Jiří STODOLA

ENHANCEMENT OF MILITARY VEHICLE AVAILABILITY THROUGH ADVANCED MAINTENANCE CONCEPTS AND TECHNOLOGIES

Reviewer: Milan LÁNSKÝ

Abstract:

The article is a basic analytic material dealing with problems of military techniques maintenance. It analyses current state and assumed development of maintenance of combat, special and transport vehicles, and airplanes in particular NATO countries.

The Importance of Availability/Readiness

From the operational perspective, weapon system effectiveness is a function of capability, system readiness, mission reliability, and survivability. The overall readiness of military forces and the associated readiness/availability of vehicle and other military equipment to meet mission requirements have been high profile issues in several NATO countries over the past ten years. One reason for this is that the high cost of military forces keeps them constantly in the budget spotlight. Secondly, there have also been changes in the perceived threat environment following the end of the Cold War in 1990, the terrorist attacks on the World Trade Centre in 2001, and subsequent terrorist attacks around the world. Thirdly, there has been a trend to concentrate more capability in fewer military vehicles. This trend has heightened the importance of vehicles readiness, while making it more difficult to achieve. Availability/readiness can be viewed as a function of two major parameters. One of these is the reliability of the vehicle in a given operational scenario. Reliability is defined in NATO ARMP-7 as the ability of a system to perform a required function under stated conditions for a specified period of time. The reliability of a vehicle depends on both the design and the maintenance/support of the vehicle. A less reliable design will require more corrective maintenance and will be less available for operational use. Similarly, a vehicle that does not receive preventive maintenance i.e., servicing, lubrication, component replacements/rework ("hard time" tasks), and inspections for potential failures ("on condition” tasks) - at the optimum times for the particular design and operational scenario will not perform as reliably as intended and will require more corrective maintenance. The other major parameter affecting vehicle availability/readiness is the time taken to perform corrective and preventive maintenance. This also depends on both the design and the in-service support of the vehicle, but requires measures additional to those related to reliability. In summary, the primary ways of increasing vehicle availability/readiness are to increase the reliability of the vehicle and reduce the time spent on corrective and preventive maintenance. For best effect, both actions require coordinated effort during design and maintenance/support. In the case of in-service aircraft, design modifications may be needed to implement an improved maintenance concept.

1. Mission Reliability and Availability/Readiness are Directly Linked

As the above presented definition of system effectiveness implies, a vehicle must not only be available when required, it must also function as required during the mission. Otherwise, the effective availability at 1st line can be dramatically reduced with serious operational consequences. For example, several combat/strike vehicles may have to be launched to ensure that one remains fully functional on a high priority target, or many extra transport missions and extra time may be needed to move important cargo into a theatre of operations. Thus, vehicle availability at 1st line and mission reliability are directly linked. Moreover, all measures to improve mission reliability will improve availability. Therefore, we should give high importance to maintenance/support concepts and technologies that can improve mission reliability. For example, approaches that could provide significant periods of maintenance-free operation at 1st line should be investigated, since they would deal simultaneously with availability and mission reliability under wartime conditions.

2. Trade-Offs and the Relationship Between Availability and Life-Cycle Cost

Cost is a trade-off in all the system properties/outcomes that collectively constitute effectiveness. Making trade-offs is not a simple matter, since some of the system properties are interrelated, and each is a complex function of many other variables. An approach promoted in the acquisition process to facilitate trade-offs is to define threshold (minimum) requirements and achievable objectives for the various properties/outcomes. The difference between the threshold and objective for a given property/outcome can be regarded as the "trade space". The acquisition process for the vehicles must balance life-cycle cost, schedule, and the parameters that collectively determine whether the system is be effective in its assigned mission, i.e., capability, system readiness, mission reliability, and survivability. The in-service support of the vehicles must maintain the required effectiveness under changing circumstances while optimizing life-cycle cost. The current consensus appears to be that to achieve the required availability/readiness the design of the vehicle and in-service support system must meet specific supportability criteria. Further, the in-service support system must be managed so as to monitor performance against these supportability criteria and adapt as necessary to maintain the required availability/readiness at minimum life-cycle cost. The relationship between availability/readiness and life-cycle cost is not always immediately obvious, and needs to be considered by AVT-RTO-NATO. Many recent national initiatives in military logistics appear to have been driven by a political imperative to reduce military expenditures in general. The improvement of vehicle availability is one way to achieve this, since it can be used to justify smaller fleets and smaller detachments in deployed operations. Many recent national initiatives in military logistics have also been driven by the need to change from the relatively static operational posture of the Cold War era to the more expeditionary operational posture that appears to be needed for the foreseeable future. This expeditionary posture includes a strong emphasis on joint (air/land) operations, which has justified greater integration among the services. This in turn has provided opportunities for cost savings on maintenance/support. A common thread in all recent national initiatives in military logistics has been a requirement to maintain or improve on weapon system effectiveness, while making all the other changes. Initiatives that have a proven record of improving availability with a beneficial or neutral effect on life-cycle costs are obviously of our interest. For example, US Army has found that changes made in the 1990s from four levels to two levels of maintenance reduced life cycle costs as intended, but also unexpectedly degraded fleet availability. A further investment in spares was needed to restore the required availability. Therefore, in studying the potential impact of advanced maintenance concepts and technologies on availability, we should also assess their impact on life-cycle costs and the balance between cost and system effectiveness for all required operating environments. Many detailed issues are involved in such assessments.

