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INTEGRATED LOGISTIC SUPPORT IN THE NH90 PROJECT

by

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Abstract

Experience of multi-national weapon system programmes has shown that design decisions taken early in a programme have a major impact on the Life Cycle Costs (LCC), meaning 80-90 percent are already committed when only 10-20 percent of these LCC's have been spent.

Integrated Logistic Support (ILS) can be regarded as the integration of the following disciplines:

- Designer,
- Operational user,
- Maintainer.

In order to reduce these LCC this so called 'triangle' consultation must start prior to the start of the conceptual design phase and should be continued throughout the complete systems life cycle.

Strong emphasis on system Reliability, Availability, Maintainability and Testability (RAM&T) at the start of the conceptual design phase, will result in higher Design and Development (D&D) Costs. However, the In-Service costs form a major part of the system LCC and therefore is an attractive area for cost reduction. Due to ILS a better supportable design will be accomplished with lower Operating and Support costs.

France, West Germany, Italy and the Netherlands have launched in 1987 the definition of a medium size helicopter called NH90 (Nato Helicopter for the 1990's). Industry is represented by Aerospatiale, MBB, Gruppo Agusta and Fokker. Two NH90 versions will be developed; a Tactical Transport Helicopter (TTH) and a Nato Frigate Helicopter (NFH).

For an effective and efficient ILS implementation, a NH90 ILS Plan was developed by Industry and the Nations in a combined effort.

1. Introduction

The goal of this paper is to justify the principle of Integrated Logistic Support and show the implementation of it in the NH90 programme.

The following aspects are covered:

- ILS characteristics,
- ILS Plan for the NH90,
- Activities to influence the design for supportability.

2. ILS Characteristics

During the last decades performance and supportability of an airborne weapon system were considered on an individual basis in the design process by respectively the systems engineering and logistics engineering functions. This traditional design approach led to systems which met their operational requirements, but were expensive to operate and did not meet the predicted availability. Costly modifications to improve this situation were necessary. Figure 1-3, representing LCC breakdowns of US military helicopters, show that the support aspect is the major costdriver and subsequently is the most attractive area to look for cost reductions.

60% of the LCC is generated by Logistic Support, while 92% of these logistic support costs are so-called recurring costs. Figure 3 shows that of these recurring costs 70% is assigned to labor costs.

