Linköping Studies in Science and Technology

Thesis No. 1386

# Using Observers for Model Based Data Collection in Distributed Tactical Operations

by

**Mirko Thorstensson**

Submitted to Linköping Institute of Technology at Linköping University in partial fulfilment of the requirements for the degree of Licentiate of Engineering

Department of Computer and Information Science
Linköpings universitet
SE-581 83 Linköping, Sweden

Linköping 2008

# Using Observers for Model Based Data Collection in Distributed Tactical Operations

by

Mirko Thorstensson

October 2008
ISBN 978-91-7393-751-1
Linköping Studies in Science and Technology
Thesis No. 1386
ISSN 0280-7971
LiU-Tek-Lic-2008:44

ABSTRACT

Modern information technology increases the use of computers in training systems as well as in command-and-control systems in military services and public-safety organizations. This computerization combined with new threats present a challenging complexity. Situational awareness in evolving distributed operations and follow-up in training systems depends on humans in the field reporting observations of events. The use of this observer-reported information can be largely improved by implementation of models supporting both reporting and computer representation of objects and phenomena in operations.

This thesis characterises and describes observer model-based data collection in distributed tactical operations, where multiple, dispersed units work to achieve common goals. Reconstruction and exploration of multimedia representations of operations is becoming an established means for supporting taskforce training. We explore how modelling of operational processes and entities can support observer data collection and increase information content in mission histories. We use realistic exercises for testing developed models, methods and tools for observer data collection and transfer results to live operations.

The main contribution of this thesis is the systematic description of the model-based approach to using observers for data collection. Methodological aspects in using humans to collect data to be used in information systems, and also modelling aspects for phenomena occurring in emergency response and communication areas contribute to the body of research. We describe a general methodology for using human observers to collect adequate data for use in information systems. In addition, we describe methods and tools to collect data on the chain of medical attendance in emergency response exercises, and on command-and-control processes in several domains.

*This work has been supported by the Swedish Defence Research Agency, the Swedish Armed Forces and the Swedish Rescue Services Agency.*

Department of Computer and Information Science
Linköpings universitet
SE-581 83 Linköping, Sweden

# Acknowledgements

In this research I have had the opportunity to meet and collaborate with a number of people who in different ways have supported me in my efforts. For me, this journey has been fairly extended in time and I have visited different arenas and domains and therefore made numerous valuable contacts who have contributed to my work. To all these people I am deeply indebted.

First of all I would like to thank my supervisors: Henrik Eriksson for his valuable, encouraging and genuine support through good times and harder times, and my co-supervisor, mentor and dear friend Johan Jenvald for persistently believing in me and this work. Without you I would not have come this way. You have always been sources of inspiration and energy and I have enjoyed our discussions on research and other matters of work and life in general. I am deeply and truly grateful.

Secondly, I thank my colleagues and friends in the MIND research group: Magnus Morin, for his deep wisdom and supportive discussions on matters not only connected to research and work; Markus Axelsson for skilled programming and technical abilities, as well as a positive outlook on life; Pär-Anders Albinsson for all the support in the hard times, methodological insightfulness and devotion to research; Dennis Andersson for advanced programming and systems development wizardry; Mattias Johansson for a good sense of humour and for implementing NBOT and other essential tools for fieldwork, and Johan Fransson for keeping me in contact with military C2 systems. You have all contributed to the fun and excitement of applied research and field trials. It has been a privilege to work closely with you! Furthermore, I want to thank my managers at FOI, Hans-Åke Olsson and Johan Allgurén who supported me and gave me this opportunity. I am also grateful to Niklas Hallberg for supporting the work and contributing valuable comments on the manuscript. I would also like to thank Per Wikberg and Torbjörn Danielsson for extended collaboration after relocating my work to the far north. I am also grateful to Sören Palmgren, Johan Stjernberger, Håkan Hasewinkel, Joakim Dahlman, Lars-Åke Hansson, Lars Rejnus, Per-Erik Johansson, Birgitta Liljedahl, Lena Donnerfalk, Fredrik Rönning, Stefan Sjökvist, Ulf Söderman, Simon Ahlberg and many other colleagues at the Swedish Defence Research Agency. I would also like to thank Steven Savage and Jeffery Lewis for valuable comments on the manuscript and for helping me improve my English.

A large part of this research was funded by the Swedish Armed Forces and without the personal devotion and engagement of my colleagues in arms I would not have come this far. My gratitude goes to Dag N H Malmström, Peter Sjöstrand, Mikael Wikh, Björn Andersson, Magnus Bender, Roger Karlsson, Jerker Andersson, William Ressel and other officer and soldier colleagues who have supported me in field trials and exercises. In the fire and rescue services, the police and medical services I have had great support from Anders Nygren, Bo Tingland, Anders Björneberg, Bo Johansson, Berndt Hedström, Andreas Nilsson and Tommy Söderberg and all other persons who participated in field trials and exercises and contributed with data or thoughts and comments.

I was also given the opportunity to meet with researchers abroad who showed warm hospitality and gave great collaboration. In particular, I am grateful to Peter Kincaid at the Institute for Simulation and Training at the University of Central

Florida, Mona Crissey at the US Army Project Execution Office for Simulation Training and Instrumentation, Gene Wiehagen at the US Army Research Development and Engineering Command, and Marcel van Berlo and Alma Schaafstal at TNO in the Netherlands.

My gratitude also goes to my colleagues and friends at Linköping University, in particular Ola Leifler, Erik Berglund and Magnus Bång for support and encouragement when restarting this undertaking, Lillemor Wallgren for her patience and support throughout the project, and to Britt-Inger Karlsson and Anne Moe for administrative support.

Lastly and certainly most sincerely, I would like to thank my wonderful wife Majken and my lovely children Johanna and Erik for their endless love, support and patience during travels and field trials. I love you very much. This is all for you!

Hörnefors, September 2008

Mirko Thorstensson

# Contents

# Chapter 1
# Introduction

Distributed tactical operations (DTO), where multiple units operate dispersed, are complex and demanding. Several geographically-separated interacting units with different subtasks strive towards a common goal in a dynamic, uncertain, and often hazardous environment. Because operational settings change dynamically, taskforce organizations must support adaptation and development of mission capabilities (Fredholm, 1996; Brehmer & Svenmarck, 1995). Computerized systems that visualize course-of-events from operations have been used successfully to show complex interactions between units, individuals, and systems. Such visualization systems can support both live command-and-control (C2) systems and post-mission training and analysis systems. Data from multiple sources in the field are fundamental to develop models of the unfolding course-of-events, as well as of unit activities and cooperation. The resulting models can support situational awareness in C2 systems, post-mission identification of strengths and shortcomings, and learning from experience (Flanagan, 1954; Raths, 1987; Rankin, Gentner & Crissey, 1995; Salas, Dickinson, Converse & Tannenbaum, 1992).

Several different data sources are required to create a satisfactory model. Although it is possible to collect data directly from information systems, people participating in the operation are still invaluable information sources. Certain qualified information has to be provided by the people in the field, such as group dynamics, human behaviour and body language, public sentiment, interaction with the local population, oral person-to-person communication in command posts, weapon handling, and use of equipment (Rouse, Cannon-Bowers & Salas, 1992; Allen, 1997). Historically, people in the field have been essential sources of information for different purposes: the commanders, who have built mental models of the evolving situation based on reports from subordinate units; reporters writing stories about the operation and analysts trying to determine what happened and how to improve the outcome and prevent failure. However, this information transfer is human-to-human communication. Naturally, the introduction of computer-based visualization systems requires more structured reporting than previously. Therefore, it is necessary to support people in reporting adequate data in computer-interpretable formats.

In this thesis, we study methods and tools for supporting human observers who collect information for use in information systems. We explicate different aspects of having people collect data from operations in the field to be used in computerized systems for reconstruction and exploration. We present a model for handling and visualizing medical resources in mass-casualty incidents and a corresponding method for collecting data from training scenarios. We describe a tool for monitoring and analysis of command-post communication, and we discuss how this tool corresponds to an underlying model of C2 communication. In addition, we elucidate aspects of model-based human data collection in the application domain of live operations, and suggest a general observer tool.

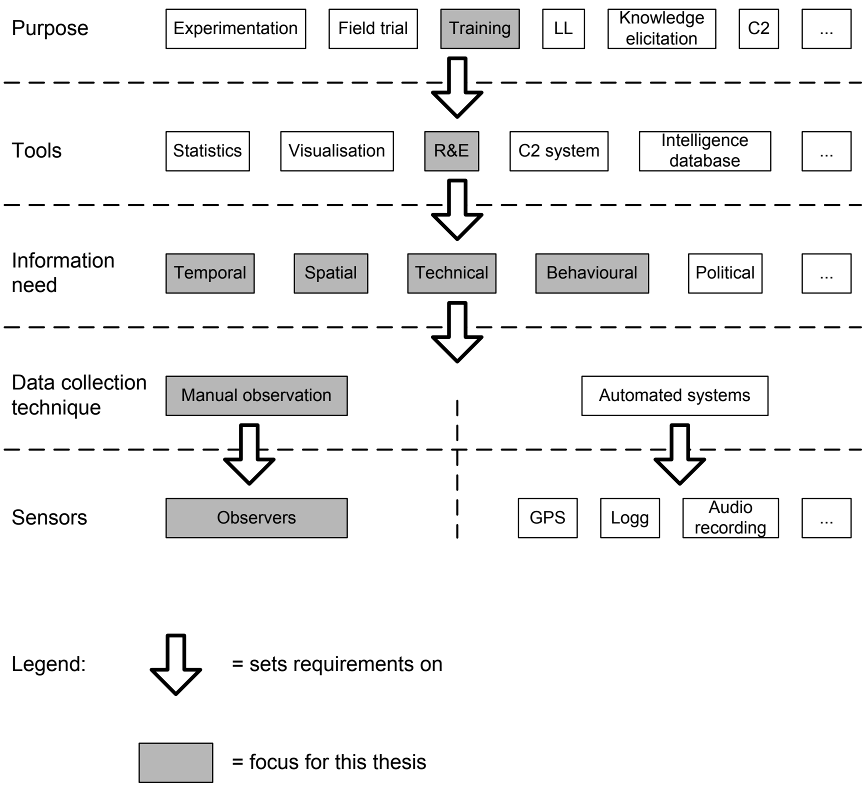



Figure 1.1: An overview of the relations between system parameters for computerized support for taskforce capability development. The shaded boxes denote the path of scope for this thesis.

## 1.1 Setting

Progress in information technology has led to new ways of improving taskforce capability by introducing new methods and tools for training (Jenvald, 1999). Conducting thorough after-action reviews (AAR) (Rankin, Gentner & Crissey, 1995; Morrison & Meliza, 1999) with support of multimedia representations of the conducted distributed tactical operation (Morin, 2002), facilitates training and learning by experience (Schön, 1983). However, computerized systems can be used in different ways to improve performance, where training is one factor, and field trials, experimentation, and command and control (C2) are others (Figure 1.1). The overall purpose of using a computer system defines requirements on what tools that must be implemented. An information-need analysis gives prerequisites on what data that are needed in the system and what data-collection techniques and sensors that are necessary. The setting for this thesis follows the areas defined in Figure 1.1, and focuses on how we can support observers in distributed tactical operations to provide accurate data for use in a computer system applying reconstruction and exploration (R&E) for training purposes.

The term *tactical operations* is normally associated with military activity, but is widely used in other organizations to refer to the level of activity that aims at achieving specific goals with a body of personnel and equipment under a unified command. The detachment may be units from one single organization, but more often it is a temporarily composition of units from multiple organizations or agencies. We will use the term *taskforce* to denote the combined units working in a tactical operation. The units in the taskforce mainly work in parallel, solving subtasks independently, and to a large extent they are dispersed geographically which means they are *distributed*.

Observers may have different roles in tactical operations. In training scenarios, observers act as data sources to collect information to facilitate after-action reviews, as well as acting as controllers and trainers. In live operations, people seldom serve exclusively as observers. In today's slimmed organizations, all personnel involved have multiple tasks to fulfill, and reporting observations can be one of them. Reporting observations, regardless of purpose, often follows an organizational or cultural tradition in terms of what to report and how to make the report. The reporting tradition can be more or less formalized, as in the military services where different memory words are used to describe the form of reporting certain observations (SoldF, 1986). Reporting observations in established formats simplifies communication within the taskforce. However, such reports are not sufficiently stringent to be interpreted directly by computers in systems for training, C2, or analysis. Therefore, it is necessary to emphasize model-based data collection (MBDC).

## 1.2 Approach

This research is part of the overall research mission of reconstruction and exploration (R&E) (Morin, 2002) for use in computer-supported taskforce training (Jenvald, 1999); systems analysis (Jenvald & Morin, 1997) and capability development of organizations, methods, personnel or systems (Morin, Jenvald & Thorstensson, 2003). Our main objective is to provide observers of distributed tactical operations with tools to support reporting of data that can be utilized in computerized systems to represent parts of the reality in models. Constructing representations of operations necessitates combining conceptual models of work in a domain with data collected from multiple sources in the field to construct computer models of human activity. The resulting model is a persistent multimedia representation of the operation – a *mission history* – that can be shared among participants, trainers, analysts and researchers (Morin, 2001).

Our approach assumes that *observers* are essential sources of information in providing data for constructing adequate mission histories. Furthermore, we believe that observers need certain support to supply relevant and reliable data. Some data are possible to collect automatically by sensors or computerized systems. For example, object positions over time using GPS receivers, and automatic recording of computer screens in command posts. However, certain data must be collected by human observers, such as the activity over time for a specific unit, and the quality of an action performed. The *model-based* approach means that we connect observations with computer models of the phenomena of interest. This approach supports the observers in *how* to report specific observations and, perhaps more important, guides the observers in *what* to report. Each model is constructed as a formal description of the entity or process we need information from, and we define in detail the parameters of interest and the necessary resolution. The models are then used as a basis for constructing reporting tools that can support observers in specific environments with what to observe and how to report.

## 1.3 Problem and research questions

This thesis deals with the problem of how to use observers to collect relevant information, usable in computer systems, from complex collaborative work sessions in the form of distributed tactical operations. Certain data cannot be collected by automated systems. This data collection requires human observation or judgement. Moreover, human observers are very flexible data-collection resources that can adapt to evolving needs and work as a back-up or as an alternative to technical systems. However, individual observers seldom agree on what details are important to observe in a mission, and how observations should be documented and reported. Hence, we can formulate our main research question as follows:

> What models and tools can we use to support observers' data collection from distributed tactical operations?

We further divide this overall problem into four different area-specific questions:

- How can we support observers to collect relevant data from the tactical setting in the domain of computer-supported military force-on-force battle training?
- How can we support observers' data collection on the chain of medical attendance in the domain of emergency response to mass-casualty incidents?
- How can we support observers' data collection on command-and-control processes regardless of domain?
- How can we support operators' data collection in live emergency response operations?

## 1.4 Contribution

The main contribution of this thesis is the systematic description of a model-based approach to using observers for data collection in distributed work sessions. The main contribution to the body of research lies in the methodological aspects in using humans to collect data to be used in information systems, and also modelling aspects for describing phenomena in emergency response and communication areas. We summarize the main contributions as follows:

- *Methodology*. The thesis describes a general methodology for using human observers in distributed training or live operation settings to collect adequate data for use in information systems. In addition, the thesis describes a method for collecting data from the chain of medical attendance in emergency response exercises. These methodologies contribute to the understanding of data collection from exercises and operations.
- *Models*. The thesis presents a model for the chain of medical attendance in mass-casualty incidents and introduces timed checkpoints (TCP). Also, we extend the model of link analysis to comprise dynamic workgroup communication. These models contribute to a better understanding of the analysis of the data collected.
- *Tools*. As part of this research, we have implemented a general, configurable tool to support observers collecting data in different environments for different purposes, the NBOT tool framework. NBOT includes a tool for documenting and reporting internal communication in staffs and workgroups. This implementation contributes to practical data collection in the field.

These results stem from research over several years and have contributed to practitioners work in the following areas: the Swedish Armed Forces Development Centre for Future Command-and-Control Systems use the NBOT system to support collecting data from experiments and field trials, and the Swedish Armed Forces Centre for CBRN (chemical, biological, radiological and nuclear) Defence use NBOT for collecting data on environmental and health risks in international missions. The models and methods for documenting the chain of medical attendance have supported identifying and remedying bottlenecks and points of friction in emergency-response organizations in several exercises. Furthermore, we believe that the results presented in this thesis are potentially useful for researchers collecting data from experiments in distributed settings, and practitioners using observers to improve training exercises.

## 1.5 Outline

This thesis is divided in two parts, where the first part includes background and motivation, the methods we use and the results obtained. Chapter 2 describes the methods we use and set our research in a context. Chapter 3 presents the main results of our research on model based data collection and observers. The work presented in this thesis is supported by four peer-reviewed publications that are summarised in Chapter 4. A discussion on our findings is presented in Chapter 5 and concluding remarks in Chapter 6. The second part of this thesis comprises the four papers that expand on subjects brought up in Chapter 3.

# Chapter 2
# Method

Developing methods for using observers as data sources in distributed tactical operations (DTO) set certain demands on the working environment for doing studies and field tests. We have applied our research mainly to large-scale exercises with a high degree of realism. The exercises have been both in the military domain and in the domain of civil emergency-response operations. In the military domain, we have had the opportunity to focus on army ground forces with mechanized units; airborne units with helicopters and light infantry; maritime forces with naval surface warfare ships and amphibious units with small boats and mobile air defence systems; as well as joint command-and-control units (Paper II) with a high degree of technical support systems. In the civil domain, we have studied fire and rescue services units and their chains of command; police units from individual operative police officers to C2 elements far from the incident scene; and medical resources (Paper I) spanning from ambulance personnel to emergency rooms and hospital C2 resources with regional co-ordination responsibilities. Furthermore, we have had the opportunity to expand our research on R&E and observers to live operations: we have performed studies in live emergency-response operations (Paper III); and military units supporting a police search and rescue operation. Some of our findings have been adapted to support missions by civil and military observers in live international operations (Paper IV).

## 2.1 Research in a realistic context

The exercises we have followed in our studies have not focused specifically on testing R&E or using observers for data collection, but to train the taskforce in particular capabilities. However, we have had the possibility to engage in the exercises and apply our methods and tools for data collection and R&E. In some cases we have had the opportunity to influence exercise design and to conduct after-action reviews to support training and learning goals. In some exercises our internal goal has been to test new methods and tools for data collection and to provide feedback and findings to responsible officers and managers after exercise completion. Applying research on DTO in exercise scenarios implies three advantages (Morin, 2002). Firstly, the researcher knows in advance the time, location, purpose, scope and participants for the operation, which gives time and room for preparation. Secondly, exercises are controlled by instructors and training officers who can adapt and control the evolving scenario to meet training goals and also research needs. For example, the scenario can be paused to adjust data-collection equipment. Thirdly, extra resources for data collection can be added, for example different types of observers. However, the application of observer data collection for R&E in live operations has given us the possibility to transfer our knowledge from training settings and to test our methods and tools in a new domain. The application of research in realistic exercises, as well as in live operations, has contributed to the development of knowledge on using observers for data collection in realistic settings, as well as developing the overall R&E methodology.

### 2.1.1 Reconstruction and exploration

As stated previously, getting an overview of complex scenarios in distributed environments with multiple units engaged in intertangled courses-of-events is difficult. It is possible to support this analysis task by using tools that can visualize a representation of the evolving situation. To support visualizing DTO we have developed methods for reconstruction and exploration (R&E), which is defined by Morin (2002). R&E aims at supporting the process of sense-making from complex scenarios and the method is generalized to be scalable and adaptable to meet the needs from scenarios regardless of:

- *Size*. The methods are applicable from a single operator or unit, acting independently or in an overall scenario, to a large taskforce operation engaging multiple units from different organizations dispersed over vast geographic areas. Different granularity of models and data collection can be applied to different units in different positions in the overall taskforce.
- *Domain*. We have used the R&E approach in different areas of military and civil-emergency operations domains.
- *Level of C2*. Command and control is often an issue of focus when studying DTO and we have used R&E to support studies from individual interaction on the lowest control level, to higher command in Force Headquarters (FHQ) and the political levels in Operations Headquarters (OHQ). One interesting feature we have utilized is to focus on specific functional chains of command within the overall command structure, for example the chain of command handling medical resources in an operation.
- *Degree of simulation*. "All but war is simulation" is the motto of the US Army Project Execution Office for Simulation Training and Instrumentation (PEO STRI), which means that all types of exercises include different levels of simulation. We have applied R&E to different realism scales, from C2 exercises with largely simulated context of superior, subordinated and lateral units; via very realistic live emergency response exercises where simulation consisted of extras acting as casualties in a realistic way; to live operations with emergency response units as well as military units.

The R&E process is described in Figure 2.1 and consists of two phases: the *reconstruction* phase and the *exploration* phase, and each phase is divided into different activities. All activities are preferably conducted as cooperative sessions between researchers and subject matter experts (SME) from the scenario, and the process is not to be regarded as linear although the information flow in the

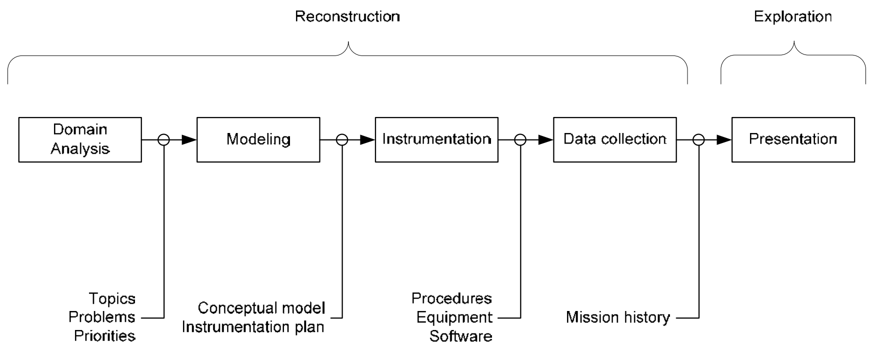



Figure 2.1: An overview of the R&E process as defined by Morin (2002). The principal activities are shown in the boxes, whereas annotated arrows show the artefacts produced by each activity.

process goes from one step to the subsequent one. Limitations in one step may necessitate a reassessment of decisions in previous activities. The first activity in the reconstruction phase is the *domain analysis* with the aim of defining and describing the overall purpose of the specific exercise. The next activity is *modelling*, which will produce object-oriented conceptual models of the processes and entities that will be registered in the scenario. Modelling forms the basis for what data is to be collected in the scenario. In the *instrumentation* activity the models are substantiated as procedures, equipment and software for data collection. Observers are here being assigned specific tasks and are equipped and trained to meet the defined requirements. The *data-collection* activity takes place during the unfolding exercise (or operation) and course-of-events defined in the previous activities are captured and registered using previously defined data-collection components. In this activity, the observers are acting in their profession to capture the data they are allocated to. The collected data are combined with the conceptual models from the modelling activity and compiled into a mission history, which is a time-synchronised, event-driven multimedia representation of the operation. In the exploration phase the *presentation* activity utilises visualization components of the MIND framework (Chapter 3.1.3) or the F-REX tool (Andersson, Pilemalm & Hallberg, 2008) to make the mission history graspable and analyzable. Exploration and analyses generates new data that can be fed back to the mission history to deepen the data set for following exploration sessions.

### 2.1.2 Application of R&E

Reconstruction and exploration is a general method that can be applied in different domains and for different purposes. We have identified an R&E utilization process with seven phases that can be applied in a cyclic manner depending on the focus. Jenvald (1999) identified seven phases of training, and Wikberg et al., (2005) suggested a seven-phase feedback model to support experimentation. Essentially, both descriptions are of the same phenomena of R&E and we suggest an amalgamation as displayed in Table 2.1. The training phases described by Jenvald (1999) originate from how to handle and utilize the compiled mission history when using a computerized training system and include a phase of data compilation after the exercise. Wikberg et al., (2005) described a more general feedback model with a stronger focus on experimentation, but without specific connection to the R&E method and corresponding models. We argue that the phases described in Table 2.1 are feasible for R&E of DTO regardless of the utilized technology, but are of course dependent on the overall purpose of the exercise or operation.