For a given operational posture, vehicle availability is a function of the demands of a particular vehicle for technical support and the time it takes to provide this technical support. To improve availability, one or both of these factors must be reduced. It is generally recognized that this is most efficiently and effectively accomplished during the design of a new vehicle and its in-service support system. However, there are many vehicles in the NATO countries that cannot be replaced with new designs in the close future. Moreover, there is a new trend in vehicle acquisition in Europe to plan for a long service life with periodic upgrades in effectiveness. Therefore, AVT-RTO-NATO should investigate ways of improving the availability of existing (legacy) vehicles as well as new vehicles being still in the design stage. It is more difficult to make a business case for changes to in-service vehicles. Nevertheless, many initiatives to improve the availability of in-service vehicle have been undertaken by NATO nations.

In many cases, changes in maintenance to improve availability bring parallel reductions in life-cycle costs. In some cases, it might be possible to show that a change in maintenance would significantly reduce life-cycle costs, but not possible to show that it would directly or indirectly improve availability. Maintenance concepts and technologies in this category could arguably be included in the workshop, because the changes would release funds, which could then be used for improvements to availability. However, in view of the limited time available, the main emphasis of the workshop should remain ways of achieving affordable improvements in availability.

3. Key Drivers and Performance Indicators of Vehicles Availability

It is possible to have good availability with respect to depot maintenance (i.e., third and fourth line maintenance), but poor availability with respect to flight-line and intermediate maintenance (i.e., first and second line maintenance). For these various maintenance levels there is also possible to provide adequate availability for steady-state environments while being incapable of meeting surge requirements. Therefore, in assessing availability, it is urgently necessary to define terminology, time frames, and operational contexts. The definitions of availability and readiness in the accompanying Excel file currently do not provide a comprehensive set of metrics for this purpose. It is important for us to obtain a full understanding of the key drivers and performance indicators of vehicle readiness/availability, to help in the assessment of alternative maintenance concepts and technologies. Since performance-based contracting for acquisition and in-service support (sometimes referred to as availability-based contracting) has been a major trend for some years, there must be many different ideas in circulation, and there is likely to be some debate on the best approaches.

3.1. Evolution of RCM

The determination of the preventive maintenance needed to achieve the desired availability and mission reliability at optimum cost is one of the key processes in the design of the vehicles and its in-service support. Preventive maintenance consists of several types of tasks: servicing; lubrication; replacements/rework of components that have reached their safe life or economic life ("hard time" tasks); inspections for potential failures ("on condition" tasks); and inspections to determine whether a hidden failure has occurred ("failure finding tasks").The process used to determine the content of maintenance schedules has a significant impact on the cost of maintenance and on vehicle availability. The subject has received considerable attention from vehicle designers, operators and regulators over the last forty years. The dominant concept called Reliability Centered Maintenance has emerged. This maintenance analysis process uses rigorous analytical procedures, such as Failure Modes Effects and Criticality Analysis (FMECA), and distinguishes between maintenance operations that are essential, economically desirable, and of no value. It has tended to replace other, less rigorous methods. Studies showed that earlier maintenance programs were not adequately effective and that there was considerable wasted effort. Among military forces, the US Army took the lead with the development and implementation of RCM on vehicle in the late 1960s and early 1970s. It collaborated with American and European vehicle manufacturers and regulatory authorities in a Maintenance Steering Group (MSG), which produced the document MSG-1 "Handbook: Maintenance Evaluation and Program Development". This document included RCM concepts and was used to develop the maintenance program for the aircraft Boeing 747. This document has undergone substantial development over the years. The latest version is MSG-3. MSG-3 has been used in most large civil vehicles. As a result of refined RCM concepts, other improvements in logic, and the inclusion of the hitherto separate Corrosion Prevention and Control Program (CPCP) has helped to create maintenance programs that are much more efficient than their predecessors. Despite high non-recurring costs, MSG-3 is being applied retrospectively to some earlier fleets. Meanwhile, military as well as civilian organizations have continued the development of the RCM process, and this is now widely applied in the vehicle industry and many other industries. The terminology of RCM maintenance analysis may vary between users.

3.2. Maintenance Levels

The RCM process helps to determine the most efficient grouping of maintenance tasks as well as the tasks to be performed. However, the grouping of maintenance tasks at different organizational levels is also subject to changing operational and command environments. In wartime conditions the mission requirements are paramount and it may be necessary to perform maintenance and maintain vehicle availability under unusual or unforeseen conditions. History shows that the organization of vehicle maintenance has been highly influenced by the need for operational commanders to have effective control over the availability of their equipment. For example, see [3].

