NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

AC/323(HFM-121)TP/62

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RTO TECHNICAL REPORT (PART I) **TR-HFM-121-Part-I**

Virtual Environments for Intuitive Human-System Interaction

(Environnements virtuels d'interaction Homme-Système Intuitive)

National Research Activities in Augmented,

Mixed and Virtual Environments

This is a Compendium to the Final Report (TR-HFM-121-Part-II).

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Distribution and Availability on Back Cover

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The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also co-ordinates RTO's co-operation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of co-operation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS Studies, Analysis and Simulation Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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Published December 2005

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ISBN 92-837-1136-X

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Virtual Environments for Intuitive Human-System Interaction

(RTO-TR-HFM-121-Part-I)

National Research Activities in Augmented, Mixed and Virtual Environments

Executive Summary

The missions that NATO is being called on to perform today place new performance requirements on military personnel driving a need for new approaches to training and equipment design. New computer technologies have the potential to prepare militaries for their new missions. During these missions, military operators will have to interact with highly complex C4ISR (Command, Control, Communications, Computer, Intelligence, Surveillance, Reconnaissance) systems and weapon system designs under high physical, mental, and emotional workload. Preparation for these challenges has to include both: Training military commanders, staffs and operators by means of appropriate media and designing equipment to include well thought out human-system interaction (HSI) that takes advantage of advances in technology and reduces operator workload and training requirements.

Augmented, Mixed, and Virtual Environments (AMVE) are new paradigms and media that provide a realistic training environment and a natural HSI using complex realistic or abstract synthetic environments. They allow trainees and human operators to experience synthetic environment that are appropriate for the tasks to be performed. Ideally, military personnel should be presented the same cues in the synthetic world that they would experience in the real world. They should be able to interact with synthetic entities as if they were real. In recent years AMVE-technologies have expanded from their original application as training media to a broad spectrum of military applications.

This report provides an overview of AMVE research and development activities in the participating nations. The military application of these technologies was found in training, teleoperation, operational mission support and command & control. Training encompasses vehicle operation training, individual skills and collective tactical training, and command and control training. Teleoperation refers to the remote control of unmanned vehicles. It also includes telemedicine, i.e. remote diagnostics and surgery. Operational mission support consists of new technologies for supporting the dismounted soldier or infantryman in his operational mission. Finally, in command & control, AMVE-technology is applied to visualize tactical situation data and geographic data in a realistic way.

Although AMVE is a research topic, there have been successful implementations of the technologies. Early on it became clear that AMVE was too large a field to include civil applications as well as military ones. Consequently, this report is limited to military institutions, companies or lead projects in the defence sector only. Even still more than 100 different activities and their interrelationships are described in detail making this report a source of information for interested persons, researchers and managers in this field.

Environnements virtuels d'interaction Homme-Système Intuitive

(RTO-TR-HFM-121-Part-I)

Activités nationales de recherche dans des environnements augmentes, mixtes et virtuels

Synthèse

Les missions confiées à l'OTAN à l'heure actuelle imposent de nouvelles contraintes de performances aux personnels militaires, qui génèrent le besoin de nouvelles méthodes de formation et de conception des équipements. Les nouvelles technologies informatiques offrent le potentiel nécessaire en vue de préparer les militaires à leurs nouvelles missions. Au cours de ces missions, les opérateurs militaires devront interagir avec des systèmes C4ISR (Commandement, Contrôle, Communications, Informatique, Renseignement, Surveillance, Reconnaissance) et des systèmes d'armes extrêmement complexes tout en assumant une charge physique, mentale et émotionnelle élevée. La préparation à ces défis doit s'appliquer : à la formation des commandants militaires, des personnels et des opérateurs au moyen de supports adaptés et à la conception des équipements pour y inclure une interaction homme-système (IHS) bien pensée, tirant parti des avancées technologiques et réduisant la charge de travail des opérateurs et les contraintes de formation.

Les environnements augmentés, mixtes et virtuels (AMVE) constituent les nouveaux paradigmes et supports offrant un environnement de formation réaliste et une IHS naturelle utilisant des environnements réalistes ou synthétiques abstraits. Ils permettent aux stagiaires et aux opérateurs humains d'expérimenter des environnements synthétiques correspondant aux tâches à réaliser. Idéalement, les personnels militaires doivent obtenir dans l'univers synthétique les mêmes indications que celles rencontrées dans le monde réel. Ils doivent pouvoir interagir avec les entités synthétiques exactement comme dans la réalité. Ces dernières années, les technologies AMVE ont évolué de leurs applications initiales en tant que supports de formation vers un large spectre d'applications militaires.

Ce compte rendu donne un aperçu des activités de recherche et de développement AMVE au sein des nations participantes. Une application militaire de ces technologies s'est révélé dans les domaines de la formation, de la télé-exploitation, du soutien en mission opérationnelle et du commandement et contrôle. La formation recouvre la formation à l'exploitation véhicule, la formation individuelle et collective aux compétences tactiques, ainsi que la formation au commandement et au contrôle. La télé-exploitation concerne la commande à distance des véhicules sans pilote. Elle recouvre également la médecine, c'est-à-dire télédiagnostic et chirurgie. Le soutien en mission opérationnelle recouvre les nouvelles technologies de soutien au combattant ou au fantassin débarqué durant sa mission opérationnelle. Enfin, dans le domaine du commandement et contrôle, la technologie AMVE est utilisée pour visualiser les données de situation tactique et les données géographiques de manière réaliste.

Bien que l'AMVE soit un sujet de recherche, il existe des mises en œuvre réussies de ces technologies. Il est apparu assez tôt que l'AMVE était un domaine trop vaste pour inclure à la fois les applications civiles et militaires. C'est pourquoi ce compte rendu se limite aux institutions militaires, aux sociétés ou aux grands projets du secteur de la défense uniquement Même dans ces conditions, plus de 100 domaines différents ainsi que leurs interactions sont décrits en détail, ce qui fait de ce compte rendu une source d'informations pour les personnes, les chercheurs et les gestionnaires concernés par ce domaine.

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Introduction

At the present time the alliance is facing important changes. These include preparing for a broader range of missions across the full spectrum of military operations, new and extended areas of operation, and new responsibilities in combating terrorism and information operations. To meet the associated requirements, innovative concepts and technologies for an efficient and effective utilization of military forces with limited manning have to be developed. This affects mission training, preparation, execution and after-action review.

In future missions, military operators will have to interact with highly complex C4ISR systems and weapon system designs under high physical, mental, and emotional workload. Therefore the ergonomic design of human-system interaction (HSI) is a critical issue. The involvement of the human operator will remain essential, as military performance will still require the human-in-the-loop.

Virtual Environment technology allows the human operator to perceive and experience sensory contact and interact dynamically with such contact in any or all modalities. In recent years the introduction and development of Virtual Environment technology has grown from its original training focus to current applications which include systems design, mission rehearsal and mission execution. The effectiveness of these applications will be dependent on the extent to which VE meets the needs of human operators.

Augmented, Mixed, and Virtual Environments (AMVE) are focusing on presenting computer-generated, synthetic scenarios in a realistic way. Ideally, the human user should not able to differ between the synthetic and the real part. He should be able to interact with the synthetic entities as if they were real. Although the baseline idea was formulated decades ago technology has just recently become powerful enough to turn it partially into reality.

Because of the high usability potential of AMVE-systems for a broad variety of applications, a NATO research task group on *Advances of Virtual Environments for Human-System Interaction* has been initialized in 2003 to survey real applications and future potentials of AMVE technology.

This report describes main project, locations and activities in participating nations. It gives a detailed compendium about the State-of-the-Art on AMVE-technology in Canada, Denmark, Germany, The Netherlands, Sweden, the UK, and the US.

Virtual, Mixed, and Augmented Survey Project – Canada

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1.0 INTRODUCTION

This document identifies Canadian sources of expertise and capability in Virtual, Mixed, and Augmented Environments. The survey identifies Canadian sources within the Department of National Defence Canada, Industry, and Academic Sectors. The survey was conducted by Greenley & Associates Inc. (G&A Inc.) in 2004.

1.1 Background

Virtual Environments (VE) can potentially support cooperative work among users who may or may not be physically distributed. Virtual environments are being used for many purposes, including training, simulation and operational applications.

A research task group (RTG 042) of the Human Factors and Medicine (HFM) panel of NATO has been established to progress the use of virtual environments for intuitive human-system interaction. The work elements of the RTG include an investigation of the potential of virtual, mixed and augmented environments as a means of providing an advanced and intuitive human-system interaction for multiple military applications and a report on the state-of-the-art and its potential. An international compendium of military, academic and industrial capabilities is being established to aid the progress of the RTG.

1.2 Objective

The objective of this document is to provide a national review of Canadian capabilities (Military, Industry, and Academic) that will contribute to the RTG's international compendium.

1.3 This Document

This document is structured according to the following sections:

- Introduction: this section provides a brief overview of the background and overall objectives of the study.
- Method: this section outlines the methodology used to conduct the survey.
- Results: this section presents all sources that were identified; each source is described in terms of the following: Background, Technology/Hardware, Publications, Contacts, and Electronic Links.

2.0 METHODOLOGY

The World Wide Web was the primary medium utilized for conducting the survey and collecting the information for each source identified. The keywords used to conduct the search on the World Wide Web are outlined in Table 1.

Table 1: Keywords used in World Wide Web Search

Virtual Environment Mixed Environment Augmented Environment Virtual Reality Mixed Reality Augmented Reality	+	University Research Technology Tools Collaborative Distributed Shared Laboratory Center Training Equipment Hardware Device Consulting Avatar Capability

Information was also collected by identifying contacts through previous work, contacting them via e-mail, and requesting information relevant to the objective of the survey.

3.0 RESULTS

The sources identified in this survey are categorized according to the Military, Industry, and Academic domains. A listing of the sources is outlined below:

Military

- Armoured School
- Army Experimentation Centre
- The Army Simulation Centre (ASC)
- Defence Research & Development Canada – Atlantic
- Defence Research & Development Canada – Ottawa
- Defence Research & Development Canada – Suffield
- Defence Research & Development Canada – Toronto
- Defence Research & Development Canada – Valcartier
- Joint Command and Staff Training Centre (JCSTC)
- Weapons Effects Simulator (WES)

There is a vast amount of resources that were not available through web-search, but are known to exist within the Canadian Forces (CF) through word-of-mouth or common knowledge. In many cases, websites that should represent CF organizations that either provide or use an M&S capability are either non-existent or are no longer active. Operational Research Groups, Army, Navy, and Air Force simulation and experimentations centers are notable organizations that are not well represented on the web. For this reason, the activities reported in this document do not fully capture the use of virtual, mixed and augmented environments by the Canadian Forces or the Department of National Defence Canada.

Industry

- Adacel Inc., Services Group
- AEgis Simulation Technologies, Inc.
- Amixima Corp.
- Arius3D
- Atlantis Systems International
- Barco
- CAE
- CMC Electronics
- CMLabs
- CyberWorld, Inc.
- Digital Image FX
- eNGENUITY Technologies
- Fakespace Systems
- Fats Canada Inc.
- General Dynamics Canada
- Greenley & Associates Inc. – Simulation and Visualisation Centre
- The HFE Group
- I-mmersion
- InSpeck Inc.
- The Learning Edge Corp.
- Lockheed Martin Canada
- Macdonald Dettwiler and Associates Ltd.
- Manitoba Virtual Reality Centre
- NRC Institute for Information Technology
- NRC Virtual Environment Technology Center
- SAFEWORK Inc. Human Modeling Technology
- Tactical Technologies Inc.
- Thales Systems Canada
- Vivid Group Inc.

Academic

- Bell Canada University Labs
- Carleton University – Aviation and Cognitive Engineering (ACE) Lab
- eyeTap Personal Imaging
- McGill University Center for Intelligent Machines

- Queens University – Touch Laboratory
- Queens University – Visual and Auditory Neurosciences Laboratory
- Ryerson University – Virtual Environment Laboratory (VEL)
- Schlumberger iCentre
- Sheridan College – Visualisation Design Institute (VDI)
- Simon Fraser University – School of Interactive Arts and Technology
- University of Alberta – Department of Computer Science
- University of British Columbia
- University of Calgary – Computer Science Department
- University of Laurentian – Virtual Reality Laboratory
- University of Ottawa
- University of Quebec in Outaouais (UQO) – Cyberpsychology Lab
- University of Toronto – Ergonomics in Teleoperation and Control Laboratory (ETC Lab)
- University of Waterloo

Each source is further described in the subsequent section of the report. Each source is described according to the following: Background, Technology/Hardware, Publications, Contacts, and Electronic Links.

Military – Armoured School

Background

No information provided

Technology/Hardware

Cougar Crew Gunnery Simulator (CCGT)

Built to simulate the turret of the Cougar, it is a two-position trainer, for the Crew Commander and Gunner. The hardware replicates the actual environment as far as space and equipment is concerned. The simulator allows crew to practice direct engagement and semi indirect engagements. It does not currently support networked simulations. The imagery is computer generated; 100 predefined scenarios enable immediate use. The simulator was designed for transport within a ten-ton truck. The instructor position consists of a station with two monitors that allow the instructor to observe what either crewmember is looking at through their sight. The instructor is able to monitor operation of the controls and switches and is able to induce faults, such as misfire. The simulator allows the engagement of both static and moving targets while from a static firing position. The operating system is windows based. The simulator was built in Montreal at Simtran.

Leopard Crew Gunnery Trainer (LCGT)

This device simulates being on the Commander/Gunner side of the Leopard turret. The hardware is built to simulate the actual turret. It has greater functionality than the CCGT, including improved computers, graphics and more options for instruction. The simulation provides the ability to fire on the move, and creation of much more elaborate scenarios to practice fire and movement. The simulation affords the possibility of being expanded by building a driver's station and loader's position. Both simulators offer an out of hatch view to the commander. The LCGT does so with a 17 monitor while the CCGT provides an external view through the use of binoculars. The LCGT is Unix based. It was developed by Siemens in the Netherlands as part of the Leopard Thermal Project.

Lav Crew Gunnery Trainer

Built for Light Armoured Vehicle gunnery training, this system shares most of the same functional characteristics as the LCGT, although it is an appended training system - thus it requires a Coyote/Lav to be used. The simulator was built by Simtran.

Publications

No publications provided

Contacts

No information provided

Electronic Links

http://www.army.forces.gc.ca/armour_school/index_e.htm

Military – Army Experimentation Centre

Background

The AEC was created in late 1998. Its first director was given the task to determine its optimal capability in terms of processes, infrastructure and personnel expertise, and to conduct its mission analysis with the view to supporting the development of concepts and other Land Staff activity. It has implemented an experimentation process, which adheres to sound scientific method principles, and has developed several plans to ensure its evolution over the next decade. Its configuration is based on its preliminary mission to assist in the development and validation of concepts for operations throughout the Spectrum of Conflict at brigade and below. Initial emphasis will be placed on command and command support at battle group level.

Technology/Hardware

Motorola ModIOS® Box

ModIOS Box is an exercise management package that enables the management of live, virtual and constructive simulation through a commercial PC workstation.

The Canadian Army Experimentation Centre plans to use the ModIOS Boxes to assist their experimentation process through a complete two-dimensional (2D) and three-dimensional (3D) exercise environment on a Dell® workstation computer.

The Army Experimentation Centre successfully used the ModIOS Boxes to observe, manage, record and debrief its recent Light Armoured Vehicle (LAV) 3 experiment, Army Experiment 5 (AE5). The purpose of these experiments was to establish and test tactics, techniques and procedures at the company, group and combat team level.

Publications

No publications provided

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Electronic Links

http://www.vcds.forces.gc.ca/dgsp/pubs/rep-pub/dda/symp/cde/chap4-b3_e.asp

Military – The Army Simulation Centre (ASC)

Background

Following the establishment of the AEC, the Army re-examined control of M&S within the Army. The Director Land Synthetic Environments (DLSE) is responsible for directing and managing a large portion of the Army's synthetic environment. He is responsible for Concepts, Doctrine and Training and the M&S facilities at the AEC and the Joint Command and Staff Training Centre (JCSTC). The ASC was established on 23 June 2000, in Kingston, Ontario. The ASC absorbed management responsibility for the AEC, the JCSTC and its regional centres, and will include a Synthetic Environment Laboratory and Repository (SELR). With the stand-up of the ASC, the AEC and JCSTC will become the Experimentation and Training Divisions of the ASC respectively. The third element of the ASC will be the Support Division, which, along other responsibilities, will look after the SELR. The SELR will test and develop new and improved SE tools and will act as the Army SE repository where terrain databases and other common elements of Army SEs will be retained and developed.

Over time, the ASC will assume greater responsibility for the uniform delivery of all simulation facilities and M&S support to the Army at large, including tactical level weapons simulators. This initiative will require an increased partnership with industry and academia. With this approach, the Army will be positioned to prioritize and co-ordinate the effective provision of all M&S support to the Army and ensure that system technical, procedural and data integrity are maintained. Finally, the ASC will serve as the Army focal point for integration of Army based M&S support to CF led experimentation, combat development, training and operational activities.

Technology/Hardware

No information provided

Publications

No information provided

Contacts

No information provided

Electronic Links

http://www.vcds.forces.gc.ca/dgsp/pubs/rep-pub/dda/symp/cde/chap4-b5_e.asp

Military – Defence Research & Development Canada – Atlantic

Background

The mandate of Defence R&D Canada – Atlantic is to conduct research and development in the areas of Underwater Sensing and Countermeasures, Naval Command & Control Information Systems, Naval Platforms, Air Platforms, Signature Management, Emerging Materials, and Modelling & Simulation. These R&D activities support operations, acquisition, maintenance, and requirements planning by Canada's Navy and Air Force.

Technology/Hardware

Virtual Combat Systems

The Virtual Combat Systems group is developing the tools and framework (synthetic environments and simulators) required to examine future combat system concepts through virtual prototyping. A virtual maritime combat system has many potential applications. The operational effectiveness of sensors, signal-processing and data fusion techniques, command decision aids, and weapon systems may be demonstrated and refined. Platforms proposed for acquisition may be assessed for their operational utility. Integration requirements associated with new systems may be explored.

