SUPPORTING THE DESIGN OF SIMULATORS FROM A TRAINING POINT OF VIEW

Daniëlle M.L. Verstegen & Yvonne F. Barnard
TNO Human Factors Research Institute
Soesterberg, The Netherlands

ABSTRACT

Simulators are frequently used for training, especially in technical and military environments. Field studies showed that the development of training simulators is often system oriented, and that the possibilities for the support of (individual) instruction, practice and feedback are not fully exploited. The effectiveness of training programs is hard to establish, because there is little attention for systematic assessment of the trainees' performance.

The MASTER methodology was developed to support the determination of functional specifications for training simulators and the design of simulator based training programs. The methodology takes training needs as the starting point and supports the designer to focus on training aspects during the iterative design process.

ABOUT THE AUTHORS

Daniëlle Verstegen is a researcher at the TNO Human Factors Research Institute. She has a background in Cognitive Science and Psychology. She is currently doing research in the field of computer and simulator based training, the development of training programs and the specification of training means.

Yvonne Barnard is a researcher at the TNO Human Factors Research Institute. She has a background in Psychology and Artificial Intelligence. The theme of her PhD thesis is open, technologically rich, learning environments. She is currently doing research in computer and simulation based training, interactive electronic technical manuals and training, and evaluation of vocational training.

SUPPORTING THE DESIGN OF SIMULATORS FROM A TRAINING POINT OF VIEW

Daniëlle M.L. Verstegen & Yvonne F. Barnard
TNO Human Factors Research Institute
Soesterberg, The Netherlands

INTRODUCTION

The rapid developments in technology in the last decades have made it possible to design advanced machines to support the execution of many complex tasks. In consequence, however, the operation and maintenance of these systems have also become complex. Training is vital, but it is also a bottleneck because operational systems are not always available for the purpose of education. When training on real systems is impossible, too dangerous or very expensive, training simulators can be a solution (Flexman & Stark, 1987). Simulators can also provide extra facilities that are not available on the real system, e.g. to register performance, provide feedback and support the instructor.

Training simulators are widely used, especially in the military field. The goal of the European Defense Research project MASTER (RTP 11.1)[1] is to investigate how the possibilities of training simulators can be used effectively and efficiently. The project started with field studies and literature studies, followed by the development of a design methodology and experimental work (Van Rooij et al., 1995; 1996; 1997). Here, the main results of the field studies will be described, and an overview of the MASTER methodology will be provided. One of the main phases, Training Program Design, will be described in more detail.

FIELD STUDIES

The purpose of the field studies was to provide an inventory of the current practices in the design and acquisition of simulators and in the delivery of simulator-based training programs. A large number of military training sites were visited and interviews were conducted with personnel involved in simulator training, in most cases instructors. Standard questionnaires were used as basis for the interviews. The main issues addressed were: the role of simulators in overall training, the development and/or purchase of simulators, selection and characteristics of trainees, selection and responsibilities of instructors, the structure of training sessions, feedback, assessment, retention and transfer and the available support for instructors.

Data from visits to 39 training simulators in The Netherlands, France, United Kingdom and Spain have been used for this paper. The 21 air-based systems were flight simulators of helicopters, fighters and transporter airplanes, and simulators of communication, navigation and weapon systems. The 7 sea-based systems were trainers for command and control tasks, and simulators of radar, sonar and electronic warfare systems. And the 11 ground-based systems were (tank) driving simulators, gunnery trainers and trainers for command and control procedures.

In this paper we will emphasize three findings from the large amount of detailed information gathered during the visits:
- Effectiveness of training programs is hard to establish
- Support facilities for instructors are meager
-Training system design is system oriented, not training oriented.

Effectiveness Of Training

It is very hard to establish the effectiveness of the training programs. In general, instructors claim that almost all trainees perform to standard after the training program (except in one case). It is, however, difficult to find more specific data. Only a few controlled studies have been performed.

[1]This research was conducted in the context of the Research and Technology Project (RTP) 11.1, one of the projects of the European Defence Research Programme EUCLID. The authors would like to thank SAINSEL (E), DASSAULT Aviation (F), DRA Centre for Human Sciences (UK), Marconi Simulation (UK) and British Aerospace (UK) for their input.

