Optimizing Maintenance Simulation Training Device Usage

Anneke Nabben MSc., Dr. Manfred Roza
Netherlands Aerospace Centre NLR
Amsterdam, the Netherlands
Anneke.Nabben@nlr.nl; Manfred.Roza@nlr.nl

ABSTRACT

Over the last decade simulation training devices have made their entrance into the aviation maintenance world. Various Maintenance Training Organizations (MTOs) have acquired Maintenance Simulation Training Devices (MSTD). However, the effective usage of such devices as an integrated part of a maintenance type training programme is not always evident. Such usage is further complicated by the fact that user and aviation authorities acceptance of such devices is not well supported. Mid 2013 a MSTD for the NH90 was delivered to the Royal Netherland Air Force (RNLAF) Helicopter Command called the NH90 VMT. During the introduction in theNH90 maintenance type training in the year thereafter, the RNLAF experienced similar issues regarding the NH90 VMT training effectiveness. To gain insight in the source of these issues and enhance the effective usage of the NH90 VMT, the RNLAF requested the Netherlands Aerospace Centre NLR to conduct a Verification and Validation (V&V) study of the NH90 VMT and it usage within the current training program.

A part of this V&V study comprised a desktop analysis into the optimal usage of MSTDs and two accompanying NH90 training evaluation experiments with the NH90 VMT. This part focussed on directly evaluating the training effectiveness related aspects of the NH90 VMT usage within the current NH90 type training program. This paper discusses the major findings and conclusions that result from this training context analysis and associated experiments. In addition, general applicable guidelines and recommendations for the effective usage of a MSTD for maintenance training will be provided, regarding the type of tasks, the level of maintenance experience and the type of instructor support. This will help any aviation maintenance training organisation to optimize the usage of their MSTD.

1 - INTRODUCTION

To train technicians in aircraft maintenance on a specific aircraft type, so-called type training is mandatory. This type training must comply with several regulatory requirements like training duration, training methods and examination as imposed by the Dutch Military Aviation Authorities (MAA-NLD) regulation MLE-66 v. 3.0, which in return builds upon the civil regulation Part-66 of European Aviation Safety Agency (EASA) [1] [2]. Aircraft maintenance type training is subdivided by the MAA-NLD in two courses: airframe/power-plant (B1.3 - Technician) and avionics/electrical systems (B2 - Technician). Both courses consist of four phases as depicted in Figure 1. The On the job training (OJT) is however only mandatory for trainees, which do not have a type specific maintenance license for another aircraft. These trainees only have a basic aircraft maintenance education when entering the maintenance type training program.

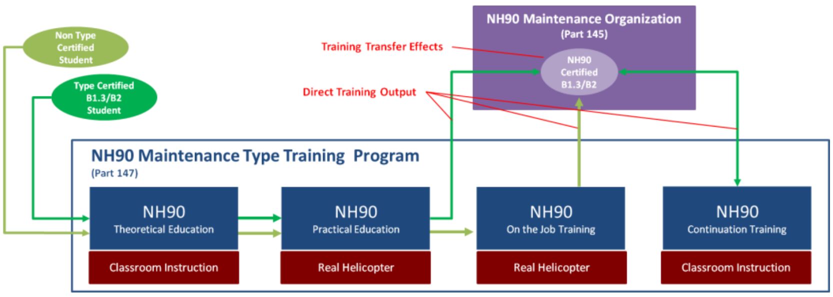


Figure 1 NH90 Aircraft Maintenance Type Training Phases

Successful completion of this training program results in a type specific B1.3 or B2 maintenance license. To keep the maintenance license valid it is necessary that each licensed technician follows continuation training (CT) for the specific aircraft type on a regular basis. Within the RNLAF the Koninklijke Militaire School Luchtmacht (KMSL) is responsible for all aircraft maintenance *type* training programs.

Since mid-2013 the NH90 Virtual Maintenance Trainer (VMT) has been introduced by KMSL in the NH90 B1.3 and B2 maintenance type training courses. The NH90 VMT is PC-based desktop MSTD that provides a 3D visual representation NH90 maintenance environment (i.e. helicopter in a hanger/platform with all maintenance equipment, supplies and consumables) with underlying simulation models. These models are capable to simulate the NH90 helicopter airframe, subsystems and other equipment behavior and provide the opportunity to train almost all maintenance procedures from the NH90 Interactive Electronic Technical Publication (IETP). Furthermore, these models also provide the instructor to insert1200 different malfunctions in the helicopter for the trainee solve. The trainee interacts with the NH90 VMT by means of three wide screen computer displays, keyboard and mouse.

