Global Connections

An introduction to the use and benefits of standards in the aerospace sector

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Foreword

“BSI is dedicated to promoting excellence throughout the aerospace sector. Working with organizations of all sizes in 172 countries worldwide, we improve performance, reduce risk and increase resilience right the way through the supply chain.”

Howard Kerr, Chief Executive, BSI

Introduction

The aerospace industry, and its supply chain, are underpinned by stringent and unwavering requirements for safety and quality. The complex technologies and systems necessary for aerospace are often developed through collaborative relationships in this highly connected sector. Given the global nature of the industry, there are well-established links between continental aviation bodies and agencies.

Perhaps not surprisingly in such a safety and quality-critical sector, standards are deeply embedded in aerospace manufacturing and supply chain partnerships. This report sees contributions on different aspects of standards application from Rolls-Royce, BAE Systems, ATI, NATS and others.

The subject of quality management is discussed on page six, with an article on how documentation specification standard BS 8888 is used by Reaction Engines on page eight. Fasteners are used to illustrate how standards are critical for even the smallest aerospace component on page 10, and the way that committees shape new and manage existing agreements using GEL/107 at BSI as an illustration, can be found on page 12.

Metrology, the science of measurement, plays an important role in aerospace engineering design. Professor Michael McCarthy Ph.D. explains why on page 16. Professor Paul Tasker, Visiting Professor in Integrated Systems Design at Cranfield University then takes an even broader perspective when he explains the concept of through-life engineering services which address the needs of high-value systems from conceptual design all the way to end-of-life, on page 18.

ISO 44001 provides guidance for identifying, developing and managing collaborative business relationships, and is discussed in relation to aerospace on page 20. The high-potential areas of digital and additive manufacturing, as well as drones, are explored on pages 22, 26 and 28 respectively.

All our aerospace standards are available digitally. BSOL (Standards Online) is the online standards database that makes using standards easier and more cost-effective. It provides 24/7 access to a comprehensive and constantly updated library of over 95,000 internationally recognized standards. You can read how UTC Aerospace Systems uses BSOL on page 24, and there's further information about the database on page 30.

Finally, continual improvement and certification maintenance are critical for an industry which demands the best in quality and safety. Turn to page 31 to learn more about our varied aerospace training and certification options ●

Dan Palmer
Head of Market Development, BSI

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The role of standards in the international aerospace industry

Iain Macleod is Managing Director of Iain Macleod Associates Ltd; he is a member of BSI Technical Committee TDW/4, and chairs subcommittee TDW/4/8. He also chairs ISO Technical Committee TC213.

Every industry uses standards; these may be national, regional or international, and they may relate to specific industries, specific processes or even specific materials. Every aspect of industrial activity is affected by standards; it would be impossible for industry to operate without them.

Standards are not new. We have had standards for weights and measures for thousands of years. The first standard definitions for the inch date back to between the 7th and 11th century AD (one inch was equal to the length of 'three grains of barley, dry and round, placed end to end, lengthwise'). Greece claims the oldest European standard, with an engraved tablet dating back to the 4th century BC; this document defines requirements for bronze fittings to be used for a portico, specifying amongst other things, the exact proportions of copper and tin to be used.

In 1901, the British Standards Institution was established (initially as the 'Engineering Standards Committee') to write and promote the use of technical standards for British industry. This was the first body of its kind to be founded in the modern world. It was followed in 1916 by the American National Standards Institute (ANSI), and by 1926 Germany, Italy, and France all had their own equivalent organizations.

The advent of widespread global trading and supply highlighted the need for a more connected approach. This was addressed through the formation of the International Organization for Standardization (ISO) in 1947, which now has over 160 member nations.

Over recent years there has been much consolidation of standards, and many national standards have been replaced by international ISO standards. America holds out to some extent; they still have a separate system for mechanical specification (the ASME Y14.5 standard), which is widely used in industries such as aerospace, automotive and energy, and they have yet to fully embrace the SI system of units. The USA does, however, participate extensively in the development of ISO standards, and sends many experts along to ISO Technical Committee meetings.

The aerospace industry is particularly dependent on standards. With so much depending on the safe and reliable operation of aircraft, standards exist to cover every aspect of the manufacture, assembly, testing and operation of aircraft.

ISO TC 213 is responsible for standards relating to mechanical specification and tolerancing, which are used in all manufacturing industries, including aerospace. These are some of the standards which

"The aerospace industry is particularly dependent on standards. With so much depending on the safe and reliable operation of aircraft, standards exist to cover every aspect of the manufacture, assembly, testing and operation of aircraft."

are in turn referenced from within BS 8888, which provides an index to the ISO system, includes much of the technical content of those ISO standards, and acts as a kind of users-guide to the ISO system.

These documents are used by many aerospace companies, and their suppliers, to make sure that components and assemblies are properly defined, consistently manufactured, interchangeable in use, and with predictable performance parameters.

The modern aerospace industry is very global in its approach, requiring for instance a wing subassembly made in the UK to fit to a wing subassembly made in Germany, interfacing with other parts from Spain, when the whole structure is put together in France. This only becomes feasible when everyone is working to the same rules and definitions for the specification and verification of components and assemblies. In other words, this only becomes possible when everyone is working to the same standards.

In the past, aerospace companies have played an important role in national and international technical committees. This has helped them ensure that their requirements are covered by the standards, and has also helped to maintain a high level of awareness of those standards within the industry; there is a very good business case to be made for being involved in this process. In recent years, with many conflicting demands for time and budgets, aerospace companies have been less active participants, but it would be to everyone's benefit if this were to change.

Anyone involved in the aerospace sector who would like to assist the work of the technical committees and play a part in the development of these standards, will always be most welcome – just make contact with TDW/4 at BSI.

Going forward, some of the key areas for standards development at BSI and ISO will include Model-Based Definition (MBD), where traditional engineering drawings are being replaced by fully-annotated 3D CAD models; new manufacturing processes, such as additive manufacturing (AM); new measurement technologies, such as X-ray computed tomography (XCT); and new developments with 3D surface texture specification and verification ●

Standards widely used in aerospace

Some of the ISO TC 213 geometrical tolerancing standards which are referenced by BS 8888 and widely used in the aerospace sector:

ISO 1101	Tolerance of form, orientation, location and run-out – generalities, definitions, symbols, indications on drawings.
ISO 5459	Datums and datum-systems for geometrical tolerances.
ISO 1660	Profile tolerancing.
ISO 5458	Positional tolerancing.
ISO 14405	Dimensional tolerancing.
ISO 2768	General tolerances.
ISO 2692	Maximum material principle.
ISO 8015	The principle of independency.
ISO 8062	Dimensional and geometrical tolerances for moulded parts.

