanwhile, General Electric has developed the "Sugar Volt" hybrid turbofan which runs on both jet fuel and batteries for Boeing; and Rolls-Royce is working on "E-Thrust" for the Distributed Electrical Aerospace Propulsion (DEAP) project for Airbus. According to Rolls' Global Head of Electrical Power and Control Systems:

Electric propulsion works when you do not sit at one design point. It would not work for a long-haul twin-aisle, any more than it would for a container ship. But for regional airliners, 100-seaters, short-takeoff-and-landing aircraft and helicopters, it could work well.[18]

Research suggests that hybrid electric propulsion will generate lower emissions and be quieter, while conserving energy and releasing less heat into the atmosphere. Electrical systems are expected to be more reliable than conventional turbines. But integrating slow-responding gas turbines with fast-acting power electronics and motors will pose a major challenge.

Current and future technical advances like these have had, and will continue to have, a tremendous impact on cable materials and designs, which have in turn facilitated new airplane architectures and easier and quicker installation. This has required thinner insulations, the increased use of aluminum for general purpose wires, cables that can endure much higher temperatures in hot engine zones, or offer higher working voltages.

3. Higher data capacity for flight operations and in-flight entertainment (IFE)

If higher fuel-efficiency and more onboard electrical power are prime concerns for the aerospace industry, the third related trend is more data onboard, and this concerns every aspect of flight operations, including avionics. Avionic systems include

[16] See: http://787updates.newairplane.com/787-Electrical-Systems/787-Electrical-System
[17] MIT Technology Review: "Once a Joke, Battery-Powered Airplanes Are Nearing Reality" at http://www.technologyreview.com/news/516576/once-a-joke-battery-powered-airplanes-are-nearing-reality/
[18] For a detailed description of ongoing developments, see Aviation Week's excellent overview, "Aviation Pursues Hybrid Electric Propulsion": http://aviationweek.com/technology/aviation-pursues-hybrid-electric-propulsion

communications, navigation, the display and management of multiple systems, and the hundreds of systems that are fitted to aircraft to perform individual functions.

The latest aircraft are constantly generating several hundred thousand parameters for collecting and analyzing data, and for spotting problems. Airlines are turning to IT solutions to improve operational efficiency, decrease costs and enhance safety. For electronic documents and charts, heavy electronic flight bags (EFBs) have been used for decades. However, when American Airlines became the first US carrier to obtain FAA approval to use iPads for all phases of flight in 2012, other airlines followed suit. Available applications include airport moving maps, satellite weather, electronic technical logs, route profile optimization for fuel saving and electronic document and static charts.[19]

However, portable devices cannot be used to run applications that pilots use to communicate with controllers via data link or navigating the aircraft, which must still be handled by high-end EFBs, meaning that NextGen systems will be a mix of installed and portable devices. One solution is to future-proof EFBs with Aircraft Information Servers so that tablets can "mimic" EFB functions, like charting, electronic documentation, en route real-time weather maps, terrain awareness, camera surveillance, and aircraft data monitoring and reporting.

According to a recent Boeing report "improved connectivity" onboard will allow a substantial improvement in flight operations, maintenance, safety and customer service:

> Pilots [can] quickly upload the latest navigation charts to their devices and monitor weather in flight, adjust flight plans to optimize fuel use, use moving runway and taxiway maps for improved situational awareness, and use a wide variety of applications to improve crew productivity and enhance safety. Cabin crew members use mobile devices with in-flight connectivity for onboard sales (including verification of credit cards to eliminate fraud), passenger services, and crew communication and to access crew reporting tools.[20]

Also, the increasing use of personal electronic devices by passengers, including laptops, tablets and e-readers is enriching the travel experience, while at the same time allowing airlines to eliminate costly and weighty entertainment systems. In the democratic digital age, it is highly likely that the next step will be to empower the passenger to create his/her own entertainment by making available in-seat digital services like WIFI, broadband, satellite connections, Twitter, Facebook, texting, etc.

