NH90 Transition from Development to Service Operation – Certification Challenges in a multi-national military environment

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Abstract

The NH90 as a Certification/Qualification project is so far unique in Europe in its technical complexity and multi-dimensionality. It underwent several distinct phases where re-adjustment of the applied methodology and structure became necessary to accommodate a changing perimeter. As such, it is considered to provide valuable lessons for application on future European multi-national military development projects. This Paper aims to present the decisions taken and the methodology put to work by the NH90 Certification/Qualification Community as well as the logic, background and rationale for these, in order to enable capitalization on the experience gained in the course of NH90 development.
When the NH90 Development Contract was established in 1992, the framework for Certification and Qualification was set up strictly to perform a full baseline type inspection of a whole newly-developed Helicopter, following a pre-defined development schedule. With export sales to foreign Nations, the introduction of development steps (such as Initial Operating Configuration and Capabilities – IOC, Final Operating Configuration and Capabilities – FOC) and the decision to qualify one specific Variant first, the concept of Delta Qualification was applied in a next step - focusing on the differences of a new target configuration versus a qualified reference baseline, both in terms of requirements to be applied and the Type Design definition. With the NH90 entering service, the need to certify Changes to the Type Design arose. The nature of these post-TC Modifications is often transversal, meaning that a Change tends to affect many or all existing NH90 Variants. The concept of the Joint Military Aviation Authorities NH90 – JMAAN – was set up drawing on civil experience and example. Within the JMAAN framework, certification of changes to the NH90´s Type Design is being managed by applying a methodology similar to the pre-EASA civil European JAA environment, where National Authorities retain the sovereignty for performing the act of Certification based on recommendations issued by the four NH90 Primary Authorities (PAs).

1 GENERAL INFORMATION

The NH90 Design & Development Contract[1] was launched in 1992, originating from a NATO requirement formulated in the late 1980s to replace ageing fleets of medium-sized transport helicopters as well as shipborne rotorcraft in the Armed Forces of several European NATO States.

On Customer side, the NATO Helicopter Management Agency – NAHEMA – was established to represent the procurement agencies of France, Italy, Germany, the Netherlands and, joining in 2001, Portugal.

On Industry side, the NHIndustries consortium – NHI – represents the Partner Companies (PCs) Eurocopter SAS, Eurocopter Deutschland GmbH, AgustaWestland and Fokker Aerostructures B.V.

The NH90 family started its development centered around 2 Versions planned to be common to all Nations:

- the land-based Troop Transport Version (Tactical Transport Helicopter - TTH)

- the Naval Version for SAR and ASW missions (NATO Frigate Helicopter - NFH).

The Helicopter is broken down into its main constituent parts and systems following a contractually agreed Industrial workshare[2], with Design as well as Manufacturing Responsibility distributed among the PCs.

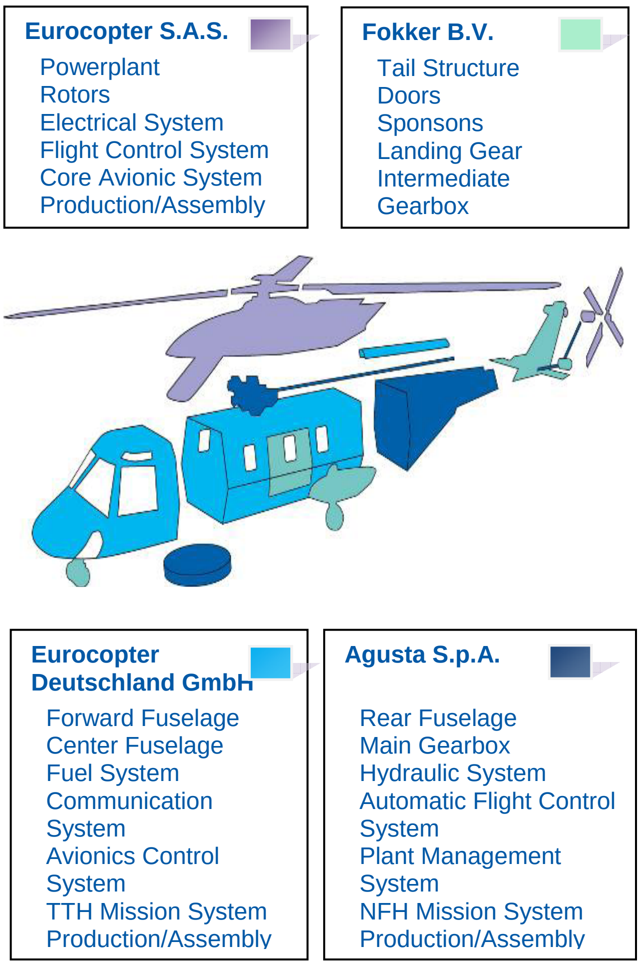

Figure 1: NH90 Industrial workshare with Design Responsibility allocation

Then, in the frame of the series production contracts - one per Customer - this NH90 family started to diversify: The Nations required specific customizations for their respective NH90s, affecting for example the choice of the engine, the radio suite, and some optional kits and equipment.

In a next step, export variants were sold and corresponding contracts were signed. The export variant configurations were derived from NAHEMA variants, picking up some options (e. g. Emergency Floatation System, Ice Protection System, Anti-Sand Filter…) from NAHEMA NH90 variants, and were further customized with nationally specific items.

The table here-below summarizes the currently existing NH90 Variants, grouping them by common main characteristics:

NH90 Version	NH90 Variant
TTH spectrum with RRTM 322 engine	TGEA for the German Army TGEE for German Air Force TPOA for Portuguese Army TGRA for the Greek Army TFIA for the Finnish Army TAUA for the Australian Army TNZA for New Zealand Army
TTH spectrum with GE T700 engine	GITA for the Italian Army
TTH spectrum with RRTM 322 engine and high cabin	BSWA/N for the Swedish Army and Navy
TTH spectrum with RRTM 322 enhanced engine	TOMF for the Omani Army / Special Forces
TTH spectrum with T700 enhanced engine	GSPA for the Spanish Army
NFH spectrum with RRTM 322 engine	NFRS/N for the French Navy NNLN for the Dutch Navy NNWN for Norwegian Navy
NFH spectrum with GE T700 engine	HITN for the Italian Navy
TTH spectrum with GE T700 engine and with NFH rotor	MITT – VertRep (Transport) Variant for the Italian Navy

Table 1: NH90 Versions and Variants

2 Initial Certification/Qualification Concept

The NH90 multi-national context involving 4 Partner Companies and 4 (later 5) NAHEMA Nations required a specific and structured organisation supported by clear roles for the different stakeholders. In the frame of Certification/Qualification activities, this organisation was based on the NH90 item/system Industrial workshare presented in Chapter 1, and on a dedicated entities set up on Industry and Official Services´ side[3].