Virtual Maritime Environment

DRDC Atlantic's Virtual Maritime Environment is currently based upon the VMSA (Virtual Maritime Systems Architecture) distributed-simulation framework developed by Australia's Defence Science and Technology Organisation (DSTO) using High Level Architecture (HLA). This framework is the result of 4-5 years of experience and development by DSTO. Through The Technical Cooperation Program (TTCP) and a bilateral memorandum of understanding Canada has obtained a number of simulation components (federates). The helm federate includes an interface that allows the user to change the direction and/or the speed of the ship. The Virtual Maritime System Simulation Display (VMSSD) provides the user with a visual representation of the particular scenario.

The Virtual Combat Systems (VCS) group at DRDC Atlantic is now in the process of developing a Common Ocean Virtual Environment (COVE) federate. COVE will provide a common representation of the acoustic environment, and a Target Motion Analysis (TMA) simulation that will model the combat system functions related to the tracking of oncoming missiles, enemy ships or submarines, and other targets.

Ocean Sensing & Modeling

There are two main efforts in modeling: model development for research purposes, and support of the CF in providing advice on models and databases. The first area concentrates on reverberation and scattering models. Considerable effort has gone into using the models to extract environmental information from measured reverberation data. Continuing effort along these lines of "environmentally-adaptive" sonar is expected to be important for future sonars.

The VSHIP Visualizer

The VSHIP Visualizer has been developed by Defence R&D Canada – Atlantic (DRDC Atlantic) for the real-time visualization of ship motion and loads in waves. It is part of ongoing DRDC Atlantic work to develop capabilities to provide real time simulation of ship motion and structural response to realistic sea environments. This will give improved assessment of ship operability, stability, and structural strength. VSHIP can presently visualize ship response results generated by several computer programs. These include the ship motion and load prediction program SHIPMO developed at DRDC Atlantic, the program THAFTS developed in the UK, and the 3D linear hydrodynamic code PRECAL developed through the Cooperative Research Ships (CRS) organization headed by Maritime Research Institute Netherlands (MARIN).

In VSHIP the user can change ship speed, ship heading (relative to the waves), wave height and wave spectrum or frequency, and immediately view changes in the seaway and the ship response. The program can combine regular wave predictions for a number of headings to provide visualization of ship response in a realistic seaway with directional wave spreading.

DRDC Atlantic has produced a software development methodology for code reuse called HOOD TK (Hierarchical Object Orientated Developers Toolkit). This toolkit encapsulates GUIs, graphics, databases, data management, and a reusable domain object library. For the VSHIP Visualizer development, HOOD technology was incorporated to make VSHIP a well-designed, integrated and extensible program application. Use of HOOD technology insures a common look and feel across all applications that are developed using HOOD as well as decreasing the amount of time needed to develop new applications.

EM Modelling

The UEMS Group is developing theoretical models to predict ELF electric propagation and scattering from conducting bodies such as mines, ships, and submarines in a conducting medium (seawater). The models will permit system performance and detection ranges to be estimated. Work has begun on the development of finite element (FE) and boundary element (BE) models of the SE and the SM signatures of Canadian ships. The FE method is used to predict the effect of degaussing current on reducing the magnetic signature of current vessels and to optimally design the degaussing coil system of future vessels. BE models are being developed to predict the magnitude of corrosion currents flowing around naval hulls, which give rise to the SE signature. The aim of BE modelling is to optimize the design of cathodic protection systems so that the SE signature is minimized while still maintaining adequate corrosion protection.

Total Mine Simulation System

To predict ship vulnerability to mine threats, the UEMS Group has collaborated with TTCP nations to develop, extend and maintain the complex Total Mine Simulation System (TMSS). TMSS software emulates ship signatures and the logic and algorithms of multi-influence mines. This emulation system is being used to provide mine vulnerability assessments for CF naval operations.

Underwater Vehicle Maneuverability

Ongoing work on the maneuvering behaviour of underwater vehicles is relevant to both manned submarines and unmanned underwater vehicles. A generic submarine maneuvering simulation code has been developed, and can model situations such as routine operations, ballast loss, and emergency maneuvers. Such a code can be used for development of submarine maneuvering limitation diagrams.

DRDC Atlantic has expertise in experimental and numerical analysis of underwater vehicle hydrodynamics. Computational fluid dynamics is routinely used to model flow around underwater vehicles. Recent experimental and numerical work has examined sternplane effectiveness, which significantly influences maneuvering performance of underwater vehicles.

Publications

A list of fact sheets can be accessed at:
http://www.atlantic.drdc-rddc.gc.ca/factsheets/factsheet-index_e.shtml

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Electronic Links http://www.atlantic.drdc-rddc.gc.ca/factsheets/20_VCS_e.shtml

Military – Defence Research & Development Canada – Ottawa

Background

DRDC Ottawa is DND's authority and centre of expertise in Defence R&D Canada for radiofrequency communications, sensing and electronic warfare; network information operations; synthetic environments; and radiation effects.

Technology/Hardware

Joint Simulation Network (JSimNet)

The JSimNet incorporates individual simulations on both Linux (SeSU) and Windows-based systems; a file server that will support both Network File System (NFS) for multiple platforms and Common Internet File System (CIFS) for web-based applications; a Content Management server that will use the MS SharePoint Portal Server and, Simulation Servers that will use a variety of simulation models and tools software such as STRIVE, S2FOCUS and STK. HTTP and FTP protocols. The FFSENet design is based upon Gigabit Ethernet technology for connectivity between DRDC networks, peripherals and a high-grade firewall.

The JSimNet will be used to run and experiment with simulation execution environments, models, simulations, tools, utilities, data interchange standards, Simulation Object Models (SOM), Federation Object Models (FOM), and related functionalities using data such as database records, video streams, graphics using terrain and visual databases, data files, and selected e-mail messages. This environment will enable the development and testing of new concepts and ideas, the experimentation, checking, and testing of content transfers and real time simulations, network and system latencies, and the storing and retrieving of a pool of M&S datasets and simulation-related content.

Uninhabited Aerial Vehicle (UAV) Research Test Bed (RTB)

The UAV Research Test Bed consists of a ground control station and a synthetic environment that includes simulations of the UAV airframe (both fixed wing and vertical-take-off-and-land), sensors (electro-optical and infrared) as well as additional computer-generated forces and weather effects. The RTB uses off-the-shelf hardware and software. The RTB is modular and flexible, allowing integration of new sensor models and platform dynamics and can easily be employed as a federate in distributed simulations.

The UAV Research Test Bed supported the ALIX live experiment in Aug/Sept, 2004 in which a UAV flew missions over the east coast of Canada. The RTB will be used for mission rehearsal to verify aspects of the intended operations, mission timelines and networked information distribution. The RTB will also be used for a set of complementary synthetic experiments to test the sensitivity of the real experiment to changes in UAV platform and sensor capabilities.

Simulation and Modeling for Acquisition, Requirements, Rehearsal and Training (SMARRT)

Defence scientists from DRDC will be an integral part of the newly established Canadian Forces Experimentation Centre (CFEC) and Modeling and Simulation Co-ordination Office located at DRDC Ottawa. The SMARRT research activity will provide tools for Concept Development and Experimentation (CDE) and will combine with the Technology Demonstration Program (TDP) to provide concepts for experimentation. Modelling and simulation techniques are part of the research methodologies currently in use at all DRDC research centres. Under SMARRT, modeling and simulation will be integrated into the research programme to support CF requirements for concept formulation, equipment specification, test and evaluation, training, mission rehearsal and platform and weapon-system upgrading. M&S research initiatives at each lab will utilize current and developing research expertise and facilities.

Avionics Simulation

DREO demonstrated a leading edge simulation of the APG-65 Radar. The simulator, called SAPHIRE, provides a state-of-the-art synthetic environment for air-to-air combat. It can emulate the current fighter radar plus evoke significant enhancements developed in-house. DREO is currently upgrading SAPHIRE to demonstrate the effects of improving the radar memory and processor. The improved model will include a link to a CF-18 cockpit simulator at BAE Systems.

Tactical Aviation Mission System Simulation

Defence R&D Canada (DRDC), the Canadian Forces and defence-related industries were recently shown the future in Air Force acquisition technology. TAMSS, the Tactical Aviation Mission System Simulation Technology Demonstration Project (TDP), one of DRDC's first TDPs, was handed over to the Air Force for exploitation.

TAMSS demonstrated a virtual environment in which crews can determine requirements on a simulated battlefield, allowing helicopter pilots to test virtual modifications before implementing them. TAMSS combines technology with human-centred design to provide an advanced capability to support acquisition decisions. The use of a synthetic environment minimizes program risk and encourages new development. Patrice Belanger, Project Director of TAMSS, says "TAMSS will provide the means to demonstrate acquisition reforms through crew-in-the-loop distributed modeling and simulation."

Armoured Vehicle Test Bed

The AVTB allows development, demonstration, and evaluation of new fire control system (FCS) or other hardware or Operator-Machine Interface concepts in a controlled virtual environment. The aim of the AVTB is to make the hardware and crew believe they are on the battlefield by accurately reproducing FCS sensor inputs and sound, motion, and visual cues.

Computer-Generated Imagery Facility

The CGIF provides visual and infrared imagery to the crew for battlefield orientation and target engagement, to the FCS for automatic target detection and tracking and other essential FCS inputs, and to the host vehicle models for producing appropriate motion cues. It provides a complete range of terrain, from smooth highways to rough cross-country, and all weather conditions.

Vehicle and Sensor Models

All physical systems and sensors that would be found in a real vehicle are modeled, including their representative accuracy and errors. For the vehicle, models represent the gun and turret servomechanisms, gun barrel dynamics, internal and external ballistics, autoloader and firing mechanism, and hull dynamics. FCS sensor models include the weapon sights, laser range finder, turret angle encoder, meteorology sensors, ammunition temperature, position/orientation system, and muzzle reference system.

Crew Enclosure

A physical representation of the inside of an AFV turret is mounted on the motion platform. All internal equipment is mocked-up, and the interior can be completely re-configured to represent any type of vehicle. Also included is a high-fidelity sound system capable of reproducing all noises up to the 130 db gun firing.

Motion Platform

The hull dynamics model, with input from other models and the crew and driver, produces vehicle motion requirements. This motion is reproduced by a six degree-of-freedom electric platform, which is capable of producing greater accelerations than would be acceptable to the crew.

Performance Monitor

Performance data is recorded on the various components of the AVTB and FCS, including the time of all button presses and control movements by the crew. In addition, all sight outputs are recorded and date-stamped, and video cameras record each crewmember. This capability enables efficient crew debriefing, precise evaluation of the SMI aspects of ALFCS, and objective evaluation of FCS performance.

SBS SimLab: Space-Based Surveillance Simulation Laboratory

SBS SimLab is a powerful computer-based facility that models a Space-Based Surveillance (SBS) system and its operation, to evaluate its performance within an overall surveillance architecture. An advanced modular software simulation package, SBS SimLab can be installed as a stand-alone, or on a network of Sun SPARC stations.

Publications

The Defence Research Reports Database can be accessed at:
http://pubs.drdc-rddc.gc.ca/pubdocs/pcow1_e.html

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Electronic Links

http://www.ottawa.drdc-rddc.gc.ca/publications/factsheets/smarrt_e.asp
http://www.ottawa.drdc-rddc.gc.ca/publications/factsheets/uav_e.asp
http://www.ottawa.drdc-rddc.gc.ca/publications/factsheets/jsimnet_e.asp

Military – Defence Research & Development Canada – Suffield

Background

DRDC Suffield activities include military engineering, mobility systems, weapons system evaluation and CB defence. Scientific and technological activities are supported by a full complement of services from meteorology, photography and field support, information services, facilities design and development, and materiel management.

Technology/Hardware

Hydraulic Test Bench

The Hydraulic Test Bench (HTB) is a general purpose tool built for the Vehicle Concepts Group at DRDC Suffield to analyze the performance of hydraulic systems and components. The HTB provides hydraulic flow, pressure, direction and the instrumentation to simulate a nearly unlimited number of hydraulic circuit configurations. It may also be used to operate other equipment.

The CMW is a graphical user interface developed for DRDC Suffield by SAIC (Science Applications International Corp.) which incorporates several computer models in a PC workstation environment for use in modeling and predicting various elements of vehicle mobility. These models include NRMM(US), TVPM, TANKDYN, SNOMOD (TREAD plus SNOTRAC) and GSIS.

Publications

No information provided

Contacts

No information provided

Electronic Links

http://www.vcds.forces.gc.ca/dgsp/pubs/rep-pub/dda/symp/cde/chap4-b5_e.asp

Military – Defence Research & Development Canada – Toronto

Background

DRDC Toronto is Canada's centre of expertise for defence research and development (R&D) in human protection and performance in extreme environments, human-systems integration, command effectiveness and behaviour, simulation and modelling and military operational medicine.

The DRDC Toronto mission is to enhance the effectiveness and ensure the health and safety of the human in any human-machine system or adverse environment.

Technology/Hardware

Noise Simulation and Modelling Facility

The quality of communications in many Canadian Forces (CF) environments is degraded by excessive noise. To optimize communications effectiveness, equipment such as headsets, respirators and communications links must be evaluated under realistic operational conditions. Communications modelling – using mannequins and test fixtures that simulate breathing, speech and hearing – provides a practical, safe and cost-effective alternative to on-site testing involving human subjects. The accurate simulation of high-noise environments, when integrated with communications modelling, provides a comprehensive facility for acoustical performance evaluations. DRDC Toronto's noise simulation chamber has been used since 1953 for a variety of noise exposure, hearing conservation and communications activities.

Noise Simulation Chamber: The noise simulation facility includes a spacious reverberant room (11 x 6 x 3m) for subjects and equipment, and a noise-shielded control room for experimenters. A library of 'military noises' is available to the user, and the chamber sound system is easily 'tuned' to accommodate new ones. Digital sound editing and numerical methods simplify the generation and presentation of test stimuli to subjects and the entry of response data into analysis routines. Dedicated monitoring and control systems promote subject safety. A recent upgrade permits the generation of infrasound that enables, for example, the faithful recreation of helicopter rotor noise.

Human Head Simulator (HHS): Developed for DRDC Toronto by the University of Toronto, the HHS is a breathing and voice simulation system coupled with a life-like headform. The voice system self-adapts to flow-restrictive equipment such as respirators. A recent upgrade permits the presentation of standard Diagnostic Rhyme Test speech lists to human listeners during the evaluation of communications links. The HHS may also be used with STIDAS (Speech Transmission Index Device using Artificial Signals), a computer-based system for the objective measurement of speech discrimination.

Binaural Auditory Simulator (BAS): The headform of this manikin is fitted with artificial ears that model the shape, texture and acoustical impedance of the human outer ear. The tympanic membranes are represented by microphones that allow the acoustical characteristics of a variety of hearing-protective or communications equipment to be assessed. The binaural 'listening' capability of the BAS also benefits three-dimensional audio research done at DRDC Toronto.

Team Decision-Making and C2 Facility

Canadian Forces (CF) operations frequently require personnel to work together while performing mentally demanding tasks under conditions of stress and uncertainty. Some tasks must be accomplished individually while others must be coordinated among team members to achieve maximum effect. Team members may work apart (i.e., distributed teams) and communicate through a medium (e.g., audio communication or computer network), or they may work in a common location (i.e., face-to-face teams). Team performance depends to a certain degree on individual-level performance; therefore, research into team decision-making cannot happen in isolation from research into individual decision-making. The TDMC2 facility, completed in 1994, is used to investigate both individual and team performance in situations analogous to military C2.

Integrated Performance Modelling Environment (IPME): A human engineering tool used for mission, function and task analysis, IPME is the result of a collaborative development effort between the United Kingdom (DERA-CHS) and Canada (DRDC Toronto). IPME produces a simulated timeline of human/ machine activities and predicts operator workload and performance. It incorporates a human information processing model and is capable of interacting with other models and simulations.

LOCATE: A computer-based design aid for workspace layouts, used to model the effectiveness of human-machine communications in visual, auditory, tactile and movement domains.

Intelligent Clothing and Equipment Sizing System (ICESS): A camera-based, digital system for accurately determining clothing and equipment sizes for CF personnel. The system has great potential for reducing the costs of issuing clothing and equipment.

Aircraft Crewstation Demonstrator (ACD): A fixed-based, interactive simulator for analyzing cockpit technologies and crew interactions in fixed and rotary wing aircraft. It features an out-of-the-window display and uses rapid virtual prototyping technologies to simulate instrument panels. It was recently used to assess the efficacy of direct voice input for helicopter control.

Helicopter Deck-Landing Simulator (HDLS): This moving-base, interactive simulator demonstrates the exploitation of virtual reality and commercial off-the-shelf technologies to train demanding military tasks. It was developed to train Sea King helicopter pilots to land aboard a Canadian Patrol Frigate in difficult conditions.

Jet Ranger Simulator: This simulator demonstrates re-configurable use virtual reality and commercial-off-the-shelf technologies for simulating hazardous helicopter tasks. The simulator is be used to investigate the efficacy of these technologies for training autorotations.

Dismounted Infantry Simulator (DIS): This simulator employs a head-mounted display and sensors that track body movements and provides the means to examine the human interface to synthetic environments. It is being used to assess methods for training small teams to work together in a virtual environment, while the team members are physically separated by large distances.

Advanced Distributed Mission Training Technology Demonstration Project

The Canadian Air Force (CAF) will be relying on greater use of simulators in the future and is embracing the concepts of Distributed Mission Training (DMT) within synthetic environments to achieve their training objectives, including interoperability with allies. Defence R&D Canada (DRDC) has initiated the Advanced Distributed Mission Training (ADMT) Technology Demonstration (TD) project to help the CF achieve these goals.

The ADMT simulates a CF-18 and is, fully interoperable with the US and other allies, to address inter-simulator networking issues, visual display fidelity, the use of constructive agents for friendly and opposing forces and the right mix of simulator and in-flight training. Collaboration with the US is supported by a Technology Research and Development Program (TRDP) Project Arrangement that was signed in September 1999.

The prime objectives of the ADMT-TD project are to advance the development of flight simulator technologies and to investigate the use of flight simulators for training team, collective, joint and coalition tasks. The ADMT-TD project supports the CF's Advanced Distributed Combat Training System (ADCTS) project through an ongoing process of technology investigation and risk reduction activities. An additional objective is to promote greater use of simulation and modelling for all elements of the Canadian Forces in equipment acquisition, operational analysis, training, mission planning and rehearsal.