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Quality fundamentals:

Aerospace supply chain confidence

Keith Allen, Chief of Engineering Processes and Standards at Rolls-Royce, discusses how quality management standards underpin key engineering processes right across the aerospace supply chain.

The modern aerospace design and manufacturing industry demands quality at every stage, and standards play an intrinsic role in managing and maintaining quality across the supply chain. Safety and reliability are major focuses for everybody involved in our industry and, as a result, quality management standards are an everyday consideration for engineers and designers. Standards also help compliance with legislative and regulatory requirements.

At Rolls-Royce, we have always used standards in our processes, and they help provide the foundation for the way we work. Our organization has an internal quality management system, which is split into around 20 high-level engineering processes. These processes feed into various work instruction rules, which contain standards.

> **Using quality standards in our processes helps maintain and improve product safety levels, and makes international trade significantly more effective.**

Because we obtain the vast majority of component parts for our manufacturing from supply chain partners, the common use of agreed standards is essential. It's the fundamental basis for consistent quality, and means we all understand exactly what is expected when we undertake supplier audit visits.

We use the newly revised AS/EN 9100 series of quality management standards, which is also a requirement for all our suppliers. Developed by the International Aerospace Quality Group (IAQG), it brings an additional level of requirements over ISO 9001. This series is published under different names in different regions, such as JISQ 9100. We also employ Nadcap process certification, and expect our suppliers to, in the same way.

Using quality standards in our processes helps maintain and improve product safety levels, and makes international trade significantly more effective. Strict compliance also helps avoid costly product or component recalls if certain requirements are not met.

Although Rolls-Royce has been associated with engineering quality for over a century, we will always push to continually improve our systems internally and in partnership with our supply chain. We are also a significant presence on various international industry committees on quality management.

Looking ahead, I believe we can evolve the way that standards are accessed, to make them more interactive and agile for the user, and take them beyond pages of text to sift through. This is important because standards are of critical importance to the aerospace industry, and thousands of engineers and designers use them every day across the supply chain.

In the shorter term, the industry has increasing responsibility to restrict and report certain chemicals used in the supply chain as the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) regulations are implemented. This will almost certainly require further changes to existing requirements, as well as the production of new dedicated standards for the aerospace supply chain ●

A common language for aerospace design specification

Stuart Webb, Design Office Manager at Reaction Engines, outlines how his team uses standards in hypersonic and space access propulsion design.

Every design team needs a common technical 'language' when developing specifications for their projects. Using an agreed framework of standards is the only way to ensure product and component specifications have incorporated all necessary considerations and requirements once they appear in a design or manufacturing plan. At Reaction Engines, we develop technologies for a new class of hypersonic propulsion system, the Synergetic Air-Breathing Rocket Engine (SABRE).

The consistent use of standards, such as BS 8888, has been central in our creation of ultra-lightweight heat exchangers, capable of cooling air streams from over 1,000°C to -150°C in less than one-twentieth of a second. Our heat exchangers stop engine components from overheating at high flight speeds, allowing SABRE class engines to power aircraft at over five times the speed of sound. BS 8888 provides a framework for our engineering drawings and geometrical tolerancing, covering all requirements for the technical specification of products and their component parts. We also refer to standards for limits and fits, materials, fabrication, welding and positioning features within components.

We find BS 8888 particularly useful because it explains the way in which engineering drawings outline and present these specifications. It covers the symbology (such as geometrical tolerances and welding types) and information that our design engineers need to include in their manufacture and assembly drawings. It also brings together, in one easy-to-follow document, all the international standards needed to prepare technical product specifications.

BS 8888 provides confidence that everybody in the industry who creates a drawing has done so to the same standard.

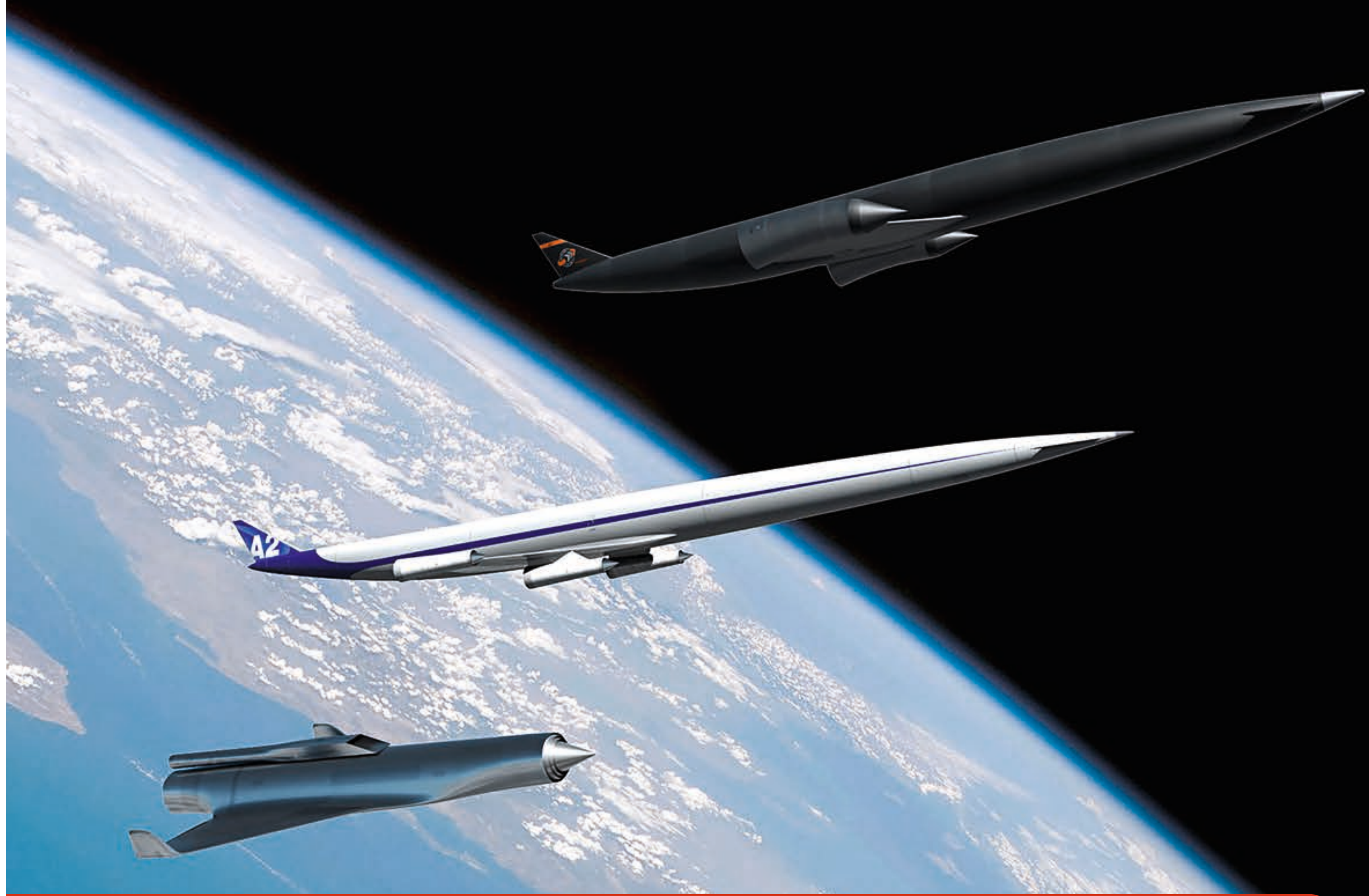
Standards allow us to work consistently and cohesively, both internally and when we work with partners and suppliers. They provide clarity and confidence in the specifications – if we are outsourcing the production of components or assemblies, we know they will be fit for purpose when they are shipped to us, since our suppliers use the same standards as we do.