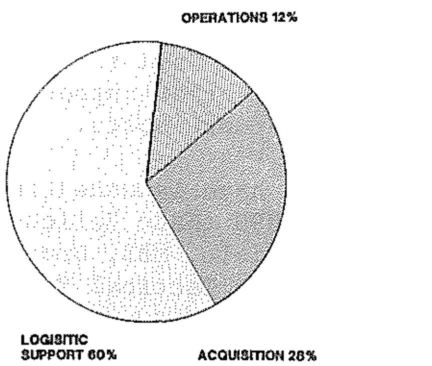


Fig.1 Primary Cost Categories

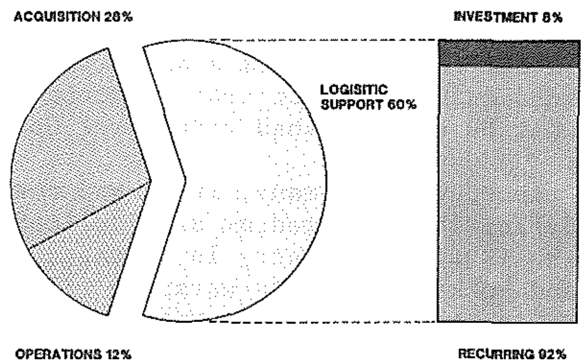


Fig.2 Logistic Support Cost Breakout

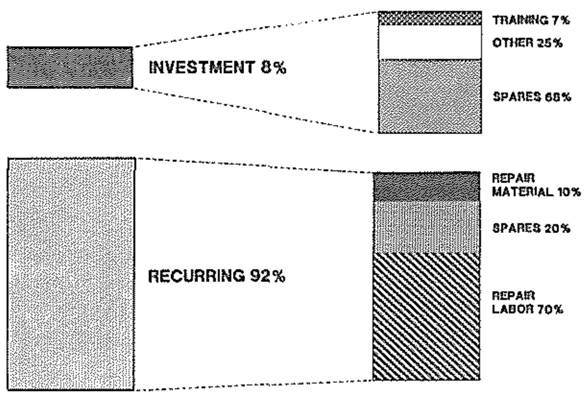


Fig.3 Logistic Support Cost Breakout Cont'd

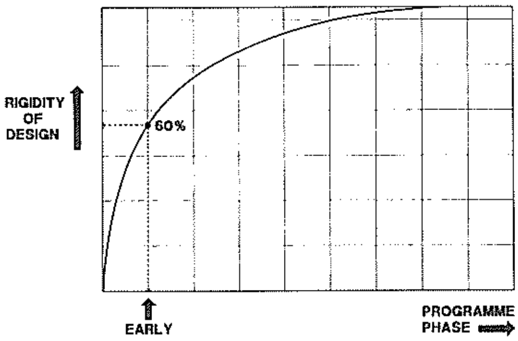
However, in the early 1970's, due to:

- Budget restraints,
- Increased complexity of systems,
- Accelerated technology progression,

the Department of Defence of the United States came to the notion that the traditional approach, consideration of supportability requirements after the design process, was no longer acceptable.

In order to eliminate above mentioned constraints it was considered necessary to integrate simultaneously the supportability requirements into the design process. At the same time though, system LCC should be given the same priority as the other design parameters.

This 'design influencing' process must start at such a moment in the design phase where the design is still flexible, see figure 4.



Approx 60% of all design decisions are already taken 3 months after start of the design phase thereby fixing 80 - 90% of the systems LCC

Fig.4 Design Influencing Process

Influencing Design for Supportability, meaning reducing logistic support cost, will result in higher D&D cost, but lower Operating and Support costs. This process is called Integrated Logistic Support (ILS). It ensures that sufficient management action and direction is applied in order to provide effective and efficient support.

ILS requires close co-operation of the following disciplines:

- Designer,
- Operational user,
- Maintainer.

This so called 'triangle' consultation should be established prior to the definition of the design requirements and continue throughout the total life cycle of the weapon system.

Outside the United States, Product Support (Logistic Engineering) itself is still regarded, not so much as an engineering function, but more as an after sales activity, closely related to Marketing and Sales.

Within Europe at the moment ILS is gradually gaining recognition up to such a degree that very recently it became a requirement in several weapon system programmes.

One of these programmes is the multi-national Nato Helicopter for the 1990's programme which was launched in 1987 by France, West Germany, Italy and the Netherlands.

The aim of ILS in the NH90 programme is to:

- Influence the operational and support requirements to design the NH90 for supportability,
- Define the support requirements best related to the NH90 weapon system design solution and to each other,
- Develop and acquire the necessary support elements,
- Provide operational phased support at lowest cost,
- Improve NH90 readiness and LCC during the operational life-cycle,
- Repeatedly evaluate support requirements throughout the service life of the system,

For an effective and efficient ILS implementation a management team and a management plan are required.

3. ILS Plan for the NH90

3.1. Introduction

On the Industry side ILS aspects are dealt with by an expert team (ET 13). This team is composed of four (4) specialists, one of each country, and is co-ordinated by Fokker.

On the Nations' side these aspects are covered by the ILS Working Group (ILSWG), chaired by the Netherlands. This working group consists of members of the four participating Nations.

The primary interface shall be between the ILSWG for the Nations and ET13 for Industry (see figure 5).
This interface ensures a more consistent and balanced approach to support management than is traditionally achieved through the individual interfaces of the specialist disciplines.