2.1 Variant Qualification File construction principle

The construction of the Qualification Compliance File (QCF) and the production of the contributing substantiation files were organized by the breakdown of the helicopter into its constituent systems and components structured in 3 levels:

- Major System
    - System
        - Item

The scheme below illustrates this mechanism for the Dynamic System:

Major System	System	Item	PC
DYNAMIC SYSTEM			EC
	ROTORS		EC
		MAIN ROTOR HEAD	EC
		MAIN ROTOR BLADES	EC
		TAIL ROTOR BLADES	EC
	TRANSMISSIONS		AW
		MAIN GEARBOX	AW
		INTERMEDIATE GEARBOX	FK
		TAIL GEARBOX & TAIL ROTOR HEAD	FK
		ROTOR BRAKE	AW
		ANTI-VIBRATION SUSPENSION SYSTEM (SARIB)	EC
		REMOTE ACCESSORY GEARBOX	EC
	POWERPLANT		EC
		ENGINE INSTALLATION	EC
		INFRA-RED SUPPRESSOR SYSTEM	EC
		SAND FILTER SYSTEM	EC
	AUXILIARY POWER UNIT		EC

Table 2: Dynamic System breakdown and PC responsibility

Each Item system design responsible (SDR) was tasked to produce the associated substantiation file covering the applicable airworthiness and performance requirements. The substantiation had to address the allocated requirements, according to the agreed Qualification Plan, where the SDR could act as Owner or Contributor. These substantiation files, collecting the relevant evidence documents and reporting the compliance status in front the concerned requirement, were named “Qualification Sheet”. Each Qualification Sheet was submitted for approval to the corresponding Authority, validating the results in one shot (and not requirement by requirement).

Upper level SDRs were tasked to assemble the contributions, in particular the reported compliance status, from their lower level constituent Items, complemented by the evidence produced at their working level (System / Major System). The compliance status was then consolidated at this level.

Complementing this “vertical” hardware organisation, a “horizontal” organisation of contributing substantiation files was created to address the transversal topics: Ensuring satisfactory operation and compatibility of the various systems at aircraft level and those items requiring compliance demonstration for the full aircraft configuration - like EMC, Flight Performance or the thermal environment.

The Aircraft (Variant) Qualification Plan identified, for each requirement, all contributors to the compliance demonstration. Among these contributors, a single Owner was nominated in front of any given requirement, in consistency with the hardware organisation. This Requirement Owner was tasked to provide the final compliance statement, reflecting the results obtained from the contributors, and to ensure that all necessary contributions were available and sufficient.

The Aircraft (Variant) Qualification Compliance File (QCF) thus reflected this multi-layer rationale. It identified, in line with the Qualification Plan, the Requirement Owner and the expected contributions, with the Owner being tasked to collect the sub-level contributions and to ensure their completion. Finally, the QCF synthetized the compliance declaration at Variant level (grey row in Table 3 below). The example shows, for one requirement, these different layers with their respective contributors from the PCs, and the owner of the requirement.

ACF	Req't Owner	Req't Contrib	Compl.	Evidence Documents
FAR29.xxx	DS	TX MGB IGB TGB&TRH RAGB	C--	QS (DS)
		DS	C--	QS (DS)
		TX	C--	QS-N632GxxxxE01/ (MGB) QS-S600AxxxxE01 (TGB&RAGB)
		MGB	C--	QTR-N636Gxxxx
		IGB	-NA	
		RAGB	C--	DDP-S639AxxxxE01 (RAGB)
		TGB&TRH	-NA	

Table 3: QCF Construction - Owner & Contributor

This methodology of QCF construction was designed to support the simultaneous qualification of several different Variants, or to be complemented in a second step when some evidence would still be missing for a given Variant.

The compliance demonstration process from the beginning combined Certification (airworthiness) and Qualification (performance) substantiation, the QCF consisting of an Airworthiness Compliance File (ACF) and a Performance Compliance File (PCF).

In this first subchapter, we have seen that the production of the substantiation files by the PCs and the final assembly rule was mainly driven by the Industrial hardware and design responsibility breakdown, and the associated task sharing between the PCs.

This approach centered around the so-called Items To Be Qualified (ITBQ) – a generalized term for any entity subject to coverage by a Qualification Sheet.

The second subchapter now will present the validation process of the substantiation files by the Certification / Qualification Authorities, focusing more particularly on the organisation on Industry and Official Services´ side, to efficiently perform this activity.

2.2 Validation Process and Stakeholder Organisation

The main stakeholders of the NH90 Certification / Qualification activity on industry side are

- The NHI Qualification Team, representing the Consortium and its 4 Partner Companies at international level
    - o 4 Qualification Teams within the PCs, managing the interfaces to their local Authority and between each other
        - ▪ Compliance Verification Engineers ("Experts" per ATA chapter) within each Partner Company´s design organisation

A mirror organisation was set up on the Customer Nations´ side leading to the following organisation:

- The NAHEMA Qualification Group (QG) representing the 4 Nations with an Industrial workshare
    - 4 National Qualification Officers (NQO), one for each Nation
        - o Supporting Expert groups providing recommendation to the QG/NQOs on their respective field of expertise
            - ▪ Flight Test
            - ▪ Maintenance
            - ▪ HMI….

The scheme below illustrates the relationship between the different stakeholders:

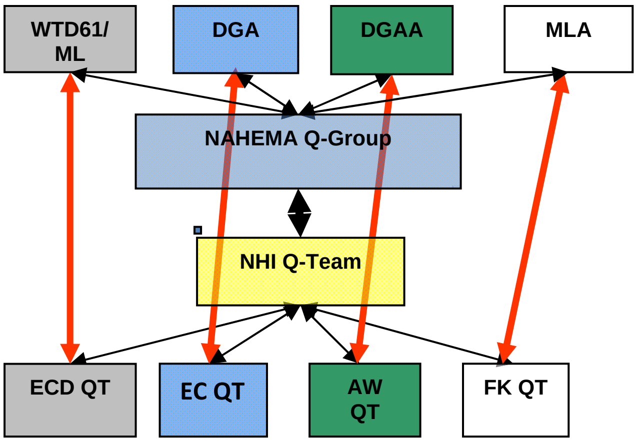

Figure 2: Interfaces between Qualification Stakeholders

In order to minimise the number of involved interfaces and stakeholders, it was decided that the substantiation files related to the first two layers (Item and System) were directly validated (as illustrated by the red arrows in Figure 2) between the Item/System Design Responsible Company (SDRC) and its local Authority (NQO). Evidence documents distribution and harmonisation meetings leading to approval of the substantiation file were so performed at national level.