Part of our design work includes pressure test rigs and equipment, so standards play a key role in ensuring that safety requirements are always correctly observed in our design output.

Looking ahead, standards will continue to be a frequent focus, both in our ongoing experimental equipment testing work and in our future projects. For example, in ensuring that the connected subsystems within our demo engine are all compliant and working harmoniously together. Also, there will be a need in time, for us to start working with flight vehicle standards from design to environmental impact, and end-of-life processes.

As technical complexity increases, standards will also ensure failures are minimized, and time and money are not wasted in unexpected remanufacture. Critically, in all our design work, the use of standards means that variability from the individual interpretation of plans and drawings never becomes an issue ●

"BS 8888 provides a framework for our engineering drawings and geometrical tolerancing, covering all requirements for the technical specification of products and their component parts."



BS 8888

The UK's national framework standard for engineering drawings and geometrical tolerancing is unique to the UK. It is such a useful document that several other countries are now following the UK's lead, and publishing similar national standards to help their industries work with the ISO system.

The right connections:

Standards in airframe fasteners

Daniel Butroid, BSI ACE/12 Committee Chair, and part of the BAE Systems Design Standards team for over 25 years, explains the importance of standards for fasteners in aerospace.

Fasteners are undoubtedly one of the most fundamental components in aerospace manufacturing. Welding, although suitable for the automotive industry, is not generally used in aluminium airframe construction mainly due to structural engineering considerations. Welding is not suitable for non-metallic airframe construction, so fasteners are used to construct aircraft.

The airframes in high-performance military jet aircraft must hold together in the intended manner under great stresses. It's the fastener's job to ensure this happens. Take the BAE Systems Hawk for example. Designed to be highly manoeuvrable, it can also reach Mach 1.15 in a dive. To safely allow this, the Hawk's airframe is very strong, designed for stresses of +9g, while the normal limit in RAF service is +7.5/-4g. This strength would not be possible without the right kind of solid fastening rivet.

Every single fastener we use in airframe construction has a crucial role to play in the performance of the aircraft, and the safety of its crew and others. At BAE Systems, we regularly use and maintain over 50 separate fastener standards, some of our own origin and some from BSI. An example of the most frequently used fastener standard in our Hawk airframe production is the BS SP 68-71 series. We also use BS EN 2089 and BS EN 2395 for materials in aircraft manufacture, and BS EN ISO 286 for hole and shaft tolerances. They all ensure we can control the quality and performance characteristics of our airframes.

We work with two different solid rivet suppliers and both comply with the same British Standards. This ensures quality and conformance, as well as giving us a common reference during communications.

We regularly conduct our own quality management assessments and visits to key supply chain partners, to ensure all relevant standards and certifications are maintained in their operations. For some aircraft, such as the Eurofighter Typhoon, we use a preferred supplier list which comes with its own component qualification and testing requirements.

The standards that we have for aerospace fasteners are likely to remain unchanged for at least the next five, if not ten years, and are suitable for current and future platforms. However, there are new applications of this fastener technology occurring. For example, fastener standards used in the Hawk airframe have recently been used in the production of our unmanned vehicles. Work is also underway on new recess designs for fasteners (such as BS A 401-420) to contribute to weight saving, improve tightening efficiency and to reduce the chance of damage to any surrounding structures.

The use of standards is essential in almost every area of our design and manufacturing activities. We refer to and use hundreds of standards every day, right across the business. Because our key partners all use the same standards, we know that everything we get from our suppliers conforms to the same standards we use in our own manufacturing.

The price of not using standards would escalate rapidly, both from a financial and reputational point of view. I estimate that we benefit from at least a 10 per cent cost saving from the use of standards across the business. Standards help us work efficiently and provide ultimate confidence in the quality of our components and products •

"The price of not using standards would escalate rapidly, both from a financial and reputational point of view. I estimate that we benefit from at least a 10 per cent cost saving from the use of standards across the business."

Standards widely used in airframe fasteners

BS EN 2395	Aerospace series. Aluminium alloy AL-P2014A-T4 or T42. Sheet and strip. 0,4 mm ≤a ≤6 mm.
BS EN ISO 286	Geometrical product specifications (GPS). ISO code system for tolerances on linear sizes. Basis of tolerances, deviations and fits.
BS SP 68-71	Specification for 100° countersunk precision head aluminium and aluminium alloy rivets.
BS EN 2089	Aluminium alloy AL-P2014A T6 or T62. Sheet and strip. 0,4 mm ≤ a ≤ 6 mm.

Working together to further industry excellence

Jo Vann, IEC TC 107 Technical Secretary and Dave Ryan, Lead Component Engineer - Control Systems Civil Aerospace at Rolls-Royce are both members of GEL/107 Process management for avionics committee. Here they underline the ongoing need for industry-wide participation in aerospace standards development.