Visualization of data from DTO is a general problem not connected to specific tools, even though we have utilized the MIND system as the major tool in our research. The method of R&E can be implemented regardless of tools, and we have had colleagues from the Swedish Armed Force (SwAF) who have applied R&E using MS PowerPoint and video players with excellent results. The essential question is: "what is the purpose of collecting data, and for what purpose is it expected to be utilized?" This is the core question in the domain analysis phase of the R&E process as defined by Morin (2002), which forms the basis for successive work in the R&E application process. The overall purpose for data collection can be, for example training, experimentation, verification, or validation, which affects the initial work in the process. However, using observers for data collection is a general, highly flexible method adaptable for different needs. Furthermore, the initial analysis defines the prerequisites for what steps of the R&E method to implement and what tools to use to support them. As mentioned above, different commercial software tools can be suitable, although we have used our own research platform, the MIND system, further described in chapter 3.1.3, in most situations. Later requirements from new domains have led to the development of a new framework for visualizing DTO, the F-REX software suite (Andersson et. al, 2008). F-REX is a system similar to MIND, with a more developed database structure that enables a stronger connection between model entities and events from different data sources, and it is built on newer software architecture utilizing modern programming language possibilities.

*Table 2.1: Description of the seven phases of R&E mission model utilization*

| No | Name | Description |
|---|---|---|
| 1 | Planning | The planning phase is the prerequisite for all subsequent phases. Definition of objectives and training goals are made according to the overall purpose and goal of the exercise. A data-collection plan, optimizing available resources is also defined. |
| 2 | Pre-Action Presentation (PAP) | A number of previously recorded training missions are presented to the trainees to prepare them for computer-supported training and also to improve their mission capability by learning from previous missions. |
| 3 | During Exercise (EX) | Monitoring and controlling data collection is paramount to secure data for subsequent data compilation and utilization in the following phases. If present, inherent simulation must be controlled. Controlling the exercise progress and alternative courses of events may also be necessary to reach defined training goals. |
| 4 | After-Action Review (AAR) | The AAR is a professional discussion about the mission that focuses on performance standards and gives opportunities to the trainees to discover for themselves what happened and why. Jenvald (1999) argued that the AAR and the debriefing process is one of the most important parts of an exercise. Furthermore, the AAR is an important opportunity to collect data on participant experiences, reflections and conclusions. |
| 5 | Post-Mission Analysis (PMA) | The PMA is an in-depth analysis performed by a team of commanders, analysts, team-leaders, and representatives from different organizations and authorities. Operational procedures, team performance, and training needs are scrutinized. Decisions on lessons identified (LI) and lessons learned (LL) should be transferred. |
| 6 | Lessons Learned (LL) | The compiled model of the mission training exercise, with added data from the AAR and the PMA can be included in a LL database for subsequent utilization, for training issues or for further analyses on trends and behaviours. |
| 7 | Knowledge Transfer (KT) | Transfer of knowledge can be made utilizing the playable mission history from the exercise in teaching scenarios in different schools or courses, but also by making it available via different media or on the internet. Written reports on statistics and or results achieved and conclusions drawn are also a possible and much used form for KT. |

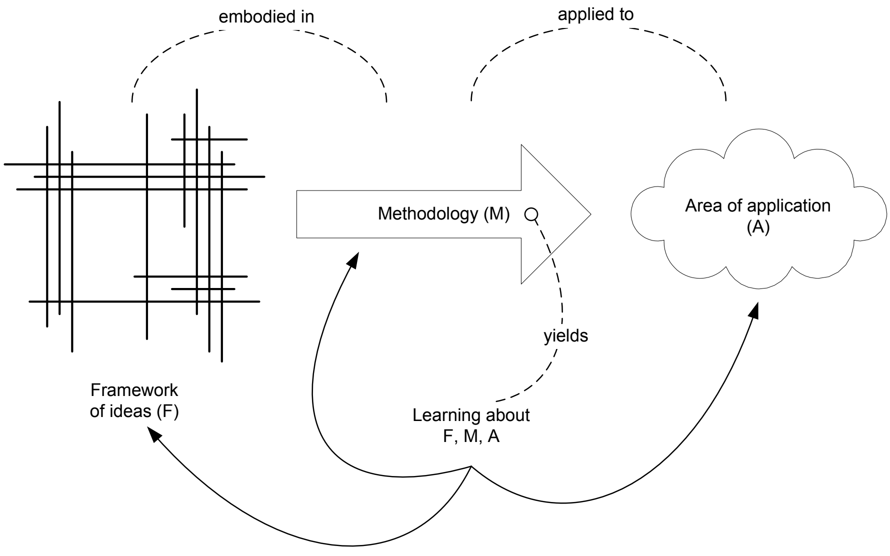



Figure 2.2: Elements relevant for any piece of research (after Checkland & Holwell, 1998). A framework of ideas (F) is used in a methodology (M) to investigate an area of concern (A).

## 2.2 The FMA model of research

The research in this thesis was conducted following the FMA model of research defined by Checkland (1991) and Checkland & Holwell (1998) to describe how researchers could adapt a *framework of ideas* (F) to define a foundation for a *methodology* (M) that could be applicable in an *area of concern* (A). Figure 2.2 describes how these elements relate to each other in a research setting. This is a general model applicable for research of all types in all scientific domains, but it is foremost formulated to define and describe how viable action research should be conducted. West & Stansfield (2001) described how this model would apply specifically for research on *information systems* (IS), and gave two examples of studies implementing the FMA model in IS action research. Morin (2002) furthermore detailed how the FMA model has been applied in developing R&E and the MIND framework, and gave a detailed description of the content in the respective elements of F, M and A in our research setting.

A framework of ideas (F) may be the theories building the foundation for a research area with statements and axioms, and also the paradigms the practitioners acknowledge and hold as valid. A methodology is a body of methods, *the principles of method* (Checkland, 1981). These methods have to be adapted to steps and procedures suitable to the specific situation at hand to be valid and support the achieved results. In many situations, the F and the M are fixed and are applied to learn more about a specific A. However, as Checkland & Holwell (1998) stated, the researcher can also learn about the F and the M if

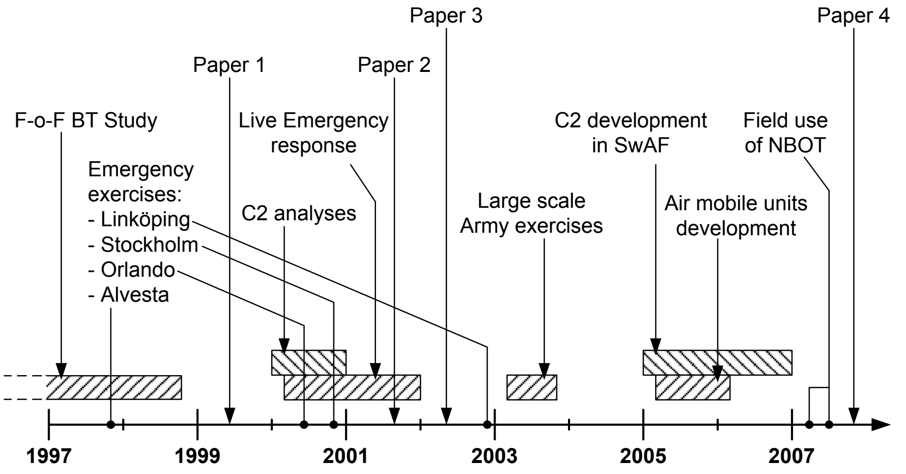



Figure 2.3: Timeline with studies and publications.

addressed properly. How the generic FMA model is applied in this research is further described below.

## 2.3 Research process and chronology

In this section, we describe the activities forming the basis of the research in this thesis, and also relate them to the FMA model of research. Table 2.2 provides an overview of the studies and their major results, and Figure 2.3 shows a graphic overview of how the activities are distributed in time.

The research in this thesis is based on case studies and field studies where methods and tools have been tested and evaluated. Each study was not designed with the single purpose of testing observer methodology or tools, but to enhance the overall concept of R&E. However, the observer methodology and tools were always a specific sub-focus in all studies.

*Table 2.2: Overview of studies forming the basis for this thesis*

| *Activity/Study* | *When* | *Results* |
|---|---|---|
| *Observers in military force-on-force battle training* | *1997-1998* | *Initial development of methods and tools supporting observers and umpires in military training situations* |
| *Emergency response exercises* | *1997, 2000-2002* | *Methods and tools to support using extras to observe casualty flow networks* |
| *Communication analyses in command and control of operations* | *2000* | *Initial methods and tools supporting observers to document and analyze command-post communication* |
| *Supporting live emergency response operations* | *2001-2002* | *Methods and tools can be adapted to support operators in acting as observers in live operations* |
| *Large scale army exercises* | *2003* | *Methods and tools can be used to provide an overview in large combined military operations* |
| *Supporting function development in air mobile units* | *2005-2006* | *Methods applied to the specific function of medical aid and evacuation in military operations* |
| *Supporting C2 development in SwAF* | *2005-2006* | *Development of a network based observer tool NBOT* |
| *Environmental and health inspectors on international missions* | *2007* | *Field use of NBOT by non-experts in international missions* |

### 2.3.1 Framework of ideas

The core framework of ideas in this thesis originates from early work on observers in military force-on-force battle training conducted together with the Swedish Armed Forces. This work was then developed to become the Battle Training Centre (STA). The core of the ideas was developed by Jenvald & Morin (Jenvald, Morin, Worm & Örnberg, 1996; Jenvald, 1996; Jenvald & Morin, 1997) and includes the potential for using modelling and simulation as training aids in military applications, and how observers are an essential source of information in those training sessions. The F has then been refined and developed (Thorstensson, 1997; Jenvald, 1999; Morin 2002) and made explicit for specific observer functions: using extras acting as casualties in emergency response exercises (Paper I); and observers documenting command-and-control communication in staff exercises (Paper II); and operators in live operations (Paper III). The F regarding observers has been retained throughout our research, although progress in information technology and development of smaller and more powerful mobile computer devices has enabled an essential development of technical support tools and corresponding methods (Paper IV).

### 2.3.2 Methodology

The aim of the research presented in this thesis has been to develop a methodology for using observers as data sources in the overall concept of R&E. However, no study performed had the single scope of focusing only on observers. All studies were made in the context of R&E. Initially, observers were regarded as an essential source of information, but the technology to support them was limited to observation protocols with corresponding data transfer tools for post-mission handling. This meant that the amount of data collected by observers was limited in our initial domain of military force-on-force battle training. However, development of the methods of using observers for data collection on casualty flow networks was not limited by technological insufficiency. Because of the development of smaller and more powerful mobile computer devices, we have been able to complement the methodology with adequate tools supporting observer methods in the field. Even though the methodology is independent of technology, practical observer work in the field can always benefit from improved technology in combination with the developed methodology.

Our studies have to a large extent followed the design of interpretive case studies and been iterative by nature. We have successively accumulated knowledge on our methodology development, and refined research questions, methods and techniques. To some extent, we have had the possibility to use quantitative data (Jenvald, Crissey, Morin & Thorstensson, 2002) although we extensively rely on qualitative interpretations of our findings from the performed studies.

### 2.3.3 Area of application

Our main areas of applications (A) have been large-scale realistic exercises with two different sub-categories of observers (1) the subject matter expert (SME) acting as observer of a familiar function within the overall scenario (Paper II), and (2) extras acting as casualties in mass-casualty emergency response operations (Paper I). However, in the study regarding live emergency response operations (Paper III) an analysis of how operators could act as observers in that setting was made. The studies of extending the network based observer tool (NBOT) described in Paper IV also considered live operations, but shared the same prerequisites as category 1 observers stated above.

Furthermore, our A includes exercises in different domains and with different levels of C2 to enable generalization of our findings. We have applied our F and M in the domains of military exercises and operations with different types of units, and in civil emergency response exercises and operations with focus on units from fire and rescue services, medical services and the police. Our A has included observation of different C2 levels, from individual operators interacting in the field or in a command post, to higher command levels with political decision makers far from the operational work.

# Chapter 3
# Model-based data collection (MBDC)

Collecting data in the setting of computer-supported taskforce training requires using multiple data sources with different characteristics and capabilities. A certain amount of data can be collected with high accuracy using technical sensors and computer systems. However, using human observers as data sources will probably always be of necessity for different reasons. The overarching goals of an exercise set the foundation for establishing a data-collection plan (Jenvald, 1999; Morin, 2002), and certain parameters must be regarded in the implementation. One factor of concern is the traditional division between what computers do well and what people do well (Sanders & McCormick, 1992). Certain data are preferably collected using automated systems, for example units' position over time using GPS receivers, or automated time-stamped recording of communication events (Axelsson, 1997). However, certain data can only be collected by observers, for example the quality of an activity executed by an operator in the scenario, where the quality aspect needs objective human judgment. Observers are also flexible data collectors and can adapt in an evolving situation to change their focus of observation, or to act as a back-up for malfunctioning automated systems. Other factors of concern are availability of technical aids, budget constraints, work environment issues, and time limitations. The decision to use humans as observers collecting data entails certain considerations, including:

- What data to collect by observers?
- How to report data to the computer system?
- What competencies do the observers need?
- How should the observers be equipped?
- How should the observers be trained?

These questions need addressing and we will discuss them further in this chapter.

## *3.1 Models*

When we use computers to assist us in handling data from reality we need to construct computerized representations of the phenomenon we study, which means that we build *computer-based models* of parts of the reality. Regardless of what type of models we construct, a model is always an abstraction of reality with a certain purpose and with certain limitations (Ljung & Glad, 1991). In this thesis, we emphasize *descriptive models* used for supporting humans, acting as observers in a computer-supported taskforce training setting, in handling information from complex distributed course of events.

A descriptive computer model of a subset of reality can be used for different purposes. For example, it can be used to visualize an evolving situation graphically in a digital terrain model or on a digitized map, or it can be used to

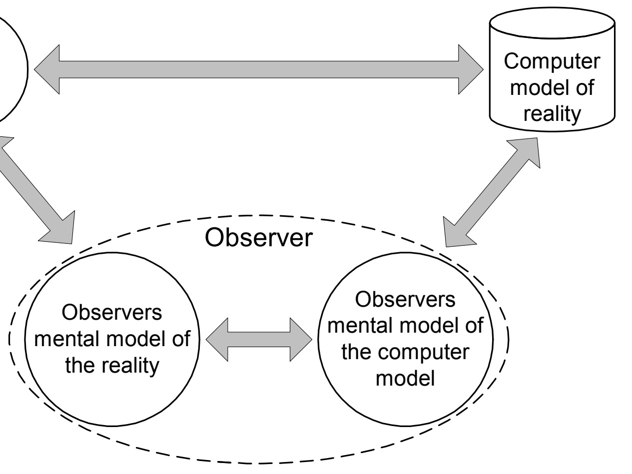



Figure 3.1: A graphic description of the relations between reality—the observers' conceptual understanding of the reality—the observers' conceptual understanding of the computer representation—and between the computer representation and reality.

keep track of consumed resources in tables. Regardless of the purpose of the model it must represent reality in a way that is anticipated and understood by the observers; that is, the model needs to correspond to the observers' mental model of that part of the reality. Moreover, the observers' mental model needs to correspond to the real world behaviour. Hence, we have a four-step correspondence that must work when having human observers and computers sharing descriptions of the world, and this is depicted in Figure 3.1.

The observers' understanding of computer models depends on their understanding of the purpose and design of the model. Introducing observers to model-based data collection requires thorough training and information on the purpose, design and representation of the models. We will further discuss observer training in Chapter 3.3.3. Understanding the computer-based model also relates to understanding the reality and the purpose of observing it. Understanding a complex reality is connected to the mental models of the reality that the observers' have acquired through experience or training. The mental model of reality conceived also depends on the roles and tasks the individual faces in the real world. These aspects must be taken into consideration when designing computer models and observer instructions as well as designing the observer training curriculum.

Designing computer models to represent phenomena from reality is always related to the purpose of making the model and how it is intended to be used. When designing models to support observers collecting data from reality it is important to ensure that the model is perceived as a viable representation of the subject of interest, and that the observers understand why certain approximations

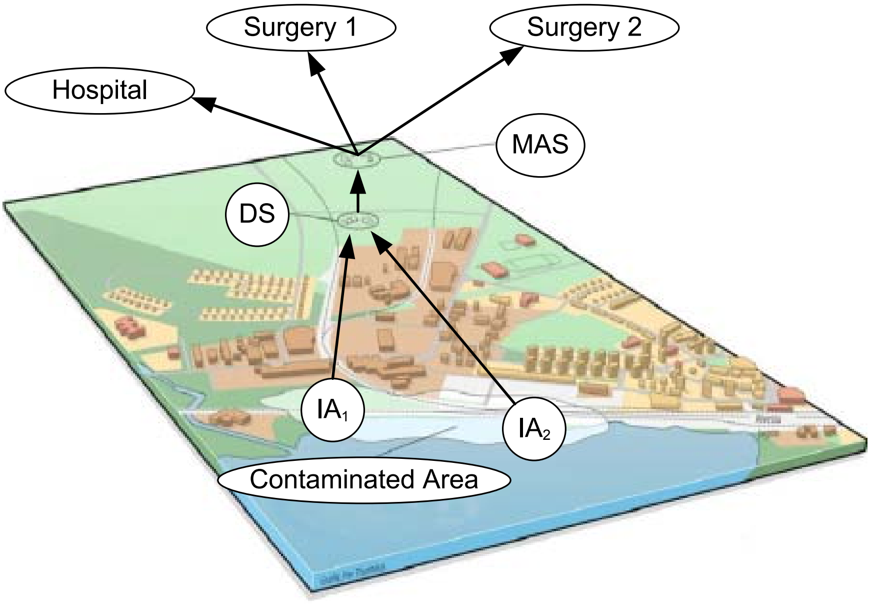



Figure 3.2: The area of operation in an emergency response exercise where casualties are transferred from the incident areas (IA), to the Decontamination Station (DS), further on to the Medical Aid Station (MAS), and from there to Hospital or Surgery.

are made. In Figure 3.2 we depict reality from an emergency response exercise with the focus on the chain of medical attendance of casualties. In this exercise scenario a mass-casualty crisis occurs as a consequence of a serious chemical release near a railway station. One important process in this scenario is to take care of all casualties and to take them to an appropriate medical facility, depending on the severity of their individual status and available medical resources. In this scenario there are two incident areas (IA) and because of the chemical contamination there is a need for decontamination of all victims before they can receive more qualified medical treatment. Hence, a decontamination station (DS) is established. After passing the decontamination station all casualties are transferred to a medical aid station (MAS) for triage and more qualified first aid before being sent to a hospital (H) or a surgery (S). In this scenario there were three different medical facilities to send the casualties to, one hospital and two surgeries.

Implementing timed checkpoints (TCP) as method (Paper I) and modeling the chain of medical attendance as a casualty-flow network (Morin, Jenvald & Thorstensson, 2000) can be made with different granularity depending on what

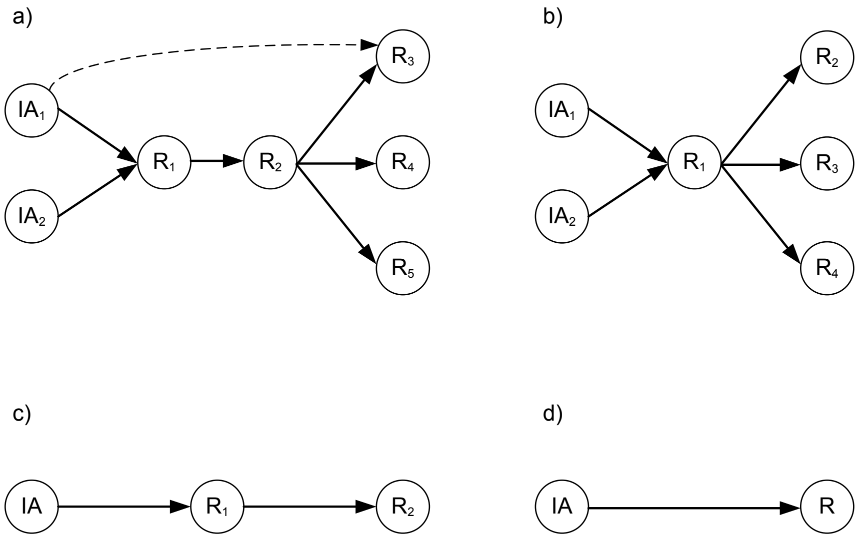



Figure 3.3: Examples of casualty-flow network models representing the operational scenario in Figure 3.1 with different representations of the incident areas (IA) and resources (R). Solid lines represent desirable casualty flows whereas dashed lines represent undesirable flows.

analyses will subsequently be made and also depending on available resources for data collection. However, these design decisions have a decisive impact on what data collection the observers will perform. The method with TCP can briefly be described as registering the time when each individual casualty passes a defined checkpoint, and the results are then visualized in a time line. The set of checkpoints is determined from the model of the actual structure of the chain of medical attendance, which is the casualty-flow network.

In Figure 3.3 we describe different casualty-flow networks that all represent the reality in the scenario in Figure 3.2, but modeled with different levels of abstraction. In Figure 3.3a each step in the casualty flow in the scenario is represented. In the impact area there are two incident areas ($IA_1$ and $IA_2$); there is the DS ($R_1$); the MAS ($R_2$); and after that the one H ($R_3$); and the two S ($R_4$ & $R_5$).

From a modeling perspective a complex casualty-flow network can be abstracted to a more simple representation which can simplify observers' work in collecting data on the actual representation, but that also exclude the possibility to analyze the handling of the casualties within the system of medical attendance. In Figure 3.3b the two resources that are allocated in the missions area of operation, the DS and the MAS, are abstracted to one single resource. Doing that simplifies measurements on that entity since all internal processing is omitted. Consequently, there will be no possibility to analyze any internal processes. In Figure 3.3c the two incident areas are abstracted to one (IA), and the three

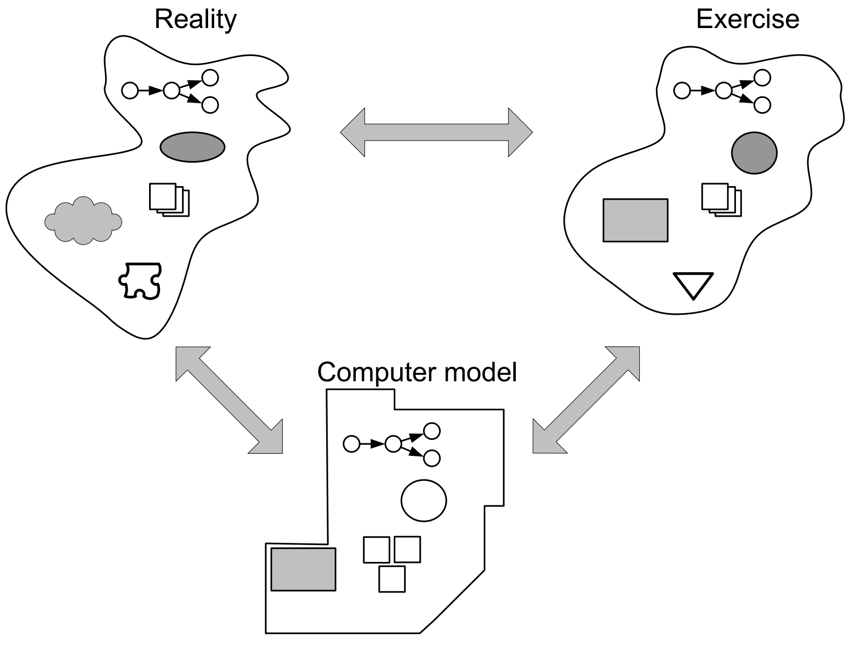



Figure 3.4: A graphic description of the relations between the operational reality—the exercise representation of the operational reality—and the computer model of the exercise and the reality.

receiving care facilities are abstracted to one ($R_2$). Abstraction of the whole chain of medical attendance is done in Figure 3.3d, where an IA and the final receiving facilities are the only measures. For the scenario in Figure 3.2, this representation can be sufficient for analyzing if the casualties reach qualified hospital or surgery resources within a specified timeframe. That is, if time is a measured parameter in the model. However, if these abstractions are done in the analysis phase after the data collection, they can support different analyses of the chain of medical attendance, and in that case they do not influence the observer models.

Equal abstractions can be made on all models in computer-supported taskforce training. For example, a tank can be represented as a complex entity with a crew of four soldiers with individual properties, organized in a hierarchical command structure, with a C2 system for communication, and different sub-systems for sights and weapons. The geographic orientation of hull, turret and different sub-systems, as well as speed, direction and resource consumption over time can also be modeled. Observers can be a key in providing some of the tank data while technical logging provides high frequency data for specific parameters. However, a simpler model of a tank could be a single entity with a position in time and space logged by a GPS-receiver that updates the position once every minute. From an observer's perspective the task can be to attach a receiver at the beginning of the exercise and to collect it afterwards.

Moreover, exercises themselves are set up to represent certain aspects of reality which means that they also are models of the reality. However, many of the computer models designed to represent entities in the exercise should be similar if designed to represent entities in the reality. A graphic description of the relations between reality, exercises and computer models can be seen in Figure 3.4.

