REQUIREMENTS DEFINITION AND QUALIFICATION FOR A HEAT FLY-BY-WIRE SYSTEM

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Abstract

The Helicopter Electro-mechanical Actuation Technology (HEAT) programme seeks to embody novel electro-mechanical main and tail rotor actuation on to the EH101 helicopter. In combination with a new quadruplex fly-by-wire flight control system, HEAT will enable the deletion of two hydraulic systems and the simplification of the aircraft configuration, with allied benefits in mass, cost of ownership and safety. Design and development of the HEAT system is well progressed, with the first flight of a demonstrator aircraft expected by early 2005.

In common with all 'new design' projects, many technological and programmatic challenges have arisen during HEAT system development. These challenges have been met, in part, by the intelligent use of innovative AgustaWestland procedures and processes. Critically, both the requirements capture and Verification and Validation processes have been approached with substantial care: requirements definition has been particularly rigorous and thorough, whilst the matching Qualification activities remain focused and appropriately controlled.

This paper describes the fundamental requirements definition and Qualification activities supporting HEAT and, in the process, affords the reader an insight into the implications of designing, specifying and proving safety-critical flight control systems.

Introduction

The design and development of Helicopter Electro-mechanical Actuation Technology (HEAT) for the EH101 helicopter (Figure 1) is well progressed. HEAT will seek to implement novel electro-mechanical main and tail rotor actuation in combination with a new fly-by-wire primary flight control system. The HEAT system is being co-developed by AgustaWestland in a Consortium partnership with BAE Systems (Avionic Systems), Claverham Ltd and the UK (MoD) Merlin Integrated Project Team.

The benefits of HEAT are substantial: deletion of the primary and secondary hydraulic systems, the removal of the accessory gearbox and the resulting simplification of the aircraft layout will result in weight savings, together with reduced maintenance overheads and improved safety. The digitisation of the primary flight control system will also facilitate the future embodiment of advanced control law technology. In the long-term, HEAT will act as a major step towards the "All Electric" aircraft, a progression that will bring further through-life customer benefits (Ref 1).

Figure 1 – AgustaWestland EH101

To-date, the HEAT system has presented a range of technical and organisation challenges. The key technical challenge has grown from the innovative use of powerful brushless DC motors for the electro-mechanical actuation of the main and tail rotor systems (Figure 2). From an organisational standpoint, the need for a suitable requirements definition system and a flexible organisation structure, allied to robust

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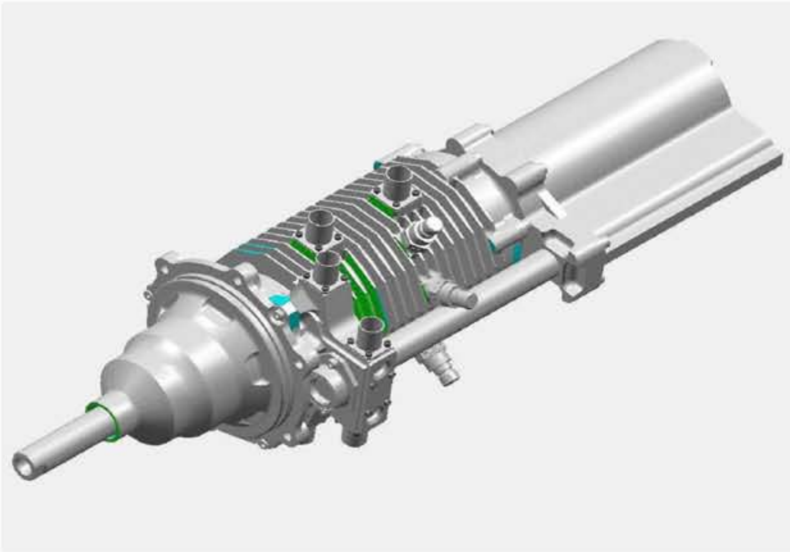

Figure 2 – HEAT Tail Rotor Actuator

inter-Consortium communication procedures, has been satisfied ensuring a quick and expedient way of working.

The design and development of novel, flight-critical technology in a challenging project demands a considered, careful approach to all aspects of the process. In particular, the need for rigorous design and qualification processes is significant. This paper describes the fundamental requirements definition and Qualification activities supporting HEAT. The subject is approached in a logical manner, taking the reader from the start of the process (HEAT requirements definition), through a discussion of requirements management and its supporting tools, finally concluding with a discussion of requirements verification and validation. Following this approach, it is hoped that the reader will gain an insight into the implications of designing, specifying and proving safety-critical flight control systems.

Overview of HEAT System

Figure 3 illustrates the HEAT system configuration which will be flown on the demonstrator EH101 Merlin aircraft. Fundamental to HEAT's operation is the use of a core four-lane (quadruplex) system. This robust architecture is designed to tolerate a single lane failure without a reduction in normal flight capability. Failure of a second lane will reduce the flight envelope capability although continued safe flight can be maintained.