> **Standards are the closest thing to a guarantee of quality that supply chain partners can give and receive.**

It's no secret that the aerospace industry maintains stringent quality and safety requirements. End user safety is a fundamental responsibility which drives so much of our design engineering, and the environmental impact of our activities are tightly regulated to minimize global impact.

We are also a low-volume/high-reliability project industry, and standardization is important to help minimize component costs. If everybody is using the same set of standard rules and specifications, it reduces the need for items to be custom-built or designed each time, keeping costs down and ensuring the required level of quality is met.

The aerospace supply chain relies on standards to function. Standards are the closest thing to a guarantee of quality that supply chain partners can give and receive. Even the smallest component will be produced to specific standards, and manufacturers are audited by supply chain customers on an ongoing basis, through routine site visits and production data interrogation, to ensure that these standards are maintained.

The way we manage these obligations as an industry is by coming together to discuss and agree common standards. Representatives from stake-holding industry organizations bring their expertise and experience together in voluntary technical committees, facilitated by BSI. Well designed and maintained standards have significant cost-saving and efficiency benefits across the supply chain. They improve confidence between trading partners, reduce material costs and new product development times and create a common reference point from which to discuss designs, plans and specifications.

Each committee has a very specific technical focus. Our work on the GEL/107 committee at BSI encompasses process management standards for avionics systems and equipment. Some of the key standards we maintain in the group relate to commercial off-the-shelf (COTS) electronic parts. These include IEC/TS 62239-1, which governs general electronic component management planning, and IEC/TS 62239-2 for electronic COTS assembly management planning.

We also work with the BS IEC 62396 series of standards which govern avionics electronic component process management, with attention to accommodating atmospheric radiation effects. This is important for both civil and military applications.

Our committee is also involved with developing standards for counterfeit prevention (PD IEC/TS 62668-1) to ensure the ongoing quality and provenance of original electrical components. We also maintain standards around lead-free solder in electronic systems, to deliver consistent reliability in aviation parts (PD IEC/TS 62647 series).

Every single aerospace standard is a collective work. The committee meetings provide a neutral discussion forum through which to develop industry-wide standards. The system of developing standards by expert technical committee also allows member organizations to share best practice and learn from each other, as well as influence and direct standards which support their business requirements. BSI plays a central role, bringing decades of experience in shaping standards, and leading and facilitating the process of reaching consensus among aerospace experts

Standards for the aerospace industry

“Because we obtain the vast majority of component parts for our manufacturing from supply chain partners, the common use of agreed standards is essential. It's the fundamental basis for consistent quality, and means we all understand exactly what is expected when we undertake supplier audit visits.”

Keith Allen, Chief of Engineering Processes and Standards at Rolls-Royce

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Quality management systems.
BS EN 9100 Series

Information security for organizations supporting civil aviation operations.
BS EN 16495:2014

Interoperability of flight data processing for application under the Single European Sky.
DD CEN/TS 16071:2010

Specification for steel bolts for aircraft.
BS 4A 102:2002+A2:2012

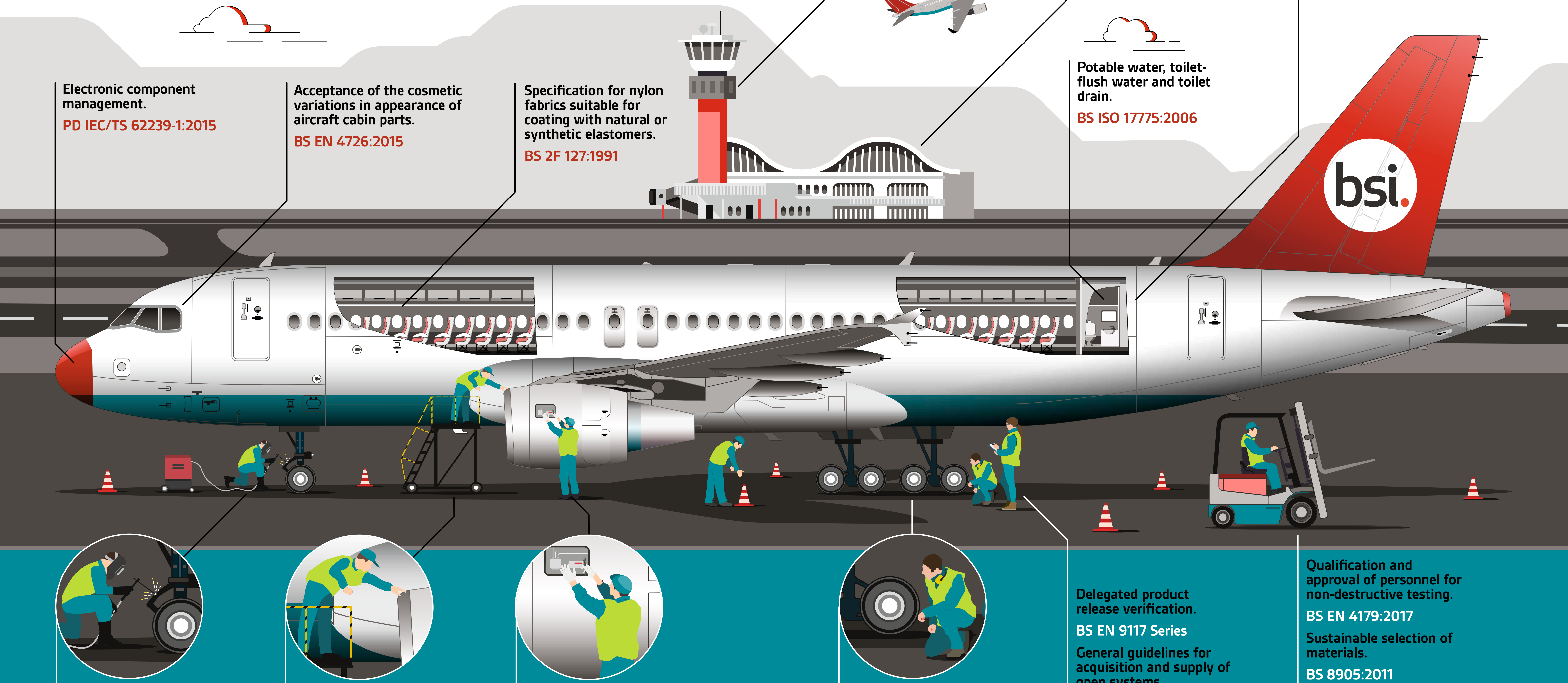
Specification for two component epoxy primer for aerospace purposes.
BS2X33:1998