As with advanced avionics and flight operations this increase of data onboard requires significant improvements in broadband data capacity, and once again this brings us back to high-end cable solutions, often requiring optical fiber replacement of the copper network for what is virtually a flying Local Area Network (LAN).

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[19] For a state-of-the-art explanation see: http://aviationweek.com/aftermarket-solutions/next-generation-efbs-integral-nextgen-cockpit

[20] From Boeing's "Current Market Outlook 2014-33": http://www.boeing.com/assets/pdf/commercial/cmo/pdf/Boeing_Current_Market_Outlook_2014.pdf
* Note that these figures can vary significantly from year to year.

4. Operational Safety

Although flying has a well-established reputation for safety compared to other modes of travel, "fear of flying" seems to be a real concern, largely due to the dramatic nature of airline crashes and the way they are reported in the media. In terms of deaths per billion kilometers, air travel is exceptionally safe*:

Air:	0.05
Bus:	0.4
Rail:	0.6
Vessel:	2.6
Car:	3.1
Bicycle:	44.6
Foot:	54.2
Motorcycle:	108.0

Put in another way: during 6 out of 10 years since 2004, airline deaths were significantly below 1,000 annually worldwide; while in 2010 alone, there were 1.24 million deaths on the world's roads. Nevertheless, the aerospace industry has continued to improve its record by a series of improvements through design, engineering, navigation aids, safety protocols and procedures.

Safety issues are omnipresent in aerospace and concern manufacturers, operators, pilots and passengers. However three important trends are extremely relevant to cables: fire and toxicity, synthetic vision in the cockpit, and overall airplane health management, which concerns maintenance.

a. Fire and toxicity

In the early eighties, two dramatic fires occurred which had an impact on the industry: Air Canada Flight 797 (1983) which resulted in death by smoke inhalation and flash burns to 23 passengers in an emergency landing in Cincinnati; and the British Airtours Flight 28M accident in Manchester, England (1985), when a take-off was aborted, resulting in the loss of 54 lives. Both tragedies raised the question of "survivability."

The Air Canada in-flight fire spread between the outer skin and inner door panels, filling the plane with smoke. The fire also burned through crucial electric cables that knocked out most of the instrumentation in the cockpit and key electrical systems, making descent physically difficult for the pilot. In addition the Public Address (PA) system failed, hampering communication to passengers. The Manchester flight was aborted due to port engine failure, which generated fire and smoke that seeped into the fuselage.

As a result of these accidents, aviation regulations around the world were changed, requiring smoke detectors in lavatories, automatic fire extinguishers, in-cabin fire enhancements, fire-blocking seat materials, emergency track lighting, etc.

"Survivability" also impacted aircraft cabling standards, since one possible cause of fires in airplanes is wiring problems that involve intermittent faults, such as wires with breached insulation touching each other, electric arcing (flashover), or short circuits.

b. Synthetic Vision Systems (SVS)

Since 2003, loss of control has been highlighted as the major cause of fatal accidents. To remedy this, Synthetic Vision Systems (SVS) offering "virtual reality" will be increasingly deployed in commercial flight decks within the next five years. Already, Airbus, Boeing, Bombardier and Embraer have committed themselves to the new systems in primary flight displays on new-build aircraft by 2018.[21]

Synthetic Vision gives a 3-D clear sky picture of runways, terrain and obstacles on the flight path ahead. It has already been widely available in business jet displays, but has not yet been installed in the cockpits of modern jetliners. SVS also includes "optical flow" which artificially mimics aircraft movement and energy awareness cues, including a flight path vector, flight path acceleration and speed error indicator that would eliminate loss-of-control accidents.

Looking even further ahead, a Synthetic Vision System (SVS) is very likely to be an integral part of a sophisticated Combined Vision System or CVS which fuses several vision inputs depending on the phase of flight.