3.3. ON Condition and Hard Time Tasks

Some of the preventive maintenance determined through the RCM process involves inspections designed to identify a "potential failure" before actual functional failure occurs. As indicated earlier, these are referred to in RCM as "on condition" tasks. The estimated interval between the reliably detectable potential failure condition and actual functional failure is known in RCM as the Potential Failure Interval (PFI). The inspections may be visual or may require special NDI equipment, test equipment, or sensor systems. They are performed at some fraction of the PF interval that is estimated to provide adequate safety. The first inspection may be delayed until a usage threshold is reached. Examples of "potential failures" are a sub-critical crack in a significant structural item, a sub-critical crack in a vehicle transmission component, the failure of one channel in a duplex or triplex fly-by-wire control system, and the exceedance of oil debris detector limits in an engine. In the case of cracks in mechanical components, the inspections tend to be referred to as "damage tolerance" inspections rather than "on condition" tasks/inspections. When it is not possible safely to detect a potential failure, components are replaced with a new or overhauled component after a pre-determined amount of usage. Such preventive maintenance tasks are referred to in RCM as "hard time tasks".

3.4. Condition Based Maintenance

Condition-Based Maintenance (CBM) is not a RCM term, and is not defined clearly in relevant manuals. This is surprising, considering how often the term has been used over the years. CBM will be defined as the concept of performing maintenance tasks only when the condition of a component indicates that it is necessary to do so for safety, operational, or cost reasons. As such, it simply represents a proper application of RCM. Recently, the term CBM has tended to imply that some of the associated condition monitoring, analysis, and decision processes are being performed by on-board systems. For example, using Prognostic and Health Management (PHM) systems (discussed later) is sometimes referred to as CBM. However, it would be unnecessarily restrictive, and perhaps historically incorrect, to define the term in this way. Users should add their own clarifications or alternative definitions when necessary. The term CBM should not be confused with "CBM+". The latter is a term recently created for policy and management purposes. It has a much broader connotation than CBM. It is relevant to note that, in the case of vehicle structure, engines, and some other highly stressed components, uncertainty and performance pressures have been a major factors in prompting a general preference for "on condition tasks" (CBM) rather than "hard time tasks". According to RCM logic, "on condition" and "hard time" preventative maintenance tasks are only needed when they provide an essential increase in the reliability (a reduction in the probability of failure) of critical safety or mission functions. If these components could be designed with an adequate safe life, no maintenance of any kind might be required during the life of the vehicle. However, in these vehicle systems, the use of a safe life without inspections is generally too risky for several reasons. Firstly, there is often large scatter (variability) in the laboratory test lives of the systems and their components. Consequently, it is difficult to design for a long enough safe life without incurring an unacceptable weight and/or performance penalty. Secondly, there are uncertainties in the past and future loading and environments of the vehicle. Consequently, any estimates of safe life must include large factors of safety and require ongoing validation against service and test experience (known in RCM terminology as "age exploration"). Finally, current analytical and validation test capabilities are limited. Therefore, it is still possible to overlook some significant items and to make the wrong assumptions in modeling and testing. Facing such uncertainties, there has been a trend to provide safety and reliability in structure, engines and other mechanical systems by means of "damage tolerance" inspections ("on condition tasks") rather than by setting safe lives for the replacement or rework of components ("hard time tasks"). In the case of vehicle and engine structure, special structural integrity programs are used by some air forces to ensure that the RCM process can be applied with appropriate rigor throughout the life-cycle.

3.5. Condition Monitoring

Although the term "Condition Monitoring (CM) " is widely used, no formal definition has yet been found in government or international standards. Therefore, depending on the circumstances, the term will be treated as synonymous with the RCM terms "on-condition task" or "failure finding task" as defined in NAVAIR 00-25-403. It will also be treated as synonymous with "inspection" as defined in ARMP-7. Inspections for the purpose of "condition monitoring" may be performed manually, semi-automatically, or automatically by various means. These include visual inspection, NDI equipment, Built-In Test Equipment (BITE), and on-board sensor systems.

3.6. Usage Monitoring

Preventative maintenance is usually scheduled according to metrics representing component usage, calendar time in service, or a combination of these criteria. Typically, working hours are used as the metric of usage. In this case, usage records can be maintained manually. When there is considerable variability in the safe life or the damage growth rates with respect to working hours, it may be possible to find a different usage metric that results in less variability. This may require the use of a sophisticated usage monitoring system.

3.7. Reducing the Downtime/Duration and Frequency of "On-Condition" Maintenance Tasks

Since the modelling, verification testing, and inspection technologies employed in defining and executing "on-condition" maintenance tasks are constantly being improved, these technologies provide a means of reducing the maintenance downtime needed to obtain the desired safety and reliability. For example, faster inspection and less intrusive inspection can both have a large impact on the duration as well as on cost of maintenance. This may be achieved through improvements in off-board equipment and procedures, or it may be achieved by partially or fully automating inspections using an on-board inspection system – e.g., a sensor system, Built-In Test Equipment (BITE), or a maintenance data recorder. Another example of how downtime may be reduced is through greater accuracy in modelling failure mechanisms, coupled with more representative validation testing. This may allow a reduction to be made in the safety factors used in estimating damage growth and safe life. When a damage tolerance concept is being used, this reduction in risk may be traded for a delay in the inspection threshold and/or longer damage tolerance inspection intervals. When a safe life concept is being used, the reduction in risk may be traded for an extension in the safe life.