The effectiveness of training can be measured in terms of learning gains: Does the trainee perform tasks better as a result of the training program? Because none of the programs start with an entrance test, this gain cannot be measured. In most cases assessment at the end of training is subjective and unstructured, which makes it difficult to draw hard conclusions on the training results. Sometimes only a paper test is used. But such a test cannot measure the acquired skill level. Effectiveness of training can also be measured in terms of transfer of acquired skills to the job environment: How do trainees perform on the real system? Also in this area there is a lack of data: usually only anecdotal stories are available. Only in a few cases performance data were collected.

The lack of insight in the effectiveness of training makes it difficult to attribute success (or failure) of training programs with simulators to specific factors. What makes a simulator an effective training medium? Is it the high fidelity, the expertise of the instructors, the amount of individual practice, the immediate feedback?

Instructor Support

Instructors usually fulfil a number of the following functions:

- organize training,
- provide instruction (in the classroom and/or during simulator training),
- start up and handle scenarios,
- monitor training sessions,
- provide feedback during training and debriefing,
- play the role(s) of other agents necessary in the scenario (e.g. enemy forces or air traffic control),
- assess performance,
- create and revise scenarios (before or during training), and
- perform maintenance duties.

The facilities that support these activities are often rather limited. Many interviewees complain about the lack of good monitoring facilities, and the facilities to register and store performance data. Making or adapting scenarios is often difficult; the available databases are sometimes outdated and incomplete.

In many cases, a syllabus is available for trainees. But –except in two cases- there is no manual for instructors. Therefore, instruction and feedback depend very much on the expertise of the individual instructor. Expertise often gets lost when the instructor leaves. The general lack of documentation also makes it difficult to review and evaluate the training procedures.

System-Oriented

The specification and acquisition of simulators seems to be largely determined by considerations of operational similarity, and the availability and affordability of current technologies. In one case, a training needs analysis had been performed. But in all other cases, there was no evidence of explicit analysis methods having been used. Sometimes the training system had been delivered together with the operational system; in other cases specifications had been derived on an ad-hoc basis, not based on an analysis of training needs. In our view, this accounts for the indiscriminate insistence on a high level of fidelity in training simulators and the widespread use of conventional training approaches such as drill and practice, or practice under supervision of an instructor. These approaches are often unduly expensive and fail to exploit the extra possibilities that could be offered by training simulators, e.g. individualization of training, immediate feedback, and the registration of trainee performance.

MASTER METHODOLOGY

Simulators are usually expensive and have many hardware components. Once built, the possibility to adapt or add facilities is very limited. The specification and design of training simulators is, therefore, very important. The main starting point underlying the MASTER methodology is that, first and foremost, simulator requirements should be derived from **training** needs instead of operational or technical considerations. As a framework for development, the Instructional System Design (e.g. Gagné and Briggs, 1979) approach is adopted, asserting that valid specifications cannot be derived without a thorough analysis of the domain, the target group of trainees, the training methods to be used, etc. In addition to these fundamental issues, the design of training systems should also take the available resources into account, such as financial means, time, expertise of personnel etc. The methodology envisions an iterative design process with three main phases:

1. Training Needs Analysis (TNA)

2. Training Program Design (TPD)
3. Training Media Specification (TMS)

During the Training Needs Analysis (TNA) the designer analyzes *what* is going to be trained. This determines which kinds of environments and tasks the training system will have to simulate. The main output of the TNA phase consists of a specification of the training objectives, which state the end terms of training, and a description of the target trainees.
To exploit the full range of instructional possibilities, it is also important to analyze *how* training will be provided. The purpose of Training Program Design (TPD) is to design a blue print (on a rather abstract level) of the training program with which the training objectives can be achieved. This information is required to specify which additional facilities will be necessary for instructional purposes, such as feedback, assessment, performance registration and scenario design.

In this paper we will concentrate on the TPD phase. The TPD methodology supports designers in focusing on training aspects and stimulates them to define, in an early stage, the specific facilities needed for training, which in the field studies were often found neglected. We will explain the main steps and relate them to the findings from the field studies.

TRAINING PROGRAM DESIGN

The goal of Training Program Design (TPD) is the development of a prospective training program: an ordered set of prototypical training scenarios and accompanying instructional strategies and interventions. The input for this step are the training objectives and information about the group of trainees that is to be trained (the output of TNA). In the context of deriving simulator requirements TPD is primarily intended as a means to this specific end, i.e. the specification of a training simulator. For this purpose, the training program is not elaborated into detail; a description of prototypical scenarios with a range of difficulty levels is sufficient.