Prior to 2013 the theoretical and continuation training phases comprised of conventional classroom instruction, and both in the practical and OJT phases training was conducted on the real helicopter. The rationale to introduce a MSTD, like the NH90 VMT, in the type training was drive by the limitations of the conventional training means:

- Classroom instruction: power-points style instruction with few student interaction and participation in combination with not appealing and challenging paper exercises
- Real helicopter: costly, limited availability, limited set of training tasks, risk on damage to the helicopter and safety

The NH90 VMT was seen as the training means to overcome these limitations. Hence should enhance the NH90 maintenance type training effectiveness (i.e. better training outcomes and transfer) and efficiency (i.e. less training cost and time). However, one year after the introduction the NH90 VMT is mostly used in the theory phase, as primarily as an “animation” means to illustrate the location, operation and (dis)assembly of the NH90 subsystems. There are many reasons for this ranging from limited user acceptance by experienced technicians who want to get ‘dirty’ hands, fear the new unknown device, instructors not well versed in using the NH90 VMT, changes in training paradigm and training needs. This was enhanced by many dis-satisfiers (e.g. hype-cycle effects) experienced in the NH90 VMT user interface and implementation by both instructors and trainees. Furthermore, the effective and efficient use of the NH90 VMT is complicated by the limitations imposed by current MAA-NLD regulations and directives. In these regulations and directives the use of MSTD and associated training methods is limited and not favored over the more traditional training means; in particular for the OJT phase. An awkward situation since for pilot type training, though a bit different in nature, the use of Flight Simulation Training Devices (FSTD) is a common, widely accepted and well regulated practice by aviation authorities [3] [4].

In order to overcome this situation the Dutch Defense Material Organization (DMO), responsible for the acquisition and sustainment of the NH90 VMT together with KMSL decided to conduct a V&V study. The key question set by KMSL for this V&V study was to determine with substantiated evidence how the NH90 VMT can optimally be deployed in all four phases of type training as either a training means to replace and/or supplement training tasks conducted with current means, in particular real helicopter training. All in such a manner that at least similar training outcomes, preferably better, can be guaranteed without negative training effects. This argument is intended to be used by the KMSL as an alternative means of compliance for the current MAA-NLD regulations and directives. Furthermore, it is intended as an argument by DMO to support the sustainment and improvement of the current NH90 VMT quality itself, and KMSL to determine requirements for the acquisition of future MSTD.

2 - RESEARCH APPROACH

For this research study the Dutch MoD preferred V&V method and NATO guidance standard has been applied, called the Generic Methodology for Verification and Validation (GM-VV) [5]. According the GM-VV guidelines the research has been broken into two related parts that collectively resulted in an acceptance recommendation to optimize the NH90 VMT device and its optimal usage [6]. The first part focused on assessing the level of fidelity, and the functional capabilities and limitations of the NH90 VMT device, and how these affect the effectiveness and efficiency of the NH90 maintenance type training program [7]. It is beyond the scope of this paper to further discuss the findings, conclusions and recommendation of this part and how these help to technically optimize MSTD in general and the NH90 VMT device specifically.

The second part of the V&V study, as presented in this paper, focused on directly evaluating the training level related aspects of the NH90 VMT usage within the current NH90 VMT type training program phases. This part applied a V&V strategy which resulted in the following subsequent research activities:

1. Training Context Analysis: analysis of the current usage of the NH90 VMT and a desktop study into factors and variables that are essential for effective transfer of maintenance simulation training are defined and analysed (Chapter 3).
2. Training Evaluation Experiment 1: focused on the comparative training evaluation of executing simple reproductive maintenance tasks according to the maintenance manual procedures (e.g. IETP) by non-licensed trainees on the NH90 VMT and on the real NH90 helicopter (Chapter 4).
3. Training Evaluation Experiment 2: focused on the comparative training evaluation of executing complex reproductive and productive maintenance tasks by B1.3/B3 licensed trainees on the NH90 VMT in relationship to real NH90 helicopter maintenance (Chapter 4).
4. MSTD Usage Guidelines Development: all results from the previous activities have been used to develop general applicable guidance to optimally use MSTDs within all aircraft type maintenance training phases (Chapter 5).