4. Major Trends in Some NATO Countries

Some relevant comments on the situation in a few NATO countries regarding vehicle availability and maintenance are given below.

4.1. United States of America

In the US Army provides a strong focus on readiness through its Material Readiness and Maintenance Policy and associated education and publicity. An overview of US managerial and technological initiatives in the areas of material readiness and maintenance can be obtained via Internet site www.acq.osd.mil/log/mppr. There are also high-level departments in the various services dealing specifically with readiness. In addition, there are other high level departments dealing with related issues such as corrosion and aging equipment. The key measures of vehicle availability currently include the percentage of time that a vehicle can perform at least one or all of its assigned missions, termed the "Mission Capable" (MC) rate and "Full Mission Capable" (FMC) rates, respectively. Statistics on availability tend to be expressed as the percentage of the fleet meeting MC or FMC goals, and/or as the average MC and FMC rates for a fleet or organization. The US Navy has been closely involved with the development of Reliability Centered Maintenance (RCM) for vehicle in collaboration with the US-European Maintenance Steering Group (MSG). Most vehicles have undergone RCM analysis. The design, manufacturing, maintenance, and logistics chains for US military vehicle have undergone "lean" analysis. This lean program addresses availability as well as cost. Dramatic reductions in cost and cycle times for depot maintenance have been achieved. Alternative contracting methods are being tried out, such as Performance Based Logistics (PBL), in which the contractor assumes responsibility for all depot maintenance and maintenance logistics and for providing the required vehicle availability. The US Congress maintains a close interest in the availability of military equipment through its Subcommittee on Readiness, and has sponsored major studies by the General Accounting Office (GAO) on vehicle availability and the "cannibalisation" of parts. The causes have been a combination of interrelated logistical and operational factors, with no dominating single problem. The GAO has also identified a need for a review of availability goals and associated metrics.

4.2. France

In 2002 France’s National Assembly expressed concern with the unsatisfactory state of the maintenance and availability - Disponibilité Technique Opérationnelle (DTO) - of its military equipment. This action followed years of relative neglect of the maintenance chain of existing equipment in favor of new procurement. The situation had been exacerbated by delays to new equipment. While the French armed forces had been responding adequately to operational requirements, new pressures from overseas deployments had accelerated the ageing of material and highlighted budget shortfalls. Some changes had already been initiated by the French Army with the creation in 1999 of integrated structures for the maintenance of vehicle components and the fleet. There have been efforts to improve efficiency through the outsourcing of some maintenance to industry, including foreign industry. Not all of them have been successful, and so there is a debate on the best approach to adopt. In general, the availability of vehicle fleets has stabilized. However, despite focused effort and investment, the availability of vehicle for example aircraft C-160 Transall fleet has continued to decrease. Perhaps a law of diminishing returns is applicable to older fleets. The Rafale multi-role fighter is expected to provide improved levels of availability and lower maintenance costs compared with earlier fleets. One innovation is the division of the vehicles into Shop Replaceable Units (SRU); therefore the complete vehicle and complete engine are not subject to depot maintenance. Built-in deployability and supportability will help maintain availability during distant deployments.

4.3. Germany

In Germany, as in the UK, the availability of air vehicle the Tornado fleet has been relatively low. The availability of the Eurofighter multi-role air vehicle is expected to be much better. EADS GmbH in Germany provides the headquarters for the German-Italian-Spanish-British Eurofighter program. The German Armed Forces deployed a new SAP system last year to integrate maintenance with logistics and other functions. It will provide global access to readiness data.

4.4. United Kingdom

In the UK, the Strategic Defence Review of 1998 triggered major changes in the logistic support arrangements for the three services. The centralization of the logistics support of Army, Royal Air Force, and Royal Navy in one agency, known as the Defence Logistics Organisation (DLO), has been the most obvious change. This comprises about 41,000 military personnel and civilians, based at more than 80 locations, and a budget of about 5B pounds, which is 20% of the UK’s total defence budget. It appears that the reasons for this centralisation were operational as well as financial ones. It was considered that greater integration would benefit joint force deployments, which occurred more frequently. In parallel with the creation of the DLO, the UK has pursued a Smart Procurement Initiative (SPI), which requires a much closer working relationship with industry during both procurement and the remainder of the life cycle. The UK is also introducing "lean" initiatives comparable to those in the USA. As part of this approach, aviation maintenance for the RAF and RN was reorganised into a single agency known as the Defence Aviation Repair Agency (DARA). Maintenance was performed by DARA in collaboration with industry. The collaboration included novel partnering arrangements. For example, DARA was in some instances a subcontractor to an industrial prime contractor for maintenance work or a modification program ordered by DARA. Several successes were achieved, but there was still huge potential for improvement across all maintenance processes and levels. Consequently, the functions of DARA are now either being absorbed into industry or returned to the Army. The 3rd and 4th line maintenance of several vehicle types and their components is now performed at one of their main operating bases, and is referred to as "depth" maintenance. Meanwhile the acquisition of new vehicle has remained the responsibility of a central government agency, which became known as the Defence Procurement Agency (DPA).