Predictive Modelling

Canadian Forces personnel frequently operate in adverse environments that can be life-threatening to the unprepared individual and can impose an impediment to maximum performance. Prediction of human response in such environments is essential to both operational and contingency planning. Mathematical modelling provides a concise and cost-effective means to obtain such predictions. Modelling also enhances scientific understanding and provides a technical platform for rapid evaluation of various untested scenarios. At DRDC Toronto, modelling expertise has been developed for three specific environments:

- cold exposure (thermal);
- diving (hyperbaric); and
- airborne contamination (respiratory).

Dismounted Soldier Simulator

The Soldier Information Requirements Technology Demonstration project (SIREQ TD) is examining capability enhancements for the individual dismounted soldier in 2010-2015. For many of these capability enhancements, building prototypes for field trials would be too costly in time and money to be feasible. The Dismounted Soldier Simulator (DSS) was developed to allow SIREQ TD to investigate potential infantry soldier capability enhancements within a synthetic environment. The DSS can provide control of complex scenarios and comprehensive measurements without many of the costs and restrictions of field trials.

The DSS immerses an infantry section leader in a 3D computer-generated battlefield using a head-mounted visual display and motion tracking. This enables the soldier to accurately perceive spatial relationships among himself and the other soldiers and objects in the simulation. Proposed capability enhancements, such as future sensor systems, can then be added to the DSS and their effect on the section leader's comprehension, decisions, and actions in a variety of scenarios can be studied in great detail. The results of studies within the DSS can be used to identify tradeoffs between competing designs and to identify capability enhancements that should be advanced to field trials. The intent of the DSS is to allow experimentation on the impact of future systems on the section leader's spatial understanding of the battlefield; it is not suited to addressing all SIREQ TD questions or all infantry actions.

Maritime Surface/Subsurface Virtual Reality Simulator (MARS VRS)

A low-cost, portable simulator for teaching ship-handling skills to junior MARS officers. This simulator employed a head-mounted display to represent the bridge of a ship.

TOW Video Interactive Gunnery Simulator

A low-cost, portable simulator for training the operators of TOW missile systems. An earlier system, the Leopard C1 Video Interactive Gunnery Simulator, was also developed by DRDC Toronto.

Publications

The Defence Research Reports Database can be accessed at:
http://pubs.drdc-rddc.gc.ca/pubdocs/pcow1_e.html

An extensive list of fact sheets can be accessed at:
http://www.toronto.drdc-rddc.gc.ca/publications/factsheets/factsheet-index_e.html

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http://www.toronto.drdc-rddc.gc.ca/about/about_e.html
http://www.toronto.drdc-rddc.gc.ca/publications/factsheets/f03_e.html
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http://www.toronto.drdc-rddc.gc.ca/publications/factsheets/t19_e.html

Military – Defence Research & Development Canada – Valcartier

Background

DRDC Valcartier improves Canada's defence capabilities by research and development, by providing independent expert advice and by investigating, demonstrating and exploiting innovative technological concepts for combat, electro-optical and command and control information systems.

Technology/Hardware

Aerodynamics

Valcartier scientists use Computational Fluid Dynamics to predict complex airflows around missile and projectile configurations (both in-service systems and novel concepts). The results contribute to the optimization of airframe/control configurations and improve the characterization of the overall flight dynamics.

Energetic Materials

By modelling the mixing process of solid ingredients, Valcartier scientists improve and optimize the processing and theological properties of polymer-based energetic materials. This approach results in munitions with effective delivery of energy on target.

Terminal Ballistics

Penetration mechanics and behind-armour effects studies are applied to the evaluation of complex high-velocity interactions between survivability enhancement systems and incoming projectiles. This expertise allows the evaluation of existing weapons and protection systems, and supports the definition and analysis of novel concepts.

Vulnerability and Lethality Analysis

The application of vulnerability and lethality assessment to the analysis of complex weapon effects and protection system effectiveness provides critical performance data. The scientists can then minimize the vulnerability or increase the lethality of equipment, optimize the platform systems, identify the performance parameters and support decision making.

Propulsion

Through a detailed study of the complex processes inside the combustion chamber of weapon propulsion systems, Valcartier scientists identify and evaluate the critical performance parameters. This advanced knowledge enables them to define novel concepts and perform trade-off analyses of advanced propulsion systems.

SLAMS

Survivability and Lethality Assessment Modelling Software

SLAMS is designed to study the lethality of weapons and the vulnerability of vehicle platforms (land, air, sea). It has the capability of direct-fire, indirect-fire and multi-hit attacks, of building complex scenarios with multiple targets, of studying the vulnerability of personnel (with or without body armour) and of analyzing the effects of behind-armour debris.

SLAMS offers a large catalog of materials to describe target-weapon scenarios. It is possible to build new targets directly (graphically) inside SLAMS or to import more complex geometries using a third party CAD/ CAM software. Several penetration algorithms are integrated into the software. These algorithms cover most cases of projectile versus target impacts. The analysis of the attack and the evaluation of the target vulnerability and projectile lethality is performed through a series of damage algorithms for each component and through system logical diagrams.

CASE ATTI: A Test Bed for Sensor Data Fusion

Concept Analysis and Simulation Environment for Automatic Target Tracking and Identification is a highly modular, structured, and flexible test bed, developed as a proof-of-concept demonstrator to achieve the continuing exploration of multi-sensor data fusion.

Publications

A list of fact sheets can be accessed at:
http://www.valcartier.drdc-rddc.gc.ca/e/publications_e.asp?page=26&lang=e

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http://www.valcartier.drdc-rddc.gc.ca/poolpdf/e/96_e.pdf

http://www.valcartier.drdc-rddc.gc.ca/poolpdf/e/170_e.pdf

http://www.valcartier.drdc-rddc.gc.ca/e/publications_e.asp?page=26&lang=e

Military – Joint Command and Staff Training Centre (JCSTC)

Background

The JCSTC provides constructive simulation support to the Army and is an integral component to how the Army will address the training domain. JCSTC has the capability to provide constructive simulation support to train commanders from section to formation level in all phases of war. The JCSTC uses several simulations, including Janus and the Command and Staff Trainer (CST).

Technology/Hardware

JANUS

A known capability, but no specific online resource available.

Command and Staff Trainer

A known capability, but no specific online resource available.

Publications

No information provided

Contacts

No information provided

Electronic Links

http://www.vcds.forces.gc.ca/dgsp/pubs/rep-pub/dda/symp/cde/chap4-b4_e.asp

Military – Weapons Effects Simulator (WES)

Background

WES is a live simulation system that will permit soldiers to accurately simulate their weapon fire with lasers and radio signals during force-on-force collective training exercises.

Technology/Hardware

The Weapon Effects Simulation system, commonly referred to as WES, is a live simulation system to be delivered as six separate suites. WES is comprised of the following sub-systems:

- Direct Fire Weapon Effects Simulators, or DFWES, include lasers mounted on all direct fire weapons such as rifles, machine guns and missiles, as well as laser detectors integrated onto soldier and vehicle players. Players are also equipped with miniature computers, radios, global positioning systems and power packs used to process, transmit and receive all engagement data. DFWES will also include the Observer Controller equipment that initializes player status and collects engagement data directly from players for field After Action Reviews. All suites will include DFWES.
- Area Weapon Effects Simulation, or AWES, is computer software generated, radio transmitted simulation of area weapon fire. Area weapons include artillery and mortars, minefields, and nuclear, biological and chemical events. Observer Controllers and the Exercise Control centre will transmit all AWES engagements. All suites will have AWES capability.
- Exercise Control, or EXCON, is a purpose-built control centre that will house all the people, hardware and software required to run WES exercises. It will include the computers, databases and software required to conduct Exercise Planning and Preparation (EPP), to monitor capture and record engagement data, and to prepare After Action Reviews (AAR) and Take Home Packages (THP). It will also include the Operator Analysts who will monitor each training exercise and highlight relevant lessons learned as they occur. Using the collected and highlighted engagement data, Army training officers will prepare AARs for the exercising units.
- Communication and Information System, or CIS, is a separate radio system used for the transmission of engagement data between the EXCON and the players in the field. Only the Wainwright suite will have a CIS.
- Contractor Conducted Logistics Support, or CCLS, is the integrated provision of all support and repair services to WES for a ten-year period following final delivery. All suites will include some form of CCLS.

Testing and delivery will start in 2004, with final deliveries complete by the end of 2005. The first full year of training with the Weapon Effects Simulation system will be 2006.

Publications

No publication provided

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Industry – Adacel Inc., Services Group

Background

Adacel provides airport virtual reality simulators and professional learning services. Their client list includes Nav Canada, the Canadian Forces, the United States Department of Defense, NASA, the Federal Aviation Administration and major educational institutions. Adacel Inc. is divided into 3 business units:

Simulation and Software Solutions – provide leading edge simulation and software services to the aviation community, including voice recognition, voice communication and visual modeling capabilities.

Professional Services – provides services that help customers maximize their simulation investment. ASG provides a complete suite of services ranging from consulting and learning to SimCenter/SimPartner programs and support services.

Air Traffic Management (ATM) Systems – development of operational systems that implement the Communications, Navigation, Surveillance / Air Traffic Management (CNS/ATM) concept. ATM's Aurora software was chosen to supply CNS/ATM automation for the FAA's Advanced Technologies and Oceanic Procedures (ATOP) program.

Technology/Hardware

Adacel has installations in over 30 countries, with systems being used in a variety of training and research and development roles. Their simulation systems use commercial off the shelf hardware to reduce acquisition and support costs. MaxSim Tower and MaxSim Radar are capable of integrated tower and radar operations. MaxSim Tower and MaxSim Radar have the flexibility to be operated in standalone configurations, or in multiple independent scenarios.

The Aviation Research and Training Tools product series includes ARTT Tower, ARTT Radar, ARTT Driver and ARTT Coms, to provide low acquisition costs and reduced operation and support costs. MaxSim VCS is a scalable, multi-channel voice communication system that enables simultaneous radio, telephone, intercommunications, public address and alarms through an intuitive and user configurable touch screen interface. MaxSim VCS can be installed as a standalone voice communications system or with other MaxSim products to provide an integrated training environment. MaxSim VCS includes the capability to record voice communications on all channels. MaxSim Speech is the latest development of Adacel's voice recognition and speech synthesis capabilities. MaxSim Speech includes synthetic voices.

Publications

White Papers can be accessed at: http://www.adacelinc.com/products/simulation/whitepapers.html

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Industry – AEgis Simulation Technologies, Inc.

Background

AEgis Simulation Technologies, Inc. is a Canadian subsidiary of The AEgis Technologies Group Inc., and offers products and services for many simulation applications. AEgis applies expertise in the following areas:

- Simulation Based Business Practice – SEBA, SBA, SMARRT
- Simulation and Software Development
- Simulation Integration – HLA/DIS technologies
- Simulation Studies and Analysis
- Training Simulator Development
- Verification, Validation and Accreditation (VV&A)
- Simulation Training – HLA, SEDRIS, and VV&A

AEgis was awarded a Standing Offer to support the Synthetic Environment Co-ordination Office (SECO) of the Canadian Forces and Department of National Defence.

Technology/Hardware

AEgis Simulation provides engineering and consulting services for modeling and simulation, including expertise in High Level Architecture (HLA); object-oriented analysis and design; simulation and software development; training simulators; simulation integration; distributed simulation; simulation technologies; concept modeling; systems engineering; verification, validation, and accreditation programs for software and simulations; and systems analysis.

A technologies overview can be accessed at: http://www.aegissim.ca/AEgisSimulation_Technologies.html.

AEgis Simulation supplies COTS modelling and simulation software products to companies around the world in industries such as aerospace, automotive, biomedical, electronics, defence, petrochemical, power generation, and process control. More information can be accessed at: http://www.aegissim.ca/AEgisSimulation_Software.html.

AEgis Simulation provides a variety of hardware interfaces for simulation -based training. AEgis delivers turn-key simulation training systems that are based upon low cost COTS. More information can be accessed at: http://www.aegissim.ca/AEgisSimulation_Hardware.html.

Publications

Press Releases can be accessed at: http://www.aegissim.ca/AEgisSimulation_News.html

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Electronic Links

http://www.aegissim.ca/AEgisSimulation_aboutUs.html

Industry – Amixima Corp.

Background

AMIXIMA provides experience in visualization and virtual reality to help businesses express their ideas with 3d animations and special effects.

Technology/Hardware

Advanced Visualisation / Virtual Reality

AMIXIMA has eight years of experience in the field of visualization technologies for use in wide variety of applications including manufacturing, medicine, architecture, construction, forensics, education, web design, data analysis, and marketing.

Publications

No publications provided

Contacts

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Toronto, Ontario M4T 1J9
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E-mail: info@amixima.com

Electronic Links

http://www.amixima.com/

Industry – Arius3D

Background

Arius3D provides tools and expertise to create high resolution, digital models of real world objects. The company's technology allows colour and shape capture at the same time, unaffected by the object's ambient lighting conditions. Arius3D's customers are from universities, museums, industry, and entertainment companies.

Technology/Hardware

The company has secured a worldwide, exclusive license to commercialize state-of-the-art, three-dimensional, colour, laser imaging technology from the National Research Council of Canada (NRC). The technology is patented by the Government of Canada and Arius3D Inc. Colour and geometric shape are collected at the same time for perfect registration. The detailed images can be compressed without loss of definition and represented in a variety of formats for use in a wide variety of applications including research and analysis, education, marketing, entertainment, conservation, replication and design.

Publications

Media news can be accessed at: http://www.arius3d.com/index.html

Contacts

Arius3D
755 The Queensway East
Unit #20
Mississauga, Ontario L4Y 4C5
CANADA

Electronic Links

http://www.arius3d.com/index.html

Industry – Atlantis Systems International

Background

Atlantis Systems International is supplies simulation and training systems for the international defence market and commercial aviation industry. The company produces computer-based desktop systems, aircrew training devices, and simulation-based maintenance trainers, which have always been part of Atlantis' business.

Atlantis has integrated virtual aircraft technology with high-fidelity aircraft hardware and simulated test equipment for aircraft maintenance training. Customers include the Royal Australian Air Force, the Canadian Forces and the US navy. Flight training solutions include cockpit procedures trainers, operational flight trainers, maintenance trainers and the HVT, a re-configurable virtual reality-based simulator for training high-precision tasks such as deck landings in all-weather conditions, long-line and mountain operations. Originally developed by Defence R&D Canada, Atlantis Systems International continues development of the system, and is licensed to markets the simulation world-wide.

Atlantis developed a simulation-based Automated Pilot Selection System (APSS) for the Canadian Department of National Defence to help screen pilot candidates as well as training simulators for a wide variety of military and commercial aircraft.

Technology/Hardware

Helicopter Cockpit Procedures Trainer

Atlantis makes cockpit procedure trainers to reduce the use of full flight simulators and operational flight trainers for teaching procedures.

Helicopter Virtual Trainer

Although this device was initially designed to teach of helicopter deck landing skills, the VR approach allows reconfiguration for training a wide range of military and civilian helicopter operations.

Publications

Brochures can be accessed at: http://www.atlantissi.com/brochures

Contacts

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E-mail: lesterhuizen@AtlantisSI.com

Electronic Links

http://www.atlantissi.com/

Industry – Barco

Background Barco develops and sells a wide range of visual projection technologies and display media, such as project screens. The company's products are used for a wide variety of visual simulations including use in air traffic control, defence & security, medical imaging, flight and ship bridge simulations.
Technology/Hardware Barco offers visualization solutions, including display technology for large, multiple screens, for use in a wide variety of applications for simulation and entertainment. The company's headquarters are in Belgium.
Publications Press Releases can be accessed at: http://www.barco.com/corporate/en/pressreleases/default.asp
Contacts **Representative for Media, Branding, Entertainment, Sports, Control Rooms, Presentation, Simulation** Barco Visual Solutions, Inc. The Airway Centre 5925 Airport Road Suite 200 Mississauga, Ontario L4V 1W1 CANADA Tel: (905) 405-6225 Fax: (905) 672-8630
Electronic Links http://www.barco.com/

Industry – CAE

Background

CAE is a leading provider of simulators and integrated training solutions for civil and military customers. The company has hundreds of simulators installed worldwide for air, maritime and land training, including simulations for power plants. It also offers a range of simulation equipment and modelling and simulation software.

Technology/Hardware

The company offers a full range of products for all types of military platforms, including full mission simulators, weapon systems trainers, deployable trainers, part task trainers, and maintenance trainers.

It also produces enabling technologies, such as state-of-the-art image generators and multi-spectrum spatial data bases, and simulation and modeling tools.

More products and services can be accessed at:
http://www.cae.com/www2004/Products_and_Services/index.shtml

Publications

The News Room can be accessed at: http://www.cae.com/www2004/News_Room/index.shtml

Contacts

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Corporate Relations
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Military Simulation and Training

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E-mail: milsim@cae.com

Civil Simulation and Training

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E-mail: customersupport@cae.com

Power Systems and Simulation

Customer Support
E-mail: PowerServ@cae.com

Montréal, Canada
E-mail: powersims@cae.com

Electronic Links

http://www.cae.com/www2004/index.shtml

Industry – CMC Electronics

Background

CMC Electronics designs, manufactures, sells and supports high-technology electronics products for the aviation, infrared sensing, global positioning and space electronics markets.

Technology/Hardware

CMC provides human factors capability and produced modular aircrew cockpit demonstrators for DND Canada. The systems were used for human system integration experimentation and for demonstrations of distributed networking. The company also developed an Enhanced Vision System (EVS) to increase flight crew situational awareness by helping them see through fog, haze, rain and at night. The system uses infrared (IR) and millimeter wave radar (MMWR) sensor systems.