In the remainder of this paper these four activities and their results are discussed in more detail.

3 - MSTD EFFECTIVENESS ANALYSIS

The training context analysis comprised a desktop study into factors and variables that are essential for effective transfer of maintenance simulation training, based on available literature. This study forms the basis for two models to assess and optimize the transfer of training when using an MSTD (Section 3.1. and 3.2). These two models help to select maintenance tasks that can be trained on a MSTD and to recognize, assess and tune training transfer influencing variables of MSTD based training programs. These two models have been used as the basis for the analysis of the current usage of the NH90 VMT, as well as for defining the two NH90 VMT training effectiveness evaluation experiments as discussed in Chapter 4.

3.1 - SIMULATION TRAINING TRANSFER MODEL

The simulation training transfer (STT) model has been developed by NLR [8], and is rooted in two other existing models: the Model of the Transfer Process of Grossman and Salas which is an Adapted model from Baldwin and Ford [9] [11] [12]. The STT is an in- and output model in which the training transfer influencing factors are the input and the training effects are the output (Figure 2). The training input factors cover four categories of variables as depicted in Figure 2.The training effects cover the various evaluation levels like reaction to learning (level 1), the actual learning (level 2), behavioural change (level 3), operational results (level 4) or ROI (level 5). ROI and even society effects (a sixth level of evaluation) are the broader effects of training. Both transfer effects and the broader effects are also impacted by non-training inputs like operational experience and organizational decisions.

It must be noted that despite the input factors are well described, the difference in the significance of the factor is not clear yet [9]. There are different effects but the results depend on the research method. There are no ultimate factors that guarantee transfer neither do all of the factors need to be developed in order to realize transfer. Assumed is that a combination of factors is for positive transfer.

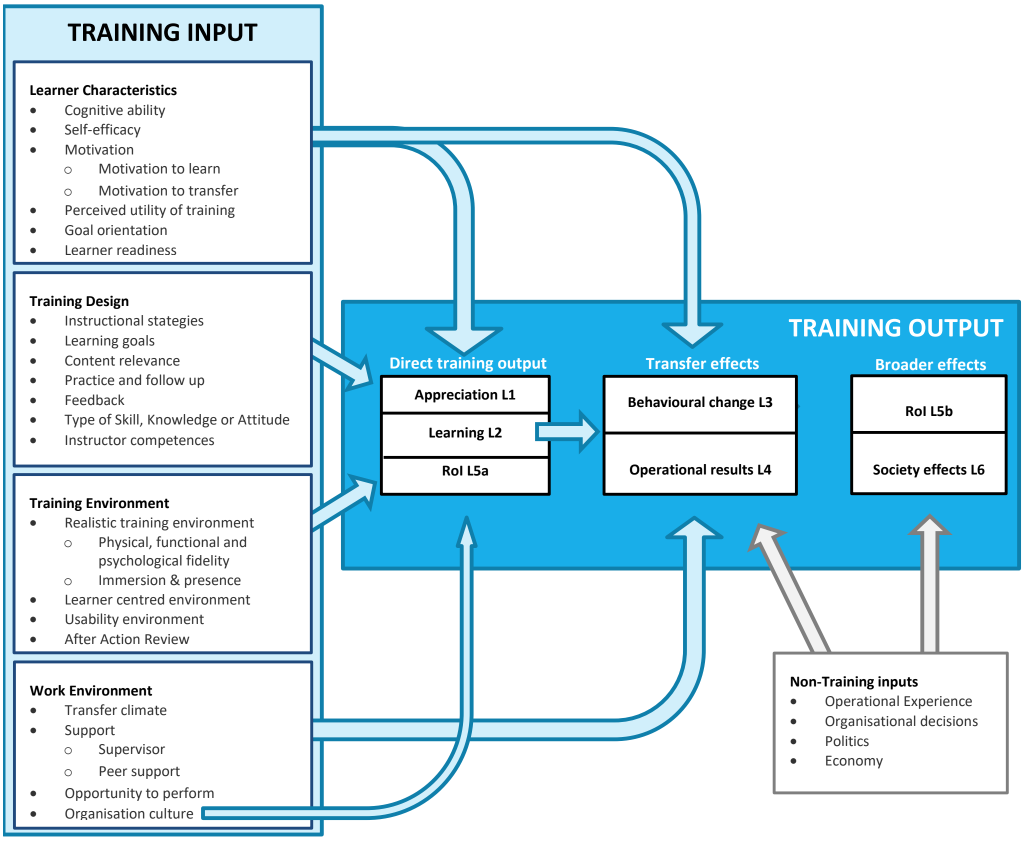
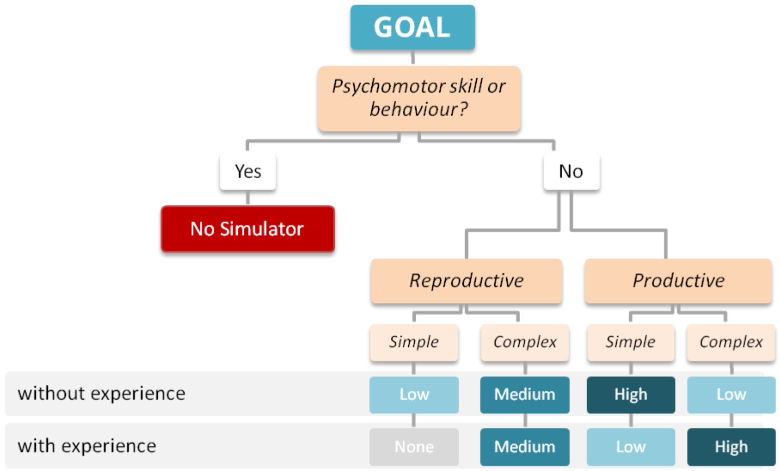