The existing pilots' inceptors and fixed flying controls are retained up to the Parallel Actuator positions, which are located behind the crew stations. At this point, the fixed flying controls interface with quadruplex RVDTs, which provide control positions for the new HEAT fly-by-wire Flight Control Computers (FCCs). Mechanical interface with Automatic Flight Control System (AFCS) Parallel Actuators is retained. This configuration allows the pilot to command the aircraft using standard EH101 flying controls, without recourse to additional aircraft familiarisation.

HEAT system computation comprises two FCCs, each containing two control lanes. The mechanical and electrical separation of both lanes within the FCCs fully preserves the quadruplex architecture, a key facet of the system's safety and integrity. The FCCs are also located at separate points within the aircraft, thus meeting essential requirements for environmental and operational separation.

HEAT will adopt a phased approach to system clearance. Initial flying will be undertaken with the existing AFCS Flight Control Computers interfacing with the new HEAT FCCs via the retained Series actuators. For further phases, and a Production solution, AFCS functionality will be re-hosted and embodied into the new digital FCCs. This re-hosting activity will yield further benefits, chiefly improved weight saving.

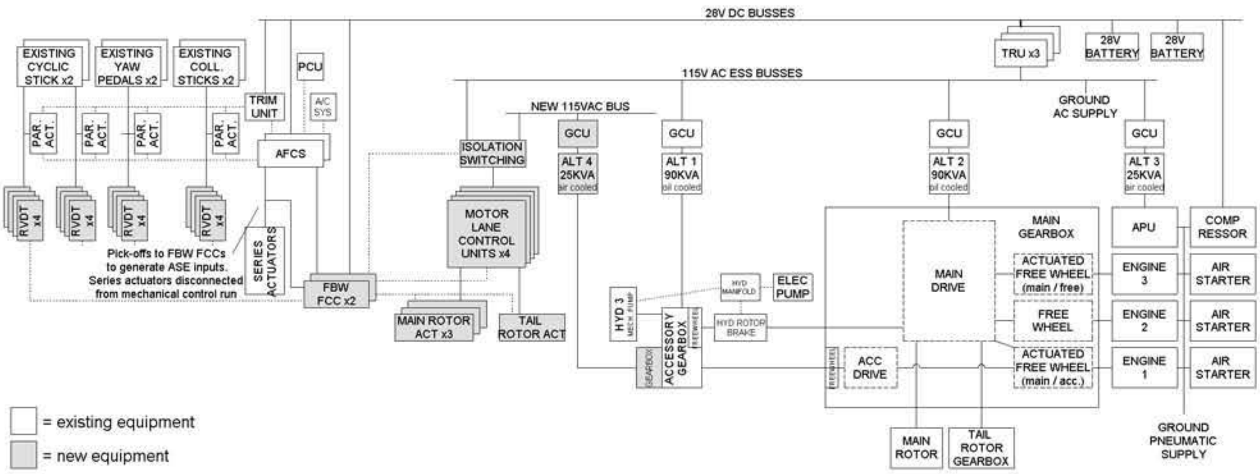

Figure 3 – HEAT System Configuration (Demonstrator Aircraft)

The introduction of electrically powered rotor actuation has significant implications for its supporting services, chiefly the aircraft's electrical generation and distribution system (EGDS). Whereas the existing implementation of the EGDS is non-flight critical, the HEAT EGDS must now own the responsibility for the safe, continued and guaranteed supply of electrical power to the actuation system. To this end, figure 3 illustrates the intended use of a 3 AC generator configuration (named ALT1, ALT2 and ALT4) for use on the demonstrator aircraft. An additional APU-driven generator is available (ALT3). Isolation switching, voltage sensing and lane switching between generators are provided in a HEAT failure management system for the generation system, integrated with failure management within the FCCs.

The Accessory Gearbox (AGB) is shown driving both ALT4 and the sole remaining hydraulic pump, HYD3, which is used for the utility systems. Although the AGB will be retained for the flight demonstration phase, Production will afford refinements to the Main Gearbox (MGB) and the subsequent removal of the AGB. This will have a significant weight saving benefit allied to lower maintenance costs.

The above description serves only as a top-level outline of HEAT system implementation. Nevertheless, it is easy for the reader to envisage the wide-ranging impact that HEAT will have on the baseline aircraft. Systems such as flight controls, electrical generation/distribution and transmission will be directly affected with many other systems indirectly impacted. With an overriding need to maintain the EH101 Merlin's substantial performance requirements, whilst simultaneously improving aircraft safety, it is therefore essential that the definition and management of requirements is approached with care.