Commercial Aviation
http://www.cmcelectronics.ca/En/Prodserv/Commav/commav_intro_en.html

Military Aviation
http://www.cmcelectronics.ca/En/Prodserv/Milav/milav_intro_en.html

Publications

Press Releases and CMC News can be accessed at:
http://www.cmcelectronics.ca/En/News/press_release_index_main_en.html

Contacts

Montréal

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600 Dr. Frederik Philips Boulevard
Saint-Laurent, Québec H4M 2S9
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Tel: (514) 748-3148
Fax: (514) 748-3100

Ottawa

CMC Electronics Inc.
415 Legget Drive
P.O. Box 13330
Ottawa, Ontario K2K 2B2
CANADA
Tel: (613) 592-6500
Fax: (613) 592-7427

Electronic Links

http://www.cmcelectronics.ca/En/index_en.html

Industry – CMLabs

Background
CMLabs provides technology and consulting services for visual simulation, including physics-based modeling of interactive 3D dynamics and geometry. The company's expertise includes fast fluid dynamics, deformable bodies and human character animation for use in animation, human factors engineering, virtual-reality, robotics, and engineering design.
Technology/Hardware
CMLabs provides a dynamics engine that applies the fundamental properties of Newtonian physics to 3D simulations that allow applications developers to build physically accurate motion models for real-time interactive simulations. One of their products is a full-featured particle system geared to virtual reality applications in the simulation industry.
Publications
Press Releases can be accessed at: http://www.cm-labs.com/news/press.php
Contacts
505-420 Notre Dame St W Montréal, Québec H2Y 1V3 CANADA Tel: (514) 287-1166 Fax: (514) 287-3360 E-mail: info@cm-labs.com
Electronic Links
http://www.cm-labs.com/

Industry – CyberWorld, Inc.

Background CyberWorld, Inc. sells virtual reality technologies and turn-key, custom solutions.
Technology/Hardware CyberWorld Inc., provides the following technologies: • Controllers – http://www.cwonline.com/store/view_category.asp?Category=13 • Headmounted Displays – http://www.cwonline.com/store/view_category.asp?Category=15 • Stereoscopic Products – http://www.cwonline.com/store/view_category.asp?Category=14
Publications Press Releases can be accessed at: http://www.cwonline.com/about/pressroom.asp
Contacts **CyberWorld, Inc.** 1500 Upper Middle Rd P.O. Box 76060 Oakville, Ontario L6M 3H5 CANADA Tel: (905) 257-9009 Fax: (905) 257-9899 **General Inquiries** E-mail: info@cwonline.com
Electronic Links http://www.cwonline.com/

Industry – Digital Image FX

Background

DIFX uses virtual reality technologies as enablers for telehealth.

Technology/Hardware

DIFX develops software utilizing the latest in VR technology and specializes in stereoscopic imaging, spatial 3D sound and telecommunication applications for medicine, education and industry.

Publications

No publications provided

Contacts

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Wayne Bell

Chief Executive Officer
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Electronic Links

http://www.digital-fx.ca/index.html

Industry – eNGENUITY Technologies

(founded in 1985 as: Virtual Prototypes Inc.)

Background

eNGENUITY Technologies Inc. develops, sells and supports software for the development of simulation-based, visual designs, i.e., human-machine interfaces, and other simulation applications.

Technology/Hardware

The company produces a software tool suite for rapid prototyping, designing, testing, and deploying human-machine interfaces, e.g., the development of dynamic, interactive, real-time graphical representations of the displays and controls found in the cockpit of an aircraft.

eNGENUITY also provides a framework for software developers to build more complex and complete simulation-based training systems, including the means to construct scenarios, and to model the dynamics of fixed and rotary wing aircraft.

Publications

Case Studies can be accessed at: http://www.engenuitytech.com/Case_Studies/index.shtml

White Papers can be accessed at: http://www.engenuitytech.com/resources/index.shtml

Contacts

Patrice Commune, President & Chief Executive Officer

Yves H. Boucher, Executive Vice President & Chief Financial Officer

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Electronic Links

http://www.engenuitytech.com/

Industry – Fakespace Systems

Background Fakespace develops and sells a wide variety of visual display systems that can be used for collaborative engineering, design, research, and entertainment applications. The company provides advanced visualization systems and integrated solutions.
Technology/Hardware Fakespace provides a variety of large scale, visual projection displays for stereoscopic or monoscopic observation. The displays can be room sized or portable, as well as scaleable, and reconfigurable. Tracking technology is employed to correct point of view during movement.
Publications Success Stories can be accessed at: http://www.fakespace.com/successes1.shtml Press Releases can be accessed at: http://www.fakespace.com/press1.shtml
Contacts **Fakespace Systems** 809 Wellington Street North Kitchener, Ontario N2G 4J6 CANADA Tel: (519) 749-3339 Fax: (519) 749-3151
Electronic Links http://www.electrohome.com/fakespace.htm http://www.fakespace.com/main1.shtml

Industry – Fats Canada Inc.

Background

FATS Canada Inc. sells training simulators, including devices for simulating small arms, air defence, and armoured vehicles. The company strives to produce training devices that have the look and feel of an actual weapon system.

Technology/Hardware

FATS training systems are based on commercial off the shelf (COTS) components. The company's products include several simulators used by the Canadian Forces, including training devices for the Eryx, TOW, Cougar, Javelin and Light Armoured Vehicle.

Publications

No information provided

Contacts

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Electronic Links

http://www.simtran.ca

Industry – General Dynamics Canada

Background General Dynamics Canada is an international supplier of military software and hardware for land, air and maritime systems. They can provide completely integrated command, control and communication systems.
Technology/Hardware General Dynamics Canada provides expertise and solutions for digital voice and data distribution, acoustic signal processing, tactical displays, multi-sensor scanning, ballistics, surveillance, and fire control. General Dynamics Canada and Canada's Department of National Defence have jointly funded simulation-based acquisitions projects including an advanced land fire control system and a future, armoured fighting vehicle. These are further outlined at: http://www.gdcanada.com/products/index.html
Publications News Releases can be accessed at: http://www.gdcanada.com/company_info/post.asp?type=News Articles can be accessed at: http://www.gdcanada.com/company_info/post.asp?type=Articles
Contacts **Ottawa** 3785 Richmond Road Ottawa, Ontario K2H 5B7 CANADA Tel: (613) 596-7000 Fax: (613) 820-5081 E-mail: info@gdcanada.com
Electronic Links http://www.gdcanada.com/company_info/index.html

Industry – Greenley & Associates Inc. – Simulation and Visualisation Centre

Background

Greenley & Associates (G&A) is a consulting services provider that offers clients expertise in the core service areas of project management, human factors, modelling and simulation, and business analysis and usability.

Technology/Hardware

Greenley & Associates employs immersive visualization technology to support system design, system evaluation, requirements analysis, training transfer analysis, and operational decision support. In 2005, a virtual command centre will be established at the G&A centre in Ottawa to aid evaluation of alternative command centre layouts and organizations.

Publications

No information provided

Contacts

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E-mail: mike@greenley.ca

Electronic Links

www.greenley.ca

Industry – The HFE Group

Background The HFE Group provides expertise in modeling and simulation, human factors engineering, training and user-interface design. The HFE Group is a user, developer, and reseller of software tools that support human-centered design of systems and trainers.
Technology/Hardware The HFE Group is a developer of High Level Architecture (HLA) and DIS-based distributed simulation applications. The company applies expertise in the integration of commercial off-the-shelf technologies and the development of physical models to provide simulation devices can be used for a variety of applications, including training, mission planning, and simulation based acquisition.
Publications No publications provided
Contacts **Ottawa** 220 Laurier Avenue West Suite 350 Ottawa, Ontario K1P 5Z9 CANADA Tel: (613) 230-8226 Fax: (613) 230-5088 Information: nadinewellwood@thehfegroup.com
Electronic Links http://www.thehfegroup.com

Industry – I-mmersion

Background

I-mmersion creates social or communal cyberspaces to represent parallel worlds for education, entertainment and simulation. The company provides solutions for connecting many users to a common, shared, virtual environment.

Technology/Hardware

An example of I-mmersion's social software is Virtual Canada. This is a 3D massively multi-player environment where thousands of people can log in as avatars and explore the regions of Canada. I-mmersion combines creativity with technology to create communal, virtual spaces.

Publications

Success Stories can be accessed at: http://www.imm-studios.com/index2.htm

Contacts

Immersion Studios

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Fax: (416) 260-7495

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Sales Inquiries

E-mail: sales@imm-studios.com

Electronic Links

http://www.imm-studios.com/index2.htm

Industry – InSpeck Inc.

Background InSpeck manufactures, produces and sells 3D scanning hardware and software that makes use of optical technology to capture forms, including human shape.
Technology/Hardware InSpeck specializes in digitizing shapes, in particular, human form, for medical application, animation, multi-media and entertainment markets. The company possesses expertise in both hardware and software.
Publications Press Releases can be accessed at: http://www.inspeck.com/press/releases/releases.asp Media Coverage can be accessed at: http://www.inspeck.com/press/coverage/coverage.asp
Contacts **Head Office** 3530 St-Laurent Blvd Suite 303 Montréal, Québec H2X 2V1 CANADA Tel: (514) 284-1101 Fax: (514) 284-1108 **Product Development Center** 2014 Jean-Talon North Suite 190 Ste-Foy, Québec G1N 4N6 CANADA Tel.: (418) 682-6161 Fax: (418) 682-3884 **General Information** E-mail: info@inspeck.com **Product & Corporate Information** Tel: (514) 284-1101 E-mail: sales@inspeck.com
Electronic Links http://www.inspeck.com/contact/contact.asp

Industry – The Learning Edge Corp.

Background The Learning Edge Corporation specializes in knowledge management and delivery solutions for corporate and institutional clients.
Technology/Hardware The company brings emerging technologies to the business and education/entertainment environments. They provide expertise, technology, and production resources needed to develop custom courseware, web-enabled products or virtual environments. Focus areas include intelligent agents and collaborative learning environments.
Publications Case Studies can be accessed at: http://www.theledge.com/cases.htm
Contacts The Learning Edge Corporation 90 Claremont Street Toronto, Ontario M6J 2M5 CANADA Tel: (416) 248-0667 E-mail: tle@theledge.com
Electronic Links http://www.theledge.com/

Industry – Lockheed Martin Canada

Background
Lockheed Martin Canada engages research, design, manufacture, and integration of advanced-technology products for the global market. The company is a leader in systems integration, software development and large-scale program management.
Technology/Hardware Lockheed Martin supplies electronic defence and surveillance systems to Canada. The company's capabilities include the integration and management of complex computer-based electronic systems; the design, manufacture and supply of military-standard computers, electronic warfare, sonar and security systems; and the provision of life cycle support for major platforms. Lockheed Martin provides a variety of training and simulation technologies, including live, virtual and construction simulations for defence and civil customers. Their products include training support and devices and for air, land and maritime environments. More information about these the company can be accessed at: http://www.lockheedmartin.com/wms/findPage.do?dsp=fec&ci=12981&sc=400
Publications Press Releases can be accessed at: http://www.lockheedmartin.com/wms/findPage.do?dsp=fnec&ti=111
Contacts Lockheed Martin Canada 3001 Solandt Road Kanata, Ontario K2K 2M8 CANADA Tel: (613) 599-3270 Fax: (613) 599-3282
Electronic Links http://www.lockheedmartin.com/wms/findPage.do?dsp=fec&ci=14848&rsbci=9&fti=124&ti=0&sc=400

Industry – MacDonald Dettwiler and Associates Ltd.

Background MacDonald, Dettwiler and Associates Ltd. provides solutions for gathering and processing large amounts of data to improve decision making and performance. Their customers include government and business.
Technology/Hardware MacDonald, Dettwiler and Associates Ltd. generates and collects property information and provides geospatial services for use in urban planning, crop management, and defence, among other possible applications.
Publications MDA News can be accessed at: http://www.mda.ca/news/index.html
Contacts **MacDonald, Dettwiler and Associates Ltd.** 13800 Commerce Parkway Richmond, British Columbia V6V 2J3 CANADA Tel: (604) 278-3411 Fax: (604) 273-9830 E-mail: invest@mda.ca or, for general inquiries, info@mda.ca
Electronic Links http://www.mda.ca/

Industry – Manitoba Virtual Reality Centre

Background

The Virtual Reality Centre is a joint effort of the Government of Canada and the Province of Manitoba. The goal of the centre is to provide industry, academia, and government opportunity to explore and exploit virtual reality technology.

Technology/Hardware

The Virtual Reality Centre contains advanced visualization tools that allow display of complex data sets for use in manufacturing, civil engineering, architecture, urban planning, product design, science, entertainment, and medicine. The facility allows for collaborative design; up to twenty users can participate at a time.

Publications

Virtual Reality Centre News can be accessed at: http://www.virtualrealitycentre.ca/news.html

Contacts

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E-mail: info@virtualrealitycentre.ca

Electronic Links

http://www.virtualrealitycentre.ca

Industry – NRC Institute for Information Technology

Background The Institute for Information Technology is part of the National Research Council of Canada. The Institute participates in R&D collaborations and partnerships in information and telecommunications technologies with business, universities and government agencies, in Canada and around the world.
Technology/Hardware The Institute for Information Technology conducts scientific research, develops technology, creates knowledge and supports innovation to benefit Canadian society. The R&D program and technology transfer activities includes innovation of enabling technologies for access to 3D information of the real world. The topics include real-world data capture for representation, visualization, collaboration in virtual environments and data mining.
Publications The publication list can be accessed at: http://iit-iti.nrc-cnrc.gc.ca/iit-publications-iti/2004_e.html
Contacts NRC IIT Staff List http://iit-iti.nrc-cnrc.gc.ca/iit-personnel-iti/iit-personnel-iti_e.html
Electronic Links http://iit-iti.nrc-cnrc.gc.ca/index_e.html

Industry – NRC Virtual Environment Technology Centre

Background

The Virtual Environment Technology Centre (VETC) is part of the Integrated Manufacturing and Technologies Institute of the National Research Council of Canada. The VETC was created to assist the exploitation of virtual environments by Canadian industry.

Technology/Hardware

The Virtual Environment Technology Centre provides access to the latest technologies and know-how for simulation based design and other VE applications. Its equipment includes a variety of immersion visual display systems for individuals and groups. The facilities include an immersive theatre and design workspaces. The VETC collaborates with academic and industrial partners.

Publications

Publications can be accessed at: http://imti-itfi.nrc-cnrc.gc.ca/publns_e.html

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Integrated Manufacturing Technologies Institute

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London, Ontario N6G 4X8
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Electronic Links

http://imti-itfi.nrc-cnrc.gc.ca/vetc_e.html

Industry – SAFEWORK Inc. Human Modeling Technology

Background SAFEWORK Inc. provides tools and expertise for static and dynamic anthropometric engineering.
Technology/Hardware The company provides human modeling capabilities and expertise for accurate, detailed investigation of human system interactions. The company's products include virtual environments for visualizing the interaction between a human form and its workspace from multiple perspectives, including immersive views.
Publications Press Releases can be accessed at: http://www.safework.com/news/news.html
Contacts **General Information** E-mail: info@safework.com
Electronic Links http://www.safework.com/safework_pro/features.html

Industry – Tactical Technologies Inc.

Background

Tactical Technologies Inc. provides simulations for electronic warfare, and engineering expertise.

Technology/Hardware

Tactical Technologies Inc. focuses on the methods and tools for simulations of radar, electronic warfare and infrared sensing and countermeasures.

Tactical Technologies Inc. offers electronic combat software simulations for surface-to-air, air-to-air, anti-ship missile, and anti-aircraft applications.

More information can be accessed at: http://www.tti.on.ca

Publications

Technical papers can be accessed at: http://www.tti.on.ca

Contacts

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E-mail: info@tti.on.ca

Electronic Links

http://www.tti.on.ca

Industry – Thales Systems Canada

Background

Thales Systems Canada provides command, control, and communications (C3) systems integration.

Technology/Hardware

The business of the company includes mission systems and sensors, communications, and C4ISR systems. The company's expertise includes integration of radar, electro-optic, navigation and C3 systems, as well as the design and development of real-time software and integrated logistics support for civilian and military applications.

Further information can be accessed at: http://www.thales-systems.ca/products/products.htm

Publications

Projects and Case Studies can be accessed at: http://www.thales-systems.ca/projects/projects_page.htm

Contacts

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Electronic Links

http://www.thales-systems.ca

Industry – Vivid Group Inc.

Background

Vivid Group Inc. provides the means to capture body motion for interaction with virtual environments.

Technology/Hardware

Vivid Group Inc. uses video-based technology to capture human motions for animation and interaction with the virtual environments. Additional sensors or other input devices are not needed.

Publications

Press Releases can be accessed at: http://www.vividgroup.com/press.html

Contacts

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Electronic Links

http://www.vividgroup.com

Academic – Bell Canada University Labs

Background

Bell Canada and the University of Toronto are cooperating in the research and development of a virtual environment that will allow collaboration among geographically distributed team members. The goal of the project is to build an effective collaborative environmental infrastructure.

Technology/Hardware

The researchers come from computer science, industrial and mechanical engineering, psychology, and sociology. The virtual environment allows teams of different sizes to perform a wide range of tasks.

Publications

The project announces that it will in the future make a library of resources available to the public via the web address below.

Contacts

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Electronic Links

http://www.bul.mie.utoronto.ca/index.html

Academic – Carleton University – Aviation and Cognitive Engineering (ACE) Lab

Background

The Aviation and Cognitive Engineering Laboratory (ACE) is part of the Center for Applied Cognitive Research at Carleton University, in Ottawa. The goal of the ACE laboratory is to discover and apply fundamental principles of human perception and cognition to research and design for aviation.

Technology/Hardware

The staff conducts fundamental research on human perception and cognition to enhance the understanding of fundamental processes and applies knowledge of perception and cognition to the design and evaluation of human-machine systems.

The laboratory participates in the Tactical Aviation Mission System Simulation (TAMSS) technology demonstration project of Defence R&D Canada by developing qualitative and quantitative measures and models of situational awareness.

The Canadian Foundation for Innovation (CFI) has recently provided funds to establish a center for Advanced Studies in Visualization and Simulation (V-SIM). The initiative includes partners from the simulation industry, including CAE Inc.

Publications

Recent publications and presentations can be accessed at: http://www.carleton.ca/ace/publications.html

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Electronic Links

http://www.carleton.ca/ace/index.html

Academic – eyeTap Personal Imaging

Background

Formerly known as the Humanistic Intelligence Laboratory (HI Lab), EyeTap Personal Imaging Lab (ePI Lab), at the University of Toronto, focuses on computer vision and intelligent image processing.