4.5. Canada

In Canada, the Army, and Air Force were unified in the late 1960s, and so any benefits associated with integrated logistics systems have presumably been carried out. The benefits of RCM were recognized some time ago, and all Canadian Forces vehicles are nowadays maintained using schedules developed using MSG-3 maintenance analysis. Vehicle structure is also subject to maintenance analysis based on the US Army Vehicle Structural Integrity Program (VSIP) in MIL-STD-1530A but structural life management methods also draw on the experience of the UK and Australia. The Canadian Forces have been among the pioneers of risk analysis and damage tolerance analysis in engines. Significant savings have been realized on the T-56 engine that powers the air vehicle CP-140 and C-130 fleets, and more are forecast as a result of this investment. The current focus is on improving methods of partnering and contracting with industry for vehicle support. In this regard, Canada’s efforts are comparable with those of other NATO countries. There are difficulties in applying performance-based contracts to existing programs, but the concept of "power by the hour" contracting has been fully embraced in Canada’s new maritime helicopter program. In this program, twenty-eight CH-148 Cyclone helicopters, which are based on the S-92, have been ordered from Sikorsky. The helicopter will be operated from frigates in various roles including Anti-Submarine Warfare (ASW). The acquisition contract and the In-Service Support (ISS) contract were both signed in 2005. Sikorsky will be responsible for most of the ISS and for delivering the required vehicle availability for a period of 20 years. An interesting initiative in Canada has been the establishment of an independent military authority that does not share staff with the project management and engineering authorities for each vehicle type.

5. HUM and PHM Systems

Prognostic and Health Management (PHM) System is defined as follows: "Diagnostic or prognostic devices and systems that are used to monitor equipment condition and provide indications to the operator or maintainer. These systems may also initiate automatic actions to deal with the condition(s) sensed or predicted. "

For purposes of this article, this definition will also be used for a Health and Usage Monitoring (HUM) system. HUM/PHM systems may consist of on-board and off-board elements. A wireless link might be used to download data while the vehicle/aircraft is on the ground or at some stage of flight. The term "prognosis" will be taken to mean the estimation of, or an estimate of, the rate of future damage growth and/or the remaining safe life. This estimate is based on the output of predictive models within the prognostic system, which couple information from usage monitoring, condition monitoring, past, current and anticipated future environmental and operational conditions, the original design assumptions regarding service environments, and previous component and system level testing. Currently, prognostic systems consist mostly of engineers using personal computers and special software and working with data that have been gathered in various ways. However, there is growing interest in using on-board systems to perform prognostic functions. Better prognosis, whether performed on-board or off-board, could reduce the duration and frequency of maintenance in several ways. In the case of "hard time tasks", it could allow safe lives to be extended without an increase in the risk of failure. In the case of "on condition tasks", it could allow the inspection frequency to be reduced without an increase in risk. If the condition monitoring and prognosis functions are both performed on-board, it is sometimes possible to dispense with other forms of inspection and/or to justify a longer safe life. The accuracy of prognosis, whether performed on-board or off-board, is usually improved if the usage of a component can be measured accurately. Consequently, prognostic systems usually include inputs from a usage monitoring system. Whatever on-board or off-board inspection/monitoring technology is employed, the shorter the life remaining after potential failure has been detected (the PF interval), the more technologically demanding it is to replace a safe life "hard time task" with periodic "on condition tasks". Nevertheless, there have been applications of the damage tolerance concept in service where the remaining life after the detection of potential failure was only a few flying hours. The use of HUM/PHM systems can expand the number of situations in which this can be done safely and can increase the PF interval. HUM/PHM systems have been in use for many years, particularly on vehicles, but there is much scope for improvement. The use of on-board HUM/PHM systems is regarded as a maintenance concept with considerable potential for improving vehicle availability and reducing life-cycle costs. Because of the potential benefits, a considerable amount of R&D effort is currently devoted to the discovery and application of improved HUM/PHM technologies. State of the art HUM/PHM systems are capable of detecting potential failure conditions down to the component or sub-element level. They are also able to monitor the progression of chosen failure mode indicators, e.g., heat, severe wear particles, vibration, etc., to predict when functional failures occur.

6. Integrated Logistic Support (ILS)

Several NATO nations incorporate a process known as Integrated Logistic Support (ILS) in their acquisition of new systems and the associated in-service support. In the USA, this process was implemented in the 1980s through Mil-Std-1388 "Logistics Support Analysis" (LSA) and related policy and procedure documents. LSA is defined as "a disciplined, unified, and iterative approach to the management and technical activities necessary to:

- cause support considerations to influence both requirements and design;
- define the support requirements that are optimally related to the design and to each other;
- acquire that required support;
- provide the required support over the life cycle of the equipment at lowest possible cost.