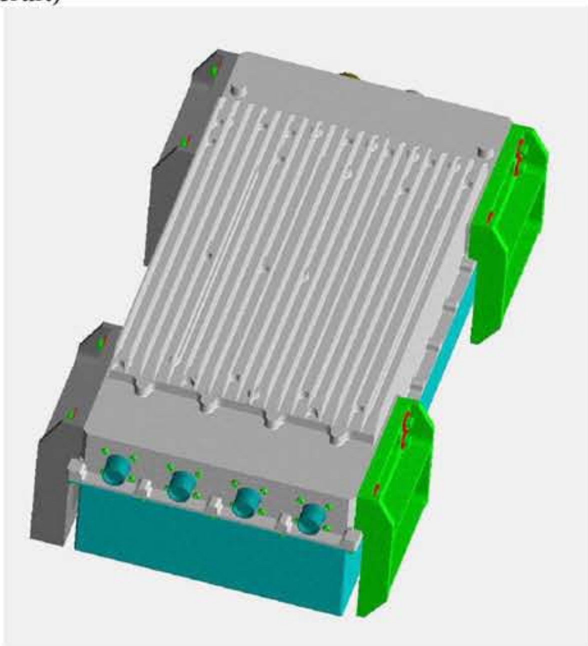

Figure 4 – HEAT Motor Lane Control Unit (MLCU)

Requirements Definition

Aerospace customers are demanding increasingly shorter development lead-times, more responsive build programmes and a clear understanding of the through-life operating cost of airborne systems. In addition to this, end users are requiring reduced system obsolescence, together with demonstrable paths to future growth in system capability.

The Aerospace Industry, faced with these very challenging standards on design and delivery performance, on quality performance and price pressure, must ensure that their activities are effective, efficient and focused on customer 'wants and needs'. Based on this reasoning, it quickly becomes apparent that the accurate definition and careful management of requirements is a key step in ensuring that customer satisfaction is achieved in a correct manner. Further to this, it can be seen that requirements management extends beyond the definition stage: it should, ultimately, afford the modern company a means of identifying future business opportunities, whilst simultaneously improving its knowledge base and extending its competitive advantage. Within aerospace engineering, this approach is encapsulated in the "right first time" and "Continuous Improvement" methodologies; the fundamental precepts of ISO9001, Kaizen and Total Quality thinking. It follows logically that a substantial proportion of effort and care should be expended on the crucial requirements definition stage.

Although the satisfaction of customer requirements is fundamental to the success of any project, of greater importance, is the need to supply a safe, airworthy system on to which requisite capability can be grown. These airworthiness requirements take on a heightened importance when the aircraft system is flight critical, as exhibited by the HEAT system, Figure 3.

The intrinsic flight critical nature of HEAT mandates a thorough, robust and auditable process for the definition of requirements. Not only should this process address requirements capture, it should also demonstrate sufficient flexibility to handle the progressive satisfaction of those requirements. Ultimately the process should provide a safe, monitored route to certification and qualification, as well as a tool for gauging and managing the through-life continued airworthiness of the system. The HEAT project has derived a suitably innovative process to answer these demands.

Requirement Source

It is a typical feature of state-of-the-art flight control technologies that the design requirements and associated guidance material emerge subsequent to the development process (Ref 2). In this respect, HEAT is no exception. A thorough review of those standards traditionally applied to rotorcraft reveals a paucity of advanced control system requirements; although appropriate guidance material is starting to emerge. Interestingly, this emerging guidance is typically descriptive, rather than prescriptive, thus leaving a significant margin for interpretation.

HEAT requirements originate from a diverse range of sources, including the following:

- Legacy EH101 requirements,
- Existing and new standards (US MIL-STDs, JAR29 (Ref 3), UK DEF STANs and British Standards BS),
- Emerging and draft standards.

Where existing or emerging guidance material has been found unsuitable for HEAT, engineers have used derived requirements from previous HEAT development work, Hazard and Operability Studies (HAZOPS) or aircraft testing. Where requirements and standards have been found to overlap, or contradict, deference to safety prevails, and a suitably prudent approach has been followed. The following example (table 1) illustrates the treatment of two HEAT requirements taken from UK MoD Defence Standard 00-970 Design and Airworthiness for Service Aircraft-Rotorcraft (Ref 7).

Table 1 Example : Resolution of contradictory HEAT requirements

Req't No.	Reference	Requirement
Q5009	DS 00-970-2 Chapter 107	**Chapter 107 : Pilot's Cockpit Controls And Instruments**
Q5030	DS 00-970-2 Chapter 107 9.1.1 (i)	9.1.1 The following controls shall be grouped together: (i) AC and DC supply switches, but not the master electrical switch,
Q271	DS 00-970-2 Chapter 207	**Chapter 207 : Active Control Systems**
Q1582	DS 00-970-2 Chapter 207 5.5.2	5.5.2 The layout of switches, indicators etc., shall be designed to minimise the probability of the crew incorrectly operating the ACS in a way which could degrade system operation. Attention shall be given to the correct positioning and sequencing of controls and switches.