Figure 2 NLR Simulation Training Transfer Model

In order to increase MSTD usage effectiveness in maintenance type training NLR developed an optimization and assessment tool that consists of four tables, one belonging to each input factor category as described by the STT model (Figure 2). Each table gives information on how to influence the input factor category to improve MSTD based training effectiveness in terms of direct training output and transfer. The first column in these tables gives the influencing variables belonging to the input factor category. The second column describes the best practices to tune each factor variable to attain an optimal training output and transfer. The third column is used to describe the actual situation (i.e. variable status) and the fourth column gives room for a subjective rating of the 'best practice' compliance level. Due to the subjectivity of the rating, it is wise to have more people score the compliance level.

3.2 - MAINTENANCE TASK SUITABILITY FILTER

The STT model also served as the input for the development of an a-priori model to determine which maintenance tasks are suitable for being trained on a desktop MSTD (Figure 3). This model is name MSTD Task Selection Filter, or in short MTS filter. The MST filter is intended as a tool for a pre selection of tasks or scenario's that could be effectively performed on desktop MSTD. In the MTS filter two levels of trainee experience are defined; without experience (e.g. ab-initio trainees) and with experience (e.g. already type certified technicians). A low score means that the tasks should best be trained with the aircraft instead of the MSTD, but additional practice of this task on the MSDT is still possible without significant chance of negative training transfer. In this case the tasks cannot be trained to proficiency with the MSTD. A medium score means that either the MSTD or the real aircraft could be used to train the tasks to proficiency. A high score means that the MSTD should be the most suitable training device to train the task and could be used to train the task to proficiency. The score none means that it is irrelevant to train the tasks on the MSTD, because the level of task does not match the level of the technician (too simple for experienced technician or too high for an inexperienced technician).



The task filter is applied as follows:

1. Determine the training goal that needs to be achieved with the task. If the training goal is to train new psychomotor skills or behavior, the MSTD is not suitable.
2. Determine the type of task. There are two types of cognitive (or mental) tasks: reproductive tasks (follow a procedure) and productive tasks (solve a problem).
3. Identify the level of the task. It can be categorized as simple or complex.
4. Identify the learner type. How much experience with the real platform does the learner have?
5. Determine the suitability score from the filter (i.e. low, medium or high)

Figure 3 NLR – MSTD Task Selection Filter

It should be noted that this MTS filter is a guideline for making a pre-selection of suitable tasks. The assumption is that the desktop MSTDs is of a minimal level of fidelity and provides those functional capabilities that enable the training aircraft maintenance procedures and scenarios virtually (excluding haptics). The establishment and assessment of such minimal compliancy requirements is not part of this paper, and was the focus of the other part of the NH90 V&V study (Chapter 2). Besides these technical variables of an MSTD there are also many other variables (See Figure 2) that influence task selection that would result in proper training transfer. Therefore, once a pre-selection has been made, a detailed analysis has to be conducted on this set of task. Such analysis comprises a walkthrough of each task on the MSTD by an experienced instructor to see if the technical capabilities are indeed sufficient to perform the task and whether or not additional instruction is required to compensate for any MSTD technical deficiencies.