Technology/Hardware

The technology and hardware support the research of wearable computing and cybernetic concepts, including mediated reality. The laboratory explores technology and use of personal imaging as the key enabling technology for augmented/mediated reality and wearable computing.

Publications

Publications can be accessed at: http://www.eyetap.org/publications/index.html

Contacts

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Electronic Links

http://www.eyetap.org/about_us/hilab/index.html

Academic – McGill University Center for Intelligent Machines

Background The goal of the Centre for Intelligent Machines (CIM) is to advance the state of knowledge in robotics, automation, artificial intelligence, computer vision, voice recognition, systems and control theory. About fourteen laboratories are included in the center.
Technology/Hardware The Shared Reality Laboratory of the Centre for Intelligent Machines is advancing the means for communicating high-fidelity data among distributed users. The researchers are investigating how context-sensitive technology can facilitate both human-computer and computer-mediated human-human interaction. A shared-reality research facility, connected by low-latency transport of high-fidelity audio and video over advanced computers networks, is being used to provide physically distributed participants with a strong sense of co-presence. The researchers in the Haptics Laboratory design and engineer software and hardware components for haptic interfaces, e.g., in the construction of surgical simulators. A variety of haptic devices have been created.
Publications Publications are accessible via the links to each laboratory from the home page of the centre.
Contacts A complete list of the center's staff members can be accessed at: http://www.cim.mcgill.ca/
Electronic Links http://www.cim.mcgill.ca/

Academic – Queen's University – Touch Laboratory

Background

The researchers of the Touch Laboratory at Queen's University study the sense of touch in humans. Their work includes how the sighted and blind use haptic exploration and manipulation, and they study haptic interfaces for teleoperation and virtual environments.

Technology/Hardware

The research of the Touch Laboratory includes the study of haptic perception and inter-sensory integration, through direct and indirect contact with familiar and unfamiliar objects. It includes behavioural measures and the design of sensors for autonomous robots.

Behavioural measures typically involve psychophysical responses, the classification of videotaped hand movements that accompany manual exploration during haptic search, response latencies, errors, oral/written questionnaire responses, and kinematic and dynamic measures of hand/arm movements.

Publications

A list of publications can be accessed at: http://pavlov.psyc.queensu.ca/~cheryl/reprints.html

Contacts

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Electronic Links

http://psyc.queensu.ca/~cheryl/labpage.html

Academic – Queen's University – Visual and Auditory Neurosciences Laboratory

Background

The Visual and Auditory Neurosciences Laboratory of Queen's University studies the processing of visual and auditory information, by animals and humans. The virtual reality group applies knowledge of multi-sensory perceptual mechanisms to the advancement of virtual and artificial perceptual environments.

Technology/Hardware

The focus of the virtual reality group, of the visual and auditory neurosciences laboratory, is the study of motion, including the distinctions between perceptions of self motion and object motion, and the perceptual differentiation of objects through motion cues. The researchers have built several VR platforms, including systems that make use of a head-mounted display and a treadmill or bicycle as the interface for travel within virtual environments that simulate large spaces, e.g., for architectural and design purposes.

Publications

Recent publications can be accessed at: http://pavlov.psyc.queensu.ca/%7Efrostlab/vr.html

Contacts

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Electronic Links

http://pavlov.psyc.queensu.ca/%7Efrostlab/index.html

Academic – Ryerson University – Virtual Environment Laboratory (VEL)

Background
The Geomatics and Virtual Environment Laboratory of Ryerson University was established to advance the integration of geo-spatial, modeling, visualization and virtual reality technologies for use in urban environment applications. The applications include land use management, 3D urban modeling, landscape mapping, disaster management, transportation planning, and informal settlement management.
Technology/Hardware
The researchers of the Geomatics and Virtual Environment Laboratory are now working on satellite remote sensing of the urban environment and web-based, environmental visualization. The topics of study include the development of algorithms for image analysis, software for extraction of man-made objects (e.g., buildings and roads) and the generation of digital elevation models from multi-spectral, remote imagery.
Publications
Publications can be accessed at http://www.geomaticseng.ryerson.ca/vel/Publication.htm
Contacts
Dr. Jonathan Li, P.Eng, OLS Director, Virtual Environment Lab Department of Civil Engineering Ryerson University Tel: (416) 979-5000 ext. 469 Fax: (416) 979-5122 E-mail: junli@ryerson.ca **Yu Li** Assistant Director Department of Civil Engineering Ryerson University E-mail: y6li@ryerson.ca
Electronic Links
http://www.geomaticseng.ryerson.ca/vel/default.htm

Academic – Schlumberger iCentre

Background

The Schlumberger iCentre is part of the Calgary Centre for Innovative Technology (CCIT), University of Calgary. It provides visualization facilities, scientific computation, and interactive conferencing for academic researchers and industry clients.

Technology/Hardware

The Schlumberger iCentre is a multi-disciplinary laboratory that provides large-format, immersive 3d displays to enable collaborative work and visual presentation. The center is used for studies of biomechanics, environmental impact, resource development, infrastructure renewal, and product development.

A list technologies is available at http://www.ccit.com/index.php?option=content&task=view&id=186

Publications

Faculty publications can be accessed at:
http://www.ccit.com/index.php?option=content&task=view&id=131&Itemid=150

Contacts

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Electronic Links

http://www.ccit.com/index.php?option=content&task=view&id=113

Academic – Sheridan College – Visualisation Design Institute (VDI)

Background The Visual Design Institute (VDI) of Sheridan College in Oakville, Ontario, has an Interactive Virtual Environment Laboratory that finds ways to extract meaningful information from databases using real-time, interactive, three dimensional visual displays.
Technology/Hardware No information provided
Publications No information provided
Contacts For information on the VDI, contact: avrim@acm.org
Electronic Links http://www.sheridaninstitute.ca/info/ord/vdi.html

Academic – Simon Fraser University – School of Interactive Arts and Technology

Background The School of Interactive Art and Technology at Simon Fraser University includes the Interactive Visualization Laboratory, (iVizLab) and the Shared Virtual Environment Laboratory. The iVizLab pursues socially based, interactive visualizations to enhance communication, collaboration and learning and the Shared Virtual Environment Laboratory pursues immersive virtual reality.
Technology/Hardware The iVizLab is using 3D facial animation to understand the non-verbal communications of the human face and body. The applications include human interfaces to computers, web and other communication systems. The researchers are also making use of avatars, AI and character-based agents to advance social communication and telepresence. The Shared Virtual Environment Laboratory is exploring multi-sensory cuing, including vision, sound and tactile senses for immersion and shared virtual environments, including representation by avatars.
Publications Publications for the iVizlab can be accessed at: http://ivizlab.sfu.ca/publications.php No publications link is available for the Shared Virtual Environment Laboratory.
Contacts **Steve DiPaola** Directory Associate Professor School of Interactive Arts & Technology Faculty of Applied Sciences Simon Fraser University Tel: (604) 268-7479 Fax : (604) 268-7488 E-mail: sdipaola@sfu.ca An extensive list of the research staff can be accessed at: http://www.sfu.ca/~siat/research/archives/000237.html
Electronic Links http://ivizlab.sfu.ca/about.php http://www.sfu.ca/~siat/research/archives/cat_research.html

Academic – University of Alberta – Department of Computer Science

Background

The Department of Computer Science at the University of Alberta includes The Man Machine Interface Laboratory and Computer Graphics Research Group. The goals of the Man Machine Interface laboratory include research in new man-machine interfaces, the development of human centered automation systems, the development of systems for complex and dynamic environments and exploration of basic cognitive process in man-machine interfaces. The Computer Graphics Research Group addresses image based rendering, texture analysis and synthesis, animation, and shadowing and geometric modeling.

Technology/Hardware

The Man Machine Interface laboratory includes a CAVE-like environment with large format projection and a portable EEG/VR system. The research projects include the exploration and advancement of realism in VR, intuitive systems, visualization of data, and high speed networking. The Computer Graphics Research Group developed the MR toolkit, a very early set of software tools for the production of virtual reality systems and other forms of 3D user interfaces. The main author, Dr. Mark Green, has moved to the City University of Hong Kong.

Publications

Publications are provided for each staff member at: http://www.cs.ualberta.ca/ammi/

Contacts

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Electronic Links

http://www.cs.ualberta.ca/ammi/

Academic – University of British Columbia

Background

The University of British Columbia contains the Imager Laboratory for Graphics, Visualization and HCI within the Department of Computer Science. The goal of this laboratory is to advance the science of computer graphics, computer animation, human computer interaction, visualization and computational geometry. The Faculty of Graduate studies includes the Media and Graphics Interdisciplinary Centre (MAGIC). It is linked to other departments and faculties and explores computer graphics, animation, human-computer interaction, and multimedia.

Technology/Hardware

A wide range of expertise is available on topics related to human computer interaction and media, however, the specific laboratory resources are not identified on web.

Publications

Publications can be accessed at: http://www.cs.ubc.ca/nest/imager/imager.html

Contacts

Contact information can be accessed at: http://www.cs.ubc.ca/nest/imager/imager-web/People/people.html

Electronic Links

http://www.cs.ubc.ca/nest/imager/imager.html

http://www.cs.ubc.ca/nest/magic/home

http://www.cs.ubc.ca/nest/magic/projects/hands/home

Academic – University of Calgary – Computer Science Department

Background

The Department of Computer Science of the University of Calgary contains the laboratory for Human Computer Interaction (HCI) and Computer Supported Cooperative Work (CSCW). The HCI activities include investigation of the way people invoke computer actions and navigate hypertext structures such as the World Wide Web. The CSCW helps support geographically distributed small teams for collaboration.

Technology/Hardware

A complete list of projects can be accessed at: http://grouplab.cpsc.ucalgary.ca/projects/

Publications

Publications can be accessed at: http://grouplab.cpsc.ucalgary.ca/papers/index.html

Contacts

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Electronic Links

http://grouplab.cpsc.ucalgary.ca/index.html

Academic – University of Laurentian – Virtual Reality Laboratory

Background

The Mining Innovation, Rehabilitation and Applied Research Corporation (MIRARCO) is located in Sudbury Ontario, Canada's largest industrial mining centre. Its Virtual Research Laboratory allows multidisciplinary teams to visualize complex datasets. MIRARCO results from a collaboration between Laurentian University and the private and public sectors. They promote mining innovation and provide a bridge between researchers and industry.

Technology/Hardware

The Virtual Reality Laboratory provides a high-resolution stereo projection on a 22' x 8' spherical screen. An earth modeling software package is used to transform the complex mathematical data into 3D visual images. The VRL can also be used for different applications including engineering, architecture, environmental monitoring, urban planning, equipment design, and medicine.

Publications

Selected publications can be accessed at: http://www.mirarco.org/publications.php#selectedpublications

Contacts

MIRARCO – Mining Innovation

Laurentian University
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CANADA
http://www.mirarco.org/staff.php

Electronic Links

http://www.mirarco.org/aboutvr.php

http://www.mirarco.org/facilities.php

Academic – University of Ottawa

Background

The University of Ottawa houses the Distributed & Collaborative Virtual Environments Research Laboratory (DISCOVER) within the School of Information Technology and Engineering (SITE).

Technology/Hardware

Two major applications have developed. These include Virtual e-commerce and Industrial Training. The current research topics of DISCOVER include telehaptics, distributed and collaborative virtual environments, intelligent sensor networks, ubiquitous computing and intelligent agents. More project information can be accessed at: http://www.discover.uottawa.ca/. The facilities include high-end image generators and a long screen that can fold to form a CAVE-like environment.

Publications

A publications list can be accessed at: http://www.discover.uottawa.ca/

Contacts

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Electronic Links

http://www.discover.uottawa.ca/

Academic – University of Québec in Outaouais (UQO) – Cyberpsychology Lab

Background The Cyberpsychology Laboratory is a research centre of the University of Quebec in Outaouais (UQO) and the Pierre-Janet Hospital. The researchers study underlying psychological processes, clinical effectiveness and applied applications in psychology.
Technology/Hardware The research of the center involves virtual reality and the implementation of psychological intervention by videoconference. The studies assess the effectiveness of videoconferencing and virtual reality in the treatment of disorders, such as agoraphobia.
Publications Publications can be accessed at: http://www.uqo.ca/cyberpsy/labo_en.htm#publi
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Electronic Links http://www.uqo.ca/cyberpsy/cyber_en.htm#def

Academic – University of Toronto – Ergonomics in Teleoperation and Control Laboratory (ETC Lab)

Background

The Ergonomics in Teleoperation and Control Laboratory is part of the Department of Mechanical and Industrial Engineering at the University of Toronto. The laboratory conducts research in the human factors and ergonomics of telerobotics, stereoscopic displays, virtual reality, and augmented reality.

Technology/Hardware

The laboratory created an augmented reality system that makes use of graphical overlay and stereoscopic viewing and a system for virtual telerobotic control.

Publications

Publications are listed at: http://etclab.mie.utoronto.ca/ETC-Bibliography.html

Contacts

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Electronic Links

http://vered.rose.toronto.edu/

Academic – University of Waterloo

Background

The Computer Graphics Laboratory of the University of Waterloo conducts research in curve and surface design, rendering, colour imaging, and user interfaces.

Technology/Hardware

Links to software packages being developed by the members of the Computer Graphics Laboratory can be accessed at: http://www.cgl.uwaterloo.ca/Software/

Publications

No information provided

Contacts

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Virtual Reality in Denmark

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1.0 INTRODUCTION

VR-projects in Denmark can be categorised as either civilian or military. Civilian projects are either commercial or research and development. They will be mentioned in the next chapter. Military VR-projects are either simulators or research and development. The military projects will be mentioned in the last chapter.

2.0 CIVILIAN PROJECTS

Commercially VR is used by television stations and advertising agencies. VR in research and development is of growing interest. Three universities have established VR laboratories or centres. These will be mentioned in the next section. Examples of research and development VR-projects will be mentioned in the following section.

A common event for both the civilian and military society is the founding in May 1999 of DK-VRS (Danish Virtual Reality Society). DK-VRS still exists, but its activities have stopped (for further information, see http://www.dk-vrs.dk/).

2.1 Civilian Research Laboratories

2.1.1 Centre for Pervasive Computing

Pervasive computing is the next generation computing environments with information & communication technology everywhere, for everyone, at all times.

Figure 1: Large CfPC Displays.

Information and communication technology will be an integrated part of our environments: from toys, milk cartons and desktops to cars, factories and whole city areas – with integrated processors, sensors, and actuators connected via high-speed networks and combined with new visualisation devices ranging from projections directly into the eye to large panorama displays.

The Centre for Pervasive Computing (CfPC) contributes to the development of:

- New concepts, technologies, products and services
- Innovative interaction between universities and companies
- A strong future basis for educating IT specialists.

Figure 2: Small CfPC Device.

Pervasive computing goes beyond the traditional user interfaces, on the one hand imploding them into small devices and appliances, and on the other hand exploding them onto large scale walls, buildings and furniture.

The activities in the centre are based on competencies from a broad spectrum of research areas supporting pervasive computing.

Currently, the centre involves the following research areas:

- Ambient Intelligence with Tangible Objects
- Centre for Advanced Visualisation and Interaction – CAVI (described in section 2.1.2)
- Computer Supported Cooperative Work
- Database Technology
- Design Anthropology
- Embedded Systems – Embodied Agents
- Interactive Workspace
- Mobile Systems and Wireless Communication
- Modelling and Validation of Distributed Systems
- New Ways of Working
- Object Technology
- Sound as Media
- Tangible User Interaction

Some research areas are well-established, like Object Technology, some are emerging. Each area is headed by a research manager.

Most of the work in the centre is organised as research projects involving both companies and universities. Many projects cut across research areas.

Most of the work in the centre is organised as Research Projects involving both companies and universities. The 3D visualisation and interaction projects at CAVI will be mentioned later.

Further information on CfPC can be found at http://www.pervasive.dk/index.html.

2.1.2 Centre for Advanced Visualisation and Interaction

CAVI (Centre for Advanced Visualisation and Interaction) is one of the research areas in the CfPC (see section 2.1.1).

3D visualisation is becoming increasingly widespread in as diverse areas as industrial design, architecture, city planning, medicine, moving images as well as the arts. The ability to interact in new ways with 3D models offers new possibilities for the professionals in these areas.

In a unique combination, the following 3D visualisation technologies are available in CAVI:

- **3D Panorama Cinema**
  Curved screen
  Active stereo glasses
  Tracking

Figure 3: 3D Panorama Cinema at CAVI.

- The Panorama cinema is a cylinder shaped screen placed in a room that seats approximately 15-20 persons. The size and shape of the screen mean that the visual angle of the spectators is almost covered by the screen.

  Models are displayed in active stereo, i.e. a picture for the right and the left eye is displayed alternatively in a very high frequency. Without shutter glasses the spectator experiences the image as blurred. But with shutter glasses that alternate between closing off for the right and the left eye in the same frequency, the spectator experiences an illusion of 3 dimensional depth.

  The Panorama is particularly suited for displaying large-scale models within the domains of architecture and city planning.

Figure 4: 3D Panorama Cinema at CAVI in Use.

- **TAN Holobench**
  The Holobench is a combination of two 180x110 cm sized projection screens placed at right angles to each other in an L shape.

  Also here it is possible to show models in active stereo, i.e. the pictures on the screen draw a picture for the right and the left eye alternatively in a very high frequency. Without shutter glasses the spectator experiences the image as blurred. But with shutter glasses that alternate between closing off for the right and the left eye in the same frequency, the spectator experiences an illusion of 3 dimensional depths.

  A tracking system allows the spectator's gaze to be responded to through movement of the model and this heightens the impression of an object in front of the spectator's eyes.

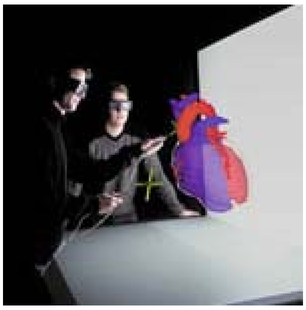

Figure 5: Holobench at CAVI.

- **Virtual Studio**
  The virtual studio or virtual stage set makes it possible to use digital 3D models as sets instead of scenography made from wood, steel, cardboard or other materials. Live recordings in a blue studio with real objects can be mixed with computerised models. It is, for example, possible for a studio host to walk into a completely blue room, sit down on a primitive wooden box and start reporting. What one sees on the television screen could then be that the host enters from a doorway, passes behind a row of plants to sit down at a speaker's desk to start reporting.