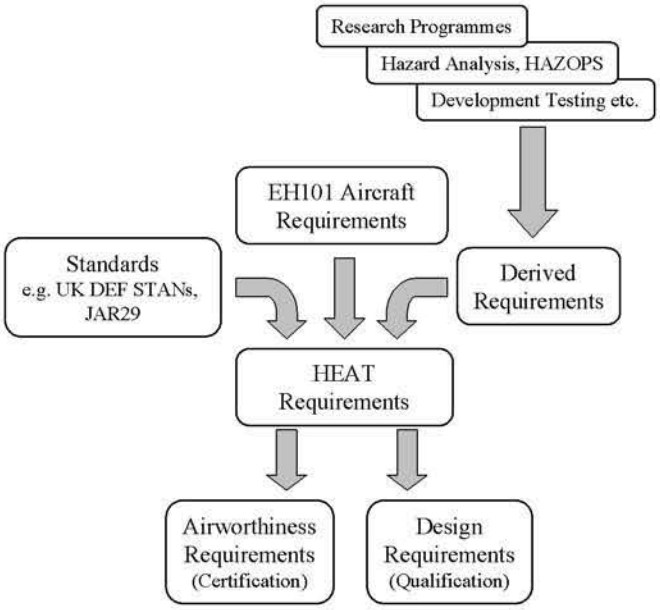

Figure 5 Partitioning of HEAT Requirements

For a standard EH101, requirement Q5030 can be implemented in a unambiguous manner; thereby ensuring that all AC and DC supply switches are co-located, leaving the pilot with a single point of operation for all EGDS controls.

However, for a HEAT-equipped aircraft, where the EGDS now forms an integral part of the new fly-by-wire system, requirement Q1582 must also be considered. Although not mutually exclusive, requirements Q5030 and Q1582 become conflicting under the current EH101 electrical switching arrangement. To resolve this conflict, HEAT engineers turned to the HEAT Safety Case and one of its components, the Fault Tree analysis. The hazard-to-accident sequence suggested that the use of a partitioned EGDS should pursue a policy of lane separation wherever possible. As such, requirement Q1582 must take precedence over requirement Q5030.

The Requirements Definition Process

A good requirements definition and management process is fundamental to the effective management and control of product development. With an ever increasing range of relevant standards and regulatory material, together with supporting guidance notes, it was deemed necessary to define an innovative process capable of offering a robust, capable, expedient, flexible and, above all, safe route to HEAT Qualification.

For HEAT, the definition of requirements is partitioned into two distinct but interrelated activities: qualification and certification. In the context of the HEAT programme, qualification plans address design and specification compliance only, whilst the Basis of Certification directly addresses issues of airworthiness. Using this regime, airworthiness requirements can be ring-fenced and independently audited as part of the Safety Case. Figure 5 provides a top-level schematic for the definition of HEAT requirements.

The following example (table 2) outlines the treatment of two HEAT requirements taken from Def Stan 00-970 Design & Airworthiness Requirements for Service Aircraft (Rotorcraft) (Ref 7).

The Electrical Systems Design Specialist retains the responsibility for meeting both requirements, although the first requirement (Q1902) is clearly an airworthiness issue. Using the process adopted by HEAT, proof-of-compliance against Q1902 must meet the satisfaction of both the Design Specialist and the HEAT Project Safety Committee (PSC).

Regardless of type, the definition of each requirement follows a 4-stage process, as follows:

- Stage A: Extraction of requirements
- Stage B: Assignment of requirements
- Stage C: Refinement of requirements
- Stage D: Agreement of requirements

Table 2 Example : Treatment of HEAT airworthiness requirements

Req't No.	Reference	Requirement
Q1902	DS 00-970-2 Chapter 706 2.4 Chapter 706 2.4(a)	2.4 No failure condition of the electrical installation resulting from a single failure, a second failure or unrevealed dormant fault, or a combination thereof shall jeopardise: a) the safety of the aircraft, or its occupants in flight, taxiing, take-off, landing, or on the ground
Q1973	DS 00-970-2 Chapter 706 4.2.1	4.2.1 Means shall be provided to monitor the voltage and load provided by each generator, and in addition a frequency meter shall be provided for ac systems.

Stage A seeks to identify all applicable HEAT requirements, whether design, performance, installation, maintenance or airworthiness. Consultation with relevant design specialists is undertaken at this point to ensure a thorough and rigorous assessment has been undertaken.

Stages B and C adopt the sole aim of ensuring that selected requirements are expressed correctly and targeted at the correct level (aircraft, system, sub-system etc.). This process requires significant time and effort. To simplify the task, the definition of HEAT requirements has followed a simple set of criteria.