Its concepts have been embraced by many other nations. Mil-Std-1388 was cancelled in the late 90s and replaced by Mil-Hdbk-502 "Acquisition Logistics", which met Congressional requirements for a less structured and rigid acquisition process. Mil-Hdbk-502 is a very well written, self-contained document that defines a systems engineering approach to the design of a vehicle that provides an optimum balance between cost, schedule, performance, and supportability. It defines acquisition logistics as a multi-functional technical management discipline associated with the design, development, test, production, fielding, sustainability, and improvement modifications of cost effective systems that achieve the user's peacetime and wartime readiness requirements. Further embellishments to the US military acquisition process were made in this context in 2004 through revisions of the US DoD 5000 policy documents. The guidelines associated with these recent adjustments in policy differ in some details from those in Mil-Hdbk-502, and it is not clear to what extent the latter document is still applicable. As mentioned earlier, the US Army developed and introduced RCM concepts into vehicle maintenance in the 1970s. Following the cancellation of Mil-Standards, they issued their RCM process as NAVAIR 00-25-403 and required that it be superimposed on any other acquisition processes. They also required that it be applied retrospectively to in-service vehicle. NAVAIR 00-25-403 is perhaps the best document available for defining and describing RCM for military vehicles. The UK and Canada have continued with an approach based on the original Mil-Std-1388 architecture under the revised name of Integrated Logistics Support. The UK has made considerable efforts to ensure that ILS and the associated R&M concepts are comprehensive, well publicized in readable documents (such as Defence Standards 00-40, 00-41, and 00-60, and the MOD Guide to ILS), and well integrated into the new vehicle/aircraft procurement processes introduced in the UK in recent years. Canada’s ILS manual, A-LM-505-001/AG-001, is a comprehensive, self-contained document in English and French. It is well written, concise, and easy to read. It clearly explains the link between in-service support and weapon system effectiveness. The ILS process as currently used by the UK and Canada is a method of implementing a comprehensive systems engineering approach to acquisition and in-service support. While the USA still uses a comparable systems engineering approach, the details are now less well defined and less consistent between documents. Therefore, it will be useful to use ILS process diagrams and definitions as a framework for our discussions. As an example, two ILS process diagrams in Def-Stan 00-60 are reproduced in Figures 1 and 2.

In Figure 1, Logistics Support Analysis (LSA) is shown as a set of core activities within the overall ILS process. Reliability and Maintainability (R&M) analysis is not specifically shown in this figure. The UK manages R&M separately from ILS, but the results are recorded and used in the LSA.

Figure 2 shows how LSA and other ILS processes are performed iteratively to the appropriate depth throughout the system's life cycle. These include updates of estimates of life-cycle cost and trade-offs against operations and supportability – i.e., the degree to which system design characteristics and planned logistic resources, including manpower, meet the system peacetime and wartime availability requirements. The life-cycle concept in Figure 2 is the conceptual DEAMS business process, which aims to provide and sustain equipment performance, and its availability, reliability and maintainability, at optimum LCC. Achievement of this requires that the equipment's entire life-cycle be managed.