Figure 6: Virtual Studio at CAVI.

- **Performance Lab**
  The performance lab is an open space and a facility for several types of experiments including experiments using a reactive performance space, which is a theatrical environment that enables physical actions to effect and manipulate electronic media. These spaces allow performers to improvise with media through a variety of means.

  Electronic media consists of any media that can be controlled from a computer. These are generally divided into four categories: visuals, light, sound and mechanical systems. Physical actions within the space consist of anything that can be sensed and interpreted by a computer. This consists of things like video based sensing, tracking systems, sound sampling, pitch detection or analogue sensors (heat, touch, bend, acceleration, etc.).

Figure 7: Performance Lab at CAVI.

  CAVI has a motion capture equipment as part of the laboratory. Motion capture is a technology that makes it possible to register the movements of a person and use the data to animate a digitally created figure. Cartoonists use motion capture equipment to animate their characters. The technology is also used in many other areas for example in the study of movement in dance, sport and medical research.

  - Onyx2 Infinite Reality2 Rack, 6X250 MHZ MIPS R10000, 1.5 Gb RAM, 2 graphics pipelines (each 64 Mb texture memory)
  - Polhemus FASTRAK (3 sensors)
  - Stereographic glasses
  - 6 Octanes
  - 20-30 O2

Several CAVI-projects will be mentioned in a section 2.2.1.

For further information on CAVI see http://www.pervasive.dk/resAreas/CAVI/CAVI_summary.htm.

2.1.3 VR Media Lab

VR Media Lab (previously VR Centre North) is located at the University of Aalborg. Its main feature is:

- **Cave with 6 walls**
  Active stereo glasses

  The Cave is a room of 2.5 x 2.5 x 2.5 meters in which continuous images can be projected onto side walls, floor, and ceiling. This creates a complete spatial presentation of the scene/model being shown, which gives the viewer a total "immersion" into the spatial virtual environment when using the "active" stereo glasses.

  By using a so-called electromagnetic tracking system the viewer can move in (or around) the visualized object. This installation is preferably for one viewer only and is designed for research and design development.

Figure 8: CAVE with 6 Walls at VR Media Lab.

Figure 9: CAVE at VR Media Lab in Use.

- **3D Auditorium**
  Passive stereo glasses

  The 3D Auditorium accommodates up to 80 persons placed traditionally in from of a large screen measuring 8 x 2.85 meters. The 3D Auditorium shows computer graphics in both 2D and 3D. It is possible to use the so-called "passive" stereo glasses thus presenting the objects as spatial, i.e., objects are seen as if the are in front of the screen. A magnetic tracking system has also been installed making interaction with the graphics possible. Besides the computer graphic images from other sources can be projected (PCs, VHS video and DVD), when the auditorium is used for traditional presentations.

Figure 10: Powerwall at VR Media Lab in Use.

- **Panoramic Screen**
  Active stereo glasses
  Magnetic-tracking device

  The Panorama accommodates up to 28 persons placed in front of a large cylindrical screen with a diameter of 7.1 meters, 160 degrees and a height of 3.5 meters. Because of the shape of the screen, the viewers are given a convincing spatial presentation of the virtual world. As in the 3D auditorium the Panorama can present computer graphics in both 2D and 3D as well as images from PCs, VHS video and DVD. Stereo visualization augments the spatial effect, but the number of viewers is reduced. In Panorama a magnetic tracking system has been installed, and the experience is even more realistic as the screen to an even higher extent "surrounds" the viewers.

Figure 11: Panoramic Screen at VR Media Lab in Use.

These are run by:

- Onyx2 Infinite Reality2 Rack, 6 graphics pipelines
  The three installations are driven by on large supercomputer, an ONYX2 IR2 from SGI. The ONYX is installed in a specially cooled engine room together with several other larger servers. VR Media Labs ONYX2 IR2 has 16 parallel CPU's, 2 GB Ram, 288 GB HD in Raid3 system (transfers 100 MB/sec.) and 6 graphic pipes etc.
- PC cluster
  A PC cluster is being established.

For further information on VR Media Lab see http://www.vrmedialab.dk/pr/index_e.html.

2.1.4 Centre for 3D GeoInformation

Centre for 3D GeoInformation (3DGI) brings together research, public authorities, and business communities in a unique environment of developing 3D GeoInformation applications, all based on new Virtual Reality technology as well as on information regarding urban and rural areas. This is done by establishing a Virtual Geographic Infrastructure (VGI), enabling a wide range of geographically related information to be spread via new, netbased means of communication. One of the new aspects in the project is the user interface, based on intensive use of Virtual Reality (VR) and 3D. By creating a virtual 3D model of reality and then use it as an index for many other types of information, it becomes possible to use the general human ability to familiarize with the surroundings and navigate through space.

The goal is to establish a pioneering project, which will be the central force for the very latest within VR and GIS technologies.

The purpose of Centre for 3DGI is gathering knowledge and competence during the process of creating 3D models of cities and landscapes for organising and presenting GeoInformation applications.

This will be done by:

- Collecting competence and knowledge within the field by arranging seminars/ conferences, establishing international research networks and by employing researchers within this particular field.

- Collaborating with companies, who already possess the most recent competence within VR and 3D urban and rural models or are interested in acquiring this.
- Establishing a VR user interface for looking for position-fixed information in the northern part of Jutland.
- Creating a geographical model of North Jutland, which can form the basis of digital visualisation and the marketing of the resources of the region.
- By developing a basis of knowledge and documentation for the use of a geographical communication concept covering the northern part of Jutland, adapted to the expected increased band width in digital transmission medias (Fixed and Mobile Nets) and as a framework for developing virtual environments.
- Forming the basis for future research and for building up regional knowledge within field-gis (field registration with mobile units). augmented reality (a mixture of 3D models and reality), three-dimensional user interface and the use of broad band for mobile knowledge services.

3DGI is to be a virtual exploratorium in several dimensions. This exploratorium is created partly by gathering knowledge and competence at an internationally high scientific level and partly by developing and conducting a three-dimensional model of the North Jutland region. The 3DGI will then be able to form basis for developing VR technology for the benefit of research and development, strategic functions, operational functions and the mass market in the region of North Jutland.

3DGI is funded by: the European Regional Development Fund (ERDF), Aalborg University, the National Survey and Cadastre – Denmark, Kampsax A/S, and Informi GIS A/S (Danish distributor of GIS products from ESRI and Leica Geosystems (the home page is in Danish)).

Further information on Centre for 3DGI can be found on http://www.3dgi.dk/en/3dgi.html.

2.1.5 VR•C

VR•C is a VR centre at the Technical University (DTU) in Lyngby north of Copenhagen. It is collaboration between UNI•C (a national IT-centre under the ministry of education) and The Technical University (DTU).

The objective of VR•C is to further utilization, research and education in the field of virtual reality (VR) in Denmark and Scandinavia.

Primarily virtual reality is used in connection with building activities, architecture, design and research.

VR•C's main facilities are:

- **Holowall**

  TAN Powerwall (6.5 m x 2.5 m)
  2×3 projectors (TANORAMA/Electrohome) for passive stereo
  Ascension Flock of Birds Tracking system with 2 trackers +
  1 6-degrees-of freedom mouse
  8 active speakers
  3 subwoofers
  1 Microsoft SideWinder Forcefeedback Pro joystick
  1 control for audio panel and SGI terminal

Figure 12: Powerwall at VR•C's in Use.

In the Holowall as many as 50 people at a time can experience the virtual world. By means of stereo projection and polarized spectacles the 3D objects appear spatially in front of the screen. building trade, product development and research-oriented projects.

- **Holodeck**

3 n-vision DataVisor HiRes Head Mounted Display
See-through (augmented reality)
2xXSGA CRT
Headphones and microphone
Ascension MotionStar tracking system with 8 trackers
3x24" Monitors

Figure 13: HoloDeck at VR•C.

In the Holodeck the user wears a VR helmet and sensors on his/her hands to attain integration with the virtual world.

- SGI Onyx2 InfiniteReality2 Graphic Supercomputer
  16 195 MHz MIPS R10.000 CPU's
  8 GB RAM
  356 GB Hard disc
  3 graphic pipes each with 2 Rastermanagers and up to 24 displays
- Lake Huron 20 sound computer
  8 Quad DSP processors
  32 I/O ports
- 4 SGi O2 Workstations
- 1 SGi 320 Personal Workstation

Keywords for VR•C are industry, education and research. Areas of interest are architecture and landscape modelling, scientific visualisation, visual simulation and education, and collaborative VR. For further information on VR•C see http://www.uni-c.dk/generelt/english/research/vr-c.html.

2.1.6 FORCE Technology

FORCE Technology merged in 2002 with DMI (Danish Maritime Institute).

FORCE Technology offers simulator facilities and tools for all levels of maritime education from computer-based training to full-mission simulation.

FORCE Technology possesses a number of full-mission training simulators – one with 360º graphics on 18 m diameter screens and all with a full range of bridge equipment. All can be operated individually or interactively with full passage communication between the ships.

Figure 14: View from the 360° Simulator.

Bridge A, which is the largest, has a horizontal visual field of up to 360 deg. Bridges B and C have a field of 155 deg. and Bridge D of 130 deg. The vertical visual field is 15 deg. All 4 bridges are fitted with normal maneuvering handles (but can be fitted with handles chosen by client) and with radar screens.

Figure 15: Ship Simulator.

For further information on FORCE Technology see http://www.force.dk/gb/default.htm.

2.2 Civilian VR Research and Development Projects

The projects at each of the civilian research laboratories are described in the following sections. For each laboratory the ongoing projects are described first in separate sections, and then the recently ended/finished projects are mentioned.

2.2.1 Projects at Aarhus University

2.2.1.1 Virtual Urban Planning

Partners
The partners of the project are Aarhus University, Cadpeople and COWI.

Aim
The project's goal is to develop and investigate the use of virtual reality technology, as a basis for improvement of decisions to be taken in a city region that is continually undergoing development. Virtual Urban Planning (VUP) has to function as a combined tool for the benefit of politicians, public administrations, building constructors and architects, private businesses and the town's citizens. For example, the advanced visualisation technologies available to CAVI will provide citizens and politicians with the possibility of a simultaneous experience that can be discussed during the presentation and offer an opportunity for focusing on specific details, a particular view from a definite point in the city or something similar.

The research aspect initiates from a series of earlier projects with the feature in common that they all discuss the spatial planning with the aid of digital technologies. They range from *Karlskrona2*, an internet-based multi-user system for use in citizen-based discussion of town planning, to the mixed reality game *[kollision:6400]*, where a physical lp-record is augmented by 3D models and is used for illustrating complex interrelations in the city space. The project's motive, *the town in the computer, the computer in the town*, is to deal with planning our city environment, with the aid of dynamic models of the city's space, an environment that can be experienced purely digitally or by means of, say, augmented reality-technologies in interaction with our physical world.

Results
A 3D-model is created on many levels of detail-addition, where future alterations to the physical relation in the town space can be inserted and tested. In this way, the model becomes dynamic. If, for example,

there are several construction suggestions for the same project, they can be "turned on and off" in the model and the individual changes can be evaluated in a more extensive context, since the surroundings are created in 3D. After this, not only the building process, but also its relation to the surroundings can be evaluated.

Team
Kim Halskov Madsen, Morten Lervig, Rune Nielsen, and Bo Degn.

2.2.1.2 Visualization of the Cardiovascular System

The cardiac morphology in patients with congenital heart disease is often very complex and variable from individual to individual. Consequently, accurate morphological information remains of outmost importance when planning the surgical intervention. Magnetic Resonance Imaging (MRI) is the imaging modality that currently provides the best soft tissue contrasts. New visualization techniques based on three-dimensional MRI have been developed and is now being implemented and tested clinically at Aarhus University Hospital.

Partners

- CAVI, University of Aarhus
  - Thomas Sangild Sørensen
- Aarhus University Hospital
  MR Research Center
    - Erik Morre Pedersen, MD, DMSc, PhD
  Dept. of Cardiothoracic Surgery
    - Ole Kromann Hansen, MD
  Dept. Cardiology
    - Keld Sørensen, MD
- Systematic Software Engineering
  - Søren Vorre Therkildsen

Results
The preliminary results show that cardiac morphology in congenital heart disease can be accurately reconstructed and represented by virtual models. As MR image quality continuously improves, image processing times are being reduced rapidly. This will undoubtedly make three-dimensional MRI with virtual reconstructions an important clinical investigative tool within the nearest future.

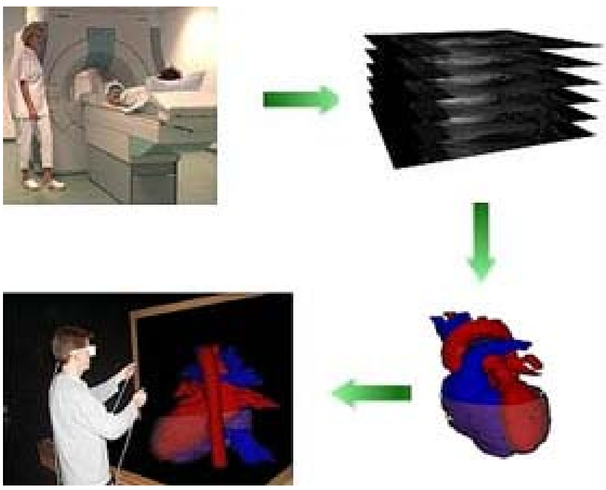

Figure 16: The Process from Scanning to Visualization on Virtual Reality Equipment.

Related research will implement elastic tissue properties, allow cutting the model and inserting patches, as first steps towards a surgical simulator/trainer.

Links
Systematic Software Engineering: Virtual Reality Heart.

2.2.1.3 Digital Theatre – Hyperopticon

The use of digital media in theatre and other time based art forms is increasing as the cost of computers decreases and the development of software programmes has been made more available to theatre technicians. Still there are many fields still to be researched and explored.

Figure 17: Digital Theatre.

The members of The Digital Theatre from the University of Aarhus have worked in the following fields of digital theatre research: the dramaturgy of digital media, virtual puppet theatre, motion capture/animation, and reactive spaces. Through experiments and productions The Digital Theatre group has explored the production and reception of theatrical spaces in order to explore interactive possibilities in digital media.

HYPEROPTICON was created from a concept of developing a particular site i.e. in a library, where a small audience might have the opportunity to explore a specific theme, a play or an event through interaction in a mixture of digital media and real-life performance.

Partners
The partners of the project are Aarhus University, Denmark, The Academy of Figurative Theatre, Norway, Studio di Progettazione, Italy, and CAVI, Aarhus, Denmark.

Goals
The scientific goal is to develop concepts and produce digital theatre experiments that can be used to further the knowledge of dramaturgical understanding and broaden the knowledge of perception of digital time based art.

One focus of the research has been to develop new forms of staging plays through an idea of exhibiting a story or a plot and to make this an interactive experience. So the investigation of space and digital technologies is also a crossover art experiment with digital media as means of production.

Themes
The last production An Angel's View was staged as an exhibition in seven stages and set up as a walk through elements of a theatre experience and an art gallery. The experiment was made to find a new concept of staging – or rather exhibiting – a text that would give the audience an opportunity to interact with this text and compose their own impression of the play.

The concept of Hyperopticon was created to bridge between the dream of being linked to everything everywhere and the nightmare of being seen everywhere by everyone to explore if there is still a human necessity in interesting interaction. The concept of an Angel's View was to see a "hyperoptic view" in light of the metaphor of an angel's view and apply this meta-view to a dramatic text (Beckett's That Time).

Results
A performance and dramaturgical theory of performance-based visual exhibitions based on a reactive space that can pick up inputs and make it possible to compose words and images.

People

- Torunn Kjølner
- Niels Lehmann
- Janek Szatkowski

Project Manager Torunn Kjølner

2.2.1.4 3D Experiences

Scandinavia and Denmark hold a prominent place in the film media. Good story telling is an imperative, and international successes are evidence of a high standard in both dramaturgy and production. 3D opens up completely new avenues and sets entirely new demands on all aspects of filming, whether dramaturgy, production or staging.

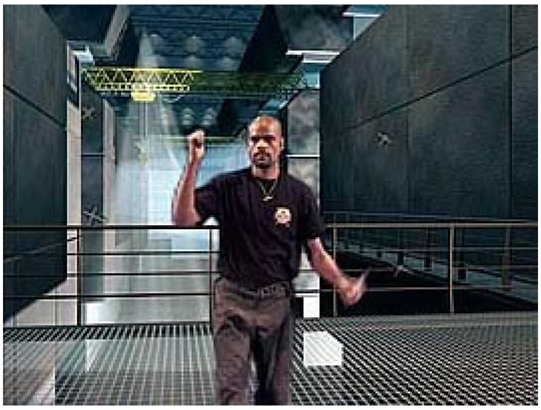

Figure 18: Using VR for Staging.

Also in the case of exhibitions, communication, entertainment and education, 3D technology is increasingly important. Today 3D is already in use in adventure parks, such as Legoland parks and Universal Studios, but 3D technology confronts great challenges and possibilities not only in this area but also in showrooms, exhibitions and education.

Partners
The partners of the project are Aarhus University and Zentropa Interaction.

Aim
The overriding aim is to investigate and develop the potential for 3D within film, interactive TV and other forms of sense-stimulating and educational areas.

The research goals are:

- To reveal and develop present and future technological possibilities and challenges within the 3D narrative and experiences;
- To investigate new possibilities and visions, which arise when classical film artistry meets virtual reality.

The industrial goal is:

- To contribute to Danish film production's development and expansion into new business areas in the context of 3D.

Results
As a result, 2 pilots will be available and one or more future scenarios:

- 3D short film pilot
- 3D pilot for interactive TV design
- Scenarios for 3D realistic experience space and communication

Figure 19: Filming Real Actors on a VR Background.

Team
Kim Halskov Madsen, Svend Erik Søfeldt, Morten Lervig, Ruben Borup, Bo Degn, Peter Friis.