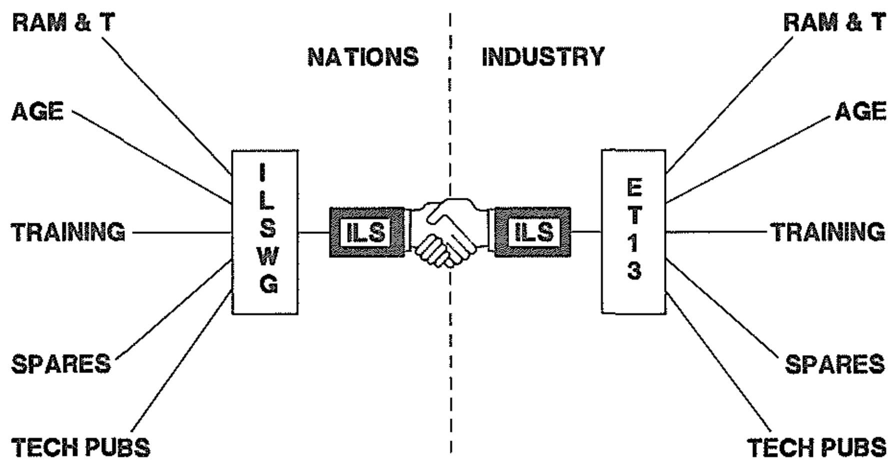


Fig.5 ILS-interface

The ILS Plan is the product of this interface during the Project Definition Phase (PDP) and is to be regarded as a management plan. It provides a management overview of all activities (engineering & logistics) to be done by Industry in meeting the availability and supportability targets as laid down in the NH90 Nato Staff Requirements (NSR).

The ILS Plan covers the following major aspects:

- Reference Logistic Support Concept,
- Reliability, Availability, Maintainability and Testability (RAM&T),
- ILS Elements,
- International Logistic Support System,
- ILS Costs.

In the following sub-chapters the ILS Plan will be elaborated.

3.2. Reference Logistic Support Concept

Because In-Service costs form 60% of the LCC, it is important to pursue cost reduction in this phase of the life cycle.

This can be achieved in two ways:

- A supportable design in which RAM&T aspects are optimized in relation to performance and weight (see ILS Plan).
- An effective and efficient logistic support system. This can be achieved by co-operation between the Nations' Services and avoidance of duplication of work. For this purpose a common international logistic support concept is needed. Specific national requirements have to be sacrificed as much as possible to the commonality of international logistic support. In this respect it is mentioned that cost-effectiveness is one of the driving criteria for the choice for this common concept.

As a first step in this process a theoretical model, the Reference Logistic Support Concept, was defined.

This model is divided in 6 chapters:

- Introduction,
- Requirements and Assumptions,
- Maintenance Concept,
- Supply Support Concept,
- Logistic Support Elements,
- Life Cycle Cost Concept.

A high degree of commonality was already realized in this Reference Concept by means of the Nations' quadri-national agreement in the following areas:

- Nato Staff Requirements (NSRs),
- Common operational scenario's for TTH and NFH. Both for peace and wartime operations,
- A common maintenance concept based upon RCM/MSG-3 and 3 levels of maintenance,
- A common supply concept based upon AECMA 2000M,
- A common policy was established for the ILS Elements, like training and technical publication.

The next step will be a comparison of this theoretical model with the Nations' existing logistic support systems.

With these results it will be possible to define the required common international logistic support systems.

3.3. Reliability, Availability, Maintainability & Testability.

A positive influence on the LCC is provided by realistic RAM&T requirements. The Nations recognized this by indicating in the NSRs that these aspects should have equal priority in relation to weight and performance. To meet these NSRs qualitative and quantitative RAM&T requirements have been produced by Industry. After review by the ILSWG, mutually agreed requirements were incorporated in the ILS Plan.

In order to check compliance to these RAM&T requirements a number of analyses have been performed, such as:

- Reliability apportionment, based on Industrial experience and User's experience of currently fielded helicopters.
- Mission reliability analysis, based on 4 typical mission profiles in order to show compliance with the NSR Mission Reliability figure.
- Maintainability allocation, showing replacement times and the number of personnel for major helicopter components. Again User experience of currently fielded helicopters was incorporated.

RAM&T activities necessary for fulfilling the RAM&T requirements have been documented in RAM&T plans.

These activities consist of procedures/responsibilities for:

- Engineering/analysis,
- Validations,
- Demonstrations.

Improvement of the RAM&T factors is considered to be an on-going process during D&D.

3.4. <u>ILS Elements</u>

In this part ILS Elements are defined and activities described in great detail. These elements will form the basis for the ILS system for In-Service Support of the NH90 fleet.

Significant chapters are:

- Management and Organisation,
- Logistic Support Analysis Plan (LSA Plan),
- Technical Publication Plan,
- Training Plan,
- Material Support Plan.

Although LSA is not an ILS Element, its location here is justified because the process is the 'backbone' of ILS. The process itself consists of a series of analyses which evaluate and produce technical data on the maintenance and support requirements for a particular system. MIL-STD-1388 describes the process. Due to its inherent complexity the process should be tailored to one's specific needs in order to make it cost effective. Figure 6 gives a schematic overview.