Evolving systems like SVS and CVS confirm the need for more data capacity in tomorrow's airplane, which means light and reliable cables, Wifi capability, and a host of data, communication and sensor cables of all kinds. When it comes to flight safety, the right cables provide an imperative "nervous system" to heighten awareness, detect danger, and enable appropriate intervention.

According to the Commercial Aviation Safety Team (CAST) new systems like these, once widely installed in the global airline fleet, could eventually reduce loss-of-control risk by some 73%.

c. Airplane Health Monitoring (AHM)

Onboard data analytics are also going to revolutionize aircraft maintenance, which has traditionally been "by the book," via timely and periodic A,B,C and D checks under the guidance and approval of the FAA, Transport Canada or the European Aviation Safety Agency (EASA).

Technological advances and massive global fleet renewal by 2025 will completely reshape the Maintenance, Repair and Overhaul (MRO) business. More onboard data will power predictive maintenance to minimize unplanned work on next-generation aircraft.[22]

With aircraft like the Airbus A350 generating hundreds of thousands of parameters, with the right software they can be processed and analyzed to spot problems before they lead to service disruption, or even worse.

> Airbus is already scratching the surface with it real-time health monitoring service, available for the A380 and A350 and being tested on the AS330. Far more than

[21] For details, consult "Airbus, Boeing Set Sights On Synthetic Vision" in *Aviation Week's* 4 May 2015 issue: http://aviationweek.com/commercial-aviation/airbus-boeing-set-sights-synthetic-vision and http://aviationweek.com/business-aviation/regulators-market-determine-fate-synthetic-vision-guidance-systems

[22] See "MRO Bracing For A New, Data-Driven Future" at: http://aviationweek.com/commercial-aviation/mro-bracing-new-data-driven-future on which this brief section was based.

> pushing status information to the ground in real-time, Airbus uses onboard communications functionality to query sophisticated computers […] to obtain specific parameters related to a fault. The data help the manufacturer's around-the-clock technical support team get to the root of an issue and, working with the carrier's maintenance control center, determine what to do.

Data is thus rapidly becoming the primary driver of maintenance programs, and onboard wires and cables are key to this information highroad that is bound to redistribute the total MRO spend, estimated to reach $100 billion by 2025.

Already, engine manufacturers (our next trend) have gained a larger share of the aftermarket with guaranteed service agreements, by using AHM to know exactly when their engines will need overhaul.

5. Lighter, more reliable and powerful engines

If data are the brains of the aerospace business, engines are often the real drivers of change. Halfway through the millennium's second decade aerospace stands at a turning point. Order books for lighter, better and more fuel-efficient engines are at record highs.

According to a recent 2015 overview, we will soon see a generational change across the board from nearly all manufacturers:

> In addition to the fuel-efficient CFM Leap-1 and Pratt & Whitney PW1000G geared turbofan on the new narrowbodies, the next step in high-performance engines will fly on new large business jets in 2015: General Electric's Passport on the Bombardier Global 7000, Snecma's Silvercrest on the Dassault Falcon 5X, and Pratt & Whitney Canada's PW800 on the Gulfstream G500.[23]

Note that the Leap engines are currently being flight-tested for the Airbus A320neo, Comac's C919 and Boeing's 737 Max. And this is happening while CFM International already has a backlog of 12,000 powerplants for its current CFM56![24]

In the military sector, there is also a move towards turboshafts for helicopters and adaptive-cycle engines for fighters that combine high power with fuel efficiency. The goals are higher performance with around 30% lower fuel burn.

In other developments, Rolls-Royce is continuing to develop a new series of large turbofans for jumbo jets for the next decade and beyond. Buoyed by growing volumes of business in the widebody airliner market with its three-shaft Trent engine family, it continues to ramp-up to support expanding fleets of Trent 1000-powered Boeing 787s and XWB-powered Airbus A350s.