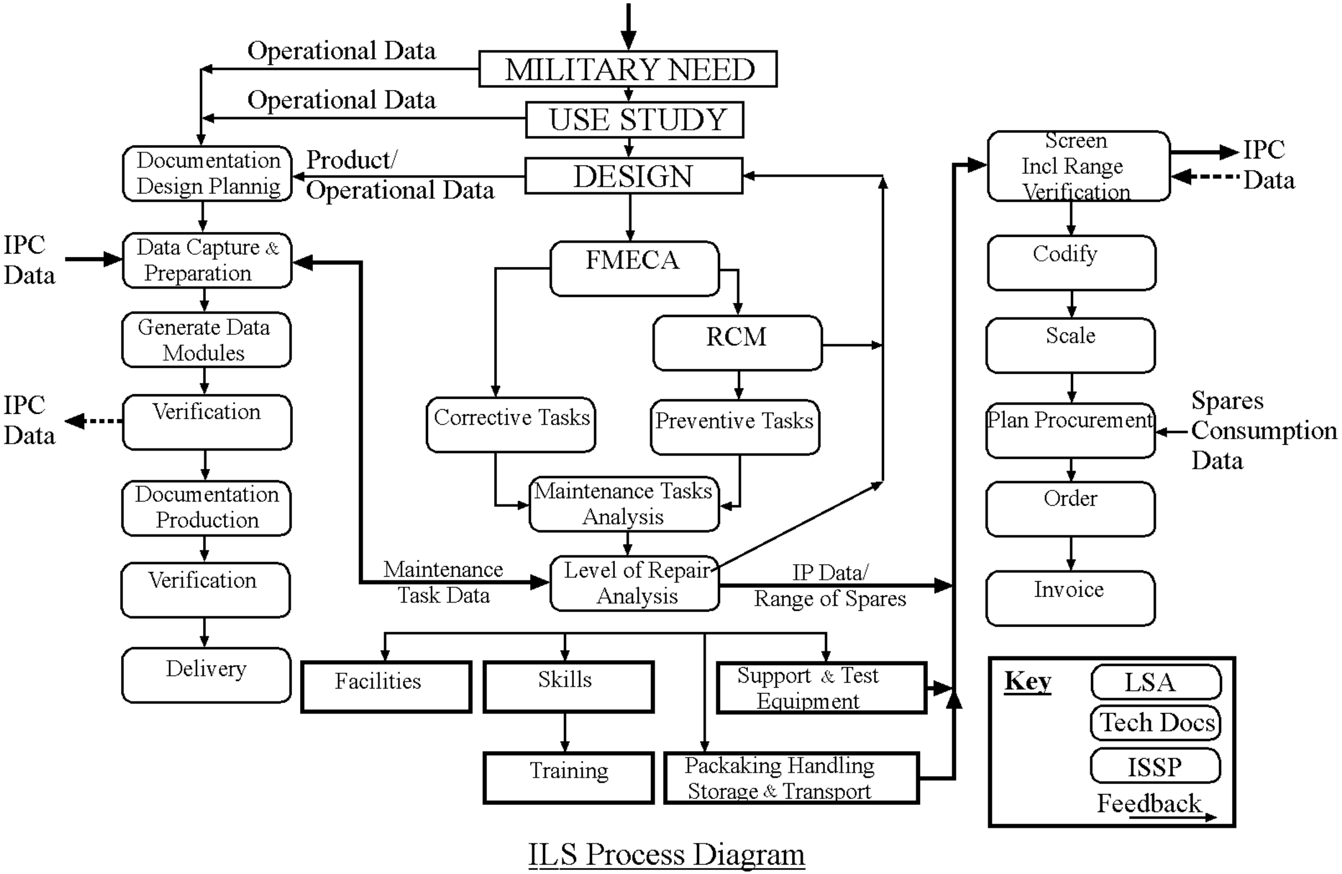

Figure 1 Process Diagram for ILS in MoD Guide to Integrated Logistic Support

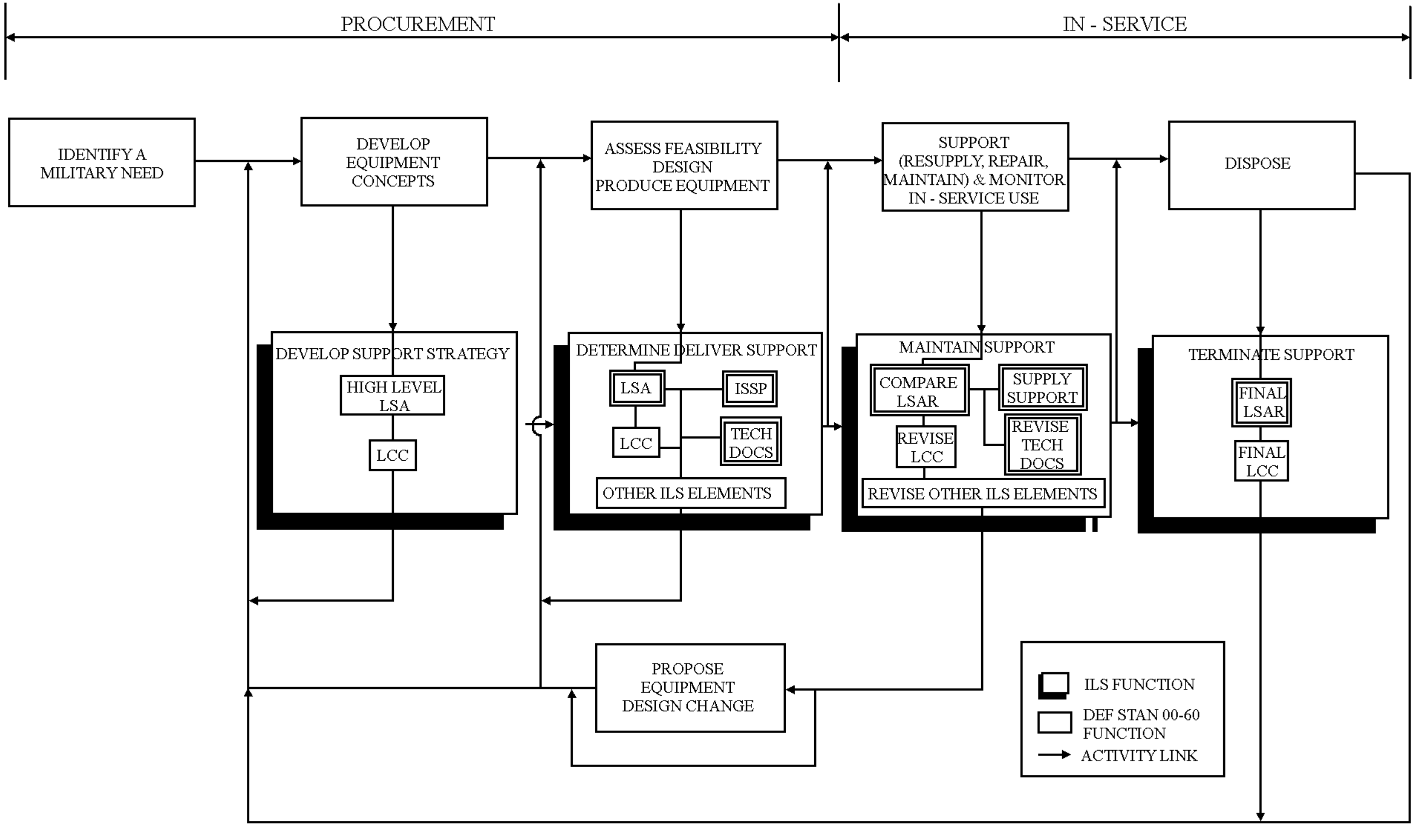

Figure 2 Importance of ILS within the Defence Equipment Acquisition and Materiel Support (DEAMS) Business Concept

In the UK and Canadian approaches, ILS has both an influence on and draws information from the following disciplines and related elements:

a) Maintenance Planning;
b) Supply Support;
c) Support and Test Equipment (S&TE);
d) Computer resources support;
e) Reliability and Maintainability (R&M), Safety, Testability and other design disciplines;
f) Facilities;
g) Manpower and Human Factors;
h) Training and Training Equipment;
i) Environmental Protection and Waste Treatment;
j) Technical Documentation;
k) Packaging, Handling, Storage and Transportation (PHS&T);
l) Disposal;
m) Design interface.

It is likely that most of these disciplines and elements are common to the approaches for acquisition and in-service support being used by other NATO nations.

7. Conclusion or why is improving maintenance vehicles necessary

The foregoing illustrations of the context of the our discussion indicate that the context is one of immense change over the past forty years with the objectives of reducing costs and improving weapons platform availability. It is likely that such change has been occurring to varying degrees in most NATO countries. The importance and scope of the change has focused the minds of many capable individuals from heads of governments downwards on the issues involved. Therefore, there must now be considerable knowledge and experience throughout NATO on the use of advanced maintenance concepts and advanced technologies to improve availability and reduce life-cycle costs. Some of this knowledge and experience can be distilled out of many international conferences on related topics. In addition, some relevant concepts and technologies have been addressed to varying degrees in the work of technical teams, past and current. However, there has not yet been a focused attempt by RTO to study our collective experience and present information and conclusions on what maintenance/support concepts and technologies are likely to be particularly effective in improving military vehicle availability.