4 -NH90 VMT TRAINING EFFECTIVENESS EVALUATION STUDY

To assess whether the NH90 VMT is a valid MSTD to training NH90 maintenance tasks that are difficult, impossible, expensive or unsafe to train on the real helicopter two experiments were set up. The experimental set up has been designed with the use of the NLR STT and MST models as discussed in the previous chapter. The pre-selection of the maintenance tasks for this experiment was done with the MST. The STT was then applied to design a ‘theoretical’ optimal MSTD training set-up around these tasks that would then be evaluated for its actual training effectiveness. The focus in both experimental designs was on modern whole task training instead of the more traditional part task training commonly found in MROs. Both experimental set ups and respective findings and conclusions are discussed in the next two subsections.

4.1 - EXPERIMENT 1 – SIMPLE REPRODUCTIVE TASK EXECUTIONS

The purpose of this experiment was to compare the trainings effectiveness of real aircraft training versus training on the NH90 VMT for simple reproductive tasks. In this experiment a comparison was made between the actual training transfer that took place after training on the NH90 VMT and the real NH90 helicopter (Figure 4). The study was designed to compare the effectiveness of real helicopter training and MSTD training through evaluation of assessor observation and student self-rating scores. Additionally students were asked to rate their satisfaction of the different training methods. Also a group interview with the different participants took place in order to support and explain the experiment outcomes.

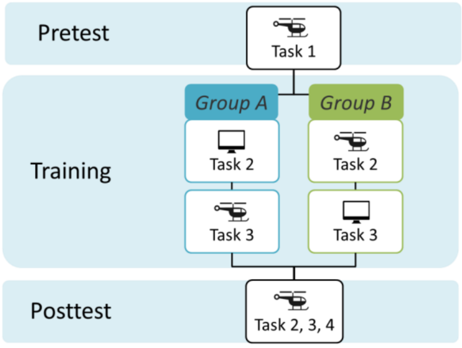


Figure 4 Schematic representation of the experiment-1 stages and its tasks

The study was a switching replications quasi-experimental group design. That is, the implementation of the treatment is repeated or replicated for two groups. And in the repetition of the treatment, the two groups switch roles. The original control group becomes the treatment group, while the original treatment acts as the control. By the end of the study all participants have received the treatment. The participants for this experiment recently finished their basic training and are starting with their type training. The students attended, prior to the experiment a NH90 VMT usage training, to learn basic operational skills. This was necessary to operate with the NH90 VMT and to provide equal chances for the desktop simulation and real aircraft training intervention. The following simple reproductive tasks, similar in difficulty, were selected and executed according the IETP:

- Task 1 – Pilot door replacement
- Task 2 – MAB filter pressure test
- Task 3 – Search light test
- Task 4 – Landing light test

From the analysis of the experimental results it can be concluded that the NH90 VMT is an effective MSTD to train simple reproductive (mainly ‘none’ psychomotor) tasks in comparison with real aircraft training, when using optimized training input conditions (i.e. from the STT model). However, students and instructors / coaches rate training with the real NH90 as more valuable for practical training and OJT phases; however there is no significant difference found between the learning with both training media. Therefore, it can be concluded that one medium is not better than the other for the selected tasks by means of the MST model.

This experiment showed that training with the NH90 VMT and with the real NH90 helicopter has both their pros and cons. Benefits of the desktop simulation are the quietness and the time to repeat the tasks, which provides opportunity to give a comprehensive explanation of the task and its underlying system. Benefits of real aircraft training are the actual hand on experience and the direct transfer to the work environment. Additionally, according to the cost-benefit analysis, the NH90 VMT is more efficient because of the low safety risks.