Rolls' new Advance, which is planned to go into service in 2020, will have a 20% better burn level than the current Trent 700 and have weight savings of 750 lb. per engine. The follow-up engine, the UltraFan will have a fuel burn at least 25% better than the Trent 700. Key technologies for the UltraFan will be an all new power gearbox, variable pitch blades and variable area nozzle. The higher pressure ratios

[23] Consult "Mid-decade, A&D Faces Range of Turning Points" at: http://aviationweek.com/defense/mid-decade-ad-faces-range-turning-points
[24] See "CFM Focuses on Leap Production Readiness" at: http://aviationweek.com/commercial-aviation/cfm-focuses-leap-production-readiness

planned fore Advance and UltraFan will mean higher operating temperatures and increased generation of nitrous oxides.

Other recent developments include Pratt & Whitney's Geared Turbofan concept (mentioned above), which is being designed to meet the high-efficiency goals of airframe-engine integration. It is intended to overcome installation challenges for NASA's new D8 Double-Bubble airliner which could enter service around 2035. The D8 is designed to burn at least 60% less fuel than the current generation of narrowbody airliners.[25]

At the same time, Airbus and Snecma are working on a 2030-timeframe for short/medium-range airliners driven by counter-rotating **open-rotor** engines which can deliver dramatic fuel-burn savings over conventional turbofans. Open-rotors burn less fuel because they can have large diameters for ultra-high bypass ratios without the drag and weight penalties of a large nacelle. To power a future narrowbody, Snecma maintains that this solution could achieve 16% fuel savings and 20dB less noise than the upcoming CFM Leap-1.

All of the above developments and breakthroughs demand high-temperature and fire-resistant cables in fire zones where manufacturers have never gone before, often with reduced weight as an added desideratum, and in high vibration environments. Within years, cables will have to handle 350 °C temperatures, while offering twice as long survivability.

6. Environmental concerns

Finally, we come to a final trend that has been in the background throughout this paper: legitimate environmental concerns. According to the International Civil Aviation Organization, the environmental impact of aviation occurs because aircraft engines emit heat, noise, particles, and gases that contribute to climate change and global dimming.

So far, despite fuel-efficient and less polluting turbofan and turboprop engines, recent increase in air travel has continued to raise levels. In the EU, greenhouse gas emissions from aviation increased by 87% between 1990 and 2006. Today, nearly 10 million people fly globally every day, and US airlines alone burned 16 billion gallons of fuel between October 2013 and September 2014.

Created in 2009, NASA's Environmentally Responsible Aviation (AERA) continues to promote cuts in drag, weight, fuel burn, noise and emissions. Europe does not have a consolidated NASA-like organization, but it does have Clean Sky which promotes ground tests of open-rotor, geared turbofan, turboshaft and diesel engines, and other tests, including smart flaps, all electric systems and power-efficient rotor blades.[26]

Clean Sky's environmental targets for 2020 include a 50% cut in CO_2 emissions from 2000 levels, and new technologies to cut CO_2 by an additional 50% before 2050. It also wishes to bring cabin noise level down to 80 dbA, and reduce external noise by

[25] For a brief summary, see "A Reversed, Tilted Future For Pratt's Geared Turbofan" at: http://aviationweek.com/technology/reversed-tilted-future-pratt-s-geared-turbofan

[26] Consult "Europe's Clean Sky 2 Program Begins" at http://aviationweek.com/awin-only/europe-s-clean-sky-2-program-begins and "NASA's Sustainable Airliner Project Goals in Sight": http://aviationweek.com/technology/nasa-s-sustainable-airliner-project-goals-sight

10 dbA to meet noise reduction goals. These recommendations are in keeping with the European Space Agency's goals under the "Observing the Earth" program.

Over a decade ago, NASA calculated that it would be possible to reduce an airliner's noise footprint 80% by 2025, but only by abandoning the traditional tube-and-wing configuration.

Airliners of the future are likely to be radically different. New shapes could include blended wing designs, where engines, fuselage, wings and flight surfaces blend into one organic entity, like some military aircraft today.