### 3.1.1 Model Design

After deciding on using human observers for manual data collection, it is necessary to develop the models that will be used. The process for developing observer data-collection models is included in the overall modeling phase of the MIND framework (Jenvald, 1999; Morin, 2002). All modeling originates from the overall purpose and goal of the exercise, which defines the purpose of data collection. The modeling phase bridges the gap between intentions and goals, expressed in an informal way by managers and commanders, and the explicit, precise representation of the scenario required to support data collection. To be successful the modeling process must involve both the managers responsible for formulating the goals and the experts in charge of the subsequent use of the data.

The input to the modeling process, which is depicted in Figure 3.5, is a preliminary formulation of the data-collection purpose. This formulation is analyzed jointly by managers and experts to establish the explicit purpose of data collection, the requirements imposed and the limitations implied. Based on the results of this analysis, the modeling experts construct a candidate model. The candidate model is then subjected to joint evaluation. In this important step the model is scrutinized to determine whether it provides a valid representation of the overall scenario and the comprising entities with respect to the requirements and limitations earlier established. Moreover, the model is examined to determine if there are any practical and affordable methods for data collection to import real data into the model. Similarly, the model is analyzed to determine if it is suitable for the overarching goal of the data collection, which is often visualization for the purpose of training or other aspects of capability development. If the model meets all requirements it is accepted and submitted for use. If the model is not accepted, the previous steps in the process are reiterated. This case can have two outcomes: 1) the model can be modified to meet the requirements; 2) the requirements have to be changed and a new candidate model constructed. In the second case it might even happen that the requirements cannot be met without violating the intention of the overall data collection. This is a negative result, but it is nevertheless better to realize that in the modeling process than after an exercise.

When evaluating the candidate model it is also important to analyze its correspondence to the potential observer's conceptual understanding of the reality, as depicted in Figure 3.1. A failure of the model to be accepted as a viable representation of reality by the personnel that will use it is not allowable, and that also necessitates a redesign.

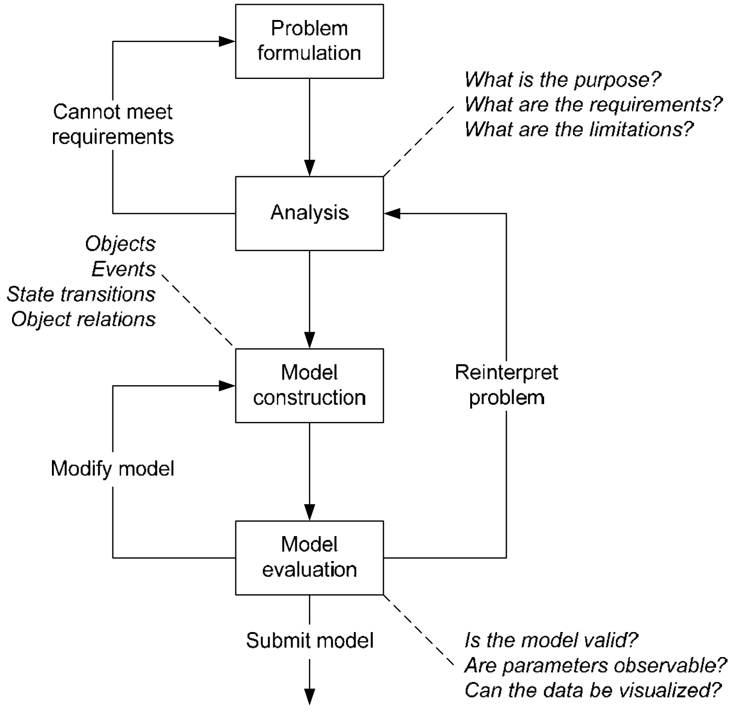



Figure 3.5: Overview of the scenario modeling process (after Morin et. al, 2000).

### 3.1.2 Model Implementation

Implementing the models to usable observer tools starts from the previously developed models and defines *how* data will be collected and *what tools* to provide for the observers. In the modeling process, decisions have been made as to the data that will be collected, which defines the boundaries for the tools to use. The first step in the implementation phase is to develop a data-collection plan (Morin, 2002) for the overall information gathering. Preparing for using observers necessitates converting the models developed to observer tools and instructions. Observer tools comprise certain artifacts, for example for measuring time and position (Chapter 3.3.4), and also an instance of observer protocols. The structure of the corresponding observer protocols will guide and support the observers in collecting required data. An explicit model with a corresponding structured observation protocol will also impose a structure on the resulting data, and limit the amount of free text in resulting reports. The data-collection plan defines the allocation of data-collection resources to meet the needs of the models developed, breaks down all model parameters into data-collection tools and specifies the use of all tools. Developing the data-collection plan requires in-depth knowledge of the advantages and drawbacks of various data-collection

**Data collection card for casualties, Front**

| **Event** | **Time point:** |
|---|---|
| Spotted at incident area: | |
| Cared for at incident area: | |
| Transported from incident area: | |
| Arrival at decontamination station: | |
| Decontaminated: | |
| Arrival at collection point: | |

**Data collection card for casualties, Back**

| **ID:** | |
|---|---|
| Name: | |
| Incident location: | Indoors / Outdoors |
| Type of injury: | |
| **Deceased Time:** | |
| Comment: | |
| | |

Figure 3.6: The front page (left) and back page (right) of the observer protocol, used in an emergency response exercise by extras acting as casualties, to document their individual observations on how they were transferred in the chain of medical attendance.

methods, and familiarity with the overall scenario and operational procedures. Therefore, developing a data-collection plan often requires collaboration between domain experts and specialists on methods and tools for collecting data.

Having identified in detail where to allocate observers and what data each specific observer is to collect, the parameters must be transferred to tangible tools. The tools can be different items, as defined in Chapter 3.3.4, which support the observer collecting specific data. One central tool in model-based data collection by observers is the *structured report* (Thorstensson, 1997). Structured reports can be implemented in observer protocols on paper or plastics, or they can be implemented in handheld devices (Paper IV). The essence of structured reports is that they provide a specific structure and format for documenting observations in observer protocols. An example of an observer protocol, corresponding to extras serving as casualties in the scenario of an emergency response operation as described in Figure 3.2, can be seen in Figure 3.6. This observer protocol implements the model of the casualty flow network for that specific exercise. In this case each extra acted as observer of his or her own transfer through the chain of medical attendance and the tools they used were the protocol, a pencil and a watch.

### 3.1.3 Model visualization

Building complex models in R&E of distributed tactical operations, containing numerous models of units, entities and processes fed with large amounts of collected data entails complications in making data comprehensible and useful for exploration and analysis. This problem was addressed by developing the MIND presentation and analysis framework (Jenvald, 1999; Morin et. al, 2000; Morin, 2002; Albinsson, Morin & Thorstensson, 2004). The main purpose of the MIND framework is to enable replaying course-of-events from distributed scenarios to make the evolving situation graspable by humans. Replay of scenarios is performed in a set of visualization tools, *views* that are designed to

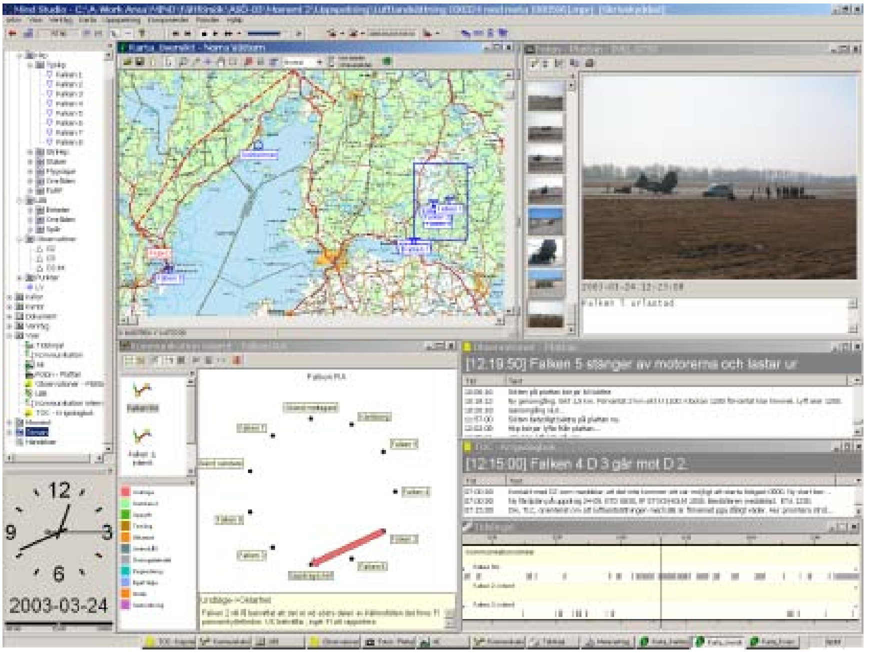


Figure 3.7: A screenshot from the MIND visualization framework showing an example of a replay of a mission history. The top-left view is the component tree, showing all components in the mission history. Thereafter, in clockwise order, are a map view, an annotated photo view, two text report views, a dynamic timeline, a communication view and finally, the mission clock. The data come from a large military exercise concerning cooperation of an airborne unit and a helicopter unit.

reflect certain aspects of the specific models and data, which are included in the framework.

The data collected from the scenario is combined with the models of artefacts and processes developed, to make up a *mission history* which is an executable, time-synchronized, event-driven multimedia model of the operation. A screenshot from a mission history replay in the MIND framework visualization tool can be seen in Figure 3.7. The data collected in the operation define discrete events in the mission history whose state variables capture aspects of the observed real-world phenomena. The relationship between observations in the real world and the corresponding state transitions in the mission history is fundamental for understanding replay of mission histories. Time is used as the primary coordination and navigation mechanism. Timestamps assigned to data in the mission history provide mapping from data to time and from time to data. The user can select to view specific time points in the mission history, or to view a dynamic replay of the course of events. When the user selects a time point, the MIND system constructs the state of the mission at that time from data available in the mission history, and synchronizes all views to reflect that state. The user can also select a data item and let the system synchronize the state of the mission around that item's corresponding time point. If the user selects a dynamic replay of the mission, the MIND system uses the successive time points to animate the corresponding changes of state and the reflected visualization in the data views.

*Table 3.1: Overview of component types in the MIND system (from Morin & Albinsson, 2005).*

| *Type* | *Description* | *Examples* |
|---|---|---|
| *Objects* | *Objects model real-world elements of a taskforce in a hierarchical fashion. State variables represent essential aspects such as location, capabilities and resources.* | *Vehicles, ships, Aircraft, People, Casualties* |
| *Events* | *Events represent time-stamped data. Events define changes in objects' state variables at particular time points corresponding to time stamps.* | *Position sample, observation report, sensor sample* |
| *Sources* | *Sources manage collections of events from a particular physical or logical source. Sources are the primary mechanism for organizing and tracing data from an operation. Sources can filter and format data.* | *Picture source, position source, audio source* |
| *Views* | *Views are presentation windows for particular types of data. Customized views are the primary means of extending the presentation capabilities of the MIND system.* | *Map view, casualty view, dynamic timeline, communication link view* |
| *Maps* | *Maps encapsulate a model of the earth, a projection method, and the logic necessary to render an image of this model in a generic map view.* | *Raster map, Vector map, generic coordinate system view* |
| *Documents* | *Documents are static data, for example text, digital photographs, video clips, audio samples, local HTML pages, and Internet URLs. A document can be made dynamic by linking it to an activation event that specifies when it was created.* | *Text, HTML, digital photograph, video clip, audio clip, URL* |

The MIND framework is component based, which means that new models, functions and views can be added in a flexible matter, thus in a straightforward way enabling integration of new data-collection tools and their corresponding models, representations and visualization tools. This design was chosen to enable a flexible research platform that can be adapted to desired studies and research goals. The price for this flexibility is that using the MIND system is rather complex and is not adapted to specific end user needs. However, the flexibility admits embedding of complexity and adaptation to specific needs if desired. Throughout the MIND system history, numerous components have been added, modified and enhanced. Principle types of components are listed in Table 3.1.

Development from the MIND framework has led to F-REX which is a tool built on a newer software architecture utilizing modern programming language possibilities. F-REX has a database connection with a data structure enabling a stronger association between model entities and data from different sources (Andersson, et al., 2008).

## 3.2 Data-collection methods

Collecting data from computer-supported training scenarios can be made using two different main techniques: (1) automated data collection; or, (2) manual observations (Jenvald, 1999). Automated data collection covers all that is done by technical devices, including everything from GPS-logs of temporal spatial data from units in the field to system logs from C2 systems or other systems on complex platforms, for example a warship in a naval warfare unit. Manual observations are information collected by observers using the method for model-based data collection. The purpose of data collection in computer-supported taskforce training is to register information from the evolving exercise operation to enable construction of a valid mission history. What data to collect and the corresponding model parameters, are decided in the model design process and originate from the overall purpose and goals of the exercise. However, data for different purposes can generally be collected in more than one way. Examples of analysis topics and corresponding means of data collection from an exercise with focus on crisis management in a mass-casualty incident are indicated in Table 3.2.

Decisions on what data source to allocate for a specific purpose depend on the quality of data that is needed, the time frame available to handle the data, economic aspects, and technical possibilities. As seen, most data except data network system logs can be collected by observers, but certain data are more convenient to collect by automated systems.

There is not a single specific solution to how data collection can meet all requirements in a variety of computer-supported training scenarios. However, there are certain installations that are designed to meet the needs of specific training issues, for example the combat training centres (CTC) or battle training centres (BTC) that are built for some country's armed forces to provide force-on-force battle training. We use the Swedish BTC as an example in Chapter 3.5.1. In the BTC environment a variety of data sources are used to build a representative mission history. In Figure 3.8 we give an example of the data flow in an emergency response exercise.

*Table 3.2: Examples of analysis topics and corresponding means of data collection*

| *Topic* | *Method* | *Means of data collection* | |
|---|---|---|---|
| | | *Automatic* | *Manual* |
| *Weather* | *Observation and measurements* | *Weather station* | *Observer* |
| *Unit movements* | *Position registration* | *Logging GPS* | *Observer* |
| *Unit activity* | *Observation of the unit* | *Fixed cameras* | *Observers* |
| *Casualty treatment* | *Timing the flow of casualties* | *Advanced RFID logging equipment* | *Observers, Casualty cards* |
| *Command and control* | *Observation of the staff* | *Logging C2 systems* | *Observers* |
| *C2 systems utilization* | *Observation of the users* | *Logging C2 systems* | *Observers* |
| *C2 data network performance* | *Measurements from servers and nodes* | *Logging in network system* | - |
| *Communications* | *Communication systems recording* | *Digital recording equipment* | *Observer* |
| *Equipment handling* | *Observation* | - | *Observers* |
| *Procedure following* | *Observation* | - | *Observers* |
| *Special events registration* | *Observation* | - | *Observers* |

Viewing the examples in Table 3.2 and inspecting the data flow in Figure 3.8 indicates that observers could be used to collect most types of data. In one sense that is correct. Observers are the most flexible data collection source, it is easy to scale up the use of observers, and they can be used to create redundancy for technical systems. However, their performance with regard to speed and precision can be low, depending on the technical support available to the observers, and thereby data can be of lower quality than desired. Nevertheless, technological development has led to an applicable possibility to equip observers with adapted computer support to let them form a man-machine system for versatile data collection with desired accuracy. Utilizing the possibilities of modern technological support, we believe there is room for improvement of both (1) computers and logics by computer scientists, and (2) of human contribution by behavioural scientists. Forming interdisciplinary research teams to further develop the concept of using observers for model-based data collection would in our opinion be of great value.

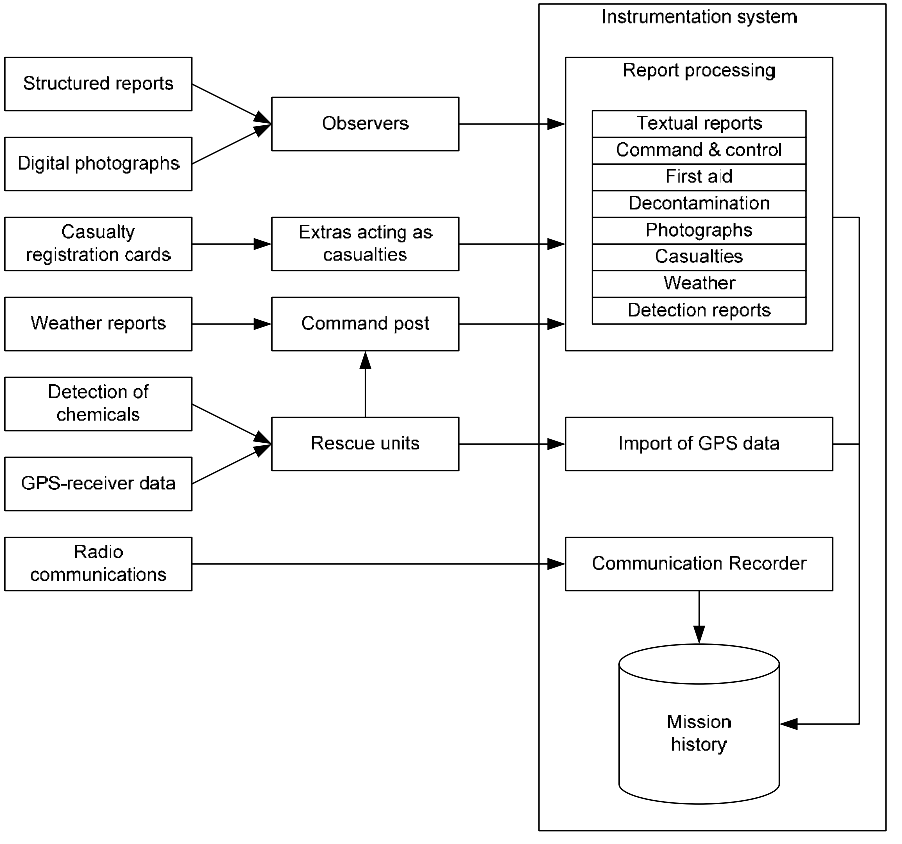



Figure 3.8: Outline of the data flow from different data sources through the data-collection systems to the final registration in the mission history of an emergency response operation to a chemical mass-casualty incident.

## 3.3 Manual observations

Humans working in the field to collect data during exercises are usually referred to as *observers*. Properly utilized they can be an exclusive and highly flexible resource for collecting high quality data from the exercise setting. However, this is not always the only task observers have. This exclusive human resource in the field is in many cases assigned to fulfill multiple tasks. They can be instructors; security personnel; or umpires with the task to judge the outcome from simulated events, for example human casualties from artillery fire in force-on-force battle training. Often the personnel acting as observers are professional subject matter experts (SME) from the work they are tasked to observe, but they are not always professional observers. Being a professional observer also means being an expert in knowing the purpose and goal of the data collection, as well as what key events to observe, and equally important how to document observations. Though not obvious, there can be downsides with using SME as observers before they are also trained to be expert observers. SME can be biased and make judgments when these are not applicable, and maybe also have their own independent opinion on what is important to observe. Seldom do they have a common opinion on how to report observations. Two factors of experience are needed to qualify as an expert observer: (1) experience from the specific domain, and (2) experience in acting as an observer using the specific observer tools. A person may be an expert in one of the two areas but should still be considered a novice observer (Jenvald et. al., 2002).

### 3.3.1 Observer background

Personnel tasked to be observers in exercises can have different backgrounds and this must be taken in regard when designing observer tasks, models, and supporting tools. In military exercises observers usually come from the instructor cadre from the trained unit. They can have different levels of knowledge in the specific tasks subjected to training and they are not always experienced senior instructors. However, they know the domain and the environment they will work in. In other scenarios the observer can be connected to the cadre of professional instructors and observers from the instrumentation facility providing the training opportunity. These observers have experience of making reports on observed events, and they are usually allocated to their expert domain and hence, are to be considered expert observers. However, in some cases they can be allocated to observe tasks outside their specific domains of expertise.

In research and development oriented experimental exercises with more focus on developing methods, tools or organizations, there may be extensive use of academic personnel acting as observers. In these cases the observers may be very experienced in tasks connected to document specific behaviours, organizations or systems utilization, but they may have less experience from the domain observed.

For certain scenarios, involving mass-casualty incidents or scenarios with large crowds of people, we have used students, conscripts or senior citizens as extras for serving as casualties or refugees. In these scenarios each extra has also served as an observer for their individual progress in the chain of medical attendance, the casualty-flow network. Here, each individual observer has had little or no knowledge of the domain they are to act in, nor in the observer tasks they are challenged with. In Table 3.3 we list how the different categories of expertise correspond.

*Table 3.3: Classification of expertise in domain and observer skill*

| *Observer expertise* | *Knowledge* | | *Description* |
|---|---|---|---|
| | *Domain* | *Observer* | |
| *Professional observer* | *High* | *High* | *The observer is a domain expert with experience acting as observer* |
| *Domain expert but unfamiliar acting as observer* | *High* | *Low* | *The observer is a domain expert but has no experience in acting as observer* |
| *Professional observer but unfamiliar with the domain* | *Low* | *High* | *The observer has little knowledge of the domain but is experienced in acting as observer* |
| *Non-professional* | *Low* | *Low* | *The observer has no knowledge of the domain, nor in acting as observer* |

### 3.3.2 Observer roles

Observers in distributed tactical operations are an exclusive and flexible resource for data collection and must be handled with care. In many cases observers are assigned other tasks in addition to collecting data from the unfolding course of events. Certainly, the assignments of tasks may also go the other way. Human resources in the field assigned to other tasks are also tasked with being observers, since they are there anyway. This may introduce conflicting focus and should be addressed when performing resource allocation for data collection. Nonetheless, in certain scenarios multiple tasking must be allowed. Human resources are limited and careful consideration must be made in how to use them. For example, in live rescue operations the primary task for all personnel is to handle the crisis at hand, and data collection is a secondary priority. The luxuries of having specific observers do not exist. In Table 3.4 we list examples of different tasks an observer can hold simultaneously in different domains, even though it is not likely, nor useful, if one individual is allocated to all defined possible tasks simultaneously.

*Table 3.4: Examples of combined observer tasks in different settings*

| *Setting* | *Instructor* | *Controller* | *Umpire* | *Actor* | *Trainee* |
|---|---|---|---|---|---|
| *Military force-on-force battle training* | *X* | *X* | *X* | *X* | |
| *Civil emergency response training* | *X* | *X* | | *X* | *X* |
| *Staff training* | *X* | | *X* | | *X* |
| *Live operations* | | | | *X* | |

### 3.3.3 Observer training

Collecting high quality data is the goal for using humans as data collection sources in distributed operations. The outcome is dependent on the skill of the individual observer, and if he or she is not an expert observer, training is required to secure best performance. Training may be needed in four different areas:

1. Purpose of collecting data;
2. Domain knowledge;
3. Utilized models and representations;
4. Data-collection methods and tools.

Understanding the overall purpose of collecting data and how that data will be used is essential in optimizing the quality of the data collected. Domain knowledge is fundamental to understanding the course-of-events and processes in the unfolding operation. It is also important for knowing how to act and behave in complex and sometimes hazardous environments. Understanding the models that represent the reality is a prerequisite for making correct documentations of the events observed. Finally, there is an obvious need to know how to use the tools and procedures for documenting observations, and equally fundamental is that the observers are motivated to do a good job.

In our studies (Jenvald et. al., 2002) we have identified differences in training levels and resulting data. We argue that differentiated training is suitable for improving skills in the four different areas stated above. Giving formal instructions is one method suitable for mediating theoretical knowledge, as for example explaining the purpose of collecting data and the design of the models utilized. However, practical training is needed to improve skills on data-collection methods and tools. Domain knowledge is one area that can be hard to train explicitly in a concentrated way, and depends on the complexity of the domain in focus. In Table 3.5 we list different types of training methods to improve observer skills, and hence, data quality.

*Table 3.5: Training methods for improving observer skills (from Jenvald et. al., 2002)*

| *Training method* | *Description* | *Comment* |
|---|---|---|
| *No training* | *No instructions are given to the observers.* | *The use of recorded reports will be very limited.* |
| *Textual instructions* | *Textual instructions are handed out before the exercise. The written instructions also support the observer during the exercise.* | *Even the most informative instruction must be read to be useful. The method of using written instructions lacks the ability to motivate the observers.* |
| *Oral and textual instructions* | *Prior to the exercise the instructors give lessons in purpose, models and how to make observations during the exercise. Additional training is given on support tools and equipment.* | *With a well-prepared lesson, the observer skill and motivation can be increased. However, it is still difficult for the trainers to identify observers who are unfamiliar with the method or new equipment.* |
| *Oral and textual instructions with examples and test observations* | *In addition to the formal education of the observers, a small-scale trial mission is performed with the opportunity for the observers to try methods and equipment.* | *Our experience from computer-supported taskforce training is that formal education in combination with a trial session with data collection is the best way to educate, motivate and encourage observers in taskforce-training exercises.* |

### 3.3.4 Observer tools

Model-based data collection by observers is a general, flexible and adaptable method that can be implemented with different levels of technological support ranging from paper and pen, to handheld computers with integrated time-, and position stamping and the possibilities to include voice recordings and photographs. What tools to provide to the observers depends on what data is to be collected, the timeframe between the data collection and data usage, and the corresponding need for data communication. Other considerations including economic aspects, the operational environment and endurance must also be taken into account.