2.2.1.5 3D Sound in 3D Space

3D visualisation in Panorama displays is a widespread means of communication within a number of areas including architectural-design and experience-oriented applications. At the same time, it has been confirmed that sound similarly provides a powerful instrument which so far has been exploited to a limited degree in 3D visualisation in panoramas and similar interactive 3D display facilities.

TC Electronic is unquestionably one of the world's leading developers and producers of sound effect equipment, including equipment for spatial simulation of multi-channel music, but has only worked to a limited extent with real-time design of the sound experience, where the listening position and the sound source are in relative motion to each other.

Partners
The partners of the project are Aarhus University and TC Electronic.

Aim
It is the project's overriding aim to develop and investigate the use of 3D sound in three-dimensional graphical spatial models.

The research goals are:

- To develop the immersion experience in 3D presentations in Panorama using the audio dimension;
- To identify future potentialities for exploiting the audio dimension in conjunction with 3D visualisations within architecture, design and experience-oriented applications;
- To improve simulations of the natural sound experience in an interactive environment.

The industrially oriented goal is:

- To develop real-time generation of 3D sound experience more fully, for example, by increasing the speed of sound processing.

Results

Software will be developed to make it possible in connection with a visual 3D model to move around in it, where 8 sound sources are positioned in the model and the sound reception corresponds to the sound position and orientation with respect to the sound sources and where the sound experience reflects the 3D room's acoustic properties. In this way the sound can be "coloured" so that it reproduces the virtual environment's sound-reflective properties more faithfully, and thereby strengthen the immersion experience, which the panorama provides.

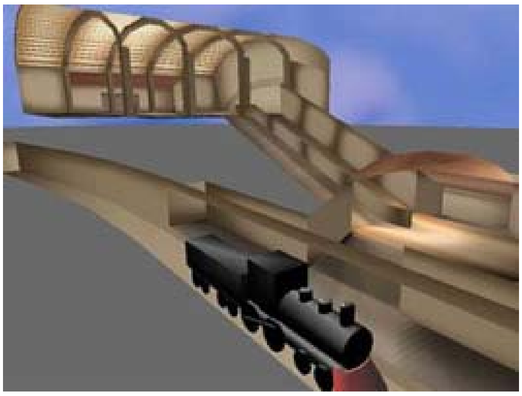

Figure 20: 3D Sound in 3D Space.

An algorithm will be developed, whereby the sound can find its way to the listener in the virtual world. That is, the sound's path to the listener takes the height of the walls, doors, corridors, etc. into account.

This has the effect that the sound not only reflects the single virtual room, in the way made possible by TC Electronic's System 6000, but also allows the sound experience to be simulated in virtual worlds consisting of many rooms.

Team

Kim Halskov Madsen, Morten Lervig, Gorm Lai, Bo Degn, and Peter Friis.

2.2.1.6 Interfaces for 3D Applications

3D models are becoming increasingly widespread and used in a diversity of areas, for instance architecture, product design, medicine, and art. At the same time pervasive computing brings us into the domain where software and 3D models must be portable between systems with different display and interaction systems some of which are integral part of physical devises or other parts of the environment. Whereas studies and development of interaction technology and styles for 2D user interfaces have a longstanding tradition, navigation and interaction in a 3D environment is fairly unexplored.

Partners

The partners of the project are Aarhus University, Personics Aps, Systematic Software Engineering A/S, RoninWorks BV (Holland) and CAVI.

Goals

The scientific goals are to advance the development of cross-platform independent interface technology for 3D virtual reality applications, and to develop a universal non-touch interface for navigation and interaction in a 3D environment. The commercial goals are to expand RoninWorks strategy of leveraging the traditional developer base by integrating knowledge of newer devices and displays, to expand the applicability of Personics equipment into new domains and to advance the interface technologies available for Systematic's products.

Themes
The proposed interface technology will transfer human gesture into 3D navigation and interaction. The development of a cross platform independent layer and a platform independent interface framework for 3D interfaces, that makes it possible to move 3D models between platforms with different display and interaction technologies.

Results
A cross platform non-touch navigation system of 3D environments and interaction tool.

People
Kim Halskov Madsen and Thomas Sangild.

2.2.1.7 Finished Projects

- **3D image processing for cranium- and brain-surgical planning and simulation** at CAVI and PET Centre at Aarhus University Hospital.
- **Digital, 3D atlas of the receptor systems of the human brain** at CAVI and PET Centre at Aarhus University Hospital.
- **Product Development**
  CAVI has for 2 years cooperated with Centre for Product Development at the Technical University of Copenhagen on visualisation. The following are examples where 3D visualisation has been used:

Arla Foods	Packaging design
Kampsax/Lundbeck	Landscape visualisation
Arkitektfirmaet Schütze A/S	Architecture
CF Møller/CADpeople	City planning
Danmarks Radio	Virtual set activities / Ren Kagemand (Danish television show)
Jydsk Dykkerfirma (Diving firm in Jutland)	Beaching Museum St. George

- **The Family Factory**
  The family factory is a theatre show that combines ordinary theatre with traditional animation, puppet handling and live 3D computer animations. The virtual creations are not just programmed ahead with a limited set of actions. Actors control them with motion capture while they perform their one role. The project is a corporation between CAVI, The Danish Film School, and Schule für Schauspiel-kunst "Ernst Bush" Berlin. Further information can be found on http://www.multimedia.au.dk/JCal/ff/fabrikinfo.html.

- **The Digital Theatre**
  An Experimentarium in 1999 examined the artistic possibilities involved in the encounter between real and virtual performers, between virtual beings in real spaces and real beings in virtual spaces. These encounters were established by various means of digital technology transforming movements in

time and space into 3D-animations via digital data. The technology used for this purpose was motion capture technique, animation programs and projection techniques. Further information can be found on http://www.daimi.au.dk/~sdela/dte/index.html.

- **Whizbang**
  From a set of measurements of the seabed, a data file is created which is visualized by means of volume rendering. It is possible to cut in the large amount of data and manipulate the model in different ways so that the data is easy to grasp. A Master's thesis project by Niels Husted and Kaare Bøgh.

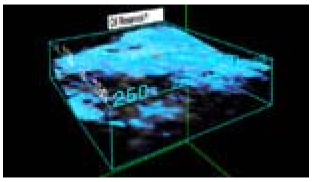

Figure 21: Whizbang.

- **Aarhus New Art Museum**
  A model of Aarhus's new art museum for the panorama cinema. The model was made in co-operation with the art department Schmidt, Hammer and Lassen for the Aarhus Art Museum and financed by the merchant department of the Aarhus City Council.

Figure 22: Aarhus New Art Museum.

- **The CAVI Building**
  A digital model of CAVI's building which was used in connection with planning and designing the building.

Figure 23: The CAVI Building.

- **Katrinebjerg Phase 2**
  A model of the Katrinebjerg phase II building was made to show visitors to CAVI how the next phase of the IT park extension will look.

Figure 24: Katrinebjerg Phase 2.

- **Katrinebjerg Phase 1**
  A 3D model showing an overall vision of the future Katrinebjerg IT City.

Figure 25: Katrinebjerg Phase 1.

- **Architectural Competition**
  Visualization of a project proposal for the TDC domicile made for the architecture firms of Jørn Schütze.

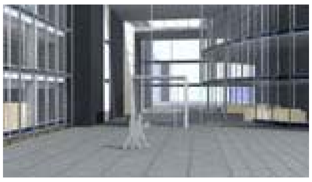

Figure 26: Architectural Competition.

2.2.2 Projects at Aalborg University

2.2.2.1 The Project of Sonderborg

Project Description

VR Media Lab has in collaboration with Cadpeople and COWI made a 3D model of some parts of the town of Sonderborg. The project was financed by the Danish National Research and Educational Buildings in connection to a new university building project.

Further information can be found on (page is under construction)
http://www.vrmedialab.dk/pr/activities/spatialmodeling/sonderborg.html.

2.2.2.2 Aalborg University Campus Model

Project Description

VR Media Lab is building a 3D model of the campus at Aalborg University. The model is going to be used as tool for the next 10 to 20 years when the university is going to be enlarged.

Further information can be found on (page is under construction)
http://www.vrmedialab.dk/pr/activities/spatialmodeling/campus.html.

2.2.2.3 CAE and CFD into Virtual Reality

CAE and CFD into Virtual Reality (CCVR) is a post-doc planning research activity at VR Media Lab by Truc Huynh and Henrik R. Nagel.

Computer-Aided Engineering (CAE) and Computational Fluid Dynamics (CFD) are developed for structural engineering application, typically on the personal computer monitor.

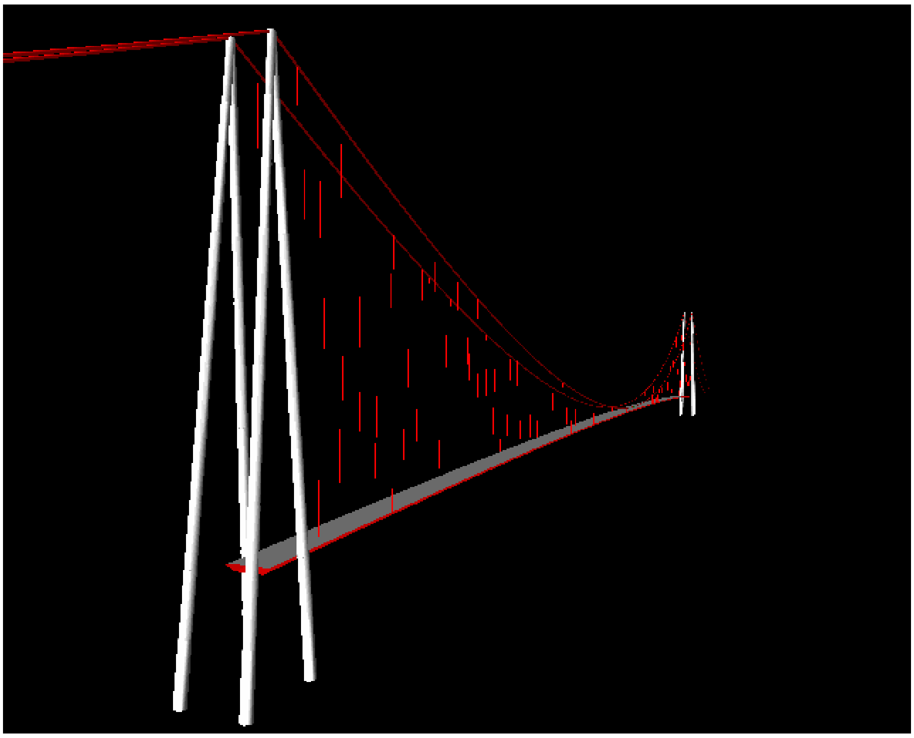

Figure 27: Computer-Aided Engineering (CAE) and Computational Fluid Dynamics (CFD) Visualized in VR.

However, it is a common desire for structural engineers that a large screen is needed for large structure, where the whole construction can be analysed in global dimension or zoomed in into a local part as well. Further, the large screen and the virtual reality device will also make the idea visible during the research step and the final presentation.

To this purpose the following is available at the VR Media Lab:

- Panorama wide screen in arc of a circle of 160°, 7.1m diameter and 3.5m height
- Wide screen of 8x2.85m
- Cave på 2,5 x 2,5 x 2,5m (C-language Application Virtual Environment)

The CCVR research is to the effect the creation and analysis of a construction in virtual reality (VR), where the suspension bridge is an example. A post-doc on "Wind-Bridge Interaction" is planed on the developing Ph.D.-thesis "Suspension Bridge Aerodynamics and Active Vibration Control", Truc Huynh, July 2000. The physical idea behind the thesis is that the girder-flap-wind interactions are studied theoretically and numerically with the goal to obtain the vibration reduction of the wind-exposed suspension bridge girder using the motion of the separate control flaps attached along the girder.

This problem can now develop graphically on the Panorama with full-span bridge-wind interaction analysis. Hence, the bridge and its motion due to the wind can be studied in three dimensional dynamic translation and rotation (also on Silicon Graphics computer monitor).

The research is planned to be a cooperation between VR Media Lab, Department of Building Technology and Structural Engineering, Aalborg University and Engineering Consulting with the similar interest to fund the project.

Step of work is planed to consist of two separated parts. One refers to CAE and CFD. The other is the transformation of the CAE and CFD graphical results into VR.

First step of CAE natural mode shapes into VR has been done sufficiently, where the bridge construction and its dynamic eigenvectors are transformed into virtual reality animation. Also the real box-girder can be animated together with the bridge vibration using geometrical assumption at the VR step.

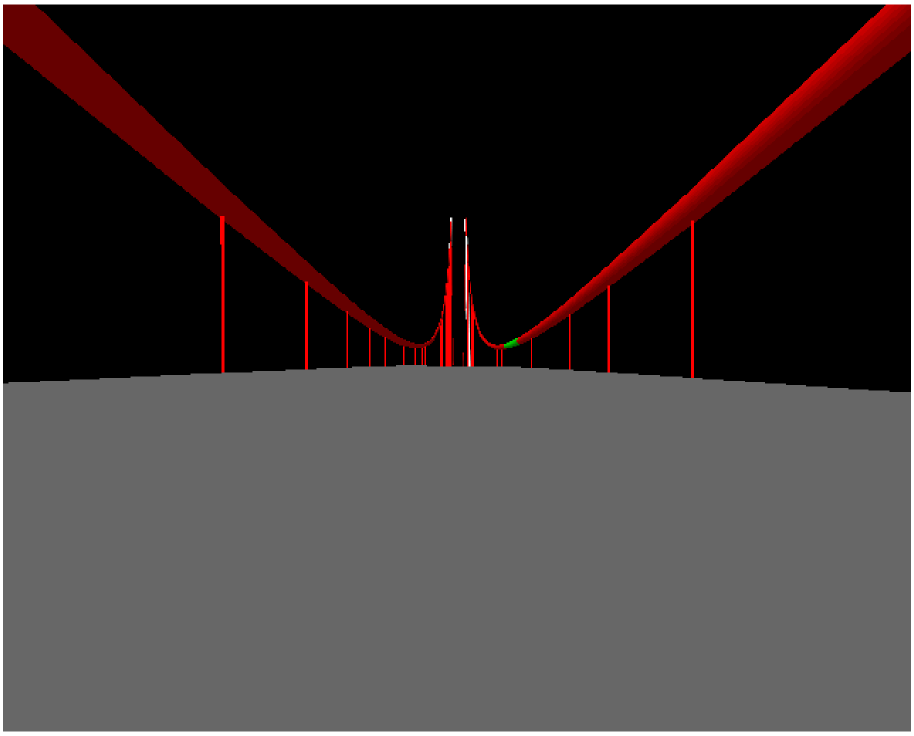

Figure 28: CAE and VR in Bridge Construction.

Further information can be found on http://www.vrmedialab.dk/pr/activities/simulation/ccvr.html.

2.2.2.4 3D Airflow

VR Media Lab has in co-operation with the Department of Building Technology and Structural Engineering (also at Aalborg University) worked on visualising airflows in buildings.

Aalborg University, the Danish Institute of Agricultural Sciences, and the Royal Veterinary and Agricultural University have concluded a five year framework program together focussing on computer simulation of ventilation, airflow, and indoor climate of stables.

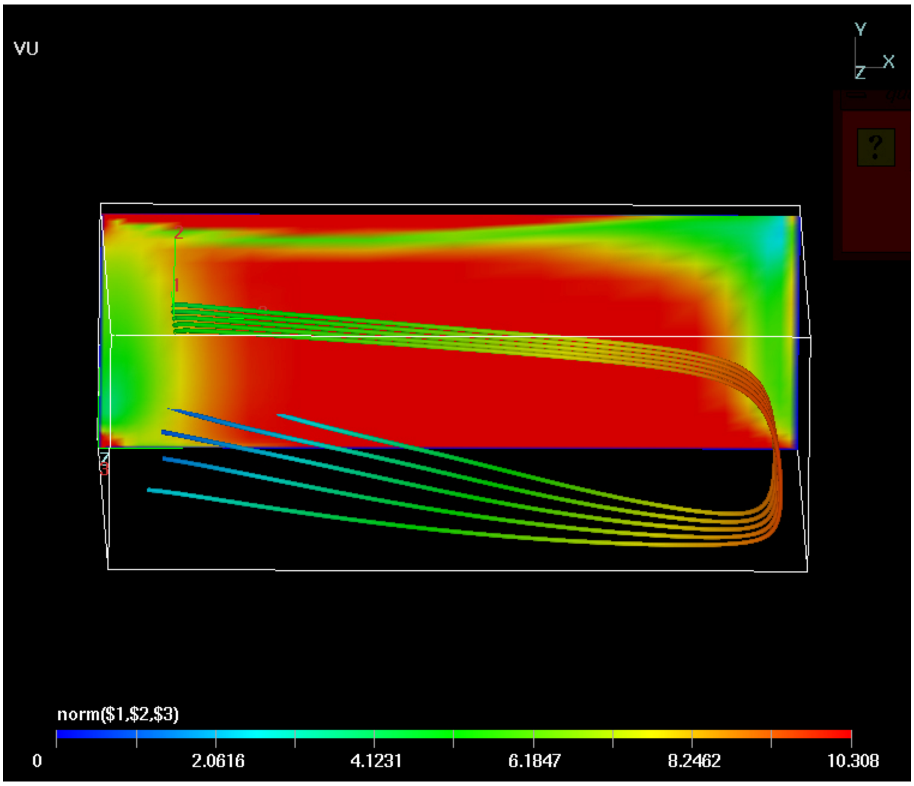

Figure 29: 3D Airflow in a Stable.

The purpose of the project is to understand and control the airflow in stables. This will make it easier to improve the working conditions for the farmers, the animal welfare, and the economy of the animal production.

The role of VR Media Lab's is to visualise the 3D computer simulations being run at the Royal Veterinary and Agricultural University and at the Department of Building Technology and Structural Engineering.

The purpose of the visualisations is to examine the details of the results of the computer simulations, which can be difficult to perceive on ordinary computer screens. The results have also been shown to consultants and companies in the ventilation business.

Further information can be found on http://www.vrmedialab.dk/pr/aktiviteter/simulering/3dluft.html (in Danish. An English version will be up soon on http://www.vrmedialab.dk/pr/activities/simulation/3dluft.html).