Potable water, toilet-flush water and toilet drain.
BS ISO 17775:2006

Electronic component management.
PD IEC/TS 62239-1:2015

Acceptance of the cosmetic variations in appearance of aircraft cabin parts.
BS EN 4726:2015

Specification for nylon fabrics suitable for coating with natural or synthetic elastomers.
BS 2F 127:1991



Welding for aerospace applications.
BS ISO 19828:2017

Identification marking of engine items.
BS EN 4300:2008

Design and installation of aircraft electrical and optical interconnection systems.
BS EN 3197:2010

Aircraft tyres and rims.
BS ISO 3324 Series

Delegated product release verification.
BS EN 9117 Series

General guidelines for acquisition and supply of open systems.
BS EN 9320:2014

Test method for non-metallic materials.
BS EN 2243 Series

Qualification and approval of personnel for non-destructive testing.
BS EN 4179:2017

Sustainable selection of materials.
BS 8905:2011

Design for manufacture, assembly, disassembly and end-of-life processing.
BS:8887:2010

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Metrology for aerospace

Metrology, the science of measurement, plays an important role in aerospace engineering design. Professor Michael McCarthy, Lead Consultant at Engineering Metrology Solutions, and Honorary Professor at University College London (UCL) explains why.

> **Metrology standards independently demonstrate the potential capability and accuracy of critical measuring equipment.**

Before the shape of an aircraft can progress from its design on a digital screen to a physical prototype, metrological principles and measurements must be applied. This is to confirm that dimensionally related aspects of the design can actually be built, and manufactured, within required tolerances. Such measurements can also be used to support design revisions which ensure optimal performance efficiency, as well as compliance with critical safety and noise requirements.

Take an aircraft's wing as an example. The correct aerodynamic design is critical to provide efficient lift and slight variations in shape and form have a huge impact on flight performance and associated fuel efficiency. Wing surfaces must also be evaluated for undesirable roughness properties which are likely to increase drag and create undesirable turbulence.

These factors require the dimensional aspects of the manufactured wing to be measured using a 3D system that has had its performance verified against a standard. In many cases written standards are not currently available and so dimensional reference material artefacts with similar physical characteristics are employed.

Ideally all dimensional measurements should be related to the metre which is the base unit of length in the International System of Units (SI). Furthermore, any measurement result, however made, should be traceable to the metre through a documented and unbroken chain of calibration which contributes to the measurement uncertainty for the result.

Each country has a National Measurement Institute (NMI). In the UK, it is the National Physical Laboratory (NPL), and in the United States, it is the National Institute of Standards and Technology (NIST). Each NMI provides its industries with traceable metrology.

Over the last decade, several portable coordinate measuring systems based on optical scanner technology have been developed. These systems enable large complex surfaces, such as wing-like structures, to be measured in situ. This contrasts with the traditional laboratory based Cartesian coordinate measuring systems. The new optical systems can also capture data from large areas, for example a few square metres, in just a few seconds. This captured 'point cloud' surface-form data can then be quickly compared with a CAD design model.

Laser trackers are another industrially focused, optically-based, single-point dimensional metrology system. They are also portable and can measure larger volumes (typically with ranges of up to tens of metres).

Another emerging laboratory based technology is X-ray tomography (XCT), which allows the dimensional measurement of internal structures and surfaces for example, measuring the dimensions of the cooling holes within a gas turbine blade.

The ISO/TC 213 committee develops and maintains the ISO 10360 series of standards relating to acceptance and reverification tests for coordinate measuring machines (CMM). Metrology standards independently demonstrate the potential capability and accuracy of critical measuring equipment.

The ongoing development of portable non-contact measurement systems will play a significant role in the future of aerospace metrology. Specific needs include their improved performance away from a controlled environment in measurement locations where factors like temperature vary and affect the geometry of the equipment and the object being measured. Self-calibration technology would overcome these challenges, and is a key but optimistic future goal ●

Key aerospace metrology standards

ISO/TC 213	The technical committee overseeing standardization in the field of geometrical product specifications, covering macro- and microgeometry specifications for dimensional and geometrical tolerancing.
ISO 10360	The standard consists of a number of parts which specify acceptance tests for verifying the performance of a range of coordinate measuring systems, including tactile-based Cartesian coordinate measuring machines (CMM), against manufacturers' specifications.

Service innovation in aerospace:

Through-life engineering

Paul Tasker, Visiting Professor in Integrated Systems Design at Cranfield University, and formerly of BAE Systems, explains the concept of Through-life Engineering Services (TES), and how it relates to the aerospace industry.

Through-life Engineering Services (TES) guarantee the required and predictable performance of a complex engineering system throughout its expected operational life. The discipline considers design, manufacture, maintenance, repair, overhaul, and disposal or re-use as well as cost optimization.

TES will be key to aerospace manufacturing productivity and high-value jobs in the circular economy of the future. The TES concept has been in existence in the defence sector since the late 1990s, and the Cranfield TES Centre was established in 2011.

TES promote an end-to-end perspective delivering a vision for sustainable aerospace manufacture and infrastructure. It enables a transformation from open-loop linear, transactional or throw-away business models to circular closed-loop alternatives which better integrate engineering with other business functions.

Future customers will only buy services: product-only providers will not exist in many technically complex fields leading to a polarization of manufacturing between the throw-away and circular economies. We estimate that this approach can provide cost savings of at least 20 per cent across much of the UK manufacturing economy in the medium-to-long term.

The key concept in this future economy is servitization. The precursors of servitization were benchmarked by the 'power-by-the-hour support' services seen in aerospace since the 1960s, and trademarked by Rolls-Royce in the 1980s. It describes a support service whereby, for a fixed sum per flying hour, a complete engine and accessory replacement service was provided. This allowed the operator to accurately forecast costs and removed the need to hold replacement parts.

A fully servitized economy will drive maintenance costs out of the aerospace supply chain. It also means companies won't need to buy major assets and will just pay for a service which combines the traditional concepts of products and services. In this economy, manufacturers that only provide products and parts will be marginalized and find themselves competing in a race to the bottom. Customers who understand TES will find real value for money from the in-service support of their assets. Many leading aerospace companies are now employing TES, including Rolls-Royce, the Ministry of Defence (MOD), BAE Systems, Boeing and, in the transport sector, Bombardier Transport.