This simplified procedure, and the reduction of nations participating to substantiation file validation at lower level was possible due to the agreement of mutual recognition between the Nations (FR, GE, IT, and NL). Practically, this meant that e.g. a substantiation file validation pronounced by the Italian NQO was automatically recognised by the FR, GE and NL NQOs as well as NAHEMA without further verification - and vice versa among all 4 Nations.

Only the Major System and transversal topic substantiation files were submitted to all 4 Nations´ approval through the NAHEMA QG. The related evidence documents produced by any given partner were distributed by NHI to NAHEMA, who was tasked to forward these documents to each Nation, to collect and centralise their comments and communicate them to the Industry via NHI. This harmonisation phase, including comment and answer correspondence and harmonisation meetings involving NHI, NAHEMA, the 4 Nations as well as Expert Group representatives when needed, and the concerned company(ies) ended with and resulted in NAHEMA acceptance of the substantiation file. This approval was issued once the 4 NQOs´ approvals had been collected by NAHEMA.

Upon completion of the validation process for all Items/Systems/Major Systems as well as transversal topics, the Variant Qualification Review Executive Meeting concluded the international qualification phase: NAHEMA formally accepted the Qualification Compliance File (QCF), and thus the harmonised compliance statement in front of each requirement, for a given aircraft configuration.

This NAHEMA acceptance (Declaration of Compliance – DoC) then formed the basis for the respective National Authority to perform Type Certification of the aircraft and produce the MTC/MTCDS.

3 Certification/Qualification Environment up to IOC: new constraints and considerations

3.1 Interim Configurations

The NH90 program experienced some difficulties (maturity of some design solutions, supplier dependencies, test scheduling). Facing reality, Industry and Nations decided to create intermediate qualification steps, starting with a reduced configuration and reduced capabilities of the aircraft to be qualified. This rationale was first applied on the NAHEMA TTH Variants.

Whereas it was initially intended to perform the NAHEMA TTH qualification for all Variants simultaneously, it was now decided to focus all efforts and resources on a single aircraft configuration. The German TTH Helicopter was selected, and this first qualification step was named Initial Operational Configuration (IOC).

This decision, as we will see further, had major consequences on the further qualification steps and the qualification of the Export Variants derived from a NAHEMA aircraft.

3.2 2006 – Task Force Modus

The processes were in place, the respective roles and responsibilities harmonised and defined. However these mechanisms, defined and agreed on paper, had never been put to practice at such a large scale as that of the NH90 Project.

To give an order of magnitude on the number of contributors to manage and, consequently, associated substantiation files to collect in respect of the pre-defined sequence shown above: On the NH90 there are roughly 1500 airworthiness requirements and 1500 performance requirements allocated to 110 Items, Systems and Major Systems, complemented by 35 transversal topics, acting as Owner and/or contributors.

Dedicated data processing and storage tools were necessary to exchange and share the huge set of data, to trace modifications from one step to the next, and to build the Qualification Compliance File.

Additional resources were allocated in the PC´s design organisations to run the preparation of the substantiation files on a large scale. The necessary and unavoidable adjustments between the different topics, the need to ensure a consistent planning of the production of the substantiation files between all partners and its monitoring, to perform the internal validation and consolidation of the lower level contributing substantiation files, and to harmonise them with the officials, were major challenges encountered as the Certification/Qualification process gained momentum.

An Industry Task Force team purely dedicated to NH90 TGEA IOC Qualification was set up, composed of representatives from the PCs working in a joint team, following a common, shared and detailed planning.

The TGEA IOC Qualification was achieved 11 months after establishment of the Task Force. This success was only possible due to the intensive efforts and strong involvement from all parties on Industry and Official Services´ side.

The Industry Task Force at its peak counted up to forty persons. During the 11 months of its operational deployment, more than 350 harmonisation meetings were held with the Officials, these alone representing more than 3000 man days of work !

This period was also a tremendous learning experience. During the Task Force phase, the stakeholders practically learned to work in the specific and complex NH90 environment. Early mistakes were corrected, processes were streamlined and tools were made more robust. Initially present doubts and intense interrogations in front of this huge task left the stage, to be replaced by trust, jointly performing step by step the production and assembly of the building blocks of the QCF.

3.3 Advantages and drawbacks

The principle driving the QCF construction turned out to be like a clockwork mechanism. It works very efficiently under some key conditions which need to be strictly respected:

- Clearly identified and frozen configuration of the aircraft to be qualified
- Pre-identified and strictly respected Owner and Contributor requirement allocation
- A strict control and validation process of any changes to the pre-defined allocation
- Harmonized and mutually respected planning between the different substantiation file responsibles consistent with the multi-layer construction principle

The experience gained during the Task Force phase was one of the keys to success of the NFH version Qualification, in which 4 Variants were qualified in parallel using the above process, optimizing the number of meetings and the respective workload from the different parties.

However, any deviation from the above rules has huge impact on the workload and on the planning. Indeed, it is easily understandable that any upper layer can be only complete its task when the contributions from lower levels are available and mature. Any delay, rework or re-definition of the lower level Qualification Sheet´s contents invariably induces rework in the upper level QS.

Knowing that some transverse topics, such as environmental conditions, EMC and lightning strike compliance demonstration are collecting inputs from almost all of the aircraft´s components, a simple change at lower level can easily generate a snow ball effect on the upper level QS, and jam the complete process.

This qualification rationale was therefore geared to a pre-defined (i.e. frozen) and fully controlled scenario. Consequently its lack of versatility in case of configuration or requirement changes, drastically affects its efficiency should those occur – which is not uncommon in the development project for a complex new-generation Helicopter, starting from a clean sheet of paper.