Airbus' 2050 concept plane – the airliner of the future – has a broader body, curved and shaped to improve airflow and provide more living space. Its wings are longer and slimmer to reduce drag and save on fuel. The U-shaped tail section shields the passengers from engine noise, while the motors themselves could be hybrid-electric-fuel-burning and nearly maintenance-free.

Materials science and new aerospace technologies involving power systems and the laws of aerodynamics will contribute to this kind of transformation. But at the core of future developments will be the essential energy and data provided by invisible networks of countless cables, hidden well out of sight from air travellers.

What is expected of a cable manufacturer?

OEMs and suppliers of systems, subsystems and components are playing a critical role in aerospace worldwide. They want to meet growing demands for quality, safety and reliability. They are also interested in improving supply and delivery logistics and creating new customer-driven services. Airlines, cargo transport and military operations are increasingly global and need a wide range of cable solutions that are aircraft fully compliant with national and world standards.

- A comprehensive range of aerospace wires and cable solutions
- Products that are compliant with a range aircraft specifications and standards worldwide
- Lighter, smaller, tougher, and more reliable wires and cables
- Abrasion-, arc-track-, fire-, and fluid-resistance and low maintenance
- Customized solutions and support for complex and advanced designs

NEXANS: ADVANCED CABLE SOLUTIONS TO MEET AEROSPACE TRENDS

For commercial aviation

In keeping with current trends in commercial aviation, defense and space, Nexans provides a comprehensive range of cables and wires, compliant with all world standards. This includes a full range of cables for aircraft, helicopters, spacecraft

and satellites; it also covers customized cables that suit specific technical requirements fully supported by quality control, R&D and aerospace-specific services.

From a safety standpoint, Nexans is continuing to meet increasingly stringent international regulations (FAA and others), but is also responding to the significant growth in market share of low-cost carriers, and is adapting its supply chain to the traffic shifts in the Middle East and the Asia-Pacific zone of operations and the needs of vibrant emergent economies.

Safety issues are also addressed through the highest quality standards (AS/EN9001, EN14001). Nexans offers a range of arc tracking, fire-resistant and fire zone cables now being widely used in the USA, Europe, Russia and China. It also sits on major normalization committees (SAE, ASD Cert) and provides in-house test lab and qualification capability to it customers.

Because enriching the passenger air travel experience is important for leisure and business fliers, Nexans is meeting needs for comfort, in-flight entertainment and connectivity. It has developed new fiber-optic solutions for high-speed data, achieved important space savings with databus rather than airframe cables, created lightweight and flexible power feeders for electronics systems, and fine-tuned interconnect solutions.

For airlines, Nexans has contributed to reducing the cost of fleet ownership and enhancing sustainability by contributing to innovative technical development to lower fuel consumption, optimize engines, lower maintenance costs, redefine electrical architecture (fly-by-wire and other electrical systems to replace pneumatics and hydraulics), and has supported efforts to create “greener” and quieter aircraft.

Aluminum-based power cable solutions save weight, while smooth cables ease and speed up installation. Also, Nexans made significant innovations to meet higher voltage requirements and ultra-high temperature demands for engines. Its advanced engineering support also includes redesign-to-cost and value-added services. Nexans achieved much of the above through an optimized supply chain via Electronic Data Interchange, Kanban, kitting, and forecast integration.

For the defense market

Nexans is assisting defense builders to eliminate hydraulic systems, incorporate all-electric actuators, and meet new power and data requirements. Its cable solutions also reduce arcing and arc propagation, adapt to weight and space limitation requirements within the airframe, and prevent dangerous corona discharges.
The company has also focused on value creation in areas perceived as essential by the customer, including investment in R&D, supporting low intensity platforms with new technologies, and developing strategic relationships with distributor channels and harness manufacturers.

For special needs, like flexibility, dynamic cut-through resistance, electromagnetic interference resistance, corona resistance, Nexans supplies products customized to specific military requirements that can be used in various types of harnesses.