Formal standards and regulation will be key enablers for innovation in aerospace TES. They will aid knowledge transfer and behavioural alignment across the service supply chain to accelerate capability development. BSI and the TES Centre are working to establish framework standards in this area building on ISO 55000, BS 11000-2, BS EN 60300, BS 8887 MADE4, and ISO 9001 towards an integrated set of behavioural, process and technical standards for TES.

We aim to represent a wider perspective on the economics of design, manufacture, commissioning, maintenance, upgrade, and decommission / re-use of complex physical assets than that currently taken by ISO 55000. This work, along with other initiatives, is now being developed by the recently formed, industry led 'TES Council'.

Looking ahead, there are practical challenges to overcome around defining a common language for the aerospace industry through the new standards. There's also a widespread need for changes to organizational culture and behaviour across the aerospace supply chain so companies can adjust to undertake TES efficiently. An example of which is better alignment between previously separate business functions like maintenance and design •

Further reading:
http://tes-council.org.uk/

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"Customers who understand TES will find real value for money from the in-service support of their assets."

Photo: The international Space Station with crew 27 by NASA. Licensed under Creative Commons.

Collaborative relationships in aerospace



Collaborative working is essential in the modern aerospace industry. NATS, the UK's leading air traffic services provider, was an early adopter of collaborative best practices and standards.

We spoke to Adrian Miller, Head of Supply Chain Collaborations, Christine Hyde, Head of Best Practice and Jeremy Hoult, Assurance and Development Manager about NATS and its approach.

Q What does NATS do?

Adrian Miller: NATS delivers air traffic navigation services to on average 6,000 flights every day through UK-controlled airspace, as well as at numerous international airports. We handled over 2.45 million flights in 2016/17 across the UK and the eastern North Atlantic. Safety is paramount in everything we do, given the volume of air traffic we manage.

Q How does NATS use standards internally?

Christine Hyde: We use standards such as ISO 9001, ISO 27001 and BS OHSAS 18001 across the organization to drive quality, efficiency, and ensure compliance with key regulations. Standards aid communication with our industry partners and different aviation bodies. For example, we comply with regulations from the International Civil Aviation Organization (ICAO), as well as the Civil Aviation Authority's (CAA) procedural requirements. We also keep a close eye on standards development through our work with BSI.

Q What is the importance of collaborative business relationship management systems in aerospace?

AM: NATS uses long-term relationships where there is a need to develop or adopt complex solutions through its supply chain, working together to optimally manage cost and risks associated with delivery and transition into operation. This is gaining a greater level of interest in the industry sector as other organizations see the value and importance of building strong, dependable, enduring relationships for mutual benefit.

CH: Using a collaborative approach, supported by relevant standards, means we can use a common language across the market and don't have to spend time building relationships every time we need to discuss an issue. We can immediately focus on solutions.

> **BS ISO 44001 helps aerospace businesses establish optimal collaborations by considering behaviour, culture and all relevant management processes.**

Q Why does NATS use standards to optimize collaborative working?

Jeremy Hoult: Using industry-wide quality standards allows us to make efficiency gains and eases communication with partners. We were one of the first companies in the world to achieve certification to ISO 44001. The standard helps us optimally develop and manage key collaborative relationships whether that's for a project with a single entity, or for multiple partnerships across complex operations. It provides an important framework to plan and embed collaborative best practices. Better collaboration means key industry players can more easily share their knowledge and insights to overcome challenges. This is critical in an industry with such complex and highly-technical systems.

ISO 44001 helps aerospace businesses establish optimal collaborations by considering behaviour, culture and all relevant management processes. Working in productive partnership with suppliers and customers is fundamental to how NATS operates and is vital to achieve the company's objectives.

Q How does ISO 44001 have an impact on the way NATS approaches industry partnerships?

AM: ISO 44001 fully reflects the way that we must work with industry partners on technology transformation as part of our commitment to the Single European Sky initiative (SESAR) which brings together the aviation industry to develop new technologies and solutions that will improve the way Europe's airspace is managed. Through ISO 44001, we benefit from strategic partnerships for collaborative working established with companies such as Indra, Leidos and Harris to share examples of operational best practice and jointly identify areas of potential risk.

These relationships are strengthened through engagement initiatives including supplier conferences, regular executive reviews, supplier interchange forums and dedicated relationship managers, underpinned by an award-winning, supply chain function.

Q How does NATS manage supplier quality?

CH: We ensure that our partners collaborate with each other in a cohesive manner to optimally manage commercial and technical risks. To do this, we subscribe to the Joint Supply Chain Accreditation Register (JOSCAR) - an accreditation system for the aerospace, defence and security sectors. It helps us collect due diligence information about our suppliers, who use it to input details of the standards they apply and the certifications they hold.

This ensures we only deal with suppliers who have the right approach to cyber security, software development, anti-bribery, anti-slavery and environmental requirements.

Q Looking ahead, what are the collaborative priorities for the industry?

JH: Collaborative working is critical for our industry now, and will only grow in importance. We work with the Civil Air Navigation Services Organization (CANSO), the global voice of air traffic management, providing a best-practice example of ISO 44001 implementation for other group members. CANSO members support over 85 per cent of world air traffic.

AM: ISO 44001 could be adopted by the industry to provide a common template for harmonious action across our supply chain. It will optimize strategic partnerships with other European air navigation service providers, and remains a critical tool to help us keep pace with ever-growing demand.

Digital manufacturing and supply chain resilience

Ben Sheridan, Market Development Manager at BSI, outlines how the rise of digital manufacturing techniques will help deliver significant supply chain improvements.

In recent years there has been much discussion around ways to improve UK productivity to keep pace with nations such as Germany and the USA[1] who have both achieved better growth rates over the last 15 years[2]. With that said, it is worth remembering that the UK aerospace sector is a notable exception[3] and has reported excellent productivity growth figures despite years of difficult economic conditions and recession.

While aerospace prime contractors successfully export most of their production, it is within the UK supply chain that the picture is less rosy. It cannot provide sufficient production volumes of the most essential products and, as a result, many suppliers are based overseas. If we look to Germany, we see it has very strong small and medium sized companies, known as the Mittelstand, which work across a wide range of different sectors. UK SMEs tend to be smaller, often putting them at a disadvantage when competing with Mittelstand firms.