3.4 Need for Flexibility

The creation of the Intermediate Configuration and Capability step configurations for the NAHEMA Variants had a direct effect on the Export aircraft:

The Export Variants being derived from NAHEMA, IOC steps were also defined for these in consequence. But even where these IOC Export Variants had a configuration very similar to the TGEA IOC, some kits not part of this configuration were mandatory for particular Export customers to put their aircraft into operation - e. g the Ice Protection System for the Finnish, the Emergency Floatation System for the Greek, or the Anti-Sand Filter for the Omani Variant.

Unfortunately, the schedule for qualification of the NAHEMA variant step equipped with such kits was thus no longer compatible with the Export Variant delivery schedule. Setting up an alternative qualification rationale became vital to qualify the Export Variants.

The new qualification rationale aimed at reducing the dependency between NAHEMA variants and the Export variant qualification schedule, and had to be able to cope with late configuration changes - resulting for example from maturity-driven design improvement.

4 New rationale - Delta Qualification Logic

4.1 Lead Variant Concept

The driving factor to define this alternative qualification logic, as stated above, was the planning aspect to ensure earliest aircraft delivery with an acceptable workload. Although the NH90 family has formally no type-certificated "Basic Vehicle" like it is normal on the commercial range, the TGEA IOC configuration was selected as the reference variant upon which the qualification activity for further configurations would be based.

This rationale[4] was generalised and standardised with the identification of a Certified Lead Variant to be used as reference baseline for both:

- The Export Variants, selecting the closest NAHEMA-qualified configuration to minimise the configuration delta and the associated delta qualification activities
- the different configuration steps (IOC, IOC+, FOC) related to a given variant, selecting the previous certified configuration as the baseline for the following one.

Starting from this Lead variant configuration, a virtual exercise was performed covering:

- the equipment exchange (e.g: removal of the baseline radio suite and replacement by the target configuration)
- addition of equipment not present on the baseline variant (e.g.: Ice Protection System)
- removal of equipment/components present on the baseline variant but not on the target configuration

The obtained delta configuration file was thus the backbone for the identification of the needed complementary qualification activity. This rationale took the name of "Delta Qualification Logic".

4.2 Scheduling Changes affect the Relationship between Variants

The inter-dependency between the different Variants initially based on the final configuration and associated qualification planning had to be completely reviewed to consider the new intermediate configurations and their revised qualification schedule.

Consideration had to be given to fact that the kits selected in the NAHEMA kit "library" had to be first qualified by NAHEMA, before being re-used on export Variants.

The Delta Qualification approach gave back some flexibility and significantly reduced the dependencies between the variant qualification schedules - which was one of the main targets.

The dependency was thus reduced to the kits and equipment still not qualified on the first contracted variant so equipped and other variants intending to re-use the qualification results.

4.3 Introduction of Installation Packages

The remaining vulnerability of the derivative / Delta Qualification approach to "domino effects", caused by changes/delays of a Baseline Variant´s development schedule, led to the concept of qualifying a kit as a stand-alone entity. Producing a stand-alone substantiation file that could get Authority approval would offer the expected calendar flexibility, decoupling it from Variant Certification. As soon as the kit qualification was approved by NAHEMA, it could be re-used on other variants.

For that, the substantiation file had to show that the impact of installation effects caused by transferring the kit from its reference aircraft (even if not contracted on the selected variant) would not affect aircraft airworthiness and that its performance requirements would be met.

The Installation Package principle was born. However, the associated Qualification Plan and Qualification Sheet format and construction to collect all relevant data were still to be defined.

4.4 Concept moving from ITBQ to QWP logic

All applicable airworthiness and performance aspects linked to the installation of an item had to be considered for the compliance demonstration. To achieve that, all possible impacts on the aircraft had to be determined and assessed.

The QS content used for QCF construction was strictly oriented toward the subject item´s airworthiness and performance demonstration itself.

Example:

A kit like the Ice Protection System is interfaced with many items and systems like the electrical generation system, the avionic system, various structural parts etc... To address all the impacts on affected Certification / Qualification requirements, using the classic ITBQ QS approach would require re-opening all QS of the Items which are interfaced with by the kit. This was definitively impractical.

A dedicated format was thus defined to cover all the impacts, and to collect in a single document all evidence documents in front the affected requirements. The format of Installation Package Qualification Plan and Installation Package Qualification Sheet were harmonised between the partners and the Authorities, in particular with the NAHEMA QG. Their methodology and structure are derived from civil certification file produced for an optional installation.

In the Installation Package QP a short description of the installation with its targeted operational envelope was given. The affected interfaces were identified and explained. This set of data was the basis for the identification of the affected requirements and contributing items and topics.

Symmetrically, the Installation Package Qualification Sheet collected the contributions to the demonstration of

- proper functioning
- non-regression
- compatibility with the aircraft´s other systems

from each interfaced or affected Item/System´s design responsible, and reported the compliance status.

The resulting Operating Limitations and/or Instructions were recorded in a dedicated Technical Note, generically named “Impact on Technical Publication”.

The compliance demonstration at Helicopter level, depending on the full aircraft configuration – such as EMC, or Thermal Environment - is specific to and thus valid only for the Variant on which it is carried out, and consequently has to be repeated for each Variant configuration.

For the Installation Package approach, it was agreed that the Qualification Sheet states “partial compliance“ for these topics, reporting in front of the related requirements the activity to be performed at variant level.

Doing so, the remaining complementary activity to extend validity of installation of the kit from one Variant to another was pre-identified and harmonised with the Authorities, significantly simplifying the re-use of the substantiation file.

A library of standard substantiation files for many different kits was thus created over time:

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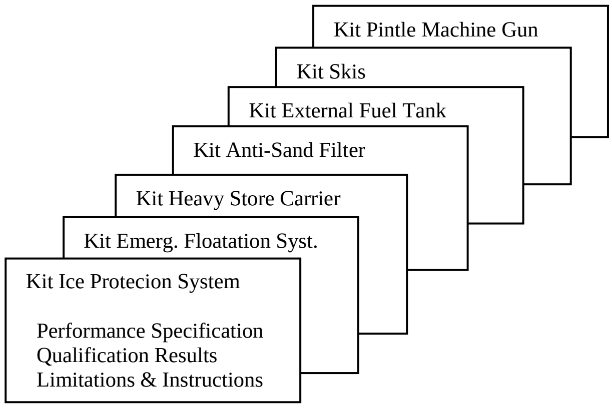


Figure 3: Library of approved Installation Package / Kit substantiation files

4.5 QCF construction - Owner & Contributor

The Installation Package approach was generalised to all kinds of changes including design improvements. The content and format of the substantiation file was also adapted to the level of complexity of the changes:

For installation of new systems and/or equipment, the Installation Package was the preferred approach, whereas for changes of existing parts of the Helicopter, Modification Substantiation Plans and Modification Substantiation Reports were compiled – being more compact than an Installation Package but following the same rationale.