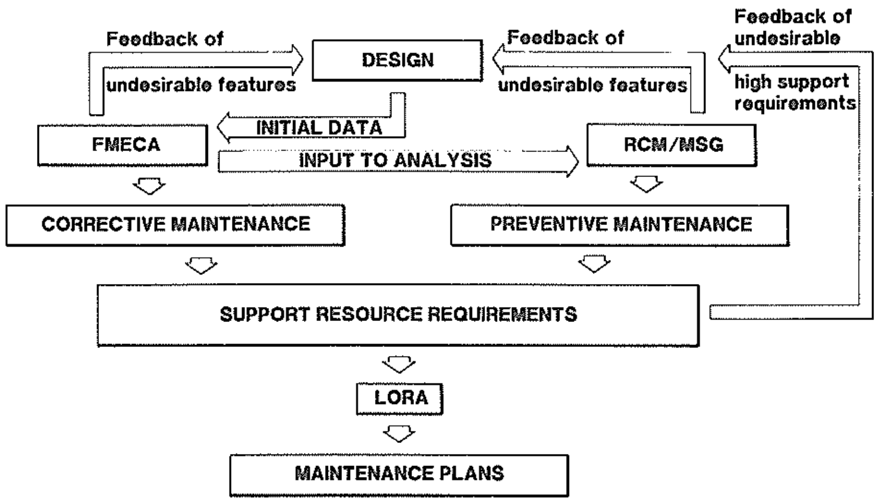


Fig.6 LSA - Process Overview

Initial design data is subjected to a Failure Mode Effect and Criticality Analysis (FMECA). Undesirable features (i.e. disastrous failure effects, economic effects) are provided as feedback to initiate redesign. The results of FMECA are inputs to a Reliability Centred Maintenance (RCM)/ Maintenance Steering Group (MSG-3) analysis, and a corrective maintenance analysis.

The RCM/MSG-3 analysis identifies the minimum preventive maintenance tasks required to realise the inherent reliability and safety of the design after consideration of both the operational and economic consequences of a failure. A corrective maintenance analysis identifies the tasks required to restore a failed item to its operational condition. Finally, the maintenance activities and the support requirements are examined and the division of work between maintenance levels are evaluated using both operational and economic criteria, involving a level of repair analysis (LORA), and maintenance plans are formulated.

3.5. International Logistic Support System.

In order to ensure that the NH90 is designed for supportability at the lowest LCC this system shall be effective and efficient, based on a common logistic support concept (see para 3.2.).

To co-ordinate, monitor and control activities in the individual support disciplines during and after D&D it is important that timely a number of working groups is established (see figure 7):

- LSA/LSAR Panel,
- Supply Support Panel,
- Training Panel,
- Technical Publications Panel,
- AGE Panel.

Due to the complex nature of this proces the LSA/LSAR Panel shall have top priority. It will be advised to the ILSWG to participate in due course of time also in the other panels as well. An adhoc Automatic Data Processing (ADP) co-ordination group should be established well in advance of the D&D Phase to develop and implement the ILS ADP system.