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Abbreviations:

AVT-RTO-NATO… Applied Vehicle Technology – Research & Technology Organization
MC … Mission Capable
FMC… Full Mission Capable
RCM …Reliability Centered Maintenance
MSG …Maintenance Steering Group
PBL … Performance Based Logistics
GAO …General Accounting Office
DTO … Disponibilité Technique Opérationnelle
SRU … Shop Replaceable Units

SAP… Support Aviation Program
DLO … Defense Logistics Organization
SPI … Smart Procurement Initiative
DARA … Defense Aviation Repair Agency
DPA … Defense Procurement Agency
VSIP … Vehicle Structural Integrity Program
ASW …Anti-Submarine Warfare
ISS …In-Service Support
FMECA …Failure Modes Effects and Criticality Analysis
CPCP …Corrosion Prevention and Control Program
PFI …Potential Failure Interval
CBM …Condition-Based Maintenance
PHM …Prognostic and Health Management
CM …condition monitoring
BITE …Built-In Test Equipment
HUM …Health and Usage Monitoring
ILS …Integrated Logistic Support
LSA …Logistics Support Analysis
R&M …Reliability and Maintainability
IPC …Illustrated Parts Catalogue
MoD … Ministry of Defense
ISSP …Integrated Supply Support Procedures
IP …Initial Provisioning
DEAMS …Defense Equipment Acquisition and Materiel Support
PHS&T …Packaging, Handling, Storage and Transportation
S&TE …Support and Test Equipment

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Introduction of Author:

STODOLA Jiří, Prof., Dipl. Eng., DrSc. is a professor of University of Defence in Brno, Faculty of Military Engineering, Department of Combat and Special Vehicles. He gives lectures at a number of universities both in the Czech Republic and abroad. He deals with theory, practice and application of vehicles technical diagnostics, reliability and maintenance. He was the head, author and co-author of 46 scientific assignments that were focused on problem solution and about 215 papers published in the Czech Republic and abroad (USA, GB, Germany, Italy, France, Finland, Korea, etc.). He represents Czech Republic in AVT (Applied Vehicle Technology) RTO (Research Technology Organization) NATO as a principal panel member.

Email: jiri.stodola@unob.cz