To summarily cover the Delta Qualification document categories - Installation Packages (IP), Modification Substantiation Reports (MSR) and the complementing Variant Level Activities (VLA) - and distinguish them from the ITBQ-oriented system, the general term of “Qualification Workpackage” (QWP) was coined. The QWP formed the fundamental element of the Delta Qualification system.

As already explained above, the qualification activity, reflected in the Variant Qualification Plan, was based on the delta configuration compared to the certified reference variant.

The design differences / changes were grouped primarily considering the reason for introducing a particular technical solution (e.g. new capability, problem correction, cost optimisation…).

The resulting QWPs were, by principle, qualified independently from one another. Variant Level Activities were a standard part of compliance demonstration at Variant level, first to perform those identified as not fully performed in the IP Qualification Sheets and MSRs, but also to verify at full aircraft level the non-regression, proper function and compatibility of the simultaneous implementation of all changes versus the baseline Variant. Specific tests and analyses considering the final aircraft configuration thus always complemented the substantiation program.

Keeping the principle of an Owner for each requirement, which had proven its robustness and efficiency, the Variant QCF construction was now based on a 2-layer principle. The first layer consisted of the Qualification Work Package file, which was then topped by the Requirement Owner (second) layer compiling the QWP results and synthesising the compliance declaration at variant level.

ACF	Req't Owner	Req't Contrib	compl.	Evidence documents
FAR29.xxx	Core system	QWP 1 QWP 2 QWP 3 QWP 4	C--	QTR non regression QWP 1 QWP 2 QWP 3 QWP 4
		Core system	C--	QTR non regression
		QWP 1	C--	QTR-(QWP1)
		QWP 2	C--	TN (QWP2)
		QWP 3	C--	DDP-(QWP3)
		QWP 4	C--	QTR (QWP4)

Table 4: Delta Qualification QCF Construction - Owner & Contributor

4.4 Delta Qualification Logic – Pro´s & Con´s

The Delta Qualification showed itself to be fully adapted for the qualification of a derivative aircraft starting from a certified reference configuration. It also made the Project capable of managing a large number of simultaneous changes introduced through the incremental configuration step approach from IOC to the final configuration FOC.

It further demonstrated a significant versatility in dealing with configuration changes, offering so a real flexibility and reducing the inter-dependency between the variant qualification planning schedules.

Structuring the delta qualification activity by breaking it down into a set of semi-independently managed changes also gives the individual modification projects a human scale. It allows the different stakeholders (the contributing specialists on Industry as well as Official Services´ side), by means of the stated reason for the change and its technical description, to easily identify the impacted systems and the necessary qualification activity.

The counter-effect of this advantage is a relative loss of global visibility on the whole set of changes. This requires a specific and significant attention on the verification activities to be performed at Variant level, in particular for the transversal topics.

By principle, the qualification of new basic Versions is definitively out of scope of the Delta Qualification process. As already mentioned earlier, therefore the NFH Version Qualification was successfully performed following the initial ITBQ-driven methodology despite the fact that at the same time most TTH Variants were already well advanced in Delta Qualifications.

5 TRANSITION FROM VARIANT QUALIFICATION TO POST-TC CHANGES

5.1 Procedural aspects

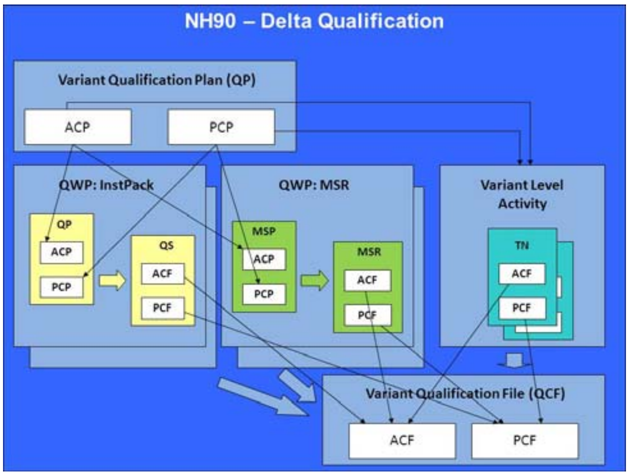
With the approaching end of the basic Development Contracts, the NH90´s Certification/Qualification environment changed substantially – although development as such by no means had ended, the procedures did not foresee any continuation after reaching the “FOC” status. This resulted in several new conditions the NH90 Program and, especially, the Certification community had to contend with:

- There was not any more a pre-defined Target Configuration which could be “worked toward” at H/C level
- Modifications were now likely to be applied individually, leading to mixed configurations in fleet operation and the corresponding compatibility considerations
- Consequently there was no possibility to allocate substantiation to Variant Level Activities any more, each Modification therefore had to be self-contained and self-sufficient
- More and more Modifications appeared with a transversal applicability, being installed on many Variants

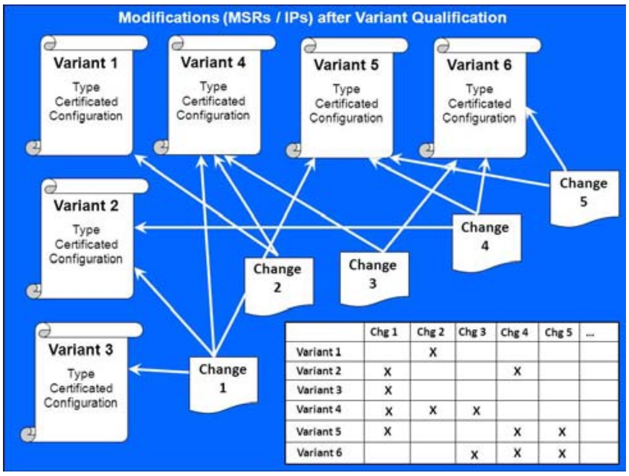
All this meant that the Variant Delta Qualification methodology no longer answered to all the needs of the Certification/Qualification process.

A situation as above is quite commonplace for civil Certification Projects, which have well-established processes in place for managing the transition phase from initial to continuing development. Civil regulations such as EASA Part 21 make provision for post-TC Modifications as a matter of course.