TPD comprises four main steps:
1. Training design
2. Specification of training activities
3. Scenario design
4. Instructional design

Training Design

In this first step an outline of the training program is constructed based upon the training objectives and the characteristics of the target group of trainees. The training design step has four substeps:
1.1 Select Training Strategy
1.2 Sequence Training Objectives
1.3 Allocate Applicable Training Media
1.4 Plan Assessment

Select Training Strategy

The designer decides which general, overall training strategies and/or learning principles will be applied during the design (and later the delivery) of training. The overall training strategy will have consequences for the sequence in which training objectives are addressed, for the assessment plan, for the design of proper training activities and for the design of instructional interventions.
Which strategies are suitable depends on the kind of training objectives that will be addressed and the characteristics of the target trainees. The drill and practice strategy, for instance, is suitable to teach factual knowledge or procedures, but not suitable to teach problem solving skills. Other factors that may influence the selection of overall training strategies are company policies and the available resources (e.g. the amount of instructors). Some overall training strategies can be combined, e.g. learning by doing and mastery learning. In other cases it may be necessary to apply different strategies, e.g. when different kinds of training objectives will be addressed.

Sequence Training Objectives

The set of training objectives that was the result of the training needs analysis is structured according to the order of the tasks from which the training objectives were derived. But this will probably not be the optimal sequence for training. In this substep the designer determines in which order the training objectives will be trained. A combination of sequencing principles can be used, e.g. teach preliminary knowledge first, group training objectives regarding the same kind of knowledge or skill, address standard and easy situations before complicated ones. It may be necessary to insert intermediate objectives when the step between two consecutive training objectives is too big for the trainees.

Allocate Applicable Training Media

The designer determines which training media could be used to train each training objective. In most cases there are several possibilities. The training objective "recognize hostile aircraft", for example, could be addressed with slides in the classroom or with pictures in a Computer Based Training (CBT) system. And the training objective "decide to fire if the aircraft is hostile" can be trained in the classroom or in a CBT system, but also in a simulator. At this stage, the designer is advised to keep the range of media relatively wide. Later on, there may be good reasons (e.g. financial restrictions) to choose not the optimal training medium, but a reasonable alternative.

Plan Assessment

The evaluation of the trainees' performance is an important aspect of training. Assessment is planned explicitly to make sure that the facilities required for assessment will be included in the functional specifications in the last phase. The assessment plan also influences the specification of instructional interventions later on.

When assessment should take place depends on the training objectives to be evaluated and the overall training strategy. For example, when the concept of mastery learning is applied, frequent assessment is required to determine when trainees are allowed to go on to the next part of training. Assessment is also necessary when different routes through the training program are foreseen.

Assessment can have different purposes. An entrance test, for example, is meant to check whether the trainees master the prerequisite knowledge and skills that they are supposed to have acquired already. At the end of training a formal test may be required to certificate trainees (achievement test). During training, assessment is likely to be necessary between training phases in order to evaluate whether it is necessary to adapt the amount and/or the content of training (progress test).

How assessment should take place depends on its purpose. For certification, for instance, a formal test with measurable criteria and data registration is required; but for the purpose of training program adaptation, an informal performance judgement of the instructor may be sufficient.

Why Is Training Design Important?

Training simulators are used for different reasons. In the field studies, most interviewees agreed with the idea that the required fidelity of the simulator should depend on the goal of training (cf. Polzella, et al., 1987): a high level of fidelity is required when the goal of simulator training is to practice tasks that cannot be practiced in the field, e.g. because they are too dangerous, too expensive or threatening to the environment. A lower level of fidelity can be sufficient when simulator training is meant to prepare trainees for the real training environment or to replace only a part of the field exercises. In a helicopter simulator without an image system, for instance, trainees can only practice flying on the instruments. Flying on sight can be covered in the real helicopter.

However, interviewees also value the ‘look and feel’ of a simulator. Most of them ask for a simulator that looks the same as the system (vehicle, plane) that it simulates. Even when they do not think that it enhances the learning of the tasks very much, they think it will be more motivating for the trainees.