Implementing model-based data collection necessitates the provision of certain data from each observed event. The modeling phase exactly defines what data to collect, but certain items always need to be included, including: time; data source, the observers' identification and position for the observation, which can be either geographic or logic. A geographic position can be logged using a specific geographic reference system like the WGS84 commonly used in GPS receivers or in Sweden the RT90 system used in paper maps. A logic position can relate to a place in a C2 hierarchy or a location in the chain of medical attendance. Sometimes, both the geographic position as well as the logic position is needed.

Figure 3.9: An observer monitoring the leader of the anti-aircraft platoon in an amphibious battalion receiving his orders. The observer equipment corresponds to Tool Kit 2. The GPS receiver is strapped to his left shoulder and the protocols are in hand.
Photo: Mirko Thorstensson.

Planned data collection requires some sort of tool which is defined in the model implementation phase. Below we will give three examples of sets of tools to provide to an observer. However, the process of combining a suitable set of tools for an observer must be performed thoroughly and must be adapted to the specific needs for each operation.

Data can also be collected from an operation in an un-planned setting. In this case there might not be any specific documentation relating each event to the evolving scenario, but information must be recalled from individual's memory (Blomgren, 2007; Andersson, 2001). There may also be supporting documentation from the scenario, but not with the original connection to a data-collection plan, for example pictures, war diaries or recorded communications (Bowden, 1999; Andersson & Jenvald, 2007). In these cases the model-based data collection for constructing a mission history is done after finalization of the incident, mostly by using a combination of data sources. Using humans as data sources in this situation can be achieved by performing interviews (Blomgren, 2007) or by having the personnel fill in forms and write reports (Andersson, 2001). This type of post-mission data collection can in a way also be referred to as model based, although not planned and prepared. Hence, the quality of some specific data must be regarded when compared to planned and prepared mission histories.

**Tool Kit 1**

From a technical viewpoint the simplest tool set for an observer is pencil and paper protocols, complemented with a watch. Simple, but powerful, this set of tools can be adapted to meet firm requirements on environmental ruggedness as well as durability over long periods of time. If the protocols are printed on waterproof papers or plastics and the watch and pencil is waterproof as well these tools support an observer in all weathers and climates, as well as following diving activities if necessary. Printing the protocol on luminous material gives some support for operation in dark environments. Hence, tool kit 1 comprises:

- Watch
- Pencil
- Protocols

Limitations in these tools come from the necessity to note the time for all observations. In some settings this might prove very hard, as when working on a rocking boat, holding on to things with one hand all the time and still observing time critical procedures, for example air defense operations. Still, a paper protocol and pen is highly flexible and gives the observer freedom of documentation, which can be good if the observer is skilled.

**Tool Kit 2**

Complementing the tools, in Tool Kit 1, with three additional items, results in a very powerful set of observer tools. A GPS receiver, a digital camera and a sound recorder further supports accurate documentation of a range of observations (Figure 3.9). Depending on the ruggedness of each specific item these tools can support harsh operational environments as well as pencil and plastic protocols. The set of tools would then comprise:

- Watch
- Pencil
- Protocols
- Handheld commercial GPS receiver for outdoor use
- Digital camera with integrated time stamping of pictures
- Sound recorder with integrated time stamping of recordings

The handheld GPS receiver can be used to track the observers' movements over time, as well as supporting the observer in documenting positions for specific observations. Documentation can be done using the waypoint functionality of the receiver, or by writing the coordinates in the protocol. One specific requirement on a GPS receiver for this use is that it time stamps each logged position. This is a standard functionality, but it needs to be assessed before equipping the observer. Documenting positions is one function that is highly improved by using a technical item such as a GPS receiver.

A camera is a valuable asset for documenting situations, environments and people in a context. The proverbial saying that a *picture says more than a* *thousand words* is often true when trying to document complex evolving situations. Andersson (2001) stated that pictures support expressing matters hard to describe with words *"The pictures is one way to make the overall impression clear and make things understandable"* (pp. 148). Even though Andersson did not implement model-based data collection, his description of the value of pictures is undoubtedly accurate. Using a digital camera with automated time stamping simplifies including pictures in the mission history. There are numerous types of cameras with different performance characteristics on the market. We have used fairly simple and affordable small commercial cameras which we have supplemented with a plastic housing designed for diving to improve environmental ruggedness.

Using a digital sound recorder for making short voice annotations on observations is one way to support the observer by limiting the need for writing observations. A risk to take into account is that spoken notes still need to follow certain protocols to support model-based data collection. This might be a lesser problem for skilled observers, but must still be taken into account when equipping observers.

#### Tool Kit 3

Supporting observers with a handheld computer gives certain additional possibilities, but also introduces some limitations. A single handheld computer with integrated GPS receiver, camera and sound recorder, implementing model-based data collection can replace all tools described above in one single item. If the handheld computer also integrates data communication capabilities, as well as voice communication, the observer can be integrated in a real time data-collection system. We have developed a research tool in this area, the *Network Based Observer Tool* (NBOT) which is described in Paper IV. The advantages with an integrated handheld computer tool is that all observer reports are automatically time stamped and positioned, and that photographs and sound recordings are included in a report structure when generated. This reduces the need for post-mission data compilation. If the requirements on observer collected data include real time transfer to a mission history, the computer solution is a prerequisite.

When using computers as observer tools it is fundamental to analyse the system performance needed from an observer stand point. Environmental factors, durability and usability needs be regarded. These parameters can set limitations on what is possible to achieve with computer tools solely, and a combination of tools might be preferable. The obvious limitations of computers are environmental factors, energy consumption issues, and in some special situations light and energy emission. Utilizing suitable equipment can in most cases compensate for these shortcomings, but nevertheless they must be addressed.

### 3.3.5 Post-mission data compilation tools

Depending on what tools an observer has used to collect data there are different needs for post-mission data compilation and data manipulation. Using a computerized tool like NBOT requires less compilation and can be limited to

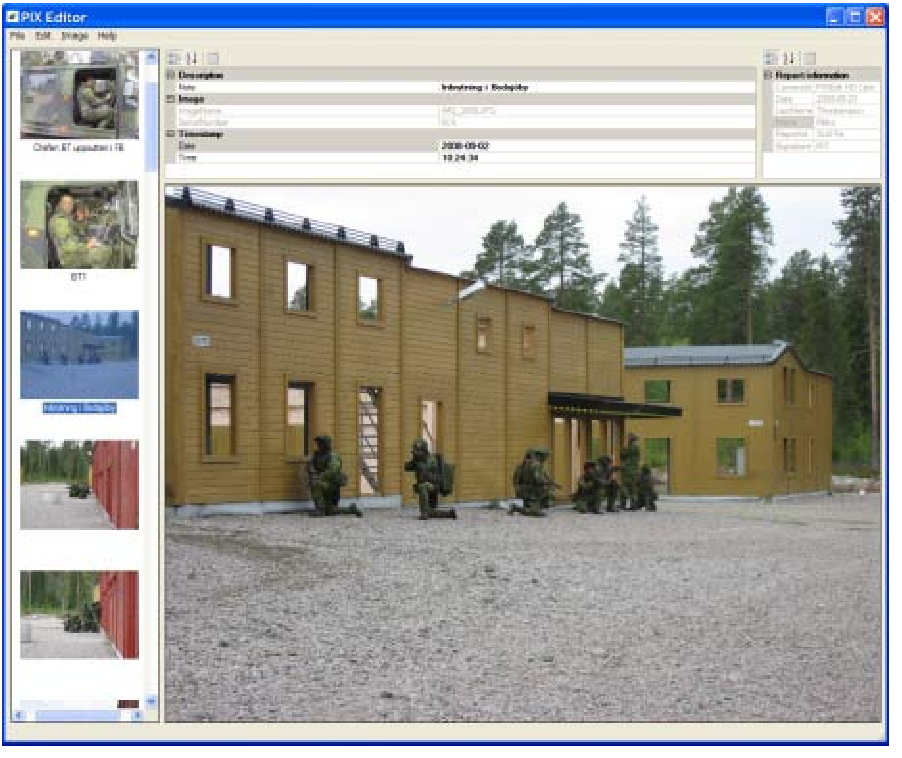



Figure 3.10: A screenshot from the PIX software showing the graphical user interface for adding observer comments to photographs from a digital camera and including them to a mission history.

connecting the handheld device to a network for data transmission. Having used paper protocols and pencil necessitates transferring data to a computer format. Different input tools can be utilized depending on how the mission history is represented. For example, using large numbers of extras as casualty markers, each of whom also serves as observer of their handling in the chain of medical attendance, can result in having hundreds of observer protocols to input to the mission history.

Using a set of tools as in Tool Kit 2 requires post-mission compilation and manipulation of data from the different devices, as well as the protocols. Data from the GPS receiver must be transferred to the mission data storage together with documentation on the log. Pictures from the digital camera must be transferred to the mission data storage. Each picture also needs to be commented with what the observer wished to illustrate with that specific picture. Observer data for traceability also needs to be documented. For the purpose of uploading pictures and data from digital cameras we have developed a software tool named PIX (Morin, Jenvald, Nygren, Axelsson & Thorstensson, 2003). The PIX software (Figure 3.10) supports observers in organizing photographs according to time stamp, adding comments, and storing information about the photographer and the situation studied. Data from a sound recorder must also be transferred and documented in the same way.

Acting as an observer of a communication network can include collecting data on sender, receiver, content and also classifying each specific communication event (Paper II). This data collection can be performed on the recorded communication after the event has occurred and in that case, it is one type of post-mission data processing. Adding metadata like classification to a certain type of data, whether a communication event or a photograph, can include some means of analysis but that is not always the case. If the classification consists of adding metadata to unbiased information, we consider it as not including an analysis. But if the classification is on a quality aspect of the data, it requires some analysis by the observer. For example, post processing of recorded speech communication from a radio network, including adding sender, receiver, classification of content, and also a brief description of the content, is a tedious work that takes some time.

Post-mission data compilation can be fairly straightforward and quickly performed, but can also involve an extensive work that requires planning, allocated time and supporting tools.

## 3.4 Observer environments

Observers are flexible and adaptable as data sources and can be utilized in a variety of settings and environments. Qualified personnel can be allocated to follow processes and tasks in different environments and as situations evolve they can adapt and change focus if necessary. Computer-supported taskforce training takes advantage of the possibilities to train units and commanders in as realistic environments as possible, which has consequences for data collection. This affects the models that can be used regarding the data that it is possible to collect and also the tools that can be used by the observers. Both technical and manual data collection must take environmental and contextual aspects into account, but certain considerations must be made regarding the specific observer environment and context. These include:

- *See but not be seen*. In some scenarios it is important that the observer can perform the task of data collection without making sounds or emitting light. This is of utmost importance if following a military unit which is concealed in the field, but might be as important from a sound perspective if following a staff exercise in an office environment.
- *Moving vehicles*. Using observers in moving vehicles (tanks, ships, helicopters, cars, boats) where little space is available, the environment is shaking, bumping and rocking, stresses both observers and tools.
- *Materially harsh environments.* Some conditions stress technical equipment more than others. Dust, humidity, precipitation and temperature must be taken into consideration when equipping observers.
- *Physically harsh environments.* Following taskforce units in the field can be very physically demanding. Heat, cold, snow, rain and the necessity of carrying observer equipment as well as individual field gear over long periods of time and distance sets certain demands on observers and tools.
- *Psychologically demanding environments*. Situations where realistic casualty scenarios are employed can be psychologically hard to deal with for observers. This is even more important to take into consideration if using observers in live operations or similar live situations where handling of real accidents or other personal tragedies may occur.
- *Health hazardous environments*. Some training sessions include health hazardous exposure which demands using adequate safety equipment. This occurs if using observers to follow rescue units responding to chemical incidents or observing smoke divers operational procedures.
- *Specialist environments*. Acting as observer can in certain scenarios require special competence. Observing mechanized force-on-force battle training in the field requires knowledge of how to act around tank units operating heavyweight vehicles with high terrain mobility and limited visibility. Following specialist units in the field, who for example do

parachuting, mountain climbing or diving, also places certain demands on observers and tools.

- *Gender and ethnicity*. Observing healthcare exercises or specific environments in international scenarios makes requirements on gender and ethnicity. In certain cultures, only women may address women, and men only men. In some situations ethnic background can be a constraint in accessibility for surroundings or information.
- *Legal aspects and security*. Collecting data from field trials with new equipment and methodology might imply security concerns on both data-collection tools, observers and the instrumentation system design and data handling. Legal aspects might be of concern regarding ownership of results. Exercises and training scenarios in the domain of emergency response might also imply legal constraints on what data that may legally be collected. Certainly, in live emergency-response operations, this factor must be addressed correctly.

Environmental concerns needs be addressed with appropriate selection, training, and equipment. In Table 3.6 we list the environmental factors above and specify appropriate strategies for addressing the problem.

*Table 3.6: Environmental factors and strategies for meeting the requirements*

| | *Means to meet requirements* | | | |
|---|---|---|---|---|
| | | | *Equipment* | |
| *Environmental factor* | *Selection* | *Training* | *Safety* | *Tools* |
| *See but not be seen or heard* | | X | | X |
| *Moving vehicles* | | X | X | X |
| *Materially harsh* | | | | X |
| *Physically harsh* | X | X | | |
| *Psychologically demanding* | X | X | | |
| *Health hazardous* | | | X | X |
| *Specialists* | X | X | | |
| *Gender and ethnicity* | X | | | |
| *Legal aspects and security* | | X | | X |

## 3.5 *Data-collection scenarios*

In this chapter we will give examples of how observers may be used in different settings. We will discuss the purpose of using observers in each domain and categorize the models, the tools, the observers and the observer training. We will categorize observers as experts or novices depending on their experience from similar situations.

### 3.5.1 Force-on-Force battle training

Training military units has introduced the concept of *force-on-force battle training*, where one unit is designated to fight another unit and modeling and simulation is used to represent factors of war that must be present to facilitate a realistic environment. Many countries have built instrumented training sites enabling realistic training of armed forces units of company, battalion and even larger sizes (Seidenman, 1998).

Originally, these training sites were designed to reflect combat situations in the large-scale war where equally sized mechanized units met in duels with heavy support of artillery and other units. These training situations still exist, although current focus has shifted towards training meeting the asymmetric threat that is present in areas where military units are engaged today. The asymmetric threat situation is constituted by a military force meeting small unorganized units using non traditional methods and weapons, for example improvised explosive devices (IED). These situations are common in the international scenarios facing peace enforcement and peace keeping units in the Balkans and Afghanistan as well as in other parts of the world. Training for these environments has gained more focus and dedicated training sites have been built, for example in the USA (Williams, 2008), to reflect these specific problems. However, the need for adequate training support is ever present, with even more focus on training parameters that is hard to measure with technical systems. Hence, the need for observers is more explicit, and the observers need tools to handle the increased complexity in their tasks. A subject of considerable interest in asymmetric warfare is the information gathering and intelligence process. This is one part of the C2 arena that needs more focus in the training setting, and here observers are essential to collect data. The military ability to handle adapted use of violence, following specific rules of engagement (ROE) and escalation steps, to achieve operational goals is still the core motivation to using military units for handling international crises. The ability to fight is essential regardless of the environment, even though the focus today is more on small unit urban warfare than on open field mechanized duels.

Whatever the environment, an instrumentation system is used to allow simulation of warfare elements like gunfire, missiles, mines and artillery and also to provide registration of course-of-events to be used in after-action reviews (AAR), (Rankin, et. al 1995; Morrison & Meliza, 1999) and subsequent in-depth analyses (Jenvald & Morin, 1997). We have developed an observer support system providing methods and tools to enhance the volume of and quality of

Figure 3.11: Parts of a tank platoon under attack in a force-on-force battle training exercise. Photo: Mirko Thorstensson.

observer-collected information from instrumented training sessions (Thorstensson, 1997) when supporting the development of the Swedish Armed Forces Battle Training Centre (SwAF BTC) (Jenvald, et. al., 1996). Other computerized tools for observer data collection have been developed for use in other settings (van Berlo, Hiemstra, & Hoekstra 2003; Hiemstra, van Berlo, & Hoekstra, 2004).

**Models used**

Developing the system and methods for force-on-force battle training for the SwAF BTC we used a set of models to enable construction of a mission history emphasizing training (for a detailed description see Jenvald, et. al., 1996 and Jenvald, 1999). For example we used:

- *Hierarchical organization models* of the participating units. In an organization tree we modeled each of the participating units to give an overview of the numbers and types of the units included.
- *Unit models* were used to describe the structure of each participating unit regarding personnel and equipment.
- *Platform models.* The participating units often included some type of weapon platform, for example a tank (Figure 3.11) or an armoured personnel carrier (APC). Vehicles and soldiers also were represented as platform models at the lowest level. The platform models were straightforward and held data on: weaponry; protection level; status regarding injuries; position; and activity.

- *Field work models.* To represent aspects of unit activity used to influence the battle space we used different models of for example minefields and terrain blocking work.
- *Simulation models.* To simulate the outcome of artillery fire or casualties from entering a minefield various different distributed simulation models were used.

Some of these models were utilized to include automated data collection, but many of them included observer data collection, or a combination of methods.

#### Observer tasks

Certain data cannot be collected by a technical instrumentation system but needs human classification. Here we give some examples of data that were collected by observers at the Swedish BTC:

- *Unit activity*, is a status in the unit model describing what the unit is doing at a specific time. An observer makes a report entry when the activity changes. Examples of activities are *marching, resting, preparing for assault, in position for assault, retreating, mining, clearing mines*. Data collection on unit activity was also done in combination with tracking of squad units who had no other instrumentation support.
- *Field work*, is not detected by automated systems and needs to be reported to be included in the simulation. A field work is the result of a unit activity including mining or building obstacles. A field work report is written and reported by an observer following a specific unit or observing a specific terrain element. A report on a minefield can include position data on each individual mine, or it can comprise the extension of the minefield and a mine density. There are different formal methods for reporting minefields. Correspondingly, reports can be made on damaged bridges or roads.
- *Casualties*, and damage as an outcome of certain weapon systems' simulation. To some extent the outcome of a shooting, artillery fire or mine explosion is taken care of by the instrumentation system, but some additional data must be added and reported by observers. When for example, a vehicle is damaged by a mine the change in status for the vehicle is simulated and communicated by the system, but the actual casualty on specific individuals is decided by the observer also acting as umpire. A soldier can for example be judged to receive shrapnel injuries in the upper torso and neck depending on his or her position in the vehicle at the instance for the explosion.

#### Observer characteristics

The observers used in force-on-force battle training in the SwAF BTC were exclusively officers acting as observer/controllers of the exercise. Two different types of observers were used: (1) officers from the trainee units acting also as unit instructors; and (2) officers from the BTC training cadre also acting as umpires, which is an observer/instructor authorized to judge the outcome of certain simulation situations. The first category of observers consisted of domain experts in their field of military expertise and serving as instructors in their home units, but they had not always had previous experience from BTC exercises. In this case, the observer is a domain expert but still a *novice observer* needing training before being assigned to perform the observation task. The second category of observers included experienced officers with previous serving records from specific military domains and also experience from acting as observers in a BTC-setting. In this case the observer is an *expert observer* ready to act in the training scenario. In the setting of the SwAF BTC instructors from the trainees' home unit are also used as umpires in their specific unit.

#### Observer training

Training military domain experts with years of accumulated knowledge from being instructors at their home units to become qualified observers in an instrumented training setting is more demanding than might be expected. Unfortunately, military domain experts tend to underrate the skills needed to perform and document high-quality observations with sufficient precision and frequency. This tendency makes it difficult to build models of evolving operations. Since the officers were all domain experts, observer training emphasized training in purpose and goal for the observers, models utilised, observer tools and also observation criteria. We conducted formal observer training sessions for one hour, which included a number of trial observations. Our findings were that most of the senior officers nevertheless needed the first live exercise training session to fully understand their task of being an observer in the instrumented setting. In the following live exercise training sessions they performed very well.

#### Observer data-collection methods and tools

For use in the SwAF BTC we developed a set of protocols implementing structured reports that were to be used together with a watch and pencil. The protocols were printed on plastic paper and were to be used for writing reports and entering them into the system after completing the training session. For entering the reports into the instrumentation system we developed a computer tool that represented all protocols and supported data compilation.

Certain types of data were required to be entered into the instrumentation system in close to real time to enable unit activities to affect the outcome of coming simulations, for example the placing of a minefield in a specific terrain area. To enable this, a semi-automated method was designed whereby the observer could call the data-collection centre by radio and make voice reports to an assistant using the tool described above for entering report items. This could be done for all reports to enhance the real time tracking of the course-of-events, and also to support observers by using a man-in-the-loop to image a *voice reporting system*.

#### Reflections

Using a complex instrumentation system such as a BTC nevertheless requires the use of observers to ensure collecting high quality data. Depending on the use of the collected data there is always a possibility to negotiate the cost and benefit of observer collected data, but having a clear picture of possibilities and restraints makes the result more adequate. If the purpose of a training session is fairly straightforward combat duel training, the use of observers can be reduced to a minimum, but if the purpose is to support capability development by analyzing operational procedures and tactics, adequate use of observers can be a key issue. BTC installations can be of more use than straightforward combat training if properly used.

However, using observers in the BTC domain is more complex than might at first appear when regarding the fact that only officers are used as observers. Military domain experts do not always have the same opinion of *what* factors are important to report, and even more seldom do they share a common opinion in *how* to make the report. This requires thorough training sessions, with emphasize in importance, methods and tools. After making sure that the observers are solving their tasks, they become qualified flexible data sources providing essential data not possible to collect by other means, at least not at a reasonable cost.

### 3.5.2 Emergency-response exercises

Realistic emergency-response exercises necessitate the use of extras acting as casualties simulating real injuries. The rescue personnel need to handle these persons as they would real casualties and the treatment over time is decisive for the outcome of each individual. We have implemented a straightforward method for registering treatment and handling of casualties in training where we use the extras as observers documenting their own anamnesis, which is then included in the overall mission history. Documentation of each casualty’s transfer through the various steps in the chain of medical attendance follows the method of timed checkpoints (TCP) (Paper I) and all treatment activities are registered with time and activity. We have used this method in several field trials (Jenvald, Rejnus, Morin & Thorstensson, 1998; Rejnus, Jenvald & Morin, 1998; Morin & Thorstensson, 2000; Crissey, Morin & Jenvald, 2001; Thorstensson, Tingland, Björneberg & Tirmén-Carelius, 2001; Thorstensson, 2003; Thorstensson, Johansson, Andersson & Albinsson, 2007). The most common method used in recruiting extras for acting as casualties in exercises is to use students from different medical schools or from other classes. Another common method is to recruit senior citizens for participation as extras, and we have also participated in exercises where conscripts from the SwAF were used as extras.


Figure 3.12: Extra acting as casualty and observer of his treatment in the casualty-flow network in an emergency response exercise. He is holding his observer protocol, depicted in Figure 3.13.
Photo: Johan Jenvald.

**Models used**

Training emergency-response operations involving casualties emphasized the use of several medical-related models to build up the resulting mission history:

- *Patient models* can be included with various degrees of complexity regarding the purpose of the training scenario. We have used different models ranging from the simple one only holding information on identification number and location of the patient, to more complex models with data on the patients age, sex, specific casualty, time and extension of all executed treatments, time for prioritization and re-prioritization, and transportation. Subjective comments from the extras have also been included in the model.

- *Casualty-flow network models* have been used to represent the chain of medical attendance implementing the method of TCP. We have used a range of models from simple ones representing two places, to complex models representing a network of multiple corresponding places.

- *Unit models* representing medical-aid units ranging from one person to composite medical-aid teams and stations.

- *Platform models* representing medical transportation units such as ambulances, helicopters and other means of medical transportation.