For military projects which – unlike civil undertakings – are limited to the contracted workscope, the transition is much more abrupt: The validity of the Development Contract with all its associated definitions for roles, responsibilities and processes usually ends with achievement of the contracted capability and configuration, and a new arrangement has to be made.



BEFORE: Delta Qualification Logic moving from reference baseline to target configuration



AFTER: Individual Change Projects affecting one or more Variants

Figure 4: Comparison between Delta Qualification and Post-TC Modification Certification environment

5.2 Organisational aspects

The interaction between Industry, Authorities and Customer required a new set-up, enabling cross-communication between all NH90 Nations and transversal management of the continuing development of NAHEMA as well as Export Variants within a common framework.

On Industry, since NHI had been managing all NH90 Variants from the beginning, internal re-organisation at NHI and the PCs could accommodate the future needs without having to re-define the role of the participating organizations.

On Official Services´ / Nations´ side, there was no all-encompassing platform available:

- NAHEMA represented the five Core Nations France, Italy, Germany, the Netherlands and Portugal. NAHEMA expanded to NAHEMO with the addition of Belgium.
- The Scandinavian Customer Nations Sweden, Finland and Norway, although grouped via the NSHP (Nordic Standard Helicopter Program) Contract for development, had individually different relationships with NAHEMA as well as with Industry for Certification/Qualification purposes.
- Each of the other Export Customer Nations, namely Australia, New Zealand, Greece, Oman and Spain all worked with individual Contracts, sometimes with NHI being in the second line and a nationally-based Company being the prime Contract Holder.

Therefore, new ways needed to be explored for managing the growing multi-national NH90 fleet, defining the roles and responsibilities of the involved stakeholders.

6 THE POST-TC WORLD – JMAAN

6.1 JMAAN background

The concept of JMAAN – the Joint Military Aviation Authorities NH90 – originated at first primarily from Continuing Airworthiness considerations:

With more and more NH90 Variants entering service operation in many countries, the need for NHI to manage airworthiness support of this mixed and widely distributed fleet became urgent.

Due to the need for quick reaction in case of incidents and for rapid distribution of information, the development-phase set-up was no longer viable.

Two options existed:

- Moving to a direct bi-lateral interaction between NHI and each Operator, Nation by Nation
- Setting up a common framework for managing the combined fleet world-wide.

The first option was never seriously considered due to its obvious drawbacks – no exchange between operators, multiplied communication channels, inevitable inconsistency in Incident treatment and progress etc…

The chosen second solution made use of the already existing infrastructure:

With NHI and NAHEMA, two organizations existed already on Industry and Customer side, which were equipped with all capabilities to technically handle every NH90 Variant.

The perimeter of this construct had to be expanded to include as far as possible all NH90 Nations, and the organization, processes and procedures needed to be aligned to be workable for everyone.

6.2 JMAAN Concept

The basis for JMAAN was the recognition of the 4 NAHEMA Authorities as technically competent Primary Authorities (PAs) for all aspects of the NH90, following the workshare defined by the NAHEMA contract. Other Military Aviation Authorities (MAAs) of the Community can validate the findings and recommendations of the PA without further verification (Lead Nation principle).

The second consideration was to install a central platform on both Industry and Operator side, with JMAAN being the Nations´ forum and NHI representing the International Industrial Organisation (IIO), to allow a coordinated exchange of information (funnel principle).

The third consideration was that only the MAAs have the legal power to perform the act of Certification for their Nation´s NH90 Variants (sovereignty principle).

For procedural commonality, the JMAAN community adopted the JMAAN-21 "Certification of NH-90 and related parts and appliances, and approval of the military design organization"[5] – an adaptation of the civil EASA Part 21 tailored to meet specific NH90 needs.

6.3 JMAAN Establishment

JMAAN-21 Version 1 was drafted by the Netherlands´ Military Authority on behalf of the community and formally adopted by the four Lead Nations per issuance of the Policy Paper "Working with JMAAN-21 aviation requirements"[6] on 14 January 2009.

In parallel, the IIO generated a Part-21 conformant process infrastructure by means of compiling a Military Design Organization Manual[7] for NHI, which rested on the Partner Companies´ nationally approved Military Design Organizations via three Design Organization Interface Documents (DOIDs),

- One for EC/ECD combined[8]
- One for AgustaWestland
- One for Fokker

This IIO infrastructure was then audited by the JMAAN PAs for compliance with JMAAN-21, resulting in the issuance of the Military Design Organization Approval (MDOA) for the IIO on 06 September 2010.

Since then, JMAAN-21 principles are being applied successfully by the JMAAN Community for all activities following Variant Qualification.

6.4 Certification aspects

Although at first brought about by Continuing Airworthiness considerations, the JMAAN set-up is equally suitable to deal with the requirements of continued NH90 development in a post-TC environment.

The Lead Nation principle is being applied on Industry as well as on Authority side.

6.5 Processing Modifications

For processing Modifications through the airworthiness approval loop, a Procedure[9] was established and harmonized between JMAAN and the IIO.

Changes to the Type Design are centrally administrated and coordinated by NHI.

Each Modification Project has a Leader (Owner) on both Industry and Authority side. For Modifications occurring within the design responsibility of one Nation, these are by default the corresponding PC and PA.

If the perimeter of the Modification and its associated compliance demonstration exceeds the boundaries of one SDRC, other Nations may become involved in a contributing role.

In such cases the Change Leader co-ordinates all contributions. He defines what is needed from contributing PCs. These will generate the needed evidence and obtain approval for this from their PA.

The Change Leader collects all evidence and submits it to the corresponding Leader PA, in case of the "foreign" contributions accompanied by the relevant contributing PA´s approval. The Leader PA completes the full technical assessment and reports its compliance finding in form of a "Recommendation for Certification".