Every correctly specified HEAT requirement must demonstrate a number of common key characteristics. Firstly, and most obviously, HEAT requirements must be correct, thus ensuring that the product is designed and built so that both safety and customer requirements are successfully met. Secondly, the requirement must be complete and must not contradict itself or other requirements. Thirdly, requirements, and in particular software requirements, must be clear and succinct so that anyone reviewing the requirement set remains cognisant of the design intent. Fourthly, each requirement must be verifiable so that a clear level of compliance can be ascertained following testing, analysis etc. Finally, requirements must always be traceable to their source, or parent requirements. This traceability should lead the reviewer to the top-level user requirement or, alternatively, the appropriate regulatory document or standard. In general, any poorly defined requirement failing to achieve the above may be misunderstood, and lead to an unsatisfactory and unsafe product.

Stage C onwards is conducted in a 'working group' consultation with the customer, resulting in an agreed compliance Verification and Validation plan at the close of Stage D.

Once the Verification and Validation process commences, compliance with airworthiness requirements will be monitored by the HEAT Project Safety Committee. In parallel with this activity, any critical process requirements will be independently verified by an overarching Independent Safety Audit Team (ISAT). Ultimately, this approach creates a valuable means of checking HEAT System Safety against the Qualification task.

Requirements Management

The complexity of aircraft systems is increasing rapidly, with fly-by-wire and electro-mechanical actuation being representative examples of this development. As a result, the scope of fully defining and controlling system design is often beyond the mind of any single individual. Ultimately, the complex interactions of new flight-critical systems require inputs from many disciplines (both technical and non-technical). As such, the management of requirements has been a vital consideration in defining, building, developing and testing the HEAT system. Any system must have the supporting tools, processes and procedures to ensure that requirements have been adequately defined, agreed and satisfied. Indeed without structure and control, developers may lose track of what they are designing, or may change requirements improperly. With increased technology turnover and a natural turnover in employees, it also necessary to record the rationale for critical decisions.

On an operational day-to-day basis, requirements management must be simple, intuitive and, in the case of HEAT, must offer practical advantages over previous systems. The management tool and supporting process should be easy to navigate and efficient in generating apposite information in a timely and coherent manner. Although simple, the requirements management process must be sufficiently robust to ensure that deviation from the process is impossible. The resultant HEAT requirements management process follows a safety orientated approach based on the following key attributes:

Auditability : HEAT requirements must be well documented and presented in a logical, structured format. The definition and satisfaction of requirements must be supported by an agreed process using recognised Quality procedures.

Traceability : A traceable route-to-compliance must be established. This 'route' must successfully map a requirement from its source to final agreed compliance. Traceability must also allow for the easy review and interrogation of requirement changes, together with any decisions and comments which affect that requirement.

Robustness : The requirement management system must afford access to requirements and their satisfaction throughout the life cycle of the aircraft. The system must be sufficiently flexible to manage requirements as the HEAT system grows and matures.

Requirements Management Tools

To successfully implement the requirements management process highlighted above, it is necessary to use an appropriately capable tool with well-specified supporting procedures. This tool must address several tasks, including the easy management of day-to-day requirements definition, the control of requirement changes and the reporting of status to interested parties.

HEAT requirements management is centralised, with all serials co-located in a single requirements capture tool (Telelogic DOORS©). The individual modules within DOORS© have been carefully designed and organised to reflect the process outlined in Figure 6, namely a cascading, systematic and traceable approach to requirement definition and satisfaction. The use of a single tool for requirements capture across the partnering Consortium members is currently yielding many benefits for HEAT, including:

- Easy traceability and auditability of sub-systems requirements to their source
- The ability to quickly, logically and intuitively navigate through the multifarious requirements which drive the design and airworthiness of an advanced fly-by-wire control system
- The ability to clearly document and account for requirement changes using a Problem Reporting system
- The ability to retain history profiles of requirement development and growth
- The ability to baseline requirements sets prior to modification
- The co-location of requirements, which eliminates both wasted effort in cross-referencing documentation and the risk of requirement duplication.
- The ability to quickly summarise and produce reports for project stakeholders

The use of single tool has the additional benefits of avoiding work duplication whilst allowing engineers to undertake requirement management tasks in parallel. Database maintenance is also simplified.

Organisational Structure

The use of a centralised approach to requirements management is reflected in the supporting HEAT organisation. Orchestration of the system falls under the remit of two Equipment Engineers and a single Project Qualification Engineer. Using appropriate measures of control, access to each requirement set within DOORS© can then be granted to those specialists holding design authority over their sub-sections of the HEAT system. In this manner, management of system-level issues remains closely controlled, while the owners of technical requirements (Design Specialists) remain tightly focussed on their tasks. The chief advantage of this route is significant. Design Specialists are, by job role and experience, more sensitive to safety and technical rigour for their sub-systems. As such, greatest value is gained by unburdening the Design Specialist from superfluous project management duties, whilst simultaneously ensuring that all team members are aware of the system-wide impact of their work

In addition to the advantages outlined above, the adoption of a small centralised team of core requirement managers is currently providing several benefits for HEAT, including

- the creation of a group held responsible for establishing, managing and maintaining technical requirements
- the existence of an organisational focus for capturing, discussing, agreeing and documenting any proposed problems, issues or changes to requirements, or their parent specifications
- Improved communication. Core HEAT members can rapidly notify the appropriate safety and design personnel concerning relevant project issues
- Increased speed of response to new or emerging technical and safety issues.