### Observer tasks

Our method is based on using the extras acting as casualties to also act as observers documenting their own progress in the chain of medical attendance (Figure 3.12). Of course this can also be addressed with additional dedicated observers allocated to specific areas, sites or units, but having the extras doing the documentation gives certain benefits, even though there are certain limitations. The benefit of having the extras acting as observers as well as casualties is that they are there and they are the utmost focus of the medical attendance. The tasks they are to perform are listed below:

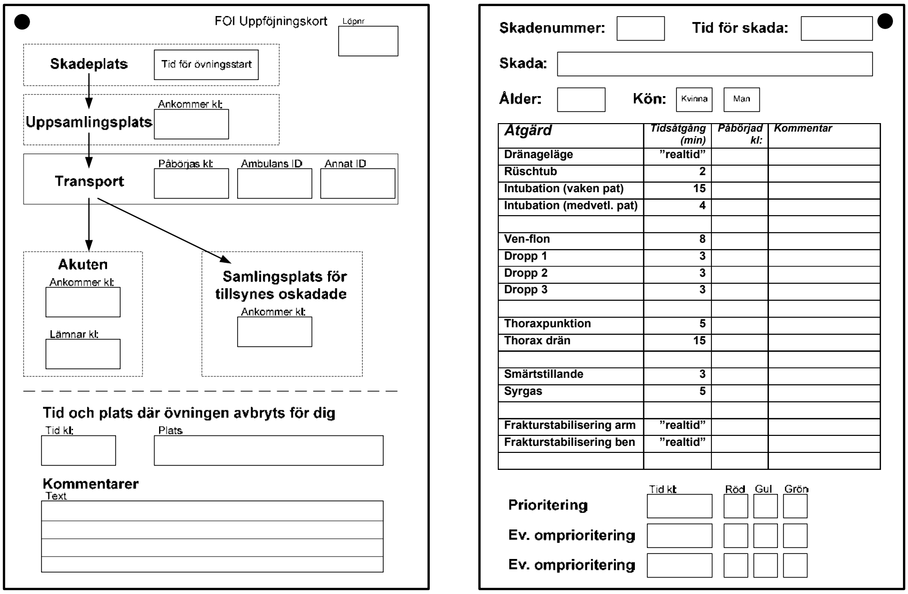
- *Acting as a casualty* is the essence of being a realistic patient for the trainees. This acting involves doing medical simulation of treatment activities, or the absence of the same.
- *Documenting treatment activities* with time and make sure the activity takes a realistic time for the trainees.
- *Document transfer in the chain of medical attendance* by noting the time for passing defined checkpoints.
- *Including subjective judgments* by noting comments on how trainees acted.

### Observer characteristics

Training emergency response to mass-casualty incidents requires a certain number of extras acting as casualties. A common way to recruit extras is to invite students from medical schools to participate in the exercises. Prior to the exercise, the students learn about medical emergency response, but cannot yet be regarded as domain experts, and it is rare that they have prior experience from acting as observers. Therefore, they must be regarded as novice observers. In some scenarios we have had students with no medical background and no experience as observers. Senior citizens are a group of people often used as extras for acting as casualties and they must also be regarded as novice observers.

### Observer training

Training students to perform as combined observers and actors in a casualty incident needs emphasis on the purpose of their task in relation to the overall mission model. The methods and required precision in registration needs to be stressed, as well as how to identify all checkpoints in the anticipated chain of medical attendance. Due to the students' inexperience of the domain as well as of the observer tasks, training is paramount to achieve acceptable results. A clear method for controlling observer handling of reports also supports a good result. We have identified a strong relation between the allocated time for training and the corresponding outcome of the data collection (Jenvald et. al., 2002).




| Atgärd | Tidsåtgång (min) | Påbörjad kl: | Kommentar |
|---|---|---|---|
| Dränageläge | ”realtid” | | |
| Rüschtub | 2 | | |
| Intubation (vaken pat) | 15 | | |
| Intubation (medvetl. pat) | 4 | | |
| | | | |
| Ven-flon | 8 | | |
| Dropp 1 | 3 | | |
| Dropp 2 | 3 | | |
| Dropp 3 | 3 | | |
| | | | |
| Thoraxpunktion | 5 | | |
| Thorax drän | 15 | | |
| | | | |
| Smärtstillande | 3 | | |
| Syrgas | 5 | | |
| | | | |
| Frakturstabilisering arm | ”realtid” | | |
| Frakturstabilisering ben | ”realtid” | | |
| | | | |



Figure 3.13: The front page (left) and back page (right) of the observer protocol used in an emergency response operation for extras acting as casualties to document their individual observations on how they were treated and transferred in the chain of medical attention.

**Data-collection methods and tools**

Tools that we have used for supporting extras documenting their treatment have been in the form of watch, pencil and protocols. Depending on the environment the protocols have been printed on paper or plastic papers to withstand environmental factors. The complexity in the tools has been in the protocols carrying information on the treatment and prioritizations. A version of protocols can be seen in Figure 3.13. An interesting detail in using students as extras is the use of modern designer watches. Adequate readings on minute values of time might not be satisfactory as “somewhere between the red and green ruby”.

**Reflections**

The quality of the data gathered is to a great extent a result of the emphasis given to training the extras in their role as observers. Nevertheless, precision is always a problem when relying on manual reading of time on wrist watches, and the lack of domain expertise is an obvious problem when it comes to understanding the dynamic organization in an emergency-response operation. This dynamism is also a problem when modelling the operation. Locations and functions are rearranged and moved during the scenario propagation and this is an essential part of the operation that must be handled and can be met by supporting extras with continuous information on the evolving organization.

### 3.5.3 C2 communication analyses

Developing new command-and-control systems for military units requires thorough analyses of future systems requirements (Albinsson, 2004). We have used the MIND system for explorative studies of tactical operations involving mechanized units, marine units, air mobile units and helicopter units and in these settings we have used researchers as observers. These field trials have been used for development of methods and techniques for data collection and data analyses, and the researchers have been observers familiar with the methods and purposes of data collection but with limited domain knowledge. One specific tool we have developed is the Extended Link Analysis (ELA) (Paper II) to support analyses and data collection on command-post communication (Thorstensson, 1998). The method combines the *link analysis* method (Chapanis, 1959) with time stamping and classification of communication events. Using the ELA method and tools and combining them with R&E in the MIND framework enables communication exploration and analyses (Albinsson & Morin, 2002) in the actual tactical context (Morin & Albinsson, 2005).

#### Models used

Communication related models we have used in the overall mission histories include:

- *Communication event models* holding data on start time, stop time, sender, receiver, classification and content. Communications can have different extensions from long dialogues to discrete sending of text or figures. There is always one sender in a communication event, but there can be more than one receiver. Classification can be done using different schemes for classification, and this can be done on the same data set, depending on what analyses are of interest. Content can be the sound in spoken communication, the text string in a computerized chat, or a graphic order in a C2 system.
- *Actor models* describing the different actors that can participate in communication in the scenario. The actors can also be units or platforms. Parameters defining the actor can be simple and may only be a name, but can also be complex and hold data on status, position, training and background.
- *Artifact models* are used to represent the different equipment or items that can be used by the actors. An actor's use of an artifact can be seen as a communication event with a classification defining the type of interaction, which for example can be "pointing" on a map or "calling" in a radio.

#### Observer tasks

Collecting data on communication involves the observer tasks to observe and use different tools to register communication events in the scenario. Depending on the scenario, position of the observer, and frequency of communication this can be an extensive task with little or no room for other data collection. Observing a command post, with up to four actors give little room for documenting other

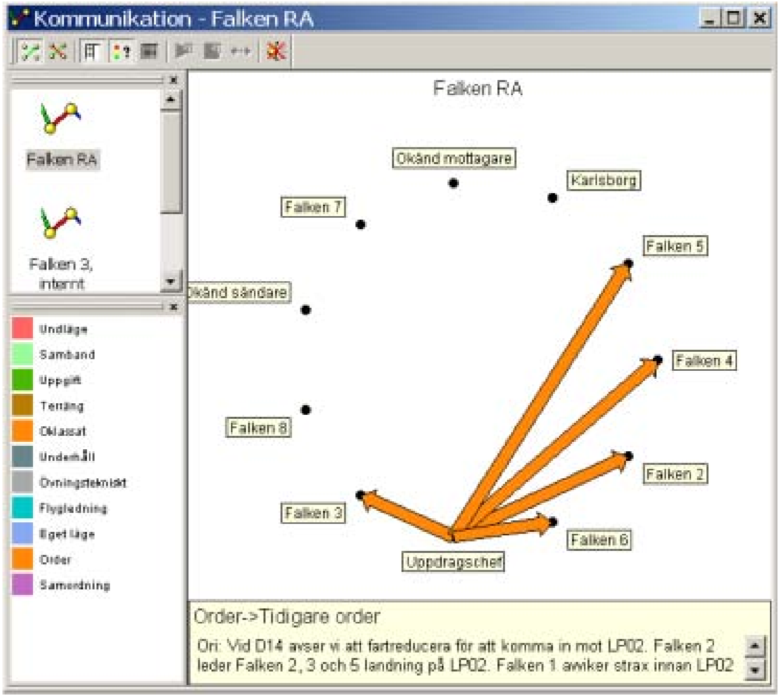



Figure 3.14: A screenshot from a MIND visualization of a communication event with a spoken order on a tactical radio channel in a helicopter unit in an army exercise.

data, whereas following a single commander in a field unit gives possibilities for documenting other courses of events.

One application of the method is to document communication events by "listening-in" on spoken communications, for example on a radio network in an army unit (Figure 3.14). Here, the same tools can be used for following real time communication. When handling communication data after executed exercises we have used different tools, but the tasks are still the same.

#### Observer characteristics

When collecting data on communication in tactical exercises we have mainly used qualified observers to investigate the boundaries of human data collection and automated data collection. Observers have been researchers with methodological and technical expertise and thorough understanding of the purpose of the models used and the purpose of the data collection, but with limited domain knowledge. This approach requires working closely with domain experts when preparing and conducting each field trial.

#### Observer training

Using methodologically qualified observers limits the training needed to domain specific issues like for example understanding the context of actors and the language they use. Safety issues have also been in focus when preparing for observing command posts in naval vessels or crew collaboration in helicopter units.

#### Data-collection methods and tools

Investigating the boundaries of human data collection and automated data-collection methods has made use of a range of tools from the simplest pencil and paper to semi-automated computerized support tools via digital cameras and video cameras with built in time stamping functionality. The ELA registration tool was developed to support registration of internal command-post communication and has been tested in various command-post settings with satisfactory results. An extension of the ELA data-collection tool is implemented in the NBOT-system described in Paper IV.

#### Reflections

After making a thorough analysis of the domain together with domain experts defining parameters for registration, observer experts perform well in capturing relevant information for building a feasible mission history with included communication. However, achieving adequate results from subsequent analyses requires methodological experts and domain experts working together to facilitate extracting relevant information from a complex data set.

Communication is a highly important part of the mission history for analyzing needs in future command-and-control systems. However, communication must always be analyzed in a relevant context. This is not always the case because of the complexity in handling large data sets from distributed tactical operations. Often, communication analyses are focused on a small part of an exercise where only one command post is studied. This might be feasible, but there is a risk for not identifying the external consequences of the command-post activities. C2 has no sole purpose, but is a prerequisite to optimize the actions of a task force.

### 3.5.4 Live emergency response operations

Developing methods and procedures for emergency response units can be supported by analyzing how real emergencies are handled. We have had the opportunity to investigate how analysis methods from the training domain can be of use in the live emergency response domain. The major difference lies in the problems concerning data collection. Documenting the course-of-events in live emergency response operations requires methods that do not strain the limited resources available for handling the emergency. Certain information can be collected with automated methods, but some data needs to be collected by humans. In live operations there are no specifically allocated observers, but data can still be collected by the personnel in the units. We have developed methods and tools to support fire ground commanders to collect specific data from emergency response operations (Paper III) and these methods have been tested, and to some extent implemented, in the Linköping Fire and Rescue Department.

**Models used**

Documenting live emergency response operations has incorporated the use of several models to construct a feasible mission history:

- *Hierarchical organization models* of the participating units. In an organization tree we modeled each of the participating units to give an overview of the numbers and types of the included units.
- *Unit models* were used to describe the structure of each participating unit regarding personnel and equipment.
- *Platform models.* The participating units include some type of platform, for example fire trucks with different capabilities that were represented as platform models. The platform models held data on equipment, available water and foam resources, position and activity.
- *Communication models* were also used with a sub-set of data described in Chapter 3.5.4.
- *Environmental models* were used to document weather parameters essential for mission analysis: temperature; precipitation; wind direction and strength.

**Observer tasks**

The main task for a fire ground commander is to lead the unit in handling the emergency, to coordinate activities and optimize resource utilization to minimize consequences of the unfolding situation. In addition to that, we tested if the commanders could also provide certain data to the mission history. Data collection performed by the fire ground commanders were mainly activity data describing units work in the scenario, or scenario data describing the unfolding situation.

**Observer characteristics**

Professional fire ground commanders are domain experts and will become observer experts when they have used the method long enough. Initially however, they were considered novice observers due to lack of experience in using the data-collection tools.

**Observer training**

Introducing the methods for data collection with the Linköping Fire and Rescue Department included initial training sessions on the method and tools to be used. We then supported the fire ground commanders in on-the-job training to increase their skills. We also had frequent discussion with the personnel to take in their views on methods and tools.

**Data-collection methods and tools**

Supporting fire ground commanders in collecting data from real incidents requires tools that are very simple to use and that do not distract attention from

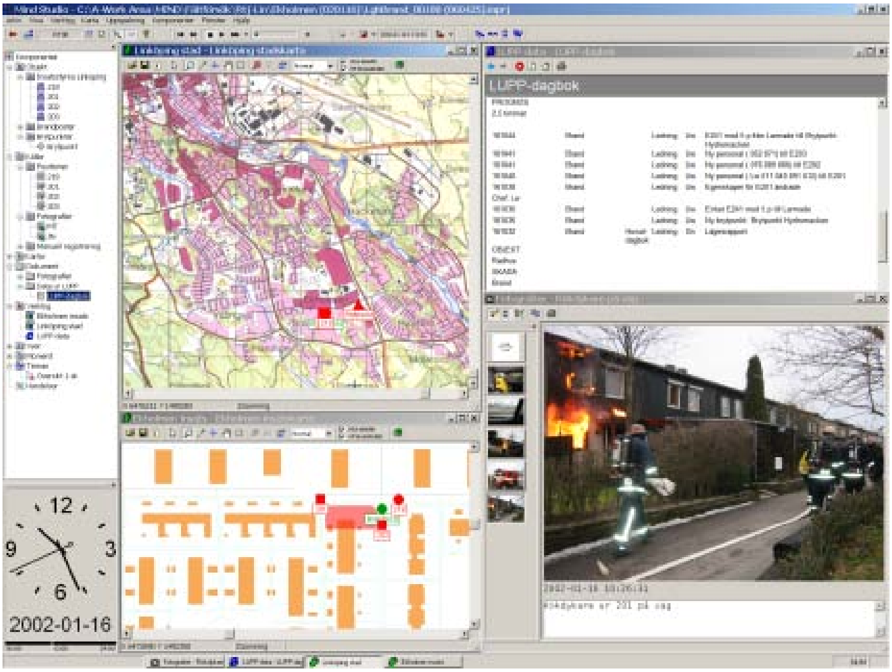



Figure 3.15: A screenshot from a MIND visualization of a live emergency response operation.

handling the incident. We used digital cameras with built in time stamping of pictures to support documentation of unit activities, scenario propagation and environmental information (Morin, Jenvald, Nygren, Axelsson, & Thorstensson, 2003). The digital camera was of a compact model with automatic settings for taking pictures. One press on the on/off button started the camera and then the observer could start taking pictures simply by pressing the shutter. We also introduced a post-mission photo processing tool for emptying pictures from the camera and transferring them to a database for later use in the mission history (Figure 3.15). The tool named PIX supported adding metadata to the pictures. Metadata consisted of mission ID, photographer ID, and comments on each picture. The method for supporting data collection with digital cameras also introduced weekly routines for holding the cameras ready for action by checking time synchronization and battery status. Also a routine for post-mission data processing was a part of the method.

**Reflections**

After using the methods for some time the data collected is becoming increasingly rich in content. The handling of the technical equipment is becoming routine and the improving insight and understanding of the value of a good dataset encourages thorough data collection. Initial findings indicate significant variation in data collection between individuals, but also indicate an increase in organizational use of recorded data as well as use of the data-collection tools.

## *3.6 Summary*

Having used a model-based data-collection approach in the examples above to support observers to collect data from distributed tactical operations in different settings with a training focus or in live operations, we can argue that observer expertise is a key to success. Observer expertise can be achieved by experience from using methods and tools or by focused training. In the beginning, training is the only way to bridge the experience gap and to support novice observers to fulfill their tasks of data collection. Training of novice observers must emphasize the overall purpose of collecting data and how that data will be used, as well as focusing on the underlying models and practical handling of the different tools supporting the observer to document data from the scenario. In one study we have seen a positive correspondence between the level of training and the results achieved from data collection.

In the examples above the most challenging scenario is to handle extras acting as casualties in emergency response exercises who are also acting as observers of their on progress in the chain of medical attendance. From an observer classification view they are almost always novice observer judged by both criterions: (1) knowledge of the domain; and (2) knowledge of being an observer. Furthermore, the models applied often contain dynamism and uncertainties, mostly regarding the casualty flow network model which is hard to clearly identify prior to being established in the ongoing exercise, and even then the model may be changed during the evolving course of events. Establishment of the chain of medical attendance is often an important training factor that must be handled by the trainees, and hence, definition of a viable model prior to the exercise is only possible in a principle description. One method to tackle this is to increase the level of training given to the extras, and to complement this with one experienced observer who documents how the trainees establish and change the model. During the exercise the experienced observer can also support the extras by giving information on how the setting is affected. This is a possible solution which we have not had resources to test, but we consider it fairly straightforward. However, training of extras from different schools or senior citizens is always hard to allocate time for, since they only are available for a very short time before the exercise starts. This is a problem that needs addressing more thoroughly in order to secure high quality data for subsequent use.

The models we have used and described above are all to be seen as potential components in a mission history from an exercise, or even a live operation. Depending on the scope and focus of the scenario it is possible to combine all models with different resolution to handle data from that particular area of interest. For example in force-on-force battle training there is always a component of C2 which can be of more or less interest depending on the focus of the exercise. Casualties are likely to occur as a consequence of combat actions, and if that is expected to be emphasized in the exercise then casualty flow network models can be included and the soldiers can be trained to be observers of their treatment. In this way all models, for example unit, platform, and actor, can be adapted to different resolution and be combined and aggregated differently to compose an adapted mission history.

Modeling chains of medical attention as casualty flow networks is a method that can also be adapted to other situations. A C2 process can be seen as a combination of communication events and a flow model with information. Hence, pieces of information in an intelligence process can be tracked in a flow model and the information activities at different sites or locations can be recorded in the same way as medical activities are recorded. In a general sense the flow network model is a logistics model that is applicable to all types of process tracking. Handling and transporting casualties in a military organisation is a part of the logistics functions. Most models are able to handle this in a general way, with a general model description that is adaptable to a multitude of different situations. This goes for the platform model we have implemented in the MIND system that can be fed with data from persons, cars, tanks, ships, helicopters, or other vehicles or objects. Furthermore, the information handling model with structured reports, as implemented in NBOT, is also general and adaptable by applying the same principles.

Returning to the examples above, we can argue that from an observer viewpoint, more expertise is needed in the more complex scenarios and models that are to be handled. The methods and tools admits the following and documenting for example, qualified medical treatment, or decision processes in higher echelon staffs in armed forces combined operations, but there is always a need for well informed and well trained observers to register relevant data from the processes.

# Chapter 4
# Summary of papers

Four papers are included in this thesis. The first three papers are peer-reviewed publications, and the fourth paper is to be submitted.

**Paper I:**
Thorstensson, M., Morin, M. & Jenvald, J. (1999). Monitoring and Visualisation Support for Management of Medical Resources in Mass-Casualty Incidents. In *Proceedings of The International Emergency Management Society's Sixth Annual Conference, TIEMS´99*, June 08–11, Delft, The Netherlands.

**Paper II:**
Thorstensson, M., Axelsson, A., Morin, M. & Jenvald, J. (2001). Monitoring and Analysis of Command-Post Communication in Rescue Operations, *Safety Science*, *39*(1–2), 51–60.

**Paper III:**
Thorstensson, M. (2002). Data Collection in Rescue Operations. In Proceedings of *The International Emergency Management Society's Ninth Annual Conference*, *TIEMS'2002*, pp. 136–147. May 14–17, Waterloo, ON, Canada.

**Paper IV:**
Thorstensson, M. (to be submitted). *Supporting Observers in the Field to Perform Model Based Data Collection*.

## 4.1 Paper I

This paper presents findings from our first study of emergency response operations and our initial results from modelling medical resources and using extras acting as casualties as observers of their own treatment. We combine a model of the casualty-flow network with the mission history to support AAR and in-depth analysis of management of medical resources. Our results inspired us to proceed on this path of research.

In the paper we present a way to model the chain of medical attendance in emergency response operations, and a method to use observers for data collection on casualty treatment and the use of medical resources. The purpose is to support monitoring and visualisation of the utilisation of medical resources. We describe the method of *timed checkpoints* (TCP) to support R&E of casualties through the chain of medical attendance. In TCP a model of the chain of medical attendance is constructed as a casualty-flow network with checkpoints at entries and exits of each identified aid station and assembly area. Whenever a casualty passes a checkpoint, the point of time is registered. The time stamps relating to one individual, together with supplementary information regarding the type and severity of the injury, form a timeline describing the treatment of that person. Timelines can be used both to compare the fate of different individuals and to analyse the flow of casualties throughout the operation. Furthermore, we describe the use of extras acting as casualties as observers of their own propagation through the chain of medical attendance, and we describe a straightforward observer tool. In this way we include the specific casualty-flow network model, together with the specific method for observer data collection, into the overall model of the unfolding operation, the mission history.

## 4.2 Paper II

This paper presents our work with integrating a model of C2 in the overall model of the operation. Here, we present a tool that became the first version of a computerised observer tool usable in command posts.

Command and control is not an end in itself. It has the purpose of taskforce performance optimisation and always takes place in the context of an overall operation. In this paper we present a method to model both internal work and internal and external communication in a command post staff by adding temporal data and classifications of content in staff member interaction and action. The resulting model is the *extended link analysis* (ELA) which we then include in the overall model of the unfolding operation, the mission history, to enable C2 analyses in operational contexts. We discuss the characteristics of staff work and C2, consequences of being out of sight from the area of operation, differences in capabilities in different units and relate that to the importance of communication aspects. Furthermore we describe an observer tool supporting ELA data collection in command post staffs. We show in detail how ELA can be implemented and discuss problems concerning using observers in command posts in different settings. We argue for the benefits of combining different specific high resolution models of objects and processes, with overall models of operations to enable R&E and analyses of assessment and decision making in realistic contexts.

## 4.3 Paper III

In this paper we describe how models and observer tools designed for use in training scenarios can be transferred to the domain of live operations. We present our initial findings from fielding prototype tools at a fire and rescue department for use real emergencies.

Live operations impose limitations on using observers as sources for MBDC. In this paper we discuss possibilities and limitations on transferring models and methods from the training domain to live emergency response operations in order to support R&E and organizational learning from experiences. We characterise differences and similarities between exercises and real scenarios and the implications for data collection opportunities. Examples of differences are the presence of real life stress and danger, no control of the emergency and the absence of instructors. A consequence of the slimmed organisations of today is the impossibility to use specifically dedicated observers with no other task to perform. In live operations all personnel need to work with the evolving emergency. However, key personnel can be given a sub-task to collect data for specific purposes. We also define crucial operational factors that affect the overall taskforce performance and, thus needs to be emphasised in the modelling phase to enable MBDC. Most of these factors are equally important to emphasise in training scenarios to enable valid conclusions from AAR and in-depth analyses of procedures and performance. We conclude the paper by presenting results on preliminary studies together with the Linköping Fire Department, who apply some of the methods and tools for MBDC in live operations.

## 4.4 Paper IV

This paper presents the development of methods and tools for MBDC based on our previous research, and taking advantage of mobile IT-solutions not available at affordable costs when we did our early work on observer tools. Here we describe a computer tool that can be adapted to support observers in different settings to provide high-quality data in short time frames at low costs.

Humans in the field have always been, and will certainly continue to be, important sources of information for different purposes. In this paper we present methods and tools supporting humans in the field to act as observers and to perform MBDC. The method is derived from the overall methodology of R&E but is adapted to focus on the use of observers as data sources. The aim is to enhance observer capability and increase the quality and amount of data collected. Furthermore, we present a tool that implements MBDC to support observers in the field to report data – the Network Based Observer Tool (NBOT). We present a system overview, the specific observer tool and corresponding tools for presenting and analysing data. The NBOT system can be used alone for handling observer data solely, or it can be used for supporting observers to act as a specific data source in the R&E approach, to support collecting data for compilation with other data sources to form a mission history for use in the framework of, for example MIND or F-REX.