4.2 - EXPERIMENT 2 – COMPLEX REPRODUCTIVE AND PRODUCTIVE TASK EXECUTION

The purpose of the second experiment was to test whether complex reproductive tasks and productive tasks that *occur rarely* (i.e. certain malfunctions) or are *expensive or unsafe to train on the real NH90* can be trained with the NH90 VMT. Due to these practical constraints it was not possible to make a direct comparison with real helicopter training. The experimental design consisted of two stages as shown in Figure 5. During the first stage the participants were trained on the NH90 VMT by an instructor. This training was based on the 'learning by doing principle' with coaching support of the instructor. Each participant performed two tasks under guidance of a coach. During the execution of the tasks the coach asked questions to reinforce and teach knowledge, skills and attitudes. The second stage of the experiment contained an independent execution of tasks on the VMT by trained and non-trained participants. In both phases, complex reproductive tasks (Remove & Install and/or Functional Test) and productive tasks (Troubleshoot) were executed.

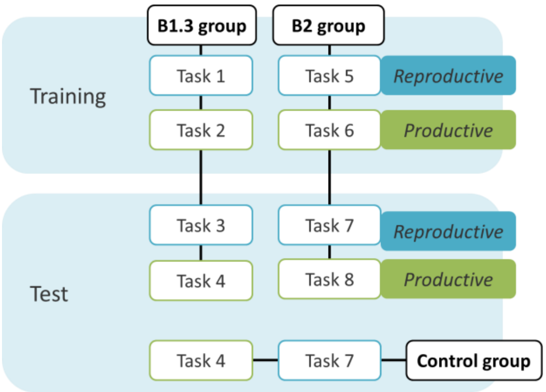


Figure 5 Schematic representation of the experiment-2 stages and its tasks

The experiment was carried out simultaneously for B1.3 and B2 technicians. The technicians who participated recently finished their OJT for the NH-90, hence had a NH90 type license. The instructors for this experiment got training in how to coach the student at the VMT. This training was based on educational principles and experiences learned from the first experiment (Section 4.1).

From the analysis of the experimental results it can be concluded that the NH90 VMT is expected to be an effective MSTD to provide equal or better training output and transfer than using the real NH90 for training (*when possible*) for complex reproductive tasks and productive tasks that occur rarely or are expensive or unsafe to train on the real NH90. It was found that performing troubleshoots (i.e. productive tasks) contributes to a higher level of system knowledge and understanding. Furthermore, complex reproductive tasks with limited psychomotor skills are expected to have added training value to the existing practical training and OJT phases. Complex reproductive tasks that involve a lot of psychomotor skills were found to be unsuitable to be trained on the NH90 VMT, unless it helps the technician to prepare and get an understanding concerning the different steps and the flow of the procedure. For example in the case when the procedure is voluminous or the task involves multiple technicians. Nevertheless, this experiment showed that training on the real helicopter in the real work environment is still needed for both practical training and OTJ phases, but may be reduced in scope and duration when applying the NH90 VMT in parallel.

Other benefits found during this experiment is that MSTD, like the NH90 VMT provide trainees sufficient time to explore the task, consider and try different productive troubleshoots strategies and provides the possibility to make mistakes. It gives the opportunity to really find out yourself what is wrong and how to solve the problem during the practical training and OJT phases, instead of by observing of experienced colleagues as is currently the case. This provides additional training outcomes and transfer on top of the regular real aircraft training. However, a precondition to attain such added training value is that MSTDs, like the NH90 VMT, is applied in a properly designed training program with proper instruction and coaching.

5 - GENERAL GUIDELINESS AND RECOMMENDATIONS FOR MSTD USAGE

The NH90 VMT V&V study as summarized in this paper showed that desktop-based MSTD, that comply with a minimal quality standard [6] [7], can have a significant added value in all aircraft maintenance type training phases over traditional training means such as class room instruction and real helicopter training:

- In *theoretical training* an MSTD are excellent means to enrich training for system logic, behavior and understanding and not for presentation purpose only.
- In both *practical training and OJT* an MSTD is valuable complementary training means for tasks that occur rarely (i.e. certain malfunctions) or are expensive or unsafe to train on the real aircraft. Moreover, MSTD can be used to replace a portion of the training tasks and training time spent on the real aircraft, in particular during practical training. However, today's generation desktop MSTDs can never fully replace maintenance type training on the real aircraft.
- In *continuation training* an MSTD is an excellent means to facilitate productive troubleshoot tasks and to re-enact specific maintenance scenarios encountered and lesson-learned in the real work environment.