In addition to delivering products that conform to most national, international and OEM standards, Nexans also has a worldwide industrial footprint which is fully

adapted to the new military and defense landscape. Three international sites serve both commercial and military customers, assuring harmonized procedures and facilities, shared skills and resources, and a common aerospace vision.

Aerospace cable solutions for safety, reliability, efficiency and adaptability

Almost half of commercial aircraft in service today are equipped with Nexans cables. Nexans is the only cable manufacturer worldwide to offer a broad spectrum of wires and cables, supported by a full range of aerospace services:

- Composite tape wrap
- Smooth surface composite
- ETFE and cross-linked ETFE extruded
- FEP and cross-linked polyalkene/kynar extruded
- PTFE extruded
- Design & Prototyping
- Testing & Qualification
- Manufacturing
- Engineering Support

Standards and specifications

Nexans wires and cables meet most national, international and OEM standards for both commercial and defense applications. They include EN, AS, WC, NSA, ASN, MIL, ABS, BMS, etc., in addition to our own rigorous aerospace standards.

A full list of standards is available online at www.nexans.com/aerospace

A full range of products and solutions

Airframe wires and cables

General-purpose airframe wires and cables are used on the flight deck, in the passenger area, in the wings and surfaces. They are used to carry signal and low level power at 28 Volt DC or 115 Volt AC, controlling everything from fasten-seatbelt signs to complex fly-by-wire sub-systems.

- Copper, copper-alloy, copper-clad aluminum or aluminum alloy
- PTFE polyimide wrapped insulation, laser markable
- Next-generation smooth surface technology, laser markable
- Cross-linked extruded insulation
- High temperature, mechanical and chemical resistant
- Low weight, small diameter, and arc-tracking resistant

Nexans smooth tape-wrap technology has been approved for use in several next-generation commercial and defense platforms in North America and China.

Cables for power transmission

Power feeders energize motors and equipment from APUs and batteries. Nexans' offer includes both European and American standards. Compact nickel-plated copper versions provide high conductivity, while larger nickel-plated aluminum versions achieve significant weight savings.

- AWG 8 to 4/0, copper or aluminum conductors to save weight
- Polyimide-wrapped/PTFE/glass-fiber insulation
- Next-generation smooth surface technology
- Cross-linked extruded insulation
- Operating temperatures up to 260°C

For Airbus A350 and A380, we created a new range of cables allowing 5% weight savings; also used in the Mars Rover automated vehicles.

Fire-zone and high-temperature area cables

For hot areas, engines and the nacelle environment. Their functions vary from carrying signals to transmitting energy. Nexans' offer includes both European and American standards. Our range of cables answer both flame/fire retardant and fire-resistant requirements.

- AWG 24 to 4/0
- Fire-proof and fire-resistant insulations
- High temperature from 260°C to 310°C
- Arc-tracking resistant
- Nickel-clad copper/copper-alloy conductors

A new generation of fire-resistant cable offer**s** two benefits: light weight and arc-tracking resistance in bundled configurations to reduce power malfunction.

Coaxial cables

For onboard HF data transmission (radio/radar/anti-collision/communications/navigation/avionics). Mil-C-17 and RG, and improved coax designs: KX for enhanced high-frequency, WZ for signal transmission, and KW7 featuring an all-aluminum weight-saving conductor.

- Silver-plated, copper, copper-alloy, copper-clad steel/aluminum
- Aerated fluoropolymer, PTFE extruded with wrapped insulation
- Single or double screen (braids, tapes, etc.)
- Low attenuation

A new "daisy" design uses air rather than foam insulation. Meeting the latest environmental regulations, it is lighter and greatly improves dielectric performance.

Databus, quad Ethernet and optical fiber

In addition to avionics, these cables serve various in-flight entertainment and communication needs. To increase data volume without increasing space requirements or weight, Nexans has optimized shielding and armoring to reduce weight by 20-60%, and offers solutions based on optical fiber.