Throughout the length of the project, assurance must be given that the HEAT-equipped aircraft remains safe and acceptable within current aircraft design and operating clearances. To this end, select HEAT activities are overseen and reviewed by an aircraft-level technical authority (EH101 Project Engineering). This top-level team retains responsibility for aircraft integration and ultimate Airworthiness Approval, including Certification of Flight.

Overall, the combination of a centralised requirements management team, together with a single requirement management tool, is helping to improve clarity of operation, uniformity of process, and consistency of requirements and responsibilities for HEAT.

Qualification

Qualification is the collective term used for those processes and activities which result in the demonstration of conformance against requirements. Based on the maxim that 'Quality is conformance to requirements' (Ref 6), it can be inferred that the level of Qualification is a direct measure of a system's Quality.

In simple terms, Qualification is the task of proving that a requirement has been satisfied to the agreement of the requirement's originator, usually the customer. For HEAT the 'Qualification process' is taken as compliance demonstration against all HEAT requirements, regardless of source. Within the project, Qualification is broken down into two distinct regimes and is generally referred to as the Verification and Validation (V&V) task.

Qualification for each sub-system or aircraft performance area falls under the responsibility of the individual Design Specialist. Responsibility for HEAT system and aircraft integration Qualification aspects is retained by the core HEAT team and EH101 Project Engineering.

Verification & Validation (V&V)

In structural terms, HEAT requirements are organised in a top-down, cascading format: aircraft level requirements flow-down to HEAT system level, which subsequently flow to sub-system level. In this format, the treatment of requirements follows the widely practised "V" shaped "Verification and Validation" process, as detailed in Figure 6. Based on this approach, HEAT sub-system components must demonstrate compliance against their functional, performance and safety requirements (Verification), followed by integration and subsequent demonstration of conformance against higher-level system requirements (Validation). This process repeats until, eventually, the HEAT system can be validated at an aircraft level.

Qualification Working Group

The Qualification task in an Aerospace programme traditionally rests with the Aircraft Contractor or System Design Authority. Typically, communication of Qualification status and final compliance to the customer is achieved through the submission of files, verification and validation matrices, test reports etc. More often than not, the majority of customer involvement occurs only at the beginning of a programme and again towards the build and qualification period.