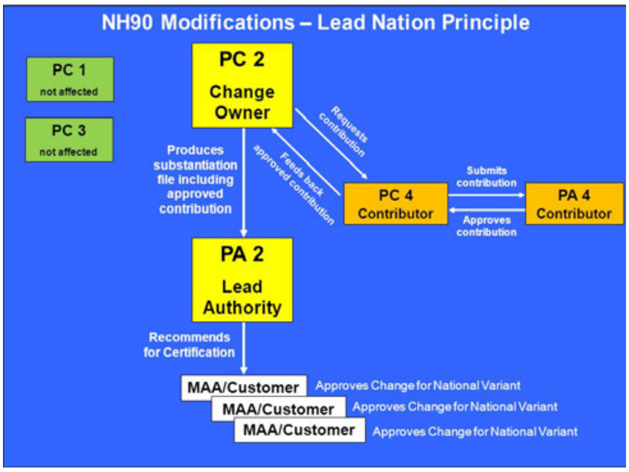


Figure 5: Processing Modifications affecting more than one Partner Company / Authority

This Recommendation completes the bilateral part of the process between Leader PC and PA. NHI then takes over, distributing the Recommendation to the affected Nations of the community and registering the MAA´s Certification statements as they come in, flowing back this information to the PCs through the IIO. NHI thus maintains an overview of the Type Certificated Configuration of all NH90 Variants.

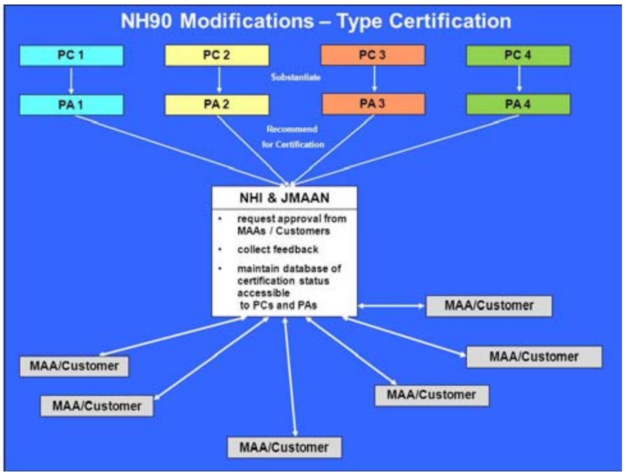


Figure 6: Certification of Changes through NHI and JMAAN (funnel principle)

Due to the sovereignty principle, the JMAAN relationship between the community´s Aviation Authorities is similar to the JAA environment in Europe, which existed before EASA. The 4 PAs with a defined share of responsibility concerning design oversight have some resemblance to the JAA Multi-National Type Investigation Teams. Since JMAAN – like JAA – has no legal power on its own, the PA´s – like a JAA Type Investigation Team – issue a Recommendation following technical assessment, which has to be turned into a legally binding Certification by the MAAs.

Figure 7: Comparison JMAAN and JAA

7 SUMMARY, CONCLUSIONS AND OUTLOOK

The NH90 Program, from a Certification/Qualification point of view, experienced almost every conceivable level of complexity. Some of its features were, and are, present in other large-scale development programmes, but the NH90 is the only one having had to deal with all of them at once:

Like some other military Programs, it is run by an Industry consortium and an international customer procurement agency – but unlike these it features parallel development of export variants in different procedural environments alongside the basic core program. Other military aircraft types also have a widely dispersed export customer base, however their scenario differs from NH90: The aircraft were fully developed for and delivered to the prime customer – usually the Armed Forces of the manufacturer´s home country (first and foremost the U.S.A.), and only then export sales of the finished product were made.

Like civil programmes, it faces an internationally diversified customer range – but unlike these it has to deal with a multitude of National Authorities and locally applicable regulations as well as specific contractual constraints. Furthermore it has to perform a combined Certification/Qualification exercise, which is not present on civil projects.

It has undergone substantial changes, both internally and regarding the geopolitical situation since its inception: Starting as a “classic” European military Joint Venture before a NATO Cold-War political background, it is now a global entity in a world dominated by multi-faceted asymmetrical conflicts.

For all the challenges arising through this development, successful solutions have been found and applied, which can be used for future projects facing any one of the multiple difficulties mastered by the NH90.

7.1 NH90 Challenges and Solutions

7.1.1 Customer Diversity

- Started as a monolithic NATO Project
- NSHP Program brought Nordic Variants
- Export Contracts brought Australia, Greece, Oman, New Zealand, Spain
- NH90 Variants for **all Customers** were developed **in parallel, with overlapping schedules**
- Some Customers have no direct Contract with NHI, but prefer to deal with locally based companies instead: Spain have contracted ECE; Australia are interfaced with Australian Aerospace.

➔ **Solution:**

  - Modified original ITBQ-driven process into Delta Qualification.
  - Read-across of Qualification results from NAHEMA to Export Variants.
  - Installation Packages allow easy transition from first qualifying Variant to target helicopter (only integration aspects to be substantiated).
  - Integrated local “front office” companies through Industry-internal contractual arrangements

7.1.2 Industry Diversity

- 4 fully developed military Design Organisations (PCs) under one umbrella (NHI)
- Wide variation in internal organization and ways of working at PCs

➔ **Solution:**
  - Adopted JMAAN-21 principles
  - Integrated IIO through NHI MDOM and DOIDs for the PCs.

7.1.3 Process Diversity

- Started with NAHEMA Process and clearly defined role for all stakeholders
- Carried out integrated Certification (airworthiness compliance) and Qualification (performance compliance) substantiation process
- Nordics Program brought
  - Norway, who subcontracted Certification /Qualification to NAHEMA
  - Sweden, who subcontracted Certification to NAHEMA, doing Qualification by itself
  - Finland, who did Certification and Qualification by itself
- Export Contracts brought
  - Australia, who subcontracted DGA for Certification/Qualification
  - Greece, who subcontracted DGA for Certification only
  - Oman, who left Qualification entirely in Industry responsibility
  - New Zealand – same as Oman,
  - Spain, who did Certification and Qualification by itself.

➔ **Solution:**
  - Made extensive use of Delta Qualification Procedure to allow re-use of evidence even with different process.
  - Established Variant Qualification Teams on Industry side, who were trained in the specific process features of their allocated Variant.

7.1.4 Technical Diversity

- Two substantially different Versions (TTH – land-based and NFH – shipborne) developed in parallel
- Wide variation in mission profiles and equipment between Variants

➔ **Solution:**
  - Performed NAHEMA Baseline (ITBQ) Certification/Qualification Process for TTH and NFH first Variants.
  - Applied Delta Qualification logic for read-across between Variants.
  - Installation Packages allow easy transition from first qualifying Variant to target helicopter (only integration aspects to be substantiated)

7.1.5 Operational Diversity

- Dependent on Customer and Contract, the responsibility sharing between Industry and Operator is variable
- Full bandwidth experienced by NH90: From Customer performing the role of TC Holder to Customer having no local Authority at all

➔ **Solution:**
  - Adopted JMAAN-21 as a common standard for managing fleet operation and continuing development.