If UK supply chains are to compete directly with these global rivals, it is unlikely that individual companies will be able to grow quickly enough to an appropriate size. A more realistic alternative, however, lies in helping companies to work together to meet emerging customer requirements, adopting a more collaborative approach. If UK companies can innovate in such a way that they will be more globally competitive then this will in turn lead to more resilient and adaptive supply chains.

The adoption of digital technologies throughout the supply chain will prove key to achieving this. Transforming our industry-wide approach in this way is crucial to maintain a competitive edge and enable companies within our aerospace supply chain to exploit advances in digital technologies, devices, data analytics and integration.

Digital manufacturing will help UK suppliers meet the technical requirements of their customers more frequently, more cost effectively and in a more timely way. This could be achieved in several ways, including the production of better, more varied components, more collaborative and customer-focused behaviour and higher levels of both labour and resource productivity.

There are several considerations and challenges in the move towards an end-to-end digital supply chain. Large primes need to ensure consistent adoption of a digital manufacturing approach across all relevant areas of their organization, and remove any obstacles to organizational change. In addition a lack of digital skills and awareness may also be addressed at all levels of the company.

The Institute for Manufacturing (IfM)[4] identified 10 key digital scenarios that describe the different ways in which companies within the supply chain will adopt digital technologies. These range from the automated replenishment of parts from suppliers, through to a fully automated and digitized factory and beyond that to managing the product when in use.

The prospects for the aerospace supply chain are exciting. For example, better visibility and agility around varying customer demand means the entire chain can improve scheduling, reduce downtime, overtime and inventory buffering. These capabilities also deliver the opportunity to improve preparations for new platform launches, reducing the time taken to bring new platforms to market as well as the likelihood of product recalls.

“Digital manufacturing will help UK suppliers meet the technical requirements of their customers more frequently, more cost effectively and in a more timely way.”

Throughout the useful life of the aircraft, digital connectivity also means maintenance can be scheduled in such a way that it reduces downtime and improves the utilization of the aircraft in service. This also means that improved scheduling to produce replacement parts can be made available as and when ready. If this capability can be rapidly rolled out and adopted it could well lead to UK manufacturing supply chains that are more resilient and competitive.

Standards organizations have a significant part to play in keeping abreast of technological innovations, as well as the timely development and provision of best practices and standards in several major areas, including:

- The interoperability of machines and data – establishing the kind of information to be recorded and in which format
- Improved use of data and the adoption of data-centric business models – enabling more informed engineering and strategic decision-making
- Design in a connected environment – more collaborative models of design
- IP governance and security - making decisions using others' data, and ensuring data ownership is clear
- Assurance for digital models and digitally manufactured products

BSI is already working with industry partners to gather, develop and share existing and emerging good practices in the adoption of digital technologies and capabilities to help underpin the continued development of resilient supply chains, and the aerospace sector is key to the success of this initiative •

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BSOL in practice:
UTC Aerospace Systems

Available 24/7 and revised every single day, BSOL is a comprehensive online library giving access to over 95,000 internationally recognized standards including ISO, EN, BS, CEN, CENELEC, ASTM and IEC. Available in one easily searchable and cost-effective location, it offers users a fast and easy way to stay up-to-date.

BSOL is used by companies across the world to create and manage their own unique standards requirements. We spoke to Andrew D King, Senior Specialist Engineer – Configuration and Standards Developer at UTC Aerospace Systems (UTAS) about how the organization makes use of BSOL.

Q Could you provide some background on UTC Aerospace Systems?

UTAS is the aerospace division of United Technologies, a global company with around 200,000 employees, and is one of the world's largest suppliers of technologically advanced aerospace and defence products. We design, manufacture and service systems and components - providing integrated solutions for commercial, regional, business and military aircraft, helicopters and other platforms. We are also a major supplier to international space programs.

In the UK, our Aerospace Systems Motor Drives Systems Centre (MDSC) specializes in the design, production and in-service support of motor-drive systems for the aerospace (helping to create the 'more electric aircraft') and defence markets. At the MDSC we also manage and facilitate all the engineering standards and specifications for our varied manufacturing projects, so a tool like BSOL is essential to our team.

Q How and why do you use standards?

Because of the complexity of our global projects we need to make sure that in all our design, specification, manufacturing and servicing activities we're always working to international quality standards. All processes, components and materials are governed by standards – from the electro-plating methods used on parts, to procedures required to properly control the manufacture of the motors and their control units.

As well as directing our internal work, standards provide an important means by which to communicate with our industry and supply chain partners – a common language we all rely on. To help maintain a uniform approach across our industry, I use the technical skills gained as a member of the BSI aerospace committee ACE/12 - Aerospace fasteners and fastening systems, as well as the SAE Industry Technologies Consortia's Engine and Airframe Technical Standards Committee (TSC) - previously known as the SBAC and then ADS.

"We've downloaded over 2,300 standards documents to date, with over 300 frequent users across our operations, design, engineering and quality departments. In the last six months alone we've logged almost 1,000 user sessions, clearly demonstrating the importance of BSOL to our everyday operations."

Q Can you outline important standards you use BSOL to maintain?

We use a number of standards which relate to fixings (washers, screws, nuts and rivets etc.) to help in the configuration packaging of electronic components and assemblies used in the electronic control boxes for our motors.

For example:

- BS SP 139 and SP 140:1969+A2:2012 - Specification for corrosion-resisting steel crinkle washers
- BS SP 126 & 127:1959+A3:2011 - Washers for unified hexagons for aircraft
- BS 4A 104:2002+A2:2012 - Specification for corrosion-resisting steel bolts (Unified hexagons and Unified threads), strength class 880 MPa, for aircraft. This is now being improved by ACE/012 to include a drilled head option, to allow the use of safety tie wire as originally purchased and not as a post-purchase activity, therefore increasing cost and lead time
- BS A 401-420:2015 - Specification for screws, pan and 100° countersunk head, hexalobular drive recess, in various materials. This is a new specification created by ACE/012, mainly for electronic packaging but with other general uses. It makes their slotted predecessors obsolete and is sponsored by UTAS MDSC

Q How do you use BSOL to manage these standards?

We've held a BSOL subscription for over 15 years, and it keeps us right up-to-date with the latest amendments, revisions and additions to critical standards. One advantage of BSOL above other standards databases is that more European standards are included in the specifications.