Focussing on the real system during design means focussing on a simulator that is very close to the real, operational system. Simulators with a high level of fidelity (especially those with advanced motion and visual systems) are very expensive, though. The MASTER methodology supports designers to focus on training aspects by making them start with choosing a training strategy and ordering the training objectives as they should be learned. The third substep, allocate potentially applicable training media, is meant to stimulate designers to think about alternatives. As the focus is now on learning, one does not automatically need to have a full-fledged simulator (cf. Stanton, 1996). For some training objectives, a much simpler medium might do as well. Considering alternatives, and their advantages and disadvantages, at an early stage will make it easier to make choices later on; e.g. when the designer discovers that certain expensive facilities are only necessary for a small part of the training objectives, or when limited resources force the designer to choose between facilities.

The last substep is an important one, given the finding from the field studies that assessment is often neglected. Assessment is necessary for two reasons: to detect gaps in the knowledge of trainees, and to evaluate the effectiveness of training and the training medium. Obviously a requirement for sound assessment is the availability of criteria. During the field visits we found that assessment criteria are sometimes not related to the task to be taught or even totally absent. In other cases the criteria are not measurable or unclear and/or illogical weighing rules are applied to determine the trainee's final grade from several performance measures. The most encountered method of assessment is an unstructured assessment by the instructor. Often, no checklists or formal, measurable criteria are available. Instructors just give their impression of the trainees' performance. This kind of assessment is very subjective: trainees depend on the instructor, not only for a fair judgement but also for an informative evaluation that will allow them to improve their performance in the future.

That lack of assessment is not a trivial matter may be illustrated by the findings regarding dropout. Dropout is not systematically registered, but it does not seem to occur frequently in most courses. Often a percentage of 5% or less is mentioned, which is extremely low. Trainees that do not master the skills at the end of the course might go undetected. As assessment at the end of the course is often informal, it is hard to say whether and how often this really occurs. Many courses also have no entrance test or strict selection criteria for trainees, so training benefits cannot be measured.

A simulator could support a much more structured and standardized approach: when measurable criteria are available, the assessment could be fully automated: the performance of trainees might be measured and logged by the system. A few cases of automated assessment were encountered during the visits, for example: a training simulator for gunners (for anti-tank guided missiles) keeps systematic scores on performance of several task elements. These scoring systems are still rather simple, though, e.g. gunnery trainers giving a hit-rate. None of the visited simulators had a more advanced diagnosing system.

Specification Of Training Activities

The goal of step 2, the specification of training activities, is twofold: first, the designer is going to develop the content of the training program further by defining what the trainee is going to do in order to learn. The second substep is process-oriented: the designer is going to focus the design process towards those training activities that are suitable for simulator training. There are two substeps:

2.1 Define Training Activities
2.2 Determine Suitability for Simulator Training

Define Training Activities

The designer defines one or more training activities for each training objective; i.e. he/she specifies what the trainee is going to do in order to achieve the training objective. For example: training activities for the training objective "be able to put a car in the right gear" might be: "study the rules concerning the relationship between gear and velocity", "practice operating the clutch" and "practice changing gear at the right moment".

In some cases the designer will define a couple of training activities for one training objective, in other cases one may suffice. This depends on the kind of training objective and on their level of detail.

Determine Suitability For Simulator Training

The designer decides which parts of training might be trained in the future training simulator. This decision should be based on the training activities defined in the previous substep, and on the possible training media that were attached to each training objective in step 1 (in the substep of allocating potentially applicable training media). The designer tags each training activity as "certainly simulator training", "maybe simulator training", or "not simulator training". The goal of this substep is process-oriented: tagging training activities will allow the designer to focus the design process of step 3, scenario design.

Why Is Specification Of Training Activities Important?

The specification of training activities serves as a further focus on the learning process: the focus is on the training activities the trainee has to perform in order to attain the training objectives. These activities can be suitable for simulator training or not.