7.1.6 Development Phase Diversity

- Due to the Interim Configuration strategy (IOC/IOC+/FOC) the Project encountered situations where the same technical change had to be treated as part of initial Variant Certification for one NH90 step, and as a post-TC Modification for the preceding one.

➔ **Solution:**
  - Certification performed for the Variant new step configuration
  - Creation of “Extension of Applicability” ECPs, either with or without additional substantiation, for the preceding step

7.2 Lessons Learned

The lessons to be learned from the NH90 Certification / Qualification history can be grouped to the various project phases.

- In the original NAHEMA development phase, the ITBQ-based process setup has proven to be an efficient means to carry out a Variant Baseline Certification/Qualification. Its success depends on a well-trained Project team and a stable, well-maintained planning with close monitoring, risk management and corresponding early and effective recovery measures in case of drift.
- This process needs to evolve as soon as the original perimeter is modified either by expanding the scope (export contracts) or be reshaping the development structure (interim configurations). The necessary flexibility is achieved by moving to the Delta Qualification principle, changing the viewpoint from ITBQ to QWP (IP, MSR, VLA). The Delta Qualification methodology has proven an efficient way of managing derivative Variant Certification. It is capable of handling the full diversity of the NH90 roster for all Customers with their national specifics.
- With entry into service, the Certification environment needs to adapt to the post-Type Certification phase, like on any development project. For NH90 this meant to become much more transversally oriented, focusing on a common way of working which is suitable for all involved partners both on Industry and Authority side. The solution here, driven by the “quasi-civil” situation of continuing development in a multi-national setup, was to adopt civil EASA Part 21 principles and make them work for NH90, resulting in JMAAN-21 and the corresponding Policy Paper, effectively re-producing a JAA-type environment in which sovereign national MAAs interact on the basis of a commonly agreed framework.

7.3 Outlook

Currently there are initiatives underway in Europe to standardize the approach to procurement of military equipment on a large scale. The European Defence Agency (EDA) has been established to oversee these activities. With the European Military Airworthiness Authorities (MAWA) developing the European Military Airworthiness Requirements (EMAR), in particular EMAR-21, the NH90 Program appears to have set the pointer into the right direction.

Especially development of military airborne systems in Europe on a large scale in future can be expected to always be a multi-national affair – and it will always be geared towards generating export sales wherever possible. In terms of Certification/Qualification, the NH90 can safely be said to “have seen it all”. The difficulties encountered and mastered provide a good catalogue of “Do´s and Don´ts” to be taken into account when setting up future programs. A tool box of proven processes and organization setups which can be applied both simultaneously and in sequence is available to suit all needs which might be envisaged in the near to mid-term future.

8. GLOSSARY

ACF	Airworthiness Compliance File
ACP	Airworthiness Compliance Plan
AF	Airworthiness Function
ASW	Anti-Submarine Warfare
ATA	Air Transport Association
AW	AgustaWestland S.p.A.
CVE	Compliance Verification Engineer
DGA	Délégation Générale pour l´Armement - (French PA/MAA)
DGAA	Direzione Generale Armamenti Aeronautico (Italian PA/MAA)
DOID	Design Organization Interface Document
EC	EUROCOPTER
ECP	Engineering Change Proposal
EDA	European Defence Agency
EMAR	European Military Airworthiness Requirement
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
ESM	Electronic Support Measures
FK	FOKKER Aerostructures B.V.
FLIR	Forward-Looking Infra-Red
FOC	Final Operating Configuration/Capability
FR	France
GE (I)	Germany
GE (II)	General Electric (T700 engine supplier)
HMI	Human-Machine Interface
IFF	Interrogator Friend/Foe
IIO	NH90 International Industrial Organization
IOC	Initial Operating Configuration/Capability
IP	Installation Package
IR	Infra-Red
IT	Italy
ITBQ	Item To Be Qualified
JAA	European Joint Aviation Authorities (now defunct)
JMAAN	Joint Military Aviation Authorities NH-90
LF	Low Frequency
LWR	Laser Warning Receiver
MAA	Military Aviation Authority
MAWA	Military Airworthiness Authorities (Europe)
MDOA	Military Design Organization Approval
MDOM	Military Design Organization Manual
MLA	Militaire Luchtvaart Autoriteiten (Netherlands PA/MAA)
MLD	Missile Launch Detector
MTC	Military Type Certificate
MTCDS	Military Type Certificate Data Sheet
NAHEMA	NATO Helicopter Management Agency
NATO	North Atlantic Treaty Organization
NBC	Nuclear, Biological and Chemical

NFH	NATO Frigate Helicopter
NHI	NHIndustries S.A.S. – the Industry Consortium holding the NH90 Contract and representing the PCs
NL	The Netherlands
NQO	National Qualification Officer
PA	Primary Authority
PC	Partner Company
PCF	Performance Compliance File
PCP	Performance Compliance Plan
QCF	Qualification Compliance File
QG	NAHEMA Qualification Group
QP	Qualification Plan
QS	Qualification Sheet
QT	NHI Qualification Team
QWP	Qualification Work Package
RRTM	Rolls-Royce/MTU/Turboméca (RRTM 322 engine supplier)
RWR	Radar Warning Receiver
SAR	Search And Rescue
SDR	System Design Responsible
SDRC	System Design Responsible Company
TC	Type Certificate
TCC	Type Certificated Configuration
TTH	Tactical Transport Helicopter
VertRep	Vertical Lift Replenishment
VLA	Variant Level Activity
WTD61/ML	Wehrtechnische Dienststelle für Luftfahrzeuge - Musterpüfwesen für Luftfahrtgerät der Bundeswehr (German PA/MAA)

9. References

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NH90 Design & Development Contract

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[3] MD S000N3587E01:
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[4] MD S000N3735E01:
NH90 Qualification Procedure

[5] JMAAN-21 version 1 dated 14 January 2009:
Certification of NH-90 and related parts and appliances, and approval of the military design organisation

[6] Policy Paper Joint Military Aviation Authorities NH-90 (JMAAN):
Working with JMAAN-21 aviation requirements

[7] MD-00-09:
NH90 Military Design Organization Manual

[8] MD S000A3402E01:
NHIndustries – EUROCOPTER / EUROCOPTER DEUTSCHLAND Design Organization and Interface Document (DOID)

[9] MD S000N1487E01:
Changes to the Type Design