We also present our findings from three different NBOT use cases. Our results indicate great potential for implementing MBDC in computer devices that can be adapted to be used by observers in different settings, from office-like experimental settings to harsh operational conditions in the field. One key is to make sure that NBOT is implemented in a device that can support work in the environment where the observer will be.

## 4.5 Additional publications by the author

### Peer-reviewed publications

Morin, M., Jenvald, J., Worm, A. & Thorstensson, M. (1998). Instrumented Force-on-Force Battle Training in Sweden: Lessons Learned during the First Five Years. In *Proceedings of The 9$^{th}$ International Training and Education Conference, ITEC98*, April 28–30, Lausanne, Switzerland. Available as FOA-R--98-00768-505--SE.

Jenvald, J., Thorstensson, M., Axelsson, M. & Morin, M. (1999). GIS Supporting Collaborative Mission Training for Rescue Operations in Hazardous Environments. In *Proceedings of The 2nd Conference on The Applications of Remote Sensing and GIS for Disaster Management*, January 19–21, Washington DC, USA. Available as FOA-R--99-01042-505--SE.

Thorstensson, M., Morin, M. & Jenvald, J. (1999). Extending a Battle Training Instrumentation System to Support Emergency Response Training. In *Proceedings of The 10th International Training and Education Conference, ITEC99*, April 13–15, The Hague, The Netherlands.

Thorstensson, M., Axelsson, M., Morin, M. & Jenvald, J. (2000). Monitoring and Analysis of Command-Post Communication in Rescue Operations. In *Proceedings of The International Emergency Management Society's seventh annual Conference, TIEMS'2000*, May 16–19, Orlando, Florida, USA.

Morin, M., Jenvald, J. & Thorstensson, M. (2000). Computer-Supported Visualization of Rescue Operations, *Safety Science, 35*(1–3), 3–27.

Thorstensson, M., Axelsson, M., Morin, M. & Jenvald, J. (2001). Computer-Supported Monitoring of Command Post Communication in Taskforce Operations: A Cognitive Systems Approach. In *Proceedings of The 12th International Training and Education Conference, ITEC'2001*, April 24–26, Lille, France.

Thorstensson, M., Tingland, B., Björneberg, A. & Tirmén-Carelius, M. (2001). Visualization of an Interagency Exercise in the Stockholm Underground. In Proceedings of *The International Emergency Management Society´s Eighth Annual Conference*, *TIEMS'2001,* June 19–22, Oslo, Norway.

Jenvald, J., Crissey, M. J., Morin, M. & Thorstensson, M. (2002). Training Novice Observers to Monitor Simulation Exercises. In *Proceedings of the 13th International Training and Education Conference, ITEC'2002,* Lille, France.

Thorstensson, M. & Wikberg, P. (2002). Model Based Data Collection in the Design and Analysis of Complex Military Systems. In *Proceedings of the 13th International Training and Education Conference, ITEC'2002,* Lille, France.

Crissey, M. J., Thorstensson, M., Morin, M. & Jenvald, J. (2002). How Modeling and Simulation Can Support MEDEVAC Training. In *Proceedings of the First Swedish-American Workshop on Modeling and Simulation, SAWMAS-2002*, pp 41–48, October 30-31, Orlando, FL, USA.

Morin, M., Crissey, M. J., Jenvald, J. & Thorstensson, M. (2003). Joint Efforts to Promote Multiple Stages of MEDEVAC Training. In *Proceedings of The 14th International Training and Education Conference, ITEC'2003*, April 29–May 1, London, UK.

Wikberg, P. & Thorstensson, M. (2003). Rapid Evaluation of Complex and Distributed Systems. In *Proceedings of 11th European Congress on Work and Organizational Psychology*, May 14–17, Lisbon, Portugal.

Morin, M., Jenvald, J., Nygren, A., Axelsson, M. & Thorstensson, M. (2003). A study of first responders' use of digital cameras for documenting rescue operations for debriefing and analysis. In *Proceedings of The International Emergency Management Society's Tenth Annual Conference, TIEMS'2003*, June 3–6, Sophia Antipolis, France.

Van Berlo, M. P. W., Thorstensson, M., Schaafstal, A. M., Morin, M., Jenvald, J. & Schraagen, J. M. C. (2003). Improving learning from emergency management training: Sweden and The Netherlands are teaming up. In *Proceedings of The International Emergency Management Society's Tenth Annual Conference, TIEMS'2003*, June 3–6, Sophia Antipolis, France.

Wikberg, P., Albinsson, P.-A., Thorstensson, M., Stjernberger, J. & Holmström, H. (2004). Methodological Aspects of Development and Evaluation of Military Command and Control Systems. In *Proceedings of 28th International Congress of Psychology*, pp. 263, August 8–13, Beijing, China.

Albinsson, P.-A., Morin, M. & Thorstensson, M. (2004). Managing metadata in collaborative command and control analysis. In *Proceedings of The 48th Annual Meeting of the Human Factors and Ergonomics Society*, September 20–24, New Orleans, USA.

**Other publications**

Thorstensson, M. (1998). *Development of Methods for Support of $C^3I$ Systems Analysis.* Methodology Report FOA-R--98-00837-503--SE, Defence Research Establishment, Linköping, Sweden.

Jenvald, J., Rejnus, L., Morin, M. & Thorstensson, M. (1998). *Computer-supported Assessment of Emergency Planning for Rescue Operations*. User report FOA-R--98-00910-505--SE, Defence Research Establishment, Linköping, Sweden.

Thorstensson, M., Morin, M., Jenvald, J. & Axelsson, M. (1999). *Initial Studies Concerning Reconstruction and Analyses of Command and Control in Future Naval Warfare.* Activity Report FOA-R--99-01240-505--SE. Defence Research Establishment, Linköping, Sweden.

Morin, M., Thorstensson, M. & Fransson, J. (2001). *Interactive Adaptive Ground-sensor Networks in a User Perspective.* Scientific report FOI-R--0343--SE. Swedish Defence Research Agency, Linköping, Sweden.

Thorstensson, M., Jenvald, J. & Morin, M. (2002). *Modeling and Visualisation of Naval Warfare Units* (in Swedish). Technical report FOI-R--0524--SE. Swedish Defence Research Agency, Linköping, Sweden.

Morin, M., Jenvald, J. & Thorstensson, M. (2003). *Methods for developing future defence forces* (in Swedish). User report FOI-R--1064--SE. Swedish Defence Research Agency, Linköping, Sweden.

Wikberg, P., Albinsson, P.-A., Danielsson, T., Holmström, H., Stjernberger, J., Thorstensson, M. & Östensson, M. (2003). *Methodological Aspects of Development and Evaluation of Military Command and Control Systems*. Scientific report FOI-R--1034--SE. Swedish Defence Research Agency, Linköping, Sweden.

Morin, M., Jenvald, J. & Thorstensson, M. (2004). *Training First Responders for Public Safety Using Modeling, Simulation and Visualization*, Presented at SimSafe-2004, June 15–17, Karlskoga, Sweden. Available as FOI-S--1315--SE.

Wikberg, P., Andersson, J., Berggren, J., Hedström, J., Lindoff, J., Rencrantz, C., Thorstensson, M. & Holmström, H. (2004). *Simulated task environments in commercial PC-games as test beds* (in Swedish). Methodology Report FOI-R--1416--SE. Swedish Defence Research Agency, Linköping, Sweden.

Thorstensson, M. & Hasewinkel, H. (2005). *OMF of air mobile battalion during ASÖ-2005* (in Swedish). Base data report FOI-R--1667--SE. Swedish Defence Research Agency, Linköping, Sweden.

Wikberg, P., Albinsson, P.-A., Andersson, D., Danielsson, T., Holmström, H., Johansson, M., Thorstensson, M. & Wulff, M.-E. (2005). *Methodological tools and procedures for experimentation in C2 system development—Concept development and experimentation in theory and practice*. Scientific report FOI-R--1773--SE. Swedish Defence Research Agency, Linköping, Sweden.

Thorstensson, M. & Hasewinkel, H. (2006). *OMF of air mobile battalion during Combined Challange-2006* (in Swedish). Base data report. FOI-R--1982--SE. Swedish Defence Research Agency, Linköping, Sweden.

Thorstensson, M., Albinsson, P.-A., Johansson, M. & Andersson, D. (2006). *MARULK 2006—Methods for developing functions, units and systems.* User Report FOI-R--2188--SE. Swedish Defence Research Agency, Linköping, Sweden.

Thorstensson, M., Johansson, M., Andersson, D. & Albinsson, P.-A. (2007). *Improved outcome of exercises—Methods and tools for training and evaluation at the Swedish Rescue Services school at Sandö*. User Report FOI-R--2305--SE. Swedish Defence Research Agency, Linköping, Sweden.

# Chapter 5
# Discussion

In this chapter we will discuss our findings regarding methods and tools for model-based data collection (MBDC) in distributed tactical operations (DTO), and aspects on generalizing our results to other domains and operational circumstances as well as other areas of application.

## 5.1 Methodology

The methodology proposed in this thesis stems from the overall R&E methodology that has been subjected to generalization in previous work by Jenvald (1999) and Morin (2002). The methodology suggested for using observers for MBDC in DTO is therefore general and applicable to different domains implementing a variety of tools. We have tested the methodology with confirming results when supporting observers to collect data in four different settings: (1) computer-supported taskforce training, (2) the chain of medical attendance in exercises with emergency response to mass-casualty incidents, (3) command-and-control processes in different domains and settings, and (4) in live emergency response operations. We believe the methodology described in Paper IV is usable on the defined level but that there is room for improvement, most of all in the content of each step in the process. Future enhancements in M&S, human factors (HF) and technology will further improve implementation of the method.

Behavioural research on operators and commanders in DTO is another area where cooperation could be mutually beneficial, particularly if the overall R&E approach is included to support handling massive datasets from experiments. Behavioural scientists use observers extensively to collect and handle data from experiments, either during ongoing experiments or after experiments that have been documented with video or sound recording. Here are opportunities to extend MBDC to also include statistical methods for inter-observer reliability (Cohen, 1960) when judging events and episodes. Furthermore, modelling of human behaviour and communication could be subjected to inter-disciplinary research with behavioural scientists and computer scientists to support data collection and visualization. A human behaviour that can be of interest to include is how humans today use available communication technology to achieve common goals (Rheingold, 2003).

## 5.2 Tools

Computers and communication equipment continue to improve at a rapid pace and the integration between them and other electronic devices follows the same pattern. This development is an advantage from an observer-tool perspective when taking advantage of smaller, more powerful, reliable handheld devices with longer uptime. However, there is still a need to adapt and develop a tool concept that really supports the observer collecting adequate data. Modern cellular telephones with open operative systems and support for custom applications open up new possibilities. Utilization of IT can meet the needs of a human-machine system for data collection straightforwardly by implementing the existing NBOT on a more powerful platform. Nevertheless, we believe that results would be improved by taking advantage of behavioural research to improve human performance, and of research on computers and logics to improve the technical support tools.

Ubiquitous computing (Weiser, 1994) is a research area of computer systems integrated in the environment and context that people work in, and in the artefacts that they use. Here, we see possibilities to enhance observer performance by utilizing research to improve foremost tools, but perhaps methods and models also. Integrating computers and other artefacts, for example maps, by using the Kartago approach (Sylverberg, Berglund, Kristensson & Leifler, 2007) to handling spatial information by combining cellular telephones and pen-based Anoto technology, by Anoto Group AB (www.anoto.com), could be an extension of the observer data-collection toolbox.

## 5.3 Future training concepts

Computer-supported taskforce training is an established concept that we argue can be improved in two ways by further development of MBDC by observers:

1. *Enhancing information content* in the mission histories, by collecting more mission relevant data from the ongoing exercise. This improvement is valid for both observers and automated data sources, but observer data collection is the most under-exploited and can be most cost efficient to improve.
2. *Augmenting knowledge-transfer (KT)* in the R&E process. KT would benefit strongly from complementing the mission history with data collected from the AAR and PMA. Improving the mission history with the actors' own thoughts, reflections, analyses, and conclusions of their own performance, would significantly improve the possibility for others to subsequently reflect on the outcome of the recorded operation. That data is preferably collected using observers implementing MBDC.

Enhancing the mission history with data from all steps in the R&E process with the purpose of improved utilization in all subsequent steps, we believe would be very beneficial for capability improvement in all domains. Armed forces and emergency-response organisations face strained budgets and spend more time in operations rather than in readiness, which will conflict with training opportunities and affect how training can be executed. High costs will reduce the numbers of large-scale exercises for emergency-response organisations, and spending time on missions will reduce exercise opportunities for military units. To avoid degrading capabilities, new training concepts are required. One possible solution is to increase utilization of computer-supported taskforce training to improve the training effects of each single exercise. Applying the R&E process, with improved MBDC, with a training focus would enhance the outcome of each training occasion.

Another training opportunity is to learn more from live operations, which is relevant for both military units and emergency-response organisations. This is much strived for and different approaches have been tested to improve learning from experience in different forms of lessons-learned (LL) tools or databases handling lessons identified (Lindgren, Almén & Rindstål, 1998; Törne, Albinsson, Bengtsson & Andersson, 2008; Törne & Sparf, 2008). We believe that these tools could benefit to a large extent by taking advantage of the R&E approach. However, constructing mission histories from live operations will place certain demands on data collection (Paper III), which is also a main objective with the increased use of computerized C2 systems. We argue that there is a coordination possibility in the development of training systems and C2 systems which we will discuss below. Furthermore, the new areas of operations for armed forces, facing new threats and corresponding needs for new capabilities and operational procedures, often as a quick reaction to an adversary's new inventions, necessitates new tools for supporting a continuous organizational learning process. These factors increase the need for continuous data collection from all live operations, even though it is not possible to use dedicated observers, due to the dangerous environments and factors explained in Chapter 3.4. Operators need to observe and collect adequate data to enable continuous post-mission reflections and adaptation of tactics to new operational circumstances and environmental aspects. Complicated cultural and historical factors must be considered. Such factors affect how one can move and walk, and who one can address and how. Different models are required for judging various aspects in relations: male-female; older-younger; officer-NCO. Development of MBDC in this area is one way to improve R&E for continuous capability development in operational organizations.

## 5.4 Towards integration of MBDC in C2 systems

Today's command-and-control systems and training systems are strictly separated. Even though in some cases C2 system information is logged in order to be included in the training system mission history, this is seldom possible. We believe this separation is counter-productive from a capability development perspective and we argue for integration of training and R&E functionality in future C2 systems. Information needed for building a comprehensive tactical overview in the replay of a mission history in a training system is very likely to be similar to information needed by commanders in the evolving operation. Also, the R&E functionality present in a training system will be of great value in a C2 system for doing follow-ups of missions performed, and subsequent operational analyses. Also, learning from real operations, as discussed above, would be made straightforward.

Even if training systems and C2 systems integration is a bigger challenge for the future, improvement of C2 systems information content can be made for existing systems by straightforward extensions using MBDC by observers. C2 systems today mostly handle unit models and processes based on data from technical systems, for example as iconic representations on a map where unit positions stems from global positioning system (GPS) tracking. Some C2 systems have enhanced the models included by introducing logistics C2 functionality to keep track of system parameters, such as fuel, weapons, and engine status for vehicles and units, but these data are almost exclusively logged by technical sensors. Data collected by personnel are almost exclusively handled as text annotations with no or little connection to any models. We see a great potential for improving information content in C2 systems by applying MBDC connecting human-collected data to models, enabling computerized representation, manipulation and analyzes support. However, more research is needed to develop feasible models, methods and adequate tools for data collection, although we believe that MBDC and the work described in this thesis can contribute as a starting point.

## 5.5 New domains

A specific military domain that can benefit in the short term from MBDC by observers is intelligence, surveillance, target acquisition and reconnaissance (ISTAR). In modern military operations, ISTAR follows mainly two paths: (1) general intelligence-information gathering relying to a large extent on human intelligence (HUMINT) for collecting data, which is people reporting observations from the field in text format. Analysts then use this data to build operational pictures of the area of operation; (2) target acquisition processes mainly use technical systems that connect specific observers to specific weapon systems with little or no information sharing to the remainder of the ISTAR functions. We believe that implementation of MBDC and tools to support operators in the field, as well as tools to support analysts, could connect those two paths and enhance the overall ISTAR capability. Of course, in the longer term we argue for integration of these ISTAR specific tools in the future C2 systems with integrated R&E and training capability.

Another domain that can make use of observers' MBDC is geographical information systems (GIS) where field operators currently work with paper protocols or laptop versions of the stationary systems. GIS are powerful tools to support, for example humanitarian relief operations dealing with epidemic outbreaks of cholera. Geographical analyzes of water resources, such as wells, rivers, and groundwater movement, together with socio-cultural movements and behaviour can greatly support epidemic mitigation and societal recovery. Tools supporting substantiated decisions based on extended medical sampling and quarantine areas would be of great use to the personnel handling the acute situation in the field. The functionality and precision in these tools depends on adequate data both on the higher level, such as ground water table distribution over time, and also low level short term data on individual social behavior over the last few days. We have identified the need for supporting operators in the field to observe and report data needed to perform geo-referencing of events, artifacts, and processes. We tested MBDC to meet preliminary requirements in one version of NBOT that was used by UN observers in Sudan acting as environmental and health inspectors. The initial trials indicated that MBDC in NBOT was a feasible start (Paper IV), but more research is needed for reaching an integrated GIS where geo-referencing support tools for field use have a defined interface to the dense databases included in powerful GIS applications.

## 5.6 Future work

Improved training of medical resources, either for the emergency response community or for the military, can be accomplished by complementing NBOT with a patient model that supports the extras acting as a casualty to improve realism in simulating the state of their health. The health simulation model could be connected to the reporting of medical treatments to support monitoring and evaluation of the medical personnel. One possible way to proceed would be to combine the research on NBOT and the use of extras for acting as casualties in live exercises with the research on patient mannequins for medical simulation (Rajput, Tu, Goldiez & Petty, 1997; Pettit, Goldiez, Petty, Rajput & Tu, 1998; Rajput & Petty, 1999). Initial investigations on these possibilities were made by Crissey, Morin & Jenvald (2001). We believe further improvement can be made and that training and evaluation of medical resources would benefit from a combination of using humans acting as casualties and mannequins for patient propagation through the system of medical attendance. Data transfers between patient simulators (mannequins) and tools supporting humans acting as casualties could improve realism in exercises. Moreover, a tested and verified system for training medical resources could also support system verification and validation of operational organizations, systems or personnel in experiments or field trials.

Data collection in research or analysis settings can also be improved by implementing MBDC and NBOT. Further improvement on the NBOT system would simplify application of MBDC for standalone use and single researchers or analysts not utilizing an overall R&E system could benefit from the MBDC approach. However, improved tools for post-mission data handling would simplify use and support data manipulation and analysis.

Formalized research studies and evaluations of MBDC and NBOT would improve the contribution to the body of research, and would be suitable to proceed with in collaboration with the Swedish Armed Forces Development Centre for Future C2 Systems (FM UtvC). NBOT could be implemented on different data-collection devices and be tested in different experimentation settings with variations in personnel, training, models and communication to begin with. This would enable factorial studies on different aspects of MBDC by observers and NBOT.

Further research on improvement of MBDC, as well as NBOT, would benefit from utilizing the possibilities of modern technology. We believe there is room for improvement of both: (1) computers and logic by computer scientists; and (2) of the human contribution by behavioral scientists.

# Chapter 6
# Conclusion

Humans in the field are, and will always be, an important source of information for all participants in distributed tactical operations and similar activities. The individuals closest to events and processes are the ones who can sense and feel what actually happens and who have an idea of the underlying causes. We have surveyed and described the area of human observers of collaborative work sessions and have implemented model-based data collection using observers. Furthermore, we have developed methods, models and tools and evaluated the approach in four different domains: (1) military force-on-force battle training, (2) training medical resources for mass-casualty incidents, (3) training command and control in distributed tactical operations, and (4) live emergency response operations. In addition, we have implemented a technical tool for supporting observers in the field and reported preliminary results on their use.

The main contribution of this thesis is the systematic description of the model-based approach to using observers for model-based data collection. Methodological aspects in using humans to collect data to be used in information systems, and also modelling aspects for phenomena occurring in emergency response and communication areas contribute to the body of research. We have described a general methodology for using human observers to collect adequate data for use in information systems. We have also described a method to collect data on the chain of medical attendance in exercises. The models we have presented are: a model for the chain of medical attendance in mass-casualty incidents where we also introduced timed checkpoints (TCP); and we have extended the model of link analysis to comprise dynamic internal workgroup communication. To support observers collecting data on the items above, or other data from other settings, we have developed a general tool—the NBOT tool framework.

We conclude that applying a methodological approach and implementing model-based data collection to support observers in distributed work sessions enhance the quality and quantity of the data acquired. We believe the results presented in this thesis can be useful for researchers collecting data from experiments in distributed settings, and practitioners using observers to improve information in training systems or other information systems.

# Chapter 7
# References


Albinsson, P.-A. (2004). *Interacting with comand and control systems: Tools for operators and designers*. Linköping Studies in Science and Technology, Thesis 1132, Linköping, Sweden: Linköpings universitet.

Albinsson, P.-A. & Morin, M. (2002). Visual exploration of communication in command and control. In *Proceedings of the 6th International Conference on Information Visualization (IV 02),* July 10–12, London, UK.

Albinsson, P.-A., Morin, M. & Thorstensson, M. (2004). Managing metadata in collaborative command and control analysis. In *Proceedings of The 48th Annual Meeting of the Human Factors and Ergonomics Society*, September 20–24, New Orleans, Louisiana, USA.

Allen, R. B. (1997). Mental Models and User Models. In M. Helander, T. K. Landauer & p. Prabhu (Eds.), *Handbook of Human-Computer Interaction, 2nd edition,* Amsterdam: Elsevier.

Andersson, D., Pilemalm, S. & Hallberg, N. (2008). Evaluation of crisis management operations using Reconstruction and Exploration. In *Proceedings of the 5th International ISCRAM Conference*, May 4–7, Washington, DC, USA.

Andersson, L. (2001). *Military leadership "when the stakes are high". Swedish military leadership focusing on peacekeeping operations* (in Swedish). Stockholm Studies in Educational Sciences, Dissertation No. 39, Stockholm, Sweden: Stockholms universitet.

Andersson, L. & Jenvald, J. (2007). We worked together in Caglavica. In *Proceedings of the Nordic Leadership Conference NOKA 2007*, June 12–15, the Military Academy, National Defence University, Santhamina, Finland.

Axelsson, M. (1997). *Computer-aided Time-stamped Sound Recoding* (in Swedish). M. Sc. Thesis LiTH-IDA-Ex-97/72, Linköping, Sweden: Linköpings universitet.

Blomgren, E. (2007). *Caglavica 17 mars 2007. Sex militära chefer berättar om ett upplopp i Kosovo* (in Swedish). Swedish Defence College, Stockholm, Sweden.

Bowden, M. (1999). *Black Hawk Down: A Story of Modern War*. New York: Penguin Books.

Brehmer, B. & Svenmarck, P. (1995). Distributed decision making in dynamic environments: Time scales and architectures of decision making. In J.-P. Caverni, M. Bar-Hillel, F. H. Barron & H. Jungermann (Eds.), *Contributions to Decision Making.* Amsterdam, Elsevier.

Chapanis, A. (1959). *Research Techniques in Human Engineering.* Baltimore: John Hopkins Press.

Checkland, P. (1981). *Systems thinking, systems practice.* Chichester: Wiley.

Checkland, P. (1991). From framework through experience to learning: the essential nature of action research. In H.-E. Nissen, H. K. Klein & R. Hirschheim (Eds.), *Information systems research: Contemporary approaches and emergent traditions,* pp. 397–403, Amsterdam: Elsevier.

Checkland, P. & Holwell, S. (1998). Action research: Its nature and validity. *Systematic Practice and Action Research, 11*(1), 9–21.

Cohen, J. (1960). A Coefficient of Agreement for Nominal Scales. *Educational and Psychological Measurement, 20*, 37–46.

Crissey, M. J., Morin, M. & Jenvald, J. (2001). Computer-Supported Emergency Response Training: Observations from a Field Exercise. In *Proceedings of The 12th International Training and Education Conference, ITEC 2001*, pp. 462–476, April 24–26, Lille, France.

Flanagan, J. C. (1954). The Critical Incident Technique. *Psychological Bulletin, 51*(1), 327–358.

Fredholm, L. (1996). Decision Making in Fire and Rescue Operations. *Journal of the Fire Service College, 2*(2).