Training activities can be similar to actual task performance, e.g. practice landing an airplane in different circumstances. But very different activities can also have high learning value, e.g. discover the most efficient way to solve a certain kind of problem, or switching roles with team members to gain insight in their information needs. During the field orientation we found that simulators are used to practice tasks in a simulated environment, but none of them supported the initial stages of learning. Initial training (i.e. acquiring basic knowledge or learning simple procedures) is usually provided by instructors in a classroom or in a briefing beforehand, or the trainees are expected to learn the required knowledge and skills from books. For example, in a helicopter simulator trainees go to the cockpit with a book to learn the functions of the different buttons. Instructors sometimes use the simulator to demonstrate correct task performance, but we have found no evidence of facilities on the simulator to support initial or remedial instruction. In two cases CBT was used in the classroom. Combining simulators and instructional or CBT-like facilities has, however, a lot of potential: instruction with live demonstrations allows the trainee to get "a feel of the system", to practice tasks and to get additional or remedial instruction just in time etc.

The methodology helps the designer to focus on those training activities that might be trained in the (future) training simulator. There are several ways to focus the design process, depending on, amongst others, limitations on resources. Designers can go through the following steps for all training activities that they would like to train in the simulator, in order to derive functional specifications for an ‘ideal’ training simulator. If, however, it becomes clear later on that not all the specified facilities can be realized, e.g. because of financial limits, they will have to turn back to a previous step to investigate which training activities can be trained with other training media without affecting the effectiveness of training. Alternatively, designers can choose to concentrate first on those training activities that can absolutely not be trained without a simulator and to go through the rest of the methodology in order to derive the minimal requirements for the training simulator. In this case, they can return to work on the remaining training activities later on, in order to investigate whether they can be trained in the simulator as well without adding too many additional facilities.

Scenario Design

In this third step the focus is on those parts of training that will probably take place in a future simulator. In the context of simulator training, exercises are usually called training scenarios. The scenarios will be used to derive functional specifications for the future simulator in a next phase (Training Media Specification). For this purpose, they do not have to be developed up to the detailed level that is required for implementation; a more abstract description specifying the kind of exercise and the foreseen range of difficulty and/or variability will suffice. The scenarios should, in other words, contain enough information to specify the training system: the kind of events that should be possible, the kind of environments that should be simulated and a description of the features and functions of the real system that should be available for training purposes.

The designer has to determine the following characteristics of the scenario:

3.1 Process

3.2 Environment characteristics

3.3 System Features and functions

Process

The designer defines which events will occur during the exercise (on a time-line) and defines which actions the trainee is supposed to perform. For example: for the training activity "practice searching environment to detect presence of submarines" (for beginning sonar operators), a prototypical scenario could be: at the beginning of the search one submarine (types: X, Y, Z) is within range; the second (types: X, Y, Z) appears only when the trainee has found and identified the first".

Environment Characteristics

The designer defines all relevant environment characteristics and - if necessary - the range of values they can take. For example: environments for a training activity like "practice searching environment to detect presence of submarines", could be: "sonar signals, transmitted through (simple to complex: sterile water without distortion, to seawater at different depths), with (0-10) distracter items (types: rocks, whales etc)".

System Features And Functions

The designer describes which features and functions of the real system should be simulated for the execution of this scenario. For example: for the training activity "practice searching environment to detect presence of submarines", the sonar signals and the controls used to operate the sonar have to be simulated. The required fidelity might differ. In our sonar example, the training activity is aimed at recognizing the sonar signals of different kinds of submarines. Therefore, it is very important that the sonar signals are simulated with high fidelity. The training activity is not aimed at the automatic execution of the procedures to operate the sonar. Therefore, the controls of the system can be represented at a lower level of fidelity.

Why Is Scenario Design Important?

By relating scenarios to the training activities, the designer focuses on training aspects, not on purely simulating operational tasks.

In the field studies we found that instructors usually work with a limited set of standard scenarios. If training can be adapted to individual training needs, which is not always the case, this is done by adapting scenarios on-line during training sessions, or providing extra practice opportunities to weaker students. Further adaptation to the individual performance of trainees is usually not possible.

Valid training scenarios should be based on training objectives, derived from an analysis of the tasks operators have to perform (cf. Wager et al., 1992). However, during the field visits we have found no evidence of elaborate didactic analyses. Often, training objectives seem to be written down on an ad-hoc basis, e.g. in the form of long lists of (sub)procedures to be mastered. Sometimes they are derived from the performance of the simulator, just listing the procedures, which can be trained with it. The most widely used training principle and often the only one is sequencing training objectives from easy to complex.