- Silver-plated, copper, copper-alloy, copper-clad steel/aluminum
- Aerated fluoropolymer, PTFE extruded with wrapped insulation
- Single or double screen (braids, tapes, etc.)
- Optical fiber: robust, fluid-resistant, rated at 125°C

Lightweight AWG databus cables are widely used on helicopter programs such as NHIndustries' NH90 multitask military helicopter and Eurocopter's Tiger attack helicopter.

Customized cables for specific applications

Our AS9100 and ISO9001 certified facilities manufacture ultra-low-weight shielded cable for satellites and coiled cables for cockpit, special sensor cables, flight-test wires, low-noise cables for vibration-prone areas, custom-built coaxial assemblies for SATCOM systems, and various hybrid cables.

- Multi-core, screened, jacketed, and extendable coil cords
- Coaxial assemblies for SATCOM
- Ultra-low-weight shields
- Hybrid cables combining hook-up wires, power feeders, shielded cables and coaxes
- Specialties, such as low-noise, flight-test, and thermocouple extension cables

Leading contractors for the US Department of Defense asked Nexans to design multifunction cables with enhanced mechanical and electrical performance.

A suite of services designed for aerospace

To further support OEMs and their first-tier customers, Nexans provides services tailored to aerospace needs, adding value to products and facilitating new approvals in keeping with national and world standards.

Customized kitting

Nexans can propose customized kitting and packaging to its customers, especially for pre-cut power cables. Kits can include other components, according to customer needs and specifications.

Training modules

At the request of OEMs, harness makers and distributors, we provide custom training on our products to explain their specific performance characteristics and benefits.

Resident engineers
If a customer has issues or questions related to wires and cables, we can assign a resident engineer to work with their research department to help them make the right choice, or facilitate acceptance according to design criteria, test information and applicable standards.

Re-design to cost
In a world where size, weight and reliability are of the utmost importance, we can help suppliers, harness makers and OEMs find optimal solutions. For example, we have pioneered the use of aluminum to achieve significant weight reduction.

Dedicated customer portals
While integrating with customer portals, Nexans can also set up dedicated portals to offer customized information according to design, manufacturing and operational needs (including technical data, commercial information, specifications, and billing).

CONCLUSION

Nexans provides a full range of cables for commercial aircraft, fighter and transport aircraft, helicopters, spacecraft and satellites.

We have a full range of capabilities in design, prototyping, testing, qualifying, manufacturing and customer support, in addition being key members and contributors to the world' most influential Standard Committees (the SAE and NEMA in the US, and ASD in Europe).

We are proven leader in standard, new and advanced aerospace wires and cables; in particular, an innovator and leader for smooth wrap product in the US, and new generations of tape wrap products (EN standard, special corona-resistant cables and lighter aluminum solutions in Europe).

We are also process experts, especially for tape wrap machines with integrated control and full data acquisition.

Nexans has consistently produced lighter, smaller, smoother, safer and more robust solutions. For example, in the area of nacelle and engine solutions we are aiming at +250°C for a 50,000 hour life cycle.

In terms of weight savings, we have achieved:

- -10% by reducing the wall thickness of power feeders
- -20% via an aerated design for coax, bus and quadrax cables
- ≤20% for aluminum shields
- ≤30% for smooth and composite insulations
- ≤40% for aluminum for conductors and shields
- ≤90% for optical fiber cable instead of copper

What makes Nexans unique is vertical integration on conductors, with support from a Metallurgy Research Center; three dedicated Aerospace manufacturing sites in the USA, France and Morocco; three Research Centers (Europe, Korea and US). Nexans is the only supplier to offer both irradiated and composite tape-wrap, including smooth technology.

For our customers this means improved safety and reliability, common and fully approved products, a highly reactive supply chain, and quality cost-effective products from nose to tail and from wing-to-wing.