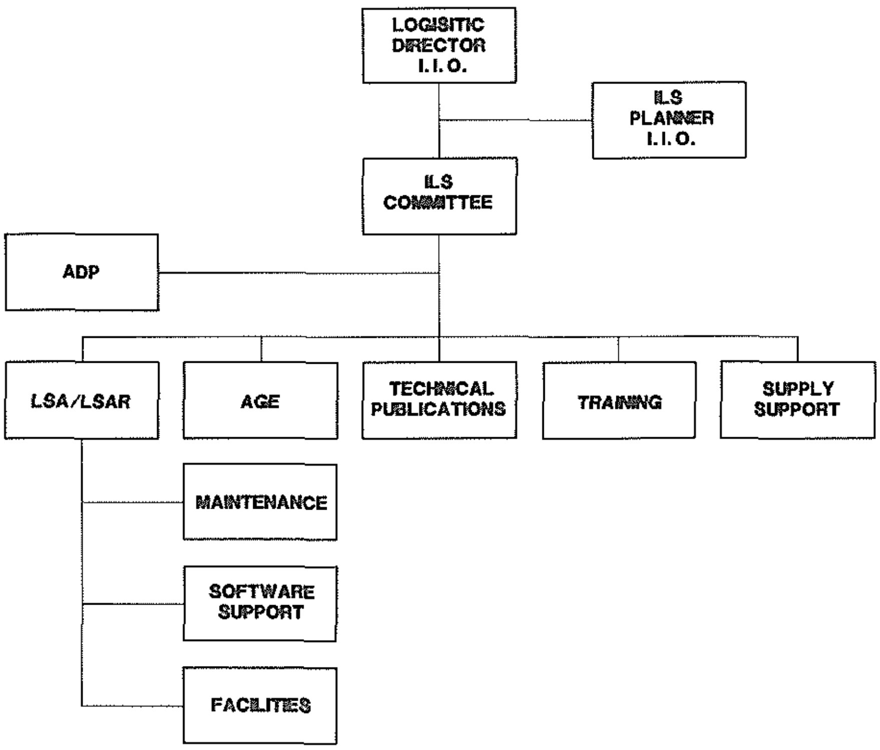


Fig.7 ILS Management

3.6. ILS Cost

Although LCC is the sum of Acquisition cost, In-Service cost and Disposal cost, this chapter presents only a cost estimating technique for the In-Service phase of the life cycle. The Acquisition cost is dealt with by an Industrial costing team.

It is now well accepted that a major portion of the total LCC is committed during the early design phase of the programme. This fact emphasizes again the importance of ILS, regardless the acceptance of the ILS concept means slightly higher D&D cost. Table 1 shows clearly the difference between traditional Product Support and ILS. The "Δ" figure for specific ILS activities is about 17%.

Table 1 Specific ILS Cost versus traditional Logistic Support cost.

Specific ILS	(%)	Traditional LS	(%)
LSA Plan	0,2	RAM&T	16,6
Review with Officials	1,5	Failure Mode and Effect Analysis	0,4
LSA	11,3	Review with Officials	0,8
Support Cost	0,6	Supply Support	11,1
ILS validation	0,8	Aerospace Ground Equipment (AGE)	28,5
ILS data	3	Training	6,3
		3e line	3
		LS data	3
		Technical Publication	7,1
		Maintenance Plan	5
		Validation	0,8
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	17,4		82,6

The following 'simplified' example places the additional 17% investment in a other perspective.

Table 2 Specific ILS investment/flying hour

Assumptions :	Total D&D ILS costs	:	100 MECU
	Number of helicopters	:	600
	Service Life	:	30 years
	Flying hours/ year	:	360
Result :	ILS cost/fh	=	Dfl. 6.-
		=	ECU 2.7

4. Activities to Influence Design for Supportability

4.1 Introduction

Influencing design for supportability throughout system development is accomplished by incorporation in the design process the key logistic related design objectives, Reliability and Maintainability.

This design influencing process can only be effective and efficient if performed in a structured way, meaning mutually approved plans and procedures. This formal process is firmly anchored in the D&D phase and tends to be time consuming in most international programmes.

This fact is contradictory to the ILS principle described earlier. To cater for this a pragmatic approach is recommended, meaning each individual Nation should develop specific activities using the vast amount of data available within their respective Services i.e.:

- Maintenance experience,
- Operational aspects,
- Availability of Industry design tools.

In the following sub-chapters the Netherlands' activities are presented.

4.2 Site Surveys

In order to design a helicopter which is optimized from the supportability point of view, it is important to emphasize this aspect already in the D&D phase. The incorporation of User experience should have particular attention and is often overlooked.

Making an inventory of User experience, it is important to indicate:

- What is the (negative or positive) experience?
- What is the (probable) cause?
- What is the recommendation of the User?

Both the Royal Netherlands Navy (RNLN) and the Royal Netherlands Airforce (RNLAF) made an inventory as described above. Fokker design engineers visited the maintenance facility of the RNLN at Naval Air Station 'De Kooy' and the depot maintenance facility of the RNLAF 'Gilze Rijen'.

During both visits the inventories produced by Service personnel created the basis for an useful discussion.

The purposes of these visits were as follows:

- Under the current worksharing Fokker will design and produce the tail of the NH90 (behind the 'folding' hinge), the sponsons and come cowlings.
  During the visits it became very clear that especially the tail is a very delicate part of the helicopter. Particularly in this area 'User feedback' is essential.
- The intention of this feedback to the designer is to create a growing understanding for the problems of the User and to educate 'fixed wing' designers.
- The visits 'forced' the maintenance personnel of the RNLN and the RNLAF to make a detailed defect analysis, to review this carefully and to present the results non-biased.