However, to accomplish the above added value and mitigate risks of negative transfer, the training program must be properly designed around the level of fidelity and functional capabilities as provided by the MSTD. The recommended guideline for this, developed by NLR from the NH90 VMT V&V study outcomes, is:

Step 1 - Conduct a training needs analysis: preferably prior to specifying or acquiring a MSTD but this also holds for already owned and used MSTD.

Step 2 - Pre-select relevant tasks: for this purpose one should use the MST filter and associated application procedure as discussed in Chapter 3.

Step 3 - Analyze task suitability: perform a walkthrough of each selected task on the MSTD by an experienced instructor to assess the MSTD level of fidelity and functional capabilities to perform the task.

Step 4 - Develop challenging scenarios: based on the outcomes of the previous three steps. Aim for MSTD usage for productive whole task training scenarios as much as possible, not only for commonly reproductive part task training scenarios.

Step 5 - Design a balanced training program: with an optimal mix of MSTD and helicopter usage in all training phases that exploits the benefits of each training media to the best possible extent. For this design one should use STT model factors and variables (Chapter 3) to optimize the overall training program outcomes and transfer.

Step 6 - Ensure high quality instruction and coaching: by resolving any MSTD (technical) task execution limitations by means of proper instruction/coaching work-around, and providing the trainee with adequate instructor/ supervision or guidance in using the MSTD, and train the instructors/coaches in adequate usage of the MSTD and familiarize them with its limitations.

Following the above guidelines will help to optimally use an MSTD and as such increase the overall effectiveness and efficiency of an aircraft maintenance type training program.

AKNOWLEGEMENTS

The authors would like to thank LtCdr. F. Müller of the Dutch DMO/NH90 Project Office and 1st Lt. J. Schuurman of KMSL/Coordinator CAI&VMT NH90 ISS for granting NLR this V&V project and their valuable input and inspiring support. Furthermore, many thanks go to all other NH90 instructors, coaches and technicians involved in this project, in particular Sgt. M. Keidel, Sgt. R. Bosma and Sgt. R. van Rooyen.

REFERENCES

[1] MAA-NLD, MAR-66 – MILITARY AVIATION REQUIREMENTS FOR THE MILITARY AIRCRAFT MAINTENANCE LICENCE, Issue 4.0, January 2014

[2] EASA, COMMISSION REGULATION (EU) No 1321/2014 on the continuing airworthiness of aircraft and aeronautical products, parts and appliances, and on the approval of organisations and personnel involved in these tasks, ANNEX III (PART-66) CERTIFYING STAFF , 26 November 2014

[3] MAA-NLD, *Advisory Circular Military - Flight Simulation Training Devices - Fixed wing and rotary wing, Issue 1.0*, June 2013

[4] EASA, *Certification Specifications for Aeroplane Flight Simulation Training Devices*, Initial issue 4 July 2012.

[5] SISO, *Guide for Generic Methodology for Verification and Validation (GM-VV) to Support Acceptance of Models, Simulations, and Data GM-VV Volume 1: Introduction*, SISO-GUIDE-001.1-2012

[6] Roza M, A.Nabben, P. Ten Hove and J. Voogd, *Verification and Validation of the NH90 Virtual Maintenance Trainer, Acceptance Recommendation*, NLR-CR-2016-256-PT-1, February 2017

[7] Roza M., J. Voogd, *Verification and Validation of the NH-90 Virtual Maintenance Trainer, System Level - Evaluation, Findings and Recommendations*, NLR-CR-2016-256-PT-2, February 2017

[8] Ten Hove P., Nabben A.C., Voskamp J.J., *Verification and Validation of the NH90 Virtual Maintenance Trainer, Training Level - Evaluation, Findings and Recommendations*, NLR-CR-2016-062, February 2017

[9] Van der Pal, J., Van der Mijden-Huijzer, S. & Korteling, H., *Determination and explanation of military simulator training effectiveness*, NLR-CR-2016-236, June 2016.

[10] Grossman, R., Salas, E. (2011). *The transfer of training: What really matters*. Instructional journal of Training and Development. Blackwell publishing Ltd.

[11] Baldwin, T. T., & Ford, J. K. (1988). Transfer of Training: A Review and Directions for Future Re. Person, 41(1), 63–105.

[12] Van Merriënboer, J.J.G. (1997). *Training complex cognitive skills: A four-component instructional design model for technical training*. Englewood Cliffs, NJ: Educational Technology Publications.