Extending and revising the set of scenarios -if possible- is the responsibility of the instructors. Instructors often complain about the difficult and laborious way to make changes in the training program, for instance to revise the scenarios.

By emphasizing the instructional aspects of scenarios, the methodology supports the designer to specify a training system that:

- Simulates all aspects required for training, but does not have a higher (and more expensive) level of fidelity then absolutely necessary.
- Allows flexible training with a valid (and easily adaptable) database of scenarios geared towards the needs of the trainees.

Design Of Instruction

The designer specifies which kind of instructional interventions should be possible before, during and after the execution of the scenarios designed in the previous step.

There are different kinds of instructional interventions, for example: feedback, guidance, remedial teaching or demonstration of the correct performance of the task. The timing of interventions can vary as well: feedback, for instance, can be provided immediately after an error or during the debriefing after the exercise is finished. Finally, different actors can perform instructional interventions. The instructor might be responsible, but it is also possible to provide instruction or feedback automatically or to ask other trainees to comment and to help their classmates. The descriptions of instructional interventions are be used in the next phase, Training Media Specification, to derive specifications for the instructional facilities.

The design of instruction in this step is a refinement of the training strategy chosen earlier. In a discovery learning approach, for instance, the trainee is stimulated to explore and discover, as far as possible without intervention. The debriefing after a training session can be used for discussion and, if necessary, additional instruction. But in a more directive approach the trainee will be corrected as soon as possible. The timing, form and content of instructional interventions also depend on the assessment plan, the kind of training activities to be executed by the trainee and the prototypical scenarios.

Why Is Design Of Instruction Important?

In the field studies we found four different feedback mechanisms:

- *Implicit feedback by system performance*

By the way the simulator behaves, the trainees understand whether procedures were correct or not. For example, hits in a gunnery simulator, crashes in a flight simulator.

- *Explicit automated feedback by the simulator*

The simulator gives the trainees explicit feedback, for example in the form of messages on the screen.

- *Feedback by the instructor*

The instructor monitors the trainee and gives verbal feedback.

- *Debriefing*

Performance is discussed after the training session, either by the instructor or in a group discussion with trainees. Sometimes it is possible to play back parts of the training sessions.

In all the visited simulators trainees receive some form of implicit feedback. This feedback is,

however, often not complete. When, for instance, the simulator has no moving base, all motion cues are lacking. This does not have to damage training; provided that the trainee can get enough information form other sources. But this is not always the case.
Even when the implicit feedback in the simulator is equal to the feedback provided by the real system, this is not necessarily for the trainee to learn from his errors and improve his performance.

We have found only one case of –quite primitive- automated feedback: a gunnery simulator, which gives a hit rate. Explicit verbal feedback provided by the instructor is the most common method. The debriefing is usually rather short when guidance during training sessions is intense, e.g. when an instructor sits next to or behind the trainee and gives feedback continuously. If not, the debriefing becomes more important. The quality of feedback seems to depend on the expertise and preference of the individual instructor. There is usually no instructor manual with a systematic description of feedback procedures. And often, support facilities for feedback, e.g. overview of performance data or playback facilities, are absent or meager.

As learning with the simulator consists mainly of practicing tasks and adapting the performance on the basis of feedback, feedback plays an important role. It allows the trainees to improve their performance, and to learn from practice. Given this important role, one would expect more explicit feedback procedures and facilities than were actually found in the field studies. By focussing the attention of the designer on the design of instruction in an early stage, built-in instruction and feedback facilities can be specified and incorporated in the future simulator. These facilities can consist of automatic instruction or feedback given by the training system, or facilities in the Instructor Operation System to support the instructors.

SUPPORTING THE DESIGNER

The MASTER target users may have quite different backgrounds. Therefore the methodology not only provides guidelines, but also supports the instructional design process itself and helps to keep the designer focused on those decisions that have direct consequences for the specifications of the training system and the training programs.