Our subscription allows 24 individual users to access BSOL at any one time, and the database is consulted frequently across 16 of our office and laboratory locations. We've downloaded over 2,300 standards documents to date, with over 300 frequent users across our operations, design, engineering and quality departments. In the last six months alone we've logged almost 1,000 user sessions, clearly demonstrating the importance of BSOL to our everyday operations.

Our BSOL subscription provides the flexibility to consult the latest standards information for inclusion in our planning activity, across the organization, in an agile and convenient manner.

Additive manufacturing:

Building on a foundation

Mark Summers, Head of Technology for Manufacturing, Materials and Structures at the Aerospace Technology Institute (ATI), outlines how additive manufacturing (AM) is taking an increasingly significant role in the aerospace supply chain.

Most people are now generally aware of the possibilities presented by additive manufacturing (AM). The last few years have seen the technology gain greater mainstream awareness and most manufacturing industries are adopting AM techniques. Aerospace is no different, with AM poised to change the manufacturing process and supply chain in the coming years.

AM offers aerospace manufacturers several significant benefits compared with traditional production methods. Unlike subtractive manufacturing, there are no wasted materials or tool set-up times. It presents cost-saving and weight reduction opportunities by drastically improving the buy-to-fly ratio (the relationship between the mass of the raw material used to produce a component and the eventual mass of the finished product).

Lighter components are now available through AM. This leads to lighter aircraft, helping in the ongoing drive to meet emission reduction targets such as those set by the Advisory Council for Aeronautical Research in Europe (ACARE). Furthermore, AM techniques allow extra technology, such as sensors, to be embedded into components, giving designers a range of new configuration possibilities. The process also reduces production delays caused by long-lead times for components which were traditionally cast or forged.

The ATI was created in 2013 to define the UK's aerospace technology strategy. It is backed by a joint government-industry commitment to invest £3.9bn in aerospace research and development by 2026. The ATI has been working to determine how to apply the AM technique for safety-critical components. A collaborative research program (TIPOW) was created to develop titanium powder for net-shaped aerospace component manufacture[1].

The major aircraft manufacturers have been developing AM capability internally or through strategic acquisition, and many companies in the aerospace supply chain are investing heavily in the technology, although they are somewhat held back by their need for certification by prime contractor cooperatives, such as Nadcap.

In terms of standards development and further research work in this arena, much is centred around materials specification and qualification for the emerging AM powder machine platforms, which themselves are growing to be able to produce larger components.

The concept of the digital twin is also being explored, whereby a virtual model of a component, with all the characteristics of the real world, is topologically optimised through high performance computing and the end to end process simulated to ensure right first time results. Other simulations can also be undertaken to predict long-term maintenance and repair requirements.

ASTM International maintains standards relevant to AM, especially those relating to machine and process classification. The industry is also agreeing on ways to standardize AM materials, with a lot of work around aluminium, titanium, and nickel alloys.

> “AM offers aerospace manufacturers several significant benefits compared with traditional production methods. Unlike subtractive manufacturing, there are no wasted materials, or tool set-up times.”

Looking ahead, with the rise of digital manufacturing and the Industry 4.0 trend[2], standards which govern and reduce variability, especially in distributed manufacturing scenarios, are needed. Variability reduction is an issue for AM and it is generally agreed that increased yields will help solve this challenge. Appropriate global standards would support the widespread production of replacement parts locally, again providing time and cost savings.

The potential for AM to transform the sector is exciting. Large near-net shape components which replace the need for forging are already here, and will only grow in size and scope. The efficiency gains described above are only the tip of the iceberg, and the aerospace supply chain may well look very different in five years ●

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Unmanned aircraft systems:

The quality standards opportunity

Robert Garbett, Chief Executive of Drone Major Group, and BSI ACE/1/-/2 Unmanned air systems committee Chair, explains the need for continued standards work in unmanned aircraft systems (UAS).

Commercial, state, and defence applications for unmanned aircraft systems (UAS) or, as they are more commonly referred to drones, are growing rapidly. As well as widespread photography and surveillance tasks, drones and their accompanying control software are being developed to provide rapid response assistance for emergency medical services. They are also used to detect latent disease in fields of crops for farmers, and asses the cleanliness and state of repair of the outside of office tower blocks. The industry has been rapidly expanding in recent years and there are many new entrants to the marketplace.

As a result of the rapid growth of this industry the regulators have been unable to keep up with the pace of this development and we have reached a point where there is a serious need for standards specifically designed for UAS. There are many applicable standards which can be applied by manufacturers to elements of a drone's technical make-up, for example those relating to blades, batteries and engines. However, manufacturers do not have to apply them, and many new market entrants do not have an aerospace engineering background.

Critical UAS-specific safety quality standards are currently missing. We need to develop standards that industry can use to set quality benchmarks around safety and reliability. Standards are needed to address UAS flight performance, to make sure drones can operate safely under any environmental conditions. We need to ensure that batteries do not fail when exposed to particular air temperatures, for example.

Also, many drones are connected to the internet to send or stream data. Therefore, we need to develop drone software security standards, to protect against the potential for hacking both in terms of taking control of the UAS and accessing the data which it may be streaming online. Looking beyond UAS, these software security challenges also exist for the wider aerospace industry as we see increasing fly-by-wire control systems in civil aircraft.

Quality standards will also have a powerful influence on the future development of the UAS industry from a commercial point of view. In time, as standards are developed and used by serious manufacturers, consumers will be able to see which drones are certified to safety and quality standards (and are applying best-practices) and which ones are not. The drone market has been estimated at many tens of billions of dollars and is forecast to continue to grow significantly over the next decade. It is important that standards are developed to protect and support this potential.

Collaboration across the industry is needed to achieve consensus on these and other drone-specific quality standards, through organizations like ISO and BSI. I assist BSI in my role as a UAS expert having written the original airworthiness maintenance policies for early military drones more than 15 years ago.

My work with ISO's UAS technical committee ISO/TC 20/SC 16 is addressing these challenges as we take an end-to-end approach to drone standards development.

Drones represent an exciting and positive development for society going forward, analogous perhaps with the rise of both the automobile and aeronautical industries of the last century. Our challenge is to ensure that we develop the protocols and standards to enable them to realize this enormous potential safely and acceptably •

"The drone market has been estimated at many tens of billions of dollars and is forecast to continue to grow significantly over the next decade. It is important that standards are developed to protect and support this potential."

Photo: TE12 test wrap UAV, June 27, 2012 by NASA. Licensed under Creative Commons.

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Stuart Webb, Reaction Engines

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