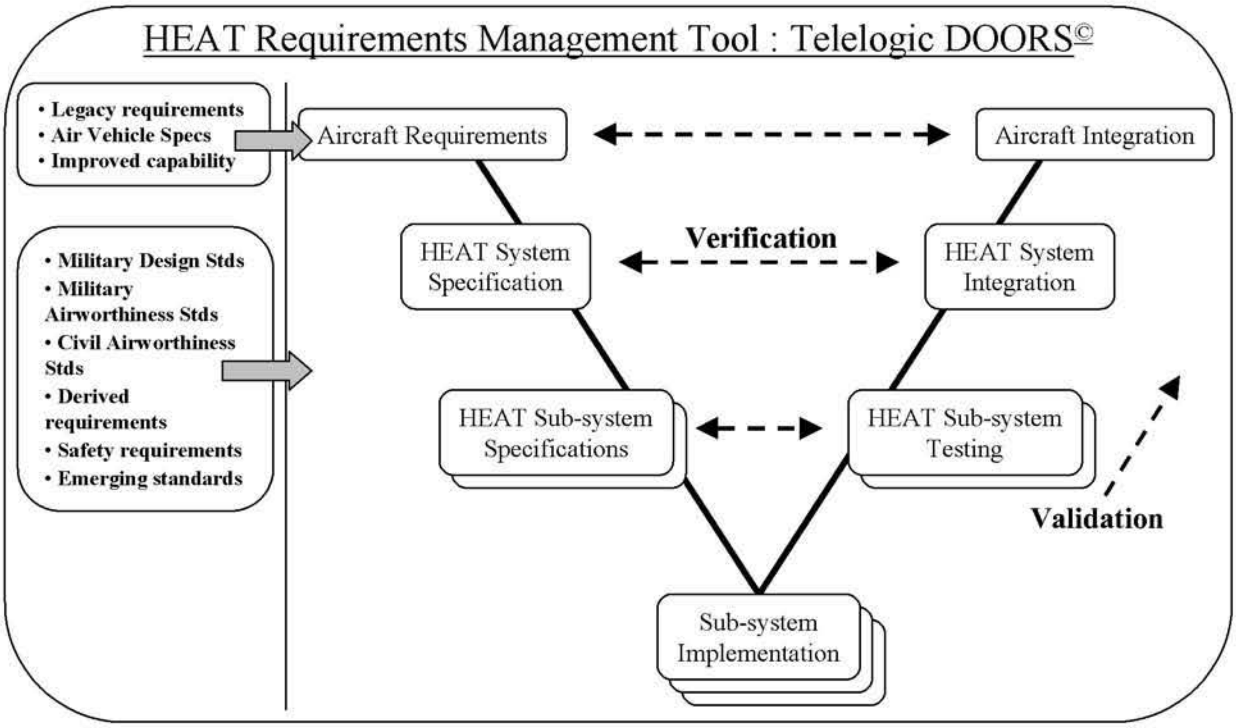

Figure 6 HEAT Requirements Management Tool

The challenging timescales of the HEAT programme and the close involvement of the customer have called for a redefined way of working. To this end, the HEAT Qualification Working Group (QWG) has been organised to reflect well-proven AgustaWestland processes, but also to embrace the need for regular contact with the customer throughout the system design cycle. QWG meetings are organised on a monthly basis (as a minimum) and follow a standardised format and reporting approach.

The regular face-to-face meetings have the double benefit of keeping the customer informed of progress, whilst allowing customer questions to be answered in a timely and expedient manner.

Problem Reporting

The need to maintain process integrity throughout the requirements definition and compliance phases is critical and, as such, has led to the creation of a bespoke HEAT Problem Reporting system. Based in DOORS©, this system is routinely used to ensure that appropriate corrective actions have been reviewed and agreed with appropriate design authorities. Unless agreed with the issuing authority, or their technical advisors, no individual is allowed to 'tailor' requirements from accepted standards.

From a safety standpoint, the co-location of requirements allows impact analyses to be quickly and reliably undertaken. Reported problems and associated changes to system level requirements can be explored and navigated at the sub-system level, and vice versa.

Requirements Definition, Qualification & the Safety Case

The HEAT Safety Case is a well-structured, well-reasoned argument, constructed with the sole aim of providing assurance that the HEAT system is acceptably safe given its operation within a known environment. Essentially, the Safety Case provides a link between HEAT requirements and their supporting compliance evidence, whilst simultaneously considering the practicalities and achievability of project objectives

At a lower level, the Safety Case's chief task is to align all of the individual safety studies, hazard reports and safety documents into a coherent whole. The Safety Case can then be used to demonstrate that the HEAT system, installed into a serviceable aircraft, is capable of safe operation. Constituent evidence for the Safety Case includes, in no specific order;

- Hazard Listings
- Failure Modes and Effects Analyses (FMEAs)
- HAZard and OPerability Study (HAZOPS) reports
- Fault Trees
- Risk Estimation matrices

In simple terms, the interrogation of these documents allows the engineer to establish causal factors contributing to the most likely accident sequences. To provide a clear articulation of the HEAT Safety Case, AgustaWestland's System Safety Department has adopted the use of Goal Structured Notation (GSN) to great effect (Ref 4).

GSN offers an efficient and robust method of expressing the HEAT safety argument. Figure 7 replicates a portion of GSN from the HEAT Safety Case. Although only a minor extract, figure 7 demonstrates the intuitive, logical approach used to argue that all relevant airworthiness requirements have been addressed and correctly defined. Ultimately, this is achieved by showing that the likelihood of overlooking any relevant regulatory and DEF STAN airworthiness requirements is extremely improbable, and that all derived requirements have been based on solid assumptions.

In terms of requirements definition, the overriding benefit of the HEAT Safety Case is the provision of an independent, structured and controlled approach to the assessment of airworthiness and safety-for-flight. Where new requirements have been identified through safety analyses, they are simply adopted by the relevant equipment or system specifications. In this manner, the Safety Case acts as a valuable check and balance mechanism for both the definition of airworthiness requirements and their compliance demonstration.

For further details on the structure, standards and approach to HEAT system safety, the reader is directed to References 4 and 5 (Refs 4 and 5).

Continuous Process Improvement

As with all aerospace technology programmes, the HEAT development process must strive for continuous improvement. It is anticipated that the benefits of continuous improvement in the HEAT requirements management process will be many, and will include:

- Improved support to HEAT production and installation
- Support to future design growth and HEAT system expansion
- Embodiment of 'lessons learnt' for future flight control programmes