The Training Program Design phase of the MASTER methodology specifies how to develop a training program. It prescribes which steps should be taken, but it does not envision a strictly linear sequence of steps. Training Program Design is an iterative process: at many points the designers may discover that their input is incomplete or that new insights have consequences for decisions taken in earlier steps. If the set of training objectives is very large, they can also choose to develop first a part of the training program for a smaller set and then go back to the first step to start work on the rest. The route through the methodology will depend, amongst others, on the preferences of the designer, on the domain, and on the amount of training objectives. Limitations on available resources, e.g. time, money, and the number of instructors available, may also influence the design process. For instance: when financial resources are limited, the designer may prefer to focus on those parts of the curriculum that can absolutely not be trained without a simulator. When, on the other hand, the number of available instructors is limited, the design of the training program, and subsequently the specification of requirements for the training simulator, should be focused on training as much as possible with a simulator with automated instruction and feed-back.

The MASTER-methodology is implemented in manuals and accompanying (prototype) software tools. These provide the necessary information and guidance for adequate and independent execution of the methodology. Prototypes of the tools have been tested and refined on the basis of evaluations in try-out studies.

The MASTER methodology describes which steps should be taken to develop a simulator-based training program. The methodology has been constructed in such a way that the main input for a (sub)step is the output of the previous (sub)step. This ensures that the designers do not skip vital steps: they cannot start working without the necessary input. The tool saves the information at all stages together with the notes designers are encouraged to make to justify their decisions. This supports the iterative design process. There are many points where the designer has to decide whether to continue work in the current step, to go on to the next step or to return to a previous step if necessary.

The tool offers specific guidelines and adjustable libraries (e.g. of scenario characteristics, training strategies) for each step. In this way expertise is built up and made available for future design. Thus, the MASTER methodology, as implemented in the tool, can function as an organizational memory. It supports designers by structuring the design process and allows them to profit from the experiences of other designers.

REFERENCES

Flexman, R.E. & Stark, E.A. (1987). Training simulators. In: G. Salvendy (Ed.). *Handbook of Human Factors (pp. 1012-1038).* New York: John Wiley & Sons.

Gagné, R.M., Briggs, L.J. (1979). *Principles of Instructional Design*, 2nd edition. New York: Holt, Rinehart and Winston.

Polzella, D.J., Hubbard, D.C., Brown, J.E., & McLean, H.C. (1987). *Aircrew training devices: utility and utilization of advanced instructional facilities: Phase IV: Summary Report*. US AFHRL Technical report Rpt-87-21.

Rooij, J.C.G.M. van, Barnard, Y.F., Verstegen, D.M.L., Bermejo Muñoz, J., Retamero Merino, S., Krawies, J. Hardinge, N., and Molloy, J. (1998). *Prototype-Validation Studies.* EUCLID RTP 11.1, MASTER Deliverable A2.4. Prepared for the Directorate of Materiel of the Royal Netherlands Army under contract no. DMKL/EUCLID/RTP 11.1 016-92-7211.11.

Rooij, J.C.G.M. van, Berlo, M.P.W. van, Verstegen, D.M.L., Bermejo Muñoz, J., Ruiz Pérez, E., González Vega, N., Krawies, J. and Hardinge, N. (1995). *Literature Review on Simulator-Based Training and Instruction*. EUCLID RTP 11.1, MASTER Deliverable A2.1. Prepared for the Directorate of Materiel of the Royal Netherlands Army under contract no. DMKL/EUCLID/RTP 11.1 016-92-7211.11.

Rooij, J.C.G.M. van, Verstegen, D.M.L., Barnard, Y.F., González Vega, N., Bermejo Muñoz, J., Krawies, J. Hardinge, N., and Molloy, J. (1996). *Field studies*. EUCLID RTP 11.1, MASTER Deliverable A2.2. Prepared for the Directorate of Materiel of the Royal Netherlands Army under contract no. DMKL/EUCLID/RTP 11.1 016-92-7211.11.

Rooij, J.C.G.M. van, Verstegen, D.M.L., Barnard, Y.F., Bermejo Muñoz, J., Krawies, J. Hardinge, N., and Molloy, J. (1997). *Training Programme Design*. EUCLID RTP 11.1, MASTER Deliverable A2.3. Prepared for the Directorate of Materiel of the Royal Netherlands Army under contract no. DMKL/EUCLID/RTP 11.1 016-92-7211.11.

Stanton, N. (1996). Simulators: a review of research and practice. *Human Factors in Nuclear Safety,* 117-140.

Wager, W. W., Polkingshorne, S., & Powley, R. (1992). Simulations: Selection and Development. *Performance Improvement Quarterly, 5(2),* 47-64.