This approach has been discussed in the ILSWG. Each Nation and corresponding industry was urged to perform a similar exercise.

Some results are presented in annex 1. Only by making these 'common' helicopter problems known to the manufacturers and continuous emphasis afterwards, they can be avoided in future designs and therefore contribute to better supportable helicopters with lower LCC.

4.3 Operational aspects

Another important aspect to be taken into account during the process of 'design to supportability'is the actual In-Service use of the helicopter. In order to have a good perception of operational handling aspects a Fokker engineering delegation paid a visit to a RNLN frigate.

Due to ideal weather conditions it was possible to make a detailed study of all helicopter activities on board of the ship, e.g.:

- Refueling,
- Lashing,
- Ranging,
- Pre/post flight inspections,
- Blade folding,
- Tail folding,
- Hangar inspections.

Especially blade and tail folding were reviewed due to the number of personnel involved. The visit clearly showed that those activities during adverse weather conditions are demanding and critical.

Fig.8 Operational Aspects

4.4 Review function

One of the management tasks for ILS is the so-called 'review function'. This function is a continuous process. However, three (3) formal milestones are normally identified:

- Preliminary design review (PDR),
- Critical design review (CDR),
- Final design review (FDR).

The objectives of these reviews are:

- Fulfilment of the operational requirements,
- Verification of the design with respect to contractual and specification requirements,
- Consideration of the logistic requirements.

Based on certain needs many meetings, visits and many representatives are involved. The amount of work necessary for the organization of design reviews is very often tremendous.

4.4.1. Integrated Design Review Teams

The tremendous workload caused by formal design reviews can be reduced by emphasizing the continuous character of the review process.
Therefore Industry recommended already in the PDP phase the set-up of 'integrated design review teams', meaning the allocation of national experts in the design teams on a permanent basis.

These allocated national experts should have the following tasks:

- Day-to-day advise to Industry with respect to the User experience.
- Close monitoring of the design activities. This is a very important task. When a full go-ahead is given the design process normally proceeds very fast. The national experts can participate daily in 'design working sessions' on an observer basis and if required advise the design/logistic engineers. By proceeding in this way the national experts can respond quickly to questions from Industry (clear 'focal point') and at the same time provide timely feedback to the National Program Office and/or International Program Office.

It is firmly believed that if experienced people are located in the design offices of the Industry a substantial amount of formal design reviews can be avoided and a substantial amount of cost therefore saved.

The liaison function of these national experts may also contribute to the fact that design reviews can be organized in a later stage and that the correct information/correct people from the side of the User are available at the design review meeting when it is organized.

4.4.2. Mock-up review

A combined team of members of the RNLN, RNLAF and a team of Fokker engineers conducted a NH90 mock-up engineering review in Marignane. Objective of this preliminary design review was to verify the maintainability aspects of the mock-up in order to ensure that the NH90 helicopter is designed for 'ease of maintenance' thus achieving the established/agreed supportability goals.

Each team conducted separate investigations in order to ensure non-biased reports. During the review a wide range of findings was recorded on paper, photo and video. Nations as well as Industry harmonized their mock-up results in order to achieve effective and unanimous design recommendations/refinements.

Fig.5 Mock-up review

5. Lessons Learned/Recommendations

Implementing ILS in multinational programmes requires some essential conditions:

- In the NH90 programme a lot of time and effort has been spent both in the understanding of the Nations' Logistic Support system (organization and procedures) and to reach agreement on a common logistic support system. For ILS it should be mandatory to have a common international logistic support system. It is recommended that European countries achieve more standardization in this field.
- A main ILS management tool is the Logistic Support Analysis (LSA). MIL-STD-1388 is a guideline for the determination of the LSA effort. Because of its essential function it is recommended that LSA tailoring is done very early in the programme.
- At the start of the D&D phase a LCC model and a Logistic Information System should be operational in order to ensure the required LCC reductions during the D&D phase.
- To avoid unnecessary and lengthy discussions/work (e.g. Glossary of Terms, LCC) all partners should timely make maximum use of existing documentation and procedures.
- Historical maintenance and operational field data shall be properly recorded and stored in such a way that it is readily available for feedback to new programmes.
- Psychology plays a very important role in the multi-national NH90 programme. Communication barriers resulting from differences in language, temperament and experience background, can only be overcome by means of mutual understanding and mutual trust.