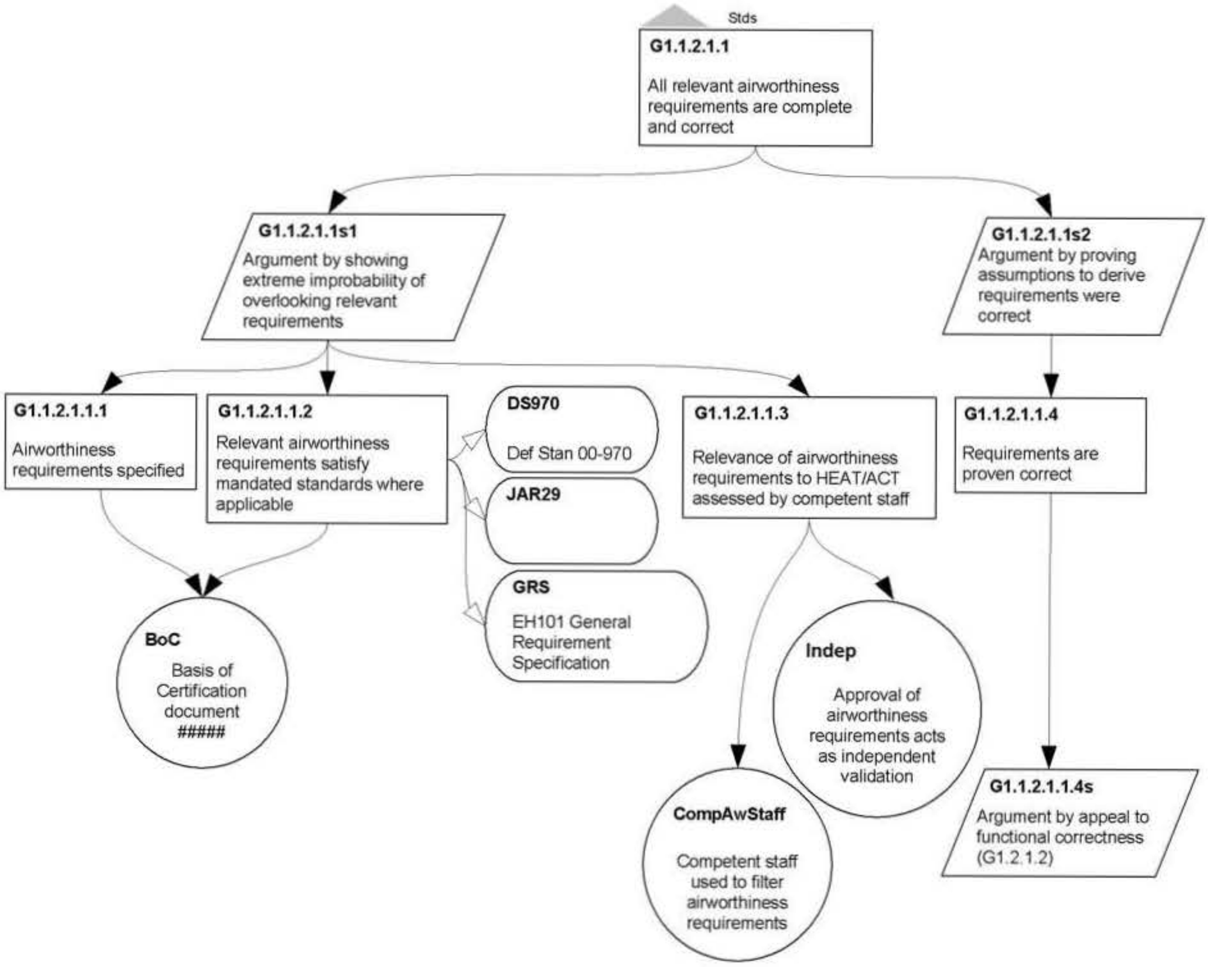

Figure 7 Goal Structured Notation (GSN) representation

- Elimination of inefficient requirement management practices
- Identification of bottleneck activities in the Verification and Validation process

As the HEAT programme enters the initial stages of rig testing and flight demonstration, the necessary requirement management tools and organisation have been set in place to allow for future process improvement.

Conclusions

The HEAT team has successfully integrated novel requirement capture, management and reporting techniques with existing, well proven AgustaWestland processes and procedures. The need for a rigorous approach to requirements capture in the context of modern business pressures has been embraced, whilst the resultant HEAT requirements management process follows a safety orientated route which is auditable, traceable and robust.

Within the HEAT Consortium, the combination of a centralised requirements management team, together with a single requirements management tool, is helping to improve clarity of operation, uniformity of process, and consistency of requirements and responsibilities for HEAT. The HEAT Qualification process has been presented, highlighting the benefits of the Qualification Working Group and the importance placed on constant communication between the customer and the HEAT Consortium industrial partners.

The use of Goal Structured Notation (GSN) to construct and develop the safety argument has been shown to provide rigor and clarity in the construction of the Safety Case. The benefits of GSN and the valuable link between requirements definition and Qualification have been demonstrated to good effect.

As the HEAT programme approaches the initial stages of rig testing and flight demonstration, the necessary requirement management tools, processes and organisation have been set in place to allow for future improvement and support.

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