APPENDIX: Some Nexans aerospace headlines and milestones

China's Changhe opts for latest-generation Z series helicopter cables
The Z-11 is a light utility helicopter developed by Changhe Aircraft Industries Corporation (CAIC), and is claimed to be the first indigenously designed helicopter in China. It was also the first Chinese helicopter to be completely designed by CAD/CAM. The multi-functional rotary-wing transport is used for both defense and commercial applications. To make this project a success, Nexans provided technical support and special expertise to find correct cable design for different helicopter environments, weight and vibration resistance. We did early design from the drawing board onwards, provided technical training to the local design staff, and contributed critical assistance for the prototype which did its first flight in 1994 and completed test flights in 2000.

Hybrid cables for demanding military applications
The US Department of Defense needed an electrical wire interconnect system that met severe weight restrictions, while offering a very high level of performance in terms of flexibility, cut-through resistance and abrasion resistance. It had to carry signal, power, and high-speed data, and had to incorporate only Mil-spec certified components. Nexans submitted four designs for hybrid cables made of twisted pairs, twin-axes, coaxes and multi-core cables to the contractor, and forwarded samples so that its partner could provide terminations and then submit the cables for rigorous testing. After extensive testing for mechanical and electrical performance, they were found to be a superior solution. Nexans and its partner were awarded the contract for eight years and have since been given a four-year extension.

Other recent important projects

- For important space and weight gains, Airbus needed a new generation of power cables compatible with lugs and terminations. Nexans created a new range of tape-wrapped cables that achieved a 5% weight gain over previous cables. Airbus is now using it in the A350 and A380 aircraft.
- To resist arc tracking and reduce power malfunction, Nexans drew on its long experience in bundles, assemblies and harnesses to create a new generation of safer fire-zone cables for densely cabled aircraft areas. This lightweight solution adheres to rigorous European norms.
- To meet new REACH regulations for coaxial cables used for navigation, avionics and anti-collision systems, Nexans developed a new "daisy" or "wagon wheel" design which uses air rather than extruded foam to deliver a lighter coax with improved dielectric performance.
- To meet the challenges of the helicopter environment, Nexans developed a lightweight AWG databus cable that delivered exceptional performance at a reasonable price. They are an integral part of NHIndustries' NH90 multitask military helicopter and Eurocopter's Tiger attack helicopter.
- Industrial Excellence Award from Airbus: See Link
- Five year contract with Airbus: See Link

For more information about the above, please consult:
http://www.nexans.com/eservice/Corporate-en/navigate_310994_1096_20_12666/Success_stories.html

About the authors

Fabien BOUVIER is Sales Manager for Aerospace and Defense markets. He experienced this market for more than 10 years facing various customers from Airlines to OEM worldwide. Expert of the Engine Aircraft market, he's driving Nexans' position among the different players.

Dominique DHENIN is Key Account manager for Airbus at Nexans. She has more than 40 years of experience in the cable industry. Before moving to her current position, she had responsibilities within Nexans in the technical department.

Olivier PINTO is Technical Manager for the Aerospace and Defense markets at Nexans. He was previously in charge of a research group at Nexans Research Center and launched a full offer of value-added services and systems for key customers within various industrial markets in Europe.

About Nexans

Nexans brings energy to life through an extensive range of cables and cabling solutions that deliver increased performance for our customers worldwide. Nexans' teams are committed to a partnership approach that supports customers in four main business areas: Power transmission and distribution (submarine and land), Energy resources (Oil & Gas, Mining and Renewables), Transportation (Road, Rail, Air, Sea) and Building (Commercial, Residential and Data Centers). Nexans' strategy is founded on continuous innovation in products, solutions and services, employee development, customer training and the introduction of safe, low-environmental-impact industrial processes. In 2013, Nexans became the first cable player to create a Foundation to introduce sustained initiatives for access to energy for disadvantaged communities worldwide. We have an industrial presence in 40 countries and commercial activities worldwide, employing close to 26,000 people and generating sales in 2014 of 6.4 billion euros. Nexans is listed on NYSE Euronext Paris, compartment A. For more information, please consult: www.nexans.com

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