6. Conclusions

- ILS requires extensive co-ordination and data exchange between Nations and Industry in order to achieve maximum commonality for design features and ILS Elements.

- National and International working groups (Nations and Industry) shall be the necessary base for close international co-operation.

- Logistic reviews will be conducted by Nations and Industry as an effective instrument to provide a better understanding between designer and logistician. Thus establishing a higher level of confidence in international co-operation and as a result a higher availability of the NH90.

Shrouds and Fairings

- Engine fairings should be heat resistant.
- Sealing of fairing hinges should be effective.
- Fairings and shrouds (between different aircraft) should be interchangeable.

Blades

- Main rotor and tail rotor blades should be interchangeable.
- Reversed assembly of blades should be made physically impossible.
- Blade edges should have effective wear resistant coating.

Composite Parts

- Composites are shock vulnerable and should in principle not be used in so-called 'step areas'.
  When used, composite 'walk ways' should be reinforced.
- Prevent direct contact between light metal and composites.
  Due to vibrations excessive wear (chafing) occurs (sliding cabin doors on airframe, fairings on airframe, etc.).
- Inspection panels should be rugged (sailor proof).

Electrical/Wiring/Cable Harnesses

- Wirings should be of sufficient length to facilitate maintenance.
- Standardized 'clippings'should be used to prevent chafing.
- Harnesses should have a growth potential to facilitate future modifications.
- Identification of wiring must be adequate to facilitate battle damage repair.

Tools/AGE

- Standardization of nuts, bolts, screws, terminal blocks, etc., is necessary to limit the number of required tools. Bolt and attaching nut should be different in size to avoid the use of two (2) separate tool sets.
- Use of specific-to-type tools should be kept to a minimum.

Vibration

- Flapping hinge bearings are wear sensitive.
  High quality (easy to replace) bearings should be used.
- Avoid over-maintenance by objective and clear vibration limits.
- Build-in vibration sensors/pick-ups should be encouraged.

Corrosion Protection

- Inspection panels should be simple in design.
- Seals should be fitted to the panels and not to the airframe structure itself so that curing can be done off-aircraft in a conditioned environment.
- Overall good waterproofness (radar dome, cabin floor, avionics compartment, etc.).
- Magnesium casings are sensitive to stress corrosion.
- Bushes, bolts and pins of the tail folding mechanism are very sensitive to (stress) corrosion.
- In order to prevent crack initiation and stress corrosion:
  * avoid sharp corners,
  * use correct number, position and diameter of rivets and blind rivets,
  * choose correct material.
- Outside air should not be used for cooling avionics equipment due to the high humidity.

Hydraulics

- Indicators for servicing should be visible from outside the helicopter.
- Hydraulic piping should not be routed in the vicinity of alternators, avionics equipment.

General

- Simplified rigging procedures reduce maintenance downtime and should therefore be encouraged.
- Military usage requires a battery capacity sufficient to facilitate operations in extreme (cold) weather conditions.
- Military usage requires a more intensive use of free wheel units. Therefore free wheel units should be of high reliability.
- Sand and poor quality windscreen wipers cause scratches on windscreens. Wear resistant screens and higher quality wipers are recommended.
- All helicopters of one customer should have the same door key.
- LRU replacement should be performed without adjustment.
- Accessibility of engines, transmission deck, rotors, etc. should be good.

List of Abbreviations

ADP	Automatic Data Processing
AECMA	Association Europeenne des Constructeurs de Materiel Aerospatiale
AGE	Aerospace Ground Equipment
CDR	Critical Design Review
D&D	Design and Development
ILS	Integrated Logistic Support
ET	Expert Team
ECU	European Currency Unit
FDR	Final Design Review
FMECA	Failure Mode Effect and Criticality Analysis
IIO	International Industry Office
ILSWG	Integrated Logistic Support Working Group
LCC	Life Cycle Cost
LORA	Level of Repair Analysis
LS	Logistic Support
LSA	Logistic Support Analysis
LSAR	Logistic Support Analysis Records
MSG	Maintenance Steering Group
NFH	Nato Frigate Helicopter
NSR	Nato Staff Requirement
PDR	Preliminary Design Review
PDP	Project Definition Phase
RAM&T	Reliability, Availability, Maintainability and Testability
RCM	Reliability Centred Maintenance
RNLAF	Royal Netherlands Airforce
RNLN	Royal Netherlands Navy
TTH	Tactical Transport Helicopter