Hiemstra, A. M. F., van Berlo, M. P. W. & Hoekstra, W. (2004). MOPED—A Mobile Evaluation System to Support Observers During Distributed Team Training. In *Proceedings of the 26th Interservice / Industry Training Simulation and Education Conference*, Orlando, Florida, USA.

Jenvald, J. (1996). *Simulation and Data Collection in Battle Training*. Linköping Studies in Science and Technology, Thesis 567, Linköping, Sweden: Linköpings universitet.

Jenvald, J. (1999). *Methods and Tools in Computer-Supported Taskforce Training*. Linköping Studies in Science and Technology, Dissertation No. 598, Linköping, Sweden: Linköpings universitet.

Jenvald, J. & Morin, M. (1997). Multiple Use of Information from Force-on-Force Battle Training. In *Proceedings of The 8th International Training and Education Conference, ITEC'97,* pp. 637–647, April 22–27, Lausanne, Switzerland.

Jenvald, J., Crissey, M. J., Morin, M. & Thorstensson, M. (2002). Training Novice Observers to Monitor Simulation Exercises. In *Proceedings of the 13th International Training and Education Conference, ITEC 2002*, pp. 68–78, April 9–11, Lille, France.

Jenvald, J., Morin, M., Worm, A. & Örnberg, G. (1996). *MIND—An Instrument for Assessment, Development and Training of Armed Forces* (in Swedish). Technical Report FOA-R--96-00351-3.8--SE, Defence Research Establishment, Linköping Sweden.

Jenvald, J., Rejnus, L., Morin, M. & Thorstensson, M. (1998). *Computer-supported Assessment of Emergency Planning for Rescue Operations*. User report FOA-R--98-00910-505--SE, Defence Research Establishment, Linköping, Sweden.

Lindgren, F., Almén, A. & Rindstål, P. (1998). *Lessons Learned in International Operations* (in Swedish). Methodology report FOA-R--98-00928-201--SE, Defence Research Establishment, Stockholm, Sweden.

Ljung, L. & Glad, T. (1991). *Modellbygge och simulering* (in Swedish). Lund, Sweden: Studentlitteratur.

Morin, M. (2001). MIND—Methods and Tools for Visualization of Rescue Operations. In *Proceedings of The International Emergency Management Society´s Eighth Annual Conference, TIEMS'2001*, June 19–22, Oslo, Norway.

Morin, M. (2002). *Multimedia Representation of Distributed Tactical Operations*. Linköping Studies in Science and Technology, Dissertation No. 771, Linköping, Sweden: Linköpings universitet.

Morin, M. & Albinsson, P.-A. (2005). Exploration and context in communication analysis. In C. Bowers, E. Salas & F. Jentsch (eds.), *Creating High-Tech Teams: Practical Guidance on Work Performance and Technology*, pp. 89–112, Washington DC: APA Press.

Morin, M., Jenvald, J., Nygren, A., Axelsson, M. & Thorstensson, M. (2003). A study of first responders' use of digital cameras for documenting rescue operations for debriefing and analysis. In *Proceedings of The International Emergency Management Society's Tenth Annual Conference, TIEMS'2003,* June 3–6, Sophia Antipolis, France.

Morin, M., Jenvald, J. & Thorstensson, M. (2000). Computer-Supported Visualization of Rescue Operations, *Safety Science, 35*(1–3), 3–27.

Morin, M., Jenvald, J. & Thorstensson, M. (2003). *Methods for developing future defence forces*. User report FOI-R--1064--SE. Swedish Defence Research Agency, Linköping, Sweden.

Morin, M. & Thorstensson, M. (2000). 346 flyktingar flydde undan terrorn när marinen övade i Blekinge (in Swedish). *FOA-tidningen 6*, December, 10–11.

Morrison, J. E. & Meliza, L. L. (1999). *Foundation of the after action review process.* Special report 42, Alexandria: United States Army Research Institute for the Behavioral and Social Sciences.

Pettit, M. B., Goldiez, B. F., Petty, M. D., Rajput, S. & Tu, H. K. (1998). Combat Trauma Patient Simulator. In *Proceedings of the 1998 Spring Simulation Interoperability Workshop*, March 9–13, Orlando FL USA.

Rajput, S. & Petty, M. D. (1999). *Combat Trauma Patient Simulation Phase 2 Architecture*, Institute for Simulation and Training, Orlando, FL, USA.

Rajput, S., Tu, H. K., Goldiez, B. F. & Petty, M. D. (1997). *Combat Trauma Patient Simulation Phase 1 Final Report*, IST-CR-97-28, Institute for Simulation and Training, Orlando, FL, USA.

Rankin, W. J., Gentner, F. C. & Crissey, M. J. (1995). After action review and debriefing methods: Technique and technology. In *Proceedings of the 17th Interservice / Industry Training Systems and Education Conference*, pp. 252–261, Albuquerque, New Mexico, USA.

Raths, J. (1987). Enhancing Understanding Through Debriefing. *Educational Leadership, 45(2),* 24–27.

Rheingold, H. (2003). *Smart Mobs: The Next Social Revolution.* Reading, MA: Perseus Publishing.

Rejnus, L., Jenvald, J. & Morin, M. (1998). Assessment of emergency Planning based on analysis of empirical data. In *Proceedings of the Sixth International Symposium on Protection against Chemical and Biological Warfare Agents, CBWPS,* pp. 377–383, Stockholm, Sweden.

Rouse, W. B., Cannon-Bowers, J. A. & Salas, E. (1992). The role of mental models in team performance in complex systems. *IEEE Transactions on Systems, Man, and Cybernetics, 22*(6), 1296–1308.

Salas, E., Dickinson, T. L., Converse, S. A. & Tannenbaum, S. I. (Eds.) (1992). *Towards an understanding of team performance and training.* Norwood, New Jersey: Wiley.

Sanders, M. S. & McCormick, E. J. (1992). *Human Factors in Engineering and Design.* London, UK: McGraw-Hill.

Schön, D. A. (1983). The reflective practitioner: How professionals think in action. New York: Basic Books.

Seidenman, P. (1998). New realism for brigade-level training. *Jane's International Defense Review, 31*(10), 34–35.

SoldF (1986). *Soldaten i Fält (SoldF)* [Swedish Armed Forces Field Manual] (in Swedish). M7742-10 00 01. Försvarets läromedelscentral (FLC), Stockholm, Sweden.

Sylverberg, T., Berglund, E., Kristensson, O. & Leifler, O. (1997). Drawing on Paper Maps: Robust On-line Symbol Recognition of Handwritten NATO Symbols using Digital Pen and Mobile Phone. In *Proceedings of The Second International Conference on Pervasive Computing and Applications (ICPCA07),* July 26–27, Birmingham, UK.

Thorstensson, M. (1997). *Structured reports for manual observations in team training*. M. Sc. Thesis LiTH-IDA-Ex-97/64, Linköping, Sweden: Linköpings universitet.

Thorstensson, M. (1998). *Development of Methods for Support of $C^3I$ Systems Analysis.* Methodology Report FOA-R--98-00837-503--SE, Defence Research Establishment, Linköping, Sweden.

Thorstensson, M. (2002). Data Collection in Rescue Operations. In Proceedings of *The International Emergency Management Society´s Ninth Annual Conference*, *TIEMS'2002*, pp. 136–147. May 14–17, Waterloo, ON, Canada.

Thorstensson, M. (2003). *Rapportering av uppföljning av sjukvårdsenheter vid samverkansövning Daniela 2002-12-11* (in Swedish). FOI Memo 03-495 Swedish Defence Research Agency, Linköping, Sweden.

Thorstensson, M., Axelsson, A., Morin, M. & Jenvald, J. (2001). Monitoring and Analysis of Command-Post Communication in Rescue Operations, *Safety Science*, *39*(1–2), 51–60.

Thorstensson, M., Johansson, M., Andersson, D. & Albinsson, P.-A. (2007). *Improved outcome of exercises - Methods and tools for training and evaluation at the Swedish Rescue Services school at Sandö*. User Report FOI-R--2305--SE. Swedish Defence Research Agency, Linköping, Sweden.

Thorstensson, M., Morin, M. & Jenvald, J. (1999). Monitoring and Visualisation Support for Management of Medical Resources in Mass-Casualty Incidents. In *Proceedings of The International Emergency Management Society's Sixth Annual Conference - TIEMS´99*, June 08–11, Delft, The Netherlands.

Thorstensson, M., Tingland, B., Björneberg, A. & Tirmén-Carelius, M. (2001). Visualization of an Interagency Exercise in the Stockholm Underground. In Proceedings of *The International Emergency Management Society´s Eighth Annual Conference*, *TIEMS'2001*, June 19–22, Oslo, Norway.

Törne, A., Albinsson, P. -A., Bengtson, J. & Andersson, D. (2008). *KUPAL—Funktionsbeskrivning v 1.0* (in Swedish). FOI Memo 2459, Swedish Defence Research Agency, Linköping, Sweden.

Törne, A. & Sparf, M. (2008). *KUPAL—Systembeskrivning v 3.0* (in Swedish). FOI Memo 2458, Swedish Defence Research Agency, Linköping, Sweden.

van Berlo, M. P. W., Hiemstra, A. M. F. & Hoekstra, W. (2003). Supporting Observers During Distributed Team Training—The Development of a Mobile Evaluation System. In *Proceedings of the NATO Symposium on Advanced Technologies for Military Training*, October 13–15, Genoa, Italy.

Weiser, M. (1994). The world is not a desktop. *Interactions, January,* 7–8.

West, D. & Stansfield, M. H. (2001). Structuring action and reflection in information systems action research studies using Checkland's FMA model. *Systematic Practice and Action Research, 14*(3), 251–281.

Wikberg, P., Albinsson, P.-A., Andersson, D., Danielsson, T. Holmström, H., Johansson, M., Thorstensson, M. & Wulff, M.-E. (2005). *Methodological tools and procedures for experimentation in C2 system development—Concept development and experimentation in theory and practice.* Scientific Report FOI-R--1773--SE. Swedish Defence Research Agency, Linköping, Sweden.

Williams, H. (2008). A tale of many cities: demands of urban warfare fuel CQB skills. *Jane's International Defence Review, 41*(October), 51–53.

LINKÖPINGS UNIVERSITET

**Avdelning, institution**
Division, department

Institutionen för datavetenskap

Department of Computer and Information Science

**Datum**
Date

2008-12-18

**Språk**
Language

- [ ] Svenska/Swedish
- [X] Engelska/English
- [ ] ___________

**Rapporttyp**
Report category

- [X] Licentiatavhandling
- [ ] Examensarbete
- [ ] C-uppsats
- [ ] D-uppsats
- [ ] Övrig rapport

___________

**URL för elektronisk version**

**ISBN** 978-91-7393-751-1

**ISRN** LiU-Tek-Lic-2008:44

**Serietitel och serienummer**
Title of series, numbering

**ISSN** 0280-7971

Linköping Studies in Science and Technology

Thesis No. 1386

**Titel**
Title

Using Observers for Model Based Data Collection in Distributed Tactical Operations

**Författare**
Author

Mirko Thorstensson

**Sammanfattning**
Abstract

Modern information technology increases the use of computers in training systems as well as in command-and-control systems in military services and public-safety organizations. This computerization combined with new threats present a challenging complexity. Situational awareness in evolving distributed operations and follow-up in training systems depends on humans in the field reporting observations of events. The use of this observer-reported information can be largely improved by implementation of models supporting both reporting and computer representation of objects and phenomena in operations.

This thesis characterises and describes observer model-based data collection in distributed tactical operations, where multiple, dispersed units work to achieve common goals. Reconstruction and exploration of multimedia representations of operations is becoming an established means for supporting taskforce training. We explore how modelling of operational processes and entities can support observer data collection and increase information content in mission histories. We use realistic exercises for testing developed models, methods and tools for observer data collection and transfer results to live operations.

The main contribution of this thesis is the systematic description of the model-based approach to using observers for data collection. Methodological aspects in using humans to collect data to be used in information systems, and also modelling aspects for phenomena occurring in emergency response and communication areas contribute to the body of research. We describe a general methodology for using human observers to collect adequate data for use in information systems. In addition, we describe methods and tools to collect data on the chain of medical attendance in emergency response exercises, and on command-and-control processes in several domains.

**Nyckelord**
Keywords
Observers, model-based data collection, distributed tactical operations, taskforce training, communication analysis, reconstruction & exploration, extended link analysis, timed checkpoints, network based observer tool

Department of Computer and Information Science
Linköpings universitet

## Linköping Studies in Science and Technology
## Faculty of Arts and Sciences - Licentiate Theses

No 17 **Vojin Plavsic:** Interleaved Processing of Non-Numerical Data Stored on a Cyclic Memory. (Available at: FOA, Box 1165, S-581 11 Linköping, Sweden. FOA Report B30062E)
No 28 **Arne Jönsson, Mikael Patel:** An Interactive Flowcharting Technique for Communicating and Realizing Algorithms, 1984.
No 29 **Johnny Eckerland:** Retargeting of an Incremental Code Generator, 1984.
No 48 **Henrik Nordin:** On the Use of Typical Cases for Knowledge-Based Consultation and Teaching, 1985.
No 52 **Zebo Peng:** Steps Towards the Formalization of Designing VLSI Systems, 1985.
No 60 **Johan Fagerström:** Simulation and Evaluation of Architecture based on Asynchronous Processes, 1985.
No 71 **Jalal Maleki:** ICONStraint, A Dependency Directed Constraint Maintenance System, 1987.
No 72 **Tony Larsson:** On the Specification and Verification of VLSI Systems, 1986.
No 73 **Ola Strömfors:** A Structure Editor for Documents and Programs, 1986.
No 74 **Christos Levcopoulos:** New Results about the Approximation Behavior of the Greedy Triangulation, 1986.
No 104 **Shamsul I. Chowdhury: S**tatistical Expert Systems - a Special Application Area for Knowledge-Based Computer Methodology, 1987.
No 108 **Rober Bilos:** Incremental Scanning and Token-Based Editing, 1987.
No 111 **Hans Block:** SPORT-SORT Sorting Algorithms and Sport Tournaments, 1987.
No 113 **Ralph Rönnquist:** Network and Lattice Based Approaches to the Representation of Knowledge, 1987.
No 118 **Mariam Kamkar, Nahid Shahmehri:** Affect-Chaining in Program Flow Analysis Applied to Queries of Programs, 1987.
No 126 **Dan Strömberg:** Transfer and Distribution of Application Programs, 1987.
No 127 **Kristian Sandahl:** Case Studies in Knowledge Acquisition, Migration and User Acceptance of Expert Systems, 1987.
No 139 **Christer Bäckström:** Reasoning about Interdependent Actions, 1988.
No 140 **Mats Wirén:** On Control Strategies and Incrementality in Unification-Based Chart Parsing, 1988.
No 146 **Johan Hultman:** A Software System for Defining and Controlling Actions in a Mechanical System, 1988.
No 150 **Tim Hansen:** Diagnosing Faults using Knowledge about Malfunctioning Behavior, 1988.
No 165 **Jonas Löwgren:** Supporting Design and Management of Expert System User Interfaces, 1989.
No 166 **Ola Petersson:** On Adaptive Sorting in Sequential and Parallel Models, 1989.
No 174 **Yngve Larsson:** Dynamic Configuration in a Distributed Environment, 1989.
No 177 **Peter Åberg:** Design of a Multiple View Presentation and Interaction Manager, 1989.
No 181 **Henrik Eriksson:** A Study in Domain-Oriented Tool Support for Knowledge Acquisition, 1989.
No 184 **Ivan Rankin:** The Deep Generation of Text in Expert Critiquing Systems, 1989.
No 187 **Simin Nadjm-Tehrani:** Contributions to the Declarative Approach to Debugging Prolog Programs, 1989.
No 189 **Magnus Merkel:** Temporal Information in Natural Language, 1989.
No 196 **Ulf Nilsson:** A Systematic Approach to Abstract Interpretation of Logic Programs, 1989.
No 197 **Staffan Bonnier:** Horn Clause Logic with External Procedures: Towards a Theoretical Framework, 1989.
No 203 **Christer Hansson:** A Prototype System for Logical Reasoning about Time and Action, 1990.
No 212 **Björn Fjellborg:** An Approach to Extraction of Pipeline Structures for VLSI High-Level Synthesis, 1990.
No 230 **Patrick Doherty:** A Three-Valued Approach to Non-Monotonic Reasoning, 1990.
No 237 **Tomas Sokolnicki:** Coaching Partial Plans: An Approach to Knowledge-Based Tutoring, 1990.
No 250 **Lars Strömberg:** Postmortem Debugging of Distributed Systems, 1990.
No 253 **Torbjörn Näslund:** SLDFA-Resolution - Computing Answers for Negative Queries, 1990.
No 260 **Peter D. Holmes:** Using Connectivity Graphs to Support Map-Related Reasoning, 1991.
No 283 **Olof Johansson:** Improving Implementation of Graphical User Interfaces for Object-Oriented Knowledge-Bases, 1991.
No 298 **Rolf G Larsson:** Aktivitetsbaserad kalkylering i ett nytt ekonomisystem, 1991.
No 318 **Lena Srömbäck:** Studies in Extended Unification-Based Formalism for Linguistic Description: An Algorithm for Feature Structures with Disjunction and a Proposal for Flexible Systems, 1992.
No 319 **Mikael Pettersson:** DML-A Language and System for the Generation of Efficient Compilers from Denotational Specification, 1992.
No 326 **Andreas Kågedal:** Logic Programming with External Procedures: an Implementation, 1992.
No 328 **Patrick Lambrix:** Aspects of Version Management of Composite Objects, 1992.
No 333 **Xinli Gu:** Testability Analysis and Improvement in High-Level Synthesis Systems, 1992.
No 335 **Torbjörn Näslund:** On the Role of Evaluations in Iterative Development of Managerial Support Sytems, 1992.
No 348 **Ulf Cederling:** Industrial Software Development - a Case Study, 1992.
No 352 **Magnus Morin:** Predictable Cyclic Computations in Autonomous Systems: A Computational Model and Implementation, 1992.
No 371 **Mehran Noghabai:** Evaluation of Strategic Investments in Information Technology, 1993.
No 378 **Mats Larsson:** A Transformational Approach to Formal Digital System Design, 1993.
No 380 **Johan Ringström:** Compiler Generation for Parallel Languages from Denotational Specifications, 1993.
No 381 **Michael Jansson:** Propagation of Change in an Intelligent Information System, 1993.
No 383 **Jonni Harrius:** An Architecture and a Knowledge Representation Model for Expert Critiquing Systems, 1993.
No 386 **Per Österling:** Symbolic Modelling of the Dynamic Environments of Autonomous Agents, 1993.
No 398 **Johan Boye:** Dependency-based Groudness Analysis of Functional Logic Programs, 1993.

No 402 **Lars Degerstedt:** Tabulated Resolution for Well Founded Semantics, 1993.

No 406 **Anna Moberg:** Satellitkontor - en studie av kommunikationsmönster vid arbete på distans, 1993.

No 414 **Peter Carlsson:** Separation av företagsledning och finansiering - fallstudier av företagsledarutköp ur ett agent-teoretiskt perspektiv, 1994.

No 417 **Camilla Sjöström:** Revision och lagreglering - ett historiskt perspektiv, 1994.

No 436 **Cecilia Sjöberg:** Voices in Design: Argumentation in Participatory Development, 1994.

No 437 **Lars Viklund:** Contributions to a High-level Programming Environment for a Scientific Computing, 1994.

No 440 **Peter Loborg:** Error Recovery Support in Manufacturing Control Systems, 1994.

FHS 3/94 **Owen Eriksson:** Informationssystem med verksamhetskvalitet - utvärdering baserat på ett verksamhetsinriktat och samskapande perspektiv, 1994.

FHS 4/94 **Karin Pettersson:** Informationssystemstrukturering, ansvarsfördelning och användarinflytande - En komparativ studie med utgångspunkt i två informationssystemstrategier, 1994.

No 441 **Lars Poignant:** Informationsteknologi och företagsetablering - Effekter på produktivitet och region, 1994.

No 446 **Gustav Fahl:** Object Views of Relational Data in Multidatabase Systems, 1994.

No 450 **Henrik Nilsson:** A Declarative Approach to Debugging for Lazy Functional Languages, 1994.

No 451 **Jonas Lind:** Creditor - Firm Relations: an Interdisciplinary Analysis, 1994.

No 452 **Martin Sköld:** Active Rules based on Object Relational Queries - Efficient Change Monitoring Techniques, 1994.

No 455 **Pär Carlshamre:** A Collaborative Approach to Usability Engineering: Technical Communicators and System Developers in Usability-Oriented Systems Development, 1994.

FHS 5/94 **Stefan Cronholm:** Varför CASE-verktyg i systemutveckling? - En motiv- och konsekvensstudie avseende arbetssätt och arbetsformer, 1994.

No 462 **Mikael Lindvall:** A Study of Traceability in Object-Oriented Systems Development, 1994.

No 463 **Fredrik Nilsson:** Strategi och ekonomisk styrning - En studie av Sandviks förvärv av Bahco Verktyg, 1994.

No 464 **Hans Olsén:** Collage Induction: Proving Properties of Logic Programs by Program Synthesis, 1994.

No 469 **Lars Karlsson:** Specification and Synthesis of Plans Using the Features and Fluents Framework, 1995.

No 473 **Ulf Söderman:** On Conceptual Modelling of Mode Switching Systems, 1995.

No 475 **Choong-ho Yi:** Reasoning about Concurrent Actions in the Trajectory Semantics, 1995.

No 476 **Bo Lagerström:** Successiv resultatavräkning av pågående arbeten. - Fallstudier i tre byggföretag, 1995.

No 478 **Peter Jonsson:** Complexity of State-Variable Planning under Structural Restrictions, 1995.

FHS 7/95 **Anders Avdic:** Arbetsintegrerad systemutveckling med kalkylkprogram, 1995.

No 482 **Eva L Ragnemalm:** Towards Student Modelling through Collaborative Dialogue with a Learning Companion, 1995.

No 488 **Eva Toller:** Contributions to Parallel Multiparadigm Languages: Combining Object-Oriented and Rule-Based Programming, 1995.

No 489 **Erik Stoy:** A Petri Net Based Unified Representation for Hardware/Software Co-Design, 1995.

No 497 **Johan Herber:** Environment Support for Building Structured Mathematical Models, 1995.

No 498 **Stefan Svenberg:** Structure-Driven Derivation of Inter-Lingual Functor-Argument Trees for Multi-Lingual Generation, 1995.

No 503 **Hee-Cheol Kim:** Prediction and Postdiction under Uncertainty, 1995.

FHS 8/95 **Dan Fristedt:** Metoder i användning - mot förbättring av systemutveckling genom situationell metodkunskap och metodanalys, 1995.

FHS 9/95 **Malin Bergvall:** Systemförvaltning i praktiken - en kvalitativ studie avseende centrala begrepp, aktiviteter och ansvarsroller, 1995.

No 513 **Joachim Karlsson:** Towards a Strategy for Software Requirements Selection, 1995.

No 517 **Jakob Axelsson:** Schedulability-Driven Partitioning of Heterogeneous Real-Time Systems, 1995.

No 518 **Göran Forslund:** Toward Cooperative Advice-Giving Systems: The Expert Systems Experience, 1995.

No 522 **Jörgen Andersson:** Bilder av småföretagares ekonomistyrning, 1995.

No 538 **Staffan Flodin:** Efficient Management of Object-Oriented Queries with Late Binding, 1996.

No 545 **Vadim Engelson:** An Approach to Automatic Construction of Graphical User Interfaces for Applications in Scientific Computing, 1996.

No 546 **Magnus Werner :** Multidatabase Integration using Polymorphic Queries and Views, 1996.

FiF-a 1/96 **Mikael Lind:** Affärsprocessinriktad förändringsanalys - utveckling och tillämpning av synsätt och metod, 1996.

No 549 **Jonas Hallberg:** High-Level Synthesis under Local Timing Constraints, 1996.

No 550 **Kristina Larsen:** Förutsättningar och begränsningar för arbete på distans - erfarenheter från fyra svenska företag. 1996.

No 557 **Mikael Johansson:** Quality Functions for Requirements Engineering Methods, 1996.

No 558 **Patrik Nordling:** The Simulation of Rolling Bearing Dynamics on Parallel Computers, 1996.

No 561 **Anders Ekman:** Exploration of Polygonal Environments, 1996.

No 563 **Niclas Andersson:** Compilation of Mathematical Models to Parallel Code, 1996.

No 567 **Johan Jenvald:** Simulation and Data Collection in Battle Training, 1996.

No 575 **Niclas Ohlsson:** Software Quality Engineering by Early Identification of Fault-Prone Modules, 1996.

No 576 **Mikael Ericsson:** Commenting Systems as Design Support—A Wizard-of-Oz Study, 1996.

No 587 **Jörgen Lindström:** Chefers användning av kommunikationsteknik, 1996.

No 589 **Esa Falkenroth:** Data Management in Control Applications - A Proposal Based on Active Database Systems, 1996.

No 591 **Niclas Wahllöf:** A Default Extension to Description Logics and its Applications, 1996.

No 595 **Annika Larsson:** Ekonomisk Styrning och Organisatorisk Passion - ett interaktivt perspektiv, 1997.

No 597 **Ling Lin:** A Value-based Indexing Technique for Time Sequences, 1997.

No 598 **Rego Granlund:** C$^3$Fire - A Microworld Supporting Emergency Management Training, 1997.
No 599 **Peter Ingels:** A Robust Text Processing Technique Applied to Lexical Error Recovery, 1997.
No 607 **Per-Arne Persson:** Toward a Grounded Theory for Support of Command and Control in Military Coalitions, 1997.
No 609 **Jonas S Karlsson:** A Scalable Data Structure for a Parallel Data Server, 1997.
FiF-a 4 **Carita Åbom:** Videomötesteknik i olika affärssituationer - möjligheter och hinder, 1997.
FiF-a 6 **Tommy Wedlund**: Att skapa en företagsanpassad systemutvecklingsmodell - genom rekonstruktion, värdering och vidareutveckling i T50-bolag inom ABB, 1997.
No 615 **Silvia Coradeschi**: A Decision-Mechanism for Reactive and Coordinated Agents, 1997.
No 623 **Jan Ollinen:** Det flexibla kontorets utveckling på Digital - Ett stöd för multiflex? 1997.
No 626 **David Byers:** Towards Estimating Software Testability Using Static Analysis, 1997.
No 627 **Fredrik Eklund:** Declarative Error Diagnosis of GAPLog Programs, 1997.
No 629 **Gunilla Ivefors:** Krigsspel coh Informationsteknik inför en oförutsägbar framtid, 1997**.**
No 631 **Jens-Olof Lindh:** Analysing Traffic Safety from a Case-Based Reasoning Perspective, 1997
No 639 **Jukka Mäki-Turja:**. Smalltalk - a suitable Real-Time Language, 1997.
No 640 **Juha Takkinen**: CAFE: Towards a Conceptual Model for Information Management in Electronic Mail, 1997.
No 643 **Man Lin**: Formal Analysis of Reactive Rule-based Programs, 1997.
No 653 **Mats Gustafsson**: Bringing Role-Based Access Control to Distributed Systems, 1997.
FiF-a 13 **Boris Karlsson:** Metodanalys för förståelse och utveckling av systemutvecklingsverksamhet. Analys och värdering av systemutvecklingsmodeller och dess användning, 1997.
No 674 **Marcus Bjäreland:** Two Aspects of Automating Logics of Action and Change - Regression and Tractability, 1998.
No 676 **Jan Håkegård**: Hiera rchical Test Architecture and Board-Level Test Controller Synthesis, 1998.
No 668 **Per-Ove Zetterlund**: Normering av svensk redovisning - En studie av tillkomsten av Redovisningsrådets rekommendation om koncernredovisning (RR01:91), 1998.
No 675 **Jimmy Tjäder**: Projektledaren & planen - en studie av projektledning i tre installations- och systemutvecklingsprojekt, 1998.
FiF-a 14 **Ulf Melin**: Informationssystem vid ökad affärs- och processorientering - egenskaper, strategier och utveckling, 1998.
No 695 **Tim Heyer**: COMPASS: Introduction of Formal Methods in Code Development and Inspection, 1998.
No 700 **Patrik Hägglund:** Programming Languages for Computer Algebra, 1998.
FiF-a 16 **Marie-Therese Christiansson:** Inter-organistorisk verksamhetsutveckling - metoder som stöd vid utveckling av partnerskap och informationssystem, 1998.
No 712 **Christina Wennestam:** Information om immateriella resurser. Investeringar i forskning och utveckling samt i personal inom skogsindustrin, 1998.
No 719 **Joakim Gustafsson:** Extending Temporal Action Logic for Ramification and Concurrency, 1998.
No 723 **Henrik André-Jönsson:** Indexing time-series data using text indexing methods, 1999.
No 725 **Erik Larsson:** High-Level Testability Analysis and Enhancement Techniques, 1998.
No 730 **Carl-Johan Westin:** Informationsförsörjning: en fråga om ansvar - aktiviteter och uppdrag i fem stora svenska organisationers operativa informationsförsörjning, 1998.
No 731 **Åse Jansson:** Miljöhänsyn - en del i företags styrning, 1998.
No 733 **Thomas Padron-McCarthy:** Performance-Polymorphic Declarative Queries, 1998.
No 734 **Anders Bäckström:** Värdeskapande kreditgivning - Kreditriskhantering ur ett agentteoretiskt perspektiv, 1998.
FiF-a 21 **Ulf Seigerroth:** Integration av förändringsmetoder - en modell för välgrundad metodintegration, 1999.
FiF-a 22 **Fredrik Öberg:** Object-Oriented Frameworks - A New Strategy for Case Tool Development, 1998.
No 737 **Jonas Mellin:** Predictable Event Monitoring, 1998.
No 738 **Joakim Eriksson:** Specifying and Managing Rules in an Active Real-Time Database System, 1998.
FiF-a 25 **Bengt E W Andersson:** Samverkande informationssystem mellan aktörer i offentliga åtaganden - En teori om aktörsarenor i samverkan om utbyte av information, 1998.
No 742 **Pawel Pietrzak:** Static Incorrectness Diagnosis of CLP (FD), 1999.
No 748 **Tobias Ritzau:** Real-Time Reference Counting in RT-Java, 1999.
No 751 **Anders Ferntoft:** Elektronisk affärskommunikation - kontaktkostnader och kontaktprocesser mellan kunder och leverantörer på producentmarknader,1999.
No 752 **Jo Skåmedal:** Arbete på distans och arbetsformens påverkan på resor och resmönster, 1999.
No 753 **Johan Alvehus:** Mötets metaforer. En studie av berättelser om möten, 1999.
No 754 **Magnus Lindahl:** Bankens villkor i låneavtal vid kreditgivning till högt belånade företagsförvärv: En studie ur ett agentteoretiskt perspektiv, 2000.
No 766 **Martin V. Howard:** Designing dynamic visualizations of temporal data, 1999.
No 769 **Jesper Andersson:** Towards Reactive Software Architectures, 1999.
No 775 **Anders Henriksson:** Unique kernel diagnosis, 1999.
FiF-a 30 **Pär J. Ågerfalk:** Pragmatization of Information Systems - A Theoretical and Methodological Outline, 1999.
No 787 **Charlotte Björkegren:** Learning for the next project - Bearers and barriers in knowledge transfer within an organisation, 1999.
No 788 **Håkan Nilsson:** Informationsteknik som drivkraft i granskningsprocessen - En studie av fyra revisionsbyråer, 2000.
No 790 **Erik Berglund:** Use-Oriented Documentation in Software Development, 1999.
No 791 **Klas Gäre:** Verksamhetsförändringar i samband med IS-införande, 1999.
No 800 **Anders Subotic:** Software Quality Inspection, 1999.
No 807 **Svein Bergum**: Managerial communication in telework, 2000.

No 809 **Flavius Gruian:** Energy-Aware Design of Digital Systems, 2000.

FiF-a 32 **Karin Hedström:** Kunskapsanvändning och kunskapsutveckling hos verksamhetskonsulter - Erfarenheter från ett FOU-samarbete, 2000.

No 808 **Linda Askenäs:** Affärssystemet - En studie om teknikens aktiva och passiva roll i en organisation, 2000.

No 820 **Jean Paul Meynard:** Control of industrial robots through high-level task programming, 2000.

No 823 **Lars Hult:** Publika Gränsytor - ett designexempel, 2000.

No 832 **Paul Pop:** Scheduling and Communication Synthesis for Distributed Real-Time Systems, 2000.

FiF-a 34 **Göran Hultgren:** Nätverksinriktad Förändringsanalys - perspektiv och metoder som stöd för förståelse och utveckling av affärsrelationer och informationssystem, 2000.

No 842 **Magnus Kald:** The role of management control systems in strategic business units, 2000.

No 844 **Mikael Cäker:** Vad kostar kunden? Modeller för intern redovisning, 2000.

FiF-a 37 **Ewa Braf**: Organisationers kunskapsverksamheter - en kritisk studie av ”knowledge management”, 2000.

FiF-a 40 **Henrik Lindberg:** Webbaserade affärsprocesser - Möjligheter och begränsningar, 2000.

FiF-a 41 **Benneth Christiansson:** Att komponentbasera informationssystem - Vad säger teori och praktik?, 2000.

No. 854 **Ola Pettersson:** Deliberation in a Mobile Robot, 2000.

No 863 **Dan Lawesson**: Towards Behavioral Model Fault Isolation for Object Oriented Control Systems, 2000.

No 881 **Johan Moe:** Execution Tracing of Large Distributed Systems, 2001.

No 882 **Yuxiao Zhao:** XML-based Frameworks for Internet Commerce and an Implementation of B2B e-procurement, 2001.

No 890 **Annika Flycht-Eriksson:** Domain Knowledge Management inInformation-providing Dialogue systems, 2001.

FiF-a 47 **Per-Arne Segerkvis**t: Webbaserade imaginära organisationers samverkansformer: Informationssystemarkitektur och aktörssamverkan som förutsättningar för affärsprocesser, 2001.

No 894 **Stefan Svarén:** Styrning av investeringar i divisionaliserade företag - Ett koncernperspektiv, 2001.

No 906 **Lin Han**: Secure and Scalable E-Service Software Delivery, 2001.

No 917 **Emma Hansson:** Optionsprogram för anställda - en studie av svenska börsföretag, 2001.

No 916 **Susanne Odar:** IT som stöd för strategiska beslut, en studie av datorimplementerade modeller av verksamhet som stöd för beslut om anskaffning av JAS 1982, 2002.

FiF-a-49 **Stefan Holgersson:** IT-system och filtrering av verksamhetskunskap - kvalitetsproblem vid analyser och beslutsfattande som bygger på uppgifter hämtade från polisens IT-system, 2001.

FiF-a-51 **Per Oscarsson:**Informationssäkerhet i verksamheter - begrepp och modeller som stöd för förståelse av informationssäkerhet och dess hantering, 2001.

No 919 **Luis Alejandro Cortes:** A Petri Net Based Modeling and Verification Technique for Real-Time Embedded Systems, 2001.

No 915 **Niklas Sandell:** Redovisning i skuggan av en bankkris - Värdering av fastigheter. 2001.

No 931 **Fredrik Elg:** Ett dynamiskt perspektiv på individuella skillnader av heuristisk kompetens, intelligens, mentala modeller, mål och konfidens i kontroll av mikrovärlden Moro, 2002.

No 933 **Peter Aronsson:** Automatic Parallelization of Simulation Code from Equation Based Simulation Languages, 2002.

No 938 **Bourhane Kadmiry**: Fuzzy Control of Unmanned Helicopter, 2002.

No 942 **Patrik Haslum**: Prediction as a Knowledge Representation Problem: A Case Study in Model Design, 2002.

No 956 **Robert Sevenius:** On the instruments of governance - A law & economics study of capital instruments in limited liability companies, 2002.

FiF-a 58 **Johan Petersson:** Lokala elektroniska marknadsplatser - informationssystem för platsbundna affärer, 2002.

No 964 **Peter Bunus:** Debugging and Structural Analysis of Declarative Equation-Based Languages, 2002.

No 973 **Gert Jervan:** High-Level Test Generation and Built-In Self-Test Techniques for Digital Systems, 2002.

No 958 **Fredrika Berglund:** Management Control and Strategy - a Case Study of Pharmaceutical Drug Development, 2002.

FiF-a 61 **Fredrik Karlsson:** Meta-Method for Method Configuration - A Rational Unified Process Case, 2002.

No 985 **Sorin Manolache:** Schedulability Analysis of Real-Time Systems with Stochastic Task Execution Times, 2002.

No 982 **Diana Szentiványi:** Performance and Availability Trade-offs in Fault-Tolerant Middleware, 2002.

No 989 **Iakov Nakhimovski:** Modeling and Simulation of Contacting Flexible Bodies in Multibody Systems, 2002.

No 990 **Levon Saldamli:** PDEModelica - Towards a High-Level Language for Modeling with Partial Differential Equations, 2002.

No 991 **Almut Herzog:** Secure Execution Environment for Java Electronic Services, 2002.

No 999 **Jon Edvardsson:** Contributions to Program- and Specification-based Test Data Generation, 2002

No 1000 **Anders Arpteg:** Adaptive Semi-structured Information Extraction, 2002.

No 1001 **Andrzej Bednarski:** A Dynamic Programming Approach to Optimal Retargetable Code Generation for Irregular Architectures, 2002.

No 988 **Mattias Arvola:** Good to use! : Use quality of multi-user applications in the home, 2003.

FiF-a 62 **Lennart Ljung:** Utveckling av en projektivitetsmodell - om organisationers förmåga att tillämpa projektarbetsformen, 2003.

No 1003 **Pernilla Qvarfordt:** User experience of spoken feedback in multimodal interaction, 2003.

No 1005 **Alexander Siemers:** Visualization of Dynamic Multibody Simulation With Special Reference to Contacts, 2003.

No 1008 **Jens Gustavsson:** Towards Unanticipated Runtime Software Evolution, 2003.

No 1010 **Calin Curescu:** Adaptive QoS-aware Resource Allocation for Wireless Networks, 2003.

No 1015 **Anna Andersson:** Management Information Systems in Process-oriented Healthcare Organisations, 2003.

No 1018 **Björn Johansson:** Feedforward Control in Dynamic Situations, 2003.

No 1022 **Traian Pop:** Scheduling and Optimisation of Heterogeneous Time/Event-Triggered Distributed Embedded Systems, 2003.

FiF-a 65 **Britt-Marie Johansson:** Kundkommunikation på distans - en studie om kommunikationsmediets betydelse i affärstransaktioner, 2003.

No 1024 **Aleksandra Tešanovic:** Towards Aspectual Component-Based Real-Time System Development, 2003.

No 1034 **Arja Vainio-Larsson**: Designing for Use in a Future Context - Five Case Studies in Retrospect, 2003.

No 1033 **Peter Nilsson:** Svenska bankers redovisningsval vid reservering för befarade kreditförluster - En studie vid införandet av nya redovisningsregler, 2003.

FiF-a 69 **Fredrik Ericsson:** Information Technology for Learning and Acquiring of Work Knowledge, 2003.

No 1049 **Marcus Comstedt:** Towards Fine-Grained Binary Composition through Link Time Weaving, 2003.

No 1052 **Åsa Hedenskog:** Increasing the Automation of Radio Network Control, 2003.

No 1054 **Claudiu Duma:** Security and Efficiency Tradeoffs in Multicast Group Key Management, 2003.

FiF-a 71 **Emma Eliason:** Effektanalys av IT-systems handlingsutrymme, 2003.

No 1055 **Carl Cederberg:** Experiments in Indirect Fault Injection with Open Source and Industrial Software, 2003.

No 1058 **Daniel Karlsson:** Towards Formal Verification in a Component-based Reuse Methodology, 2003.

FiF-a 73 **Anders Hjalmarsson:** Att etablera och vidmakthålla förbättringsverksamhet - behovet av koordination och interaktion vid förändring av systemutvecklingsverksamheter, 2004.

No 1079 **Pontus Johansson:** Design and Development of Recommender Dialogue Systems, 2004.

No 1084 **Charlotte Stoltz:** Calling for Call Centres - A Study of Call Centre Locations in a Swedish Rural Region, 2004.

FiF-a 74 **Björn Johansson:** Deciding on Using Application Service Provision in SMEs, 2004.

No 1094 **Genevieve Gorrell:** Language Modelling and Error Handling in Spoken Dialogue Systems, 2004.

No 1095 **Ulf Johansson:** Rule Extraction - the Key to Accurate and Comprehensible Data Mining Models, 2004.

No 1099 **Sonia Sangari:** Computational Models of Some Communicative Head Movements, 2004.

No 1110 **Hans Nässla:** Intra-Family Information Flow and Prospects for Communication Systems, 2004.

No 1116 **Henrik Sällberg:** On the value of customer loyalty programs - A study of point programs and switching costs, 2004.

FiF-a 77 **Ulf Larsson:** Designarbete i dialog - karaktärisering av interaktionen mellan användare och utvecklare i en systemutvecklingsprocess, 2004.

No 1126 **Andreas Borg:** Contribution to Management and Validation of Non-Functional Requirements, 2004.

No 1127 **Per-Ola Kristensson:** Large Vocabulary Shorthand Writing on Stylus Keyboard, 2004.

No 1132 **Pär-Anders Albinsson:** Interacting with Command and Control Systems: Tools for Operators and Designers, 2004.

No 1130 **Ioan Chisalita:** Safety-Oriented Communication in Mobile Networks for Vehicles, 2004.

No 1138 **Thomas Gustafsson:** Maintaining Data Consistency im Embedded Databases for Vehicular Systems, 2004.

No 1149 **Vaida Jakoniené:** A Study in Integrating Multiple Biological Data Sources, 2005.

No 1156 **Abdil Rashid Mohamed**: High-Level Techniques for Built-In Self-Test Resources Optimization, 2005.

No 1162 **Adrian Pop:** Contributions to Meta-Modeling Tools and Methods, 2005.

No 1165 **Fidel Vascós Palacios:** On the information exchange between physicians and social insurance officers in the sick leave process: an Activity Theoretical perspective, 2005.

FiF-a 84 **Jenny Lagsten:** Verksamhetsutvecklande utvärdering i informationssystemprojekt, 2005.

No 1166 **Emma Larsdotter Nilsson:** Modeling, Simulation, and Visualization of Metabolic Pathways Using Modelica, 2005.

No 1167 **Christina Keller:** Virtual Learning Environments in higher education. A study of students' acceptance of educational technology, 2005.

No 1168 **Cécile Åberg:** Integration of organizational workflows and the Semantic Web, 2005.

FiF-a 85 **Anders Forsman:** Standardisering som grund för informationssamverkan och IT-tjänster - En fallstudie baserad på trafikinformationstjänsten RDS-TMC, 2005.

No 1171 **Yu-Hsing Huang:** A systemic traffic accident model, 2005.

FiF-a 86 **Jan Olausson:** Att modellera uppdrag - grunder för förståelse av processinriktade informationssystem i transaktionsintensiva verksamheter, 2005.

No 1172 **Petter Ahlström**: Affärsstrategier för seniorbostadsmarknaden, 2005.

No 1183 **Mathias Cöster**: Beyond IT and Productivity - How Digitization Transformed the Graphic Industry, 2005.

No 1184 **Åsa Horzella**: Beyond IT and Productivity - Effects of Digitized Information Flows in Grocery Distribution, 2005.

No 1185 **Maria Kollberg**: Beyond IT and Productivity - Effects of Digitized Information Flows in the Logging Industry, 2005.

No 1190 **David Dinka**: Role and Identity - Experience of technology in professional settings, 2005.

No 1191 **Andreas Hansson**: Increasing the Storage Capacity of Recursive Auto-associative Memory by Segmenting Data, 2005.

No 1192 **Nicklas Bergfeldt:** Towards Detached Communication for Robot Cooperation, 2005.

No 1194 **Dennis Maciuszek:** Towards Dependable Virtual Companions for Later Life, 2005.

No 1204 **Beatrice Alenljung:** Decision-making in the Requirements Engineering Process: A Human-centered Approach, 2005

No 1206 **Anders Larsson:** System-on-Chip Test Scheduling and Test Infrastructure Design, 2005.

No 1207 **John Wilander:** Policy and Implementation Assurance for Software Security, 2005.

No 1209 **Andreas Käll:** Översättningar av en managementmodell - En studie av införandet av Balanced Scorecard i ett landsting, 2005.

No 1225 **He Tan:** Aligning and Merging Biomedical Ontologies, 2006.

No 1228 **Artur Wilk:** Descriptive Types for XML Query Language Xcerpt, 2006.

No 1229 **Per Olof Pettersson:** Sampling-based Path Planning for an Autonomous Helicopter, 2006.

No 1231 **Kalle Burbeck:** Adaptive Real-time Anomaly Detection for Safeguarding Critical Networks, 2006.

No 1233 **Daniela Mihailescu:** Implementation Methodology in Action: A Study of an Enterprise Systems Implementation Methodology, 2006.

No 1244 **Jörgen Skågeby:** Public and Non-public gifting on the Internet, 2006.

No 1248 **Karolina Eliasson:** The Use of Case-Based Reasoning in a Human-Robot Dialog System, 2006.

No 1263 **Misook Park-Westman:** Managing Competence Development Programs in a Cross-Cultural Organisation-What are the Barriers and Enablers, 2006.

FiF-a 90 **Amra Halilovic:** Ett praktikperspektiv på hantering av mjukvarukomponenter, 2006.

No 1272 **Raquel Flodström**: A Framework for the Strategic Management of Information Technology, 2006.

No 1277 **Viacheslav Izosimov:** Scheduling and Optimization of Fault-Tolerant Embedded Systems, 2006.
No 1283 **Håkan Hasewinkel:** A Blueprint for Using Commercial Games off the Shelf in Defence Training, Education and Research Simulations, 2006.
FiF-a 91 **Hanna Broberg:** Verksamhetsanpassade IT-stöd - Designteori och metod, 2006.
No 1286 **Robert Kaminski:** Towards an XML Document Restructuring Framework, 2006
No 1293 **Jiri Trnka:** Prerequisites for data sharing in emergency management, 2007.
No 1302 **Björn Hägglund:** A Framework for Designing Constraint Stores, 2007.
No 1303 **Daniel Andreasson**: Slack-Time Aware Dynamic Routing Schemes for On-Chip Networks, 2007.
No 1305 **Magnus Ingmarsson:** Modelling User Tasks and Intentions for Service Discovery in Ubiquitous Computing, 2007.
No 1306 **Gustaf Svedjemo**: Ontology as Conceptual Schema when Modelling Historical Maps for Database Storage, 2007.
No 1307 **Gianpaolo Conte**: Navigation Functionalities for an Autonomous UAV Helicopter, 2007.
No 1309 **Ola Leifler**: User-Centric Critiquing in Command and Control: The DKExpert and ComPlan Approaches, 2007.
No 1312 **Henrik Svensson**: Embodied simulation as off-line representation, 2007.
No 1313 **Zhiyuan He:** System-on-Chip Test Scheduling with Defect-Probability and Temperature Considerations, 2007.
No 1317 **Jonas Elmqvist:** Components, Safety Interfaces and Compositional Analysis, 2007.
No 1320 **Håkan Sundblad:** Question Classification in Question Answering Systems, 2007.
No 1323 **Magnus Lundqvist**: Information Demand and Use: Improving Information Flow within Small-scale Business Contexts, 2007.
No 1329 **Martin Magnusson:** Deductive Planning and Composite Actions in Temporal Action Logic, 2007.
No 1331 **Mikael Asplund:** Restoring Consistency after Network Partitions, 2007.
No 1332 **Martin Fransson:** Towards Individualized Drug Dosage - General Methods and Case Studies, 2007.
No 1333 **Karin Camara:** A Visual Query Language Served by a Multi-sensor Environment, 2007.
No 1337 **David Broman:** Safety, Security, and Semantic Aspects of Equation-Based Object-Oriented Languages and Environments, 2007.
No 1339 **Mikhail Chalabine:** Invasive Interactive Parallelization, 2007.
No 1351 **Susanna Nilsson:** A Holistic Approach to Usability Evaluations of Mixed Reality Systems, 2008.
No 1353 **Shanai Ardi:** A Model and Implementation of a Security Plug-in for the Software Life Cycle, 2008.
No 1356 **Erik Kuiper:** Mobility and Routing in a Delay-tolerant Network of Unmanned Aerial Vehicles, 2008.
No 1359 **Jana Rambusch**: Situated Play, 2008.
No 1361 **Martin Karresand:** Completing the Picture - Fragments and Back Again, 2008.
No 1363 **Per Nyblom:** Dynamic Abstraction for Interleaved Task Planning and Execution, 2008.
No 1371 **Fredrik Lantz:**Terrain Object Recognition and Context Fusion for Decision Support, 2008.
No 1373 **Martin Östlund:** Assistance Plus: 3D-mediated Advice-giving on Pharmaceutical Products, 2008.
No 1381 **Håkan Lundvall:** Automatic Parallelization using Pipelining for Equation-Based Simulation Languages, 2008.
No 1386 **Mirko Thorstensson:** Using Observers for Model Based Data Collection in Distributed Tactical Operations, 2008.
No 1387 **Bahlol Rahimi:** Implementation of Health Information Systems, 2008.