2.2.2.5 3D Visual Data Mining

3D Visual Data Mining is a research project at VR Media Lab

Technology to store and process large amounts of data has during the last decades improved dramatically. This has led many companies to store ever increasing amounts of customer information in large databases. The hope has been that it would be possible to discover unknown relationships in the data, and thereby obtain a knowledge which could give commercial advantages. This could, e.g., be the knowledge of which good customers would soon leave the company. This knowledge could then be used by the company to make the customers concerned a more attractive offer.

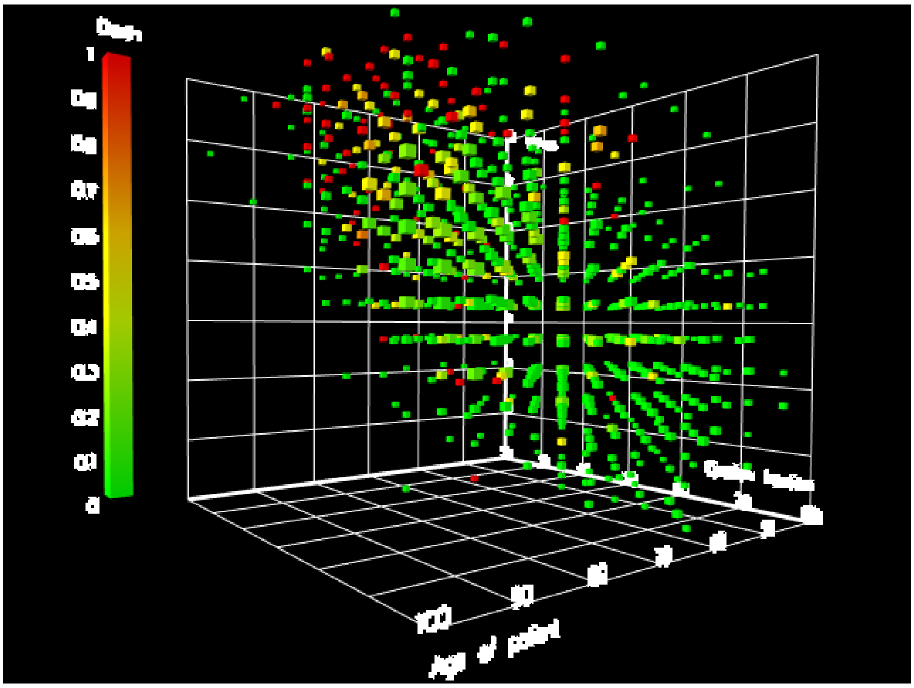

Figure 30: 3D Data Mining.

However, finding hidden relationships in large amounts of data is not easy. Purely numerical methods have been supplemented with visual methods. This has led to the emergence of “Visual Data Mining”. Visual Data Mining has traditionally employed 2D techniques, such as geometric, icon-based, pixel oriented, hierarchical, and graph-based methods. With the 3D Virtual Reality (VR) facilities available at VR Media Lab it is now possible to explore how the ability to interpret 3D objects can be used in Visual Data Mining.

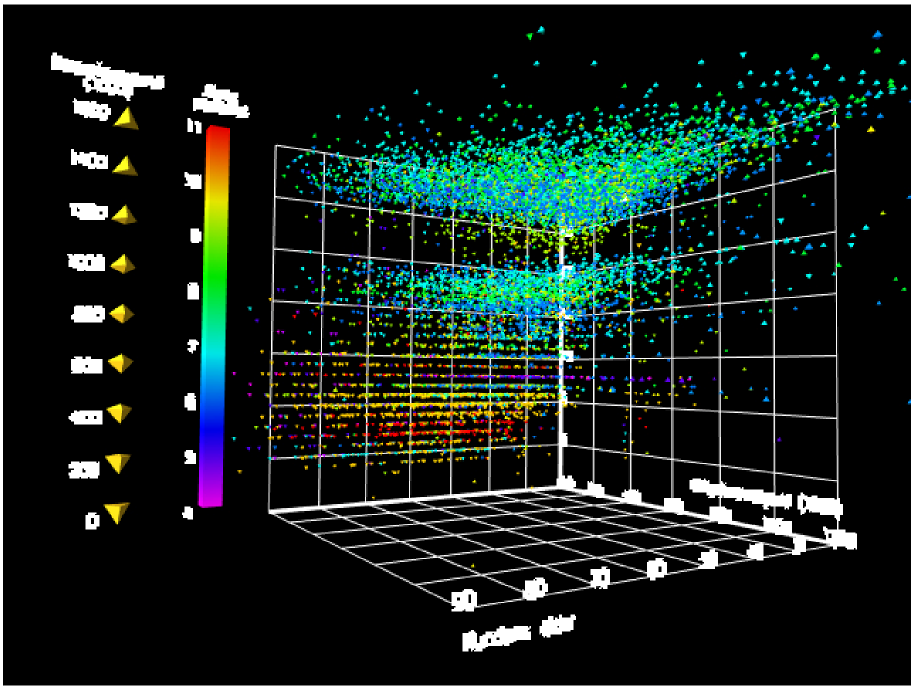

Figure 31: Visual Data Mining.

The 3DVDM project aims at exploiting all the possibilities that immersive 3D VR technology may provide to Visual Data Mining, and then adapt the data processing methods to this. The project has collaborators from four areas of science: Database Systems, Statistical Analysis, Perception Psychology, and Visualization. Researchers in the database area are responsible for handling and delivering large amounts of data from databases. Statisticians are responsible for finding interesting problems, creating statistical models for data analysis, and guiding the entire project in experiments of 3DVDM system. Perception psychology researchers are responsible for finding ways of good interaction and human perception of VR environment. Visualization researchers are dealing with the visualization of data using VR Media Lab facilities and implementation of a novel VR environment for data mining.

For further information contact Linas Bukauskas.

2.2.2.6 Learning

In cooperation with Vestas and Zenaria is VR Media Lab developing a pilot project in order to clarify the use of VR-technology in various learning situations.

This particular pilot project involves teaching of Vestas electricians thus enabling them to perform a more accurate repair of the windmill on-site.

This, however, requires a more thorough understanding of the theories behind basic electromagnetics.

The problems arise from the fact that foreign electricians do not have the same educational background as Danish electricians. Therefore the outcome of the project is an education, where the windmill electricians attend a course at VR Media Labs facilities followed by an introduction to a CD-ROM which contains VR-sequences from the course.

For further information contact John Tørring.

2.2.2.7 Vestas

One of the learning projects at VR Media Lab is called Vestas.

Project Description

The project addresses problems at two levels: at an abstract and method developing level as well as at a concrete application level.

At the first level the project presents the following problems:

- To include the newest forms of interactive multimedia and VR technology in order to develop and test new methods of learning in a virtual environment.
- To estimate to what extent different interactive technologies can be used in learning situations regarding with education and further training.
- On the basis of a specific education program to evaluate the use of educational methods and possibilities.

At the second level the following problems are presented:

- To develop a VR product for Danish as well as foreign wind turbine electricians in order to extend their qualifications.

The wind turbine industry has a considerable amount of export trade. The mounting and the following maintenance are done by foreign electricians who may not be fully qualified. Besides there may be cultural differences causing an incorrect translation of the Danish manual.

An incorrect mounting or maintenance may lead to a breakdown of the wind turbine causing unnecessary financial costs. This project aims at solving the above problems by using VR technology. By using visual means the project will give the necessary information thus being able to cope with any language or education related barriers.

Figure 32: Visualising in the Vesta.

Project Characteristics

- To be a method based on new digital technologies and interactive multimedia which improve the understanding of e.g., manuals.
- To develop a method for "digital interactive service manuals" which ensure the "on-location" use of maintenance/repair instructions.
- To develop a VR based teaching/education product.
- To develop a VR based method applicable when evaluating the influence of the mounting of a wind turbine regarding the environmental aspects; i.e., nature and town.

For further information contact Erik Kjems.

2.2.2.8 Finished Projects

- **A Music House in Aalborg**

  The city of Aalborg needs a new music house ("Musikkens Hus"). The new music house will be situated by the harbour right next to the old power plant.

  VR Media Lab made a visualization of the proposals, which were sent from several architectural firms from all over the world. These visualizations were presented to the committee of judges. Their decision was made based on the visualization of each proposal.

The winning proposal was presented at "Studenterhuset" (student house) in Aalborg in February 2003. Furthermore a report in collaboration with the Danish National Research and Educational Buildings has been issued. This report describes the entire project using the VR technology in an architectural competition.

Further information can be found on http://www.vrmedialab.dk/pr/activities/spatialmodeling/musikkenshus.html.

- **A Plan for New Housing Development**

The project of the town of Ans, Kjellerup Borough in mid Jutland is an ordinary plan for new housing development. These housing plans are made every year all over Denmark. The characteristics of this particular project are that the new housing area is at the outskirts of the town. The new housing area is situated in attractive natural scenery overlooking a meadow.

COWI, a Consulting Engineers and Planners firm in Aalborg, asked VR Media Lab if they were interested in visualizing this new housing development, as the borough of Kjellerup was very skeptical about the extent of the plan and the damage done to the area.

Figure 33: The Town of Ans.

The first step was to model the project area. COWI prepared the basic data from altitude information, ortho photos, and from a road project cut into the model.

VR Media Lab employed four students from the Architecture and Design study program, who prepared a first draft to the borough during the summer of 2000.

The next step was an alteration in the regional plan. The model was modified according to the alterations agreed upon, and the project was presented to all members of the Kjellerup Town Council in May 2001. Based on this presentation it was decided that the project was to be implemented. The area has been site developed and is now ready for its new residents.

VRML model of the project (download viewer here).

For further information see http://www.vrmedialab.dk/pr/activities/spatialmodeling/ans.html.

- **Highway at Holbæk**

  The project aimed at testing a large road project based on the facilities and equipment of VR Media Lab.

  Model conversion, model reduction, and navigation were at the top of list of things to be tested. A very simple model was presented. Only the most necessary parts of the project was modelled, i.e., all other spatial elements in the landscape (buildings, plants, or road elements) were not included in the model. Right now there are no plans for continuing this project, even though the Panorama is an obvious facility to present landscape constructions of this particular kind.

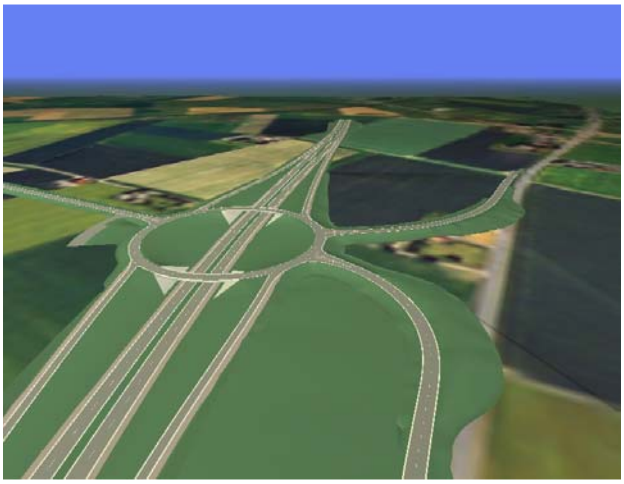

Figure 34: Highway at Holbæk.

  For further information see http://www.vrmedialab.dk/pr/activities/spatialmodeling/motorvej.html.

- **Model of NOVI 3, 4, and 5**

  The project aimed at modeling the NOVI buildings. This enabled a presentation of the models in the Panorama facility causing a discussion about the further building plans of NOVI.

  The project was divided into two parts: The first part deals with NOVI 3 and 4. This part was completed in the summer of 2000. Simultaneously models of NOVI 1 and NOVI 2 have been outlined.

  NOVI 5
  The model of NOVI5 was made at a very early stage compared to the construction itself, which was completed in the summer of 2001. VR Media Lab worked together with architect Peter Tybro from Vilhelm Lauritzen AS.

Figure 35: NOVI.

  The architect firm made traditional drawings of the building, and the modeling has been made from two-dimensional technical drawings of ground level and aspects.

  The model was being used to describe various light angles at different times of the year. These light angles were presented and evaluated in the Panorama facility. The model was also used to present choice of interior, colours and forms inside the building.

  For further information see http://www.vrmedialab.dk/pr/activities/spatialmodeling/novi.html.

- **Puppet** was a research project funded by EU-commission at the University of Aalborg. It involved developing virtual inhabited 3D rooms for educating pre-school children.

- **Staging of Virtual Inhabited 3D-spaces** was a research project funded by the Danish National Research Council involving the University of Aalborg, etc. It dealt with all kinds of aspects regarding the nature and usage of the signs system of interactive multimedia; which in general terms meant the semiotic of interactive multimedia systems. The purpose was to define a universal common language for 3D interactive multimedia systems.
- **Sound in Cyberspace** is a research project at the University of Aalborg.

2.2.3 Projects at Centre for 3DGI

The projects at Centre for 3DGI can be divided into the following Research/Development Tasks:

- Automated Extraction of 3D objects
- Qualification of 3D GeoInformation
- Queries for navigation in 3D Models
- Representation of objects
- Distributed Database System
- Viewer

Further information on 3DGI can be found on http://www.3dgi.dk/en/3dgi.html.

2.2.3.1 Qualification of 3D GeoInformation

3D models of landscapes based on orthophotos and laserscannings is becoming accessible on the internet and in other 3D environments. The technique of the software is advancing rapidly but not much guidance for building up models optimal for the users exists. The goal of the research group of 3DGI is therefore not only to develop 3D geographic software, but also to take user demands into consideration, both concerning graphical design of objects and data input, and the functional design like navigation and interaction. Developing interfaces, design and navigation at 3DGI is based on user tests and inspiration from classic and more well established research areas like cartography and web usability/GUI's.

Further information can be found on http://www.3dgi.dk/en/research/qualification.html.

2.2.3.2 Queries for Navigation in 3D Models

The main research focus lays on queries related to the 3-D Geographical database, i.e., a repository containing data related to the surface of the earth. The query result will be a pre-processed data set suitable for 3-D visualization. The aim of the queries is to enable an efficient navigation through huge amount of data stored in one or more interconnected databases. The amount of data transferred to a viewer should be minimized to potentially displayed data only.

The underlying query algorithms will take into account the level of detail of the geographical features. It will also perform automatic data pre-processing, regarded as cartographic generalization in 3-D. Only few working algorithms have been introduced, which deal solely with 2-D cartographic maps. A similar approach combined with the level of details could result in generating a more meaningful 3-D model, i.e., avoiding unnecessary details, while graphically emphasizing the features of interest.

Further information can be found on http://www.3dgi.dk/en/research/queries.html.

2.2.3.3 3DGI Viewer

The 3DGI viewer uses part of the ROAM algorithm to do level of detail on the terrain. The algorithm uses fewer triangles to represent the flat areas and more to represent the uneven areas like hills, cars, trees, and houses. The images shown in the viewer are dependent on the viewpoint dependent version of the viewer. Not only does the viewer use fewer triangles to represent the uneven areas, now it also uses more triangles for the structures close to the viewer and reduces the number of triangles far away, but is also uses viewpoint dependent continuous level of detail on the landscape. Landscape patches are geo referenced, and the viewer can handle more than one. A segmentation process of the laser scanning groups points that belong to the same plane in the same segment. In particular this is noticeably on the larger segments such as the ground and the rooftops. The first rooftops have been reconstructed. The algorithm is still unstable and makes assumptions about the houses.

Figure 36: 3DGI Viewer.

Further information on 3DGI can be found on http://www.3dgi.dk/en/3dgi.html.

2.2.4 Research Projects at VR•C

The following sections gives short presentation of research projects at VR•C. For further information on the projects please contact info@uni-c.dk.

2.2.4.1 Interactive 3D Visualization of Projects

Interactive 3D visualisation is a growth area, where interactive virtual models are used to support decision-making regarding larger projects, and for design of new products. The virtual model is used to enhance the level of information and to further communication. The virtual environments are based on CAD models and technical 3D drawings. These are imported in the VR system, enabling the user to navigate and work interactively with the different 3D objects. Among others VR•C has provided visualisation solutions and software to SEAS Energy Group regarding visualisation of a windmill farm at Nysted, Radio Denmark with regard to the new headquarters in Radio Denmark City, and a larger visualisation of the dock area for the Municipality of Copenhagen.

2.2.4.2 Scientific Visualization

With scientific visualisation researchers are provided with a tool for handling and visualising academic results. It is possible to reach totally new insight by making abstract models and large complex data volumes accessible and intelligible in a so far unseen manner.

In cooperation with DTU (The Technical University of Denmark) VR•C has carried through projects for the oil industry regarding visualisation of seismic data, and for the windmill industry regarding visual analysis of turbulence at the tip of the wing of a windmill.

Presently VR•C is taking part in a research project with Grundfos and Force in a machine-acoustics project, with the objective of developing an interactive tool for visualisation of the stream flow in pumps.

2.2.4.3 Finished Projects

- **Network-Based VR Technology**
  Network-based VR technology is an innovative research area. With visualization and broadband technology it is possible for groups across subject boundaries and geographical distances to collaborate on complex problems in a virtual 3D environment.
- **VR in Neuro Informatic** at the Technical University.
- **Simulating a combine harvester** at the Technical University.

2.2.5 Projects at COWI

In previous sections it has been mentioned that COWI is involved with the Virtual Urban Planning project and the project of Sonderborg. COWI also has development projects by itself in the areas of GIS and VR. One of these is the Skyline project.

2.2.5.1 Skyline

Figure 37: Århus, Video sequence – Windows Mediaplayer vers. (3238 kb).

COWI is distributing 3D visualization software from Skyline Software Systems. With this software and the nationwide 3D model, you can make a virtual flight across Denmark. In the Skyline 3D-viewer, TerraExlorer, you can freely navigate in a 3D world. The photo-realistic, aerial image based terrains can be accessed on the Internet through video streaming – without appreciable loss of performance.

With TerraExplorer Pro, you can create or import all the desired terrain overlay information, such as routes or text, labels and graphics, to promote specific features in the landscape.

Imagine a 3D model for an area of natural beauty, with differences of height and many cultural landmarks. You are taken into the landscape through a predefined route passing signs that tell you the names of towns and landmarks, e.g. castles and churches. The trip can be interrupted whenever you like and you can freely navigate in the model. A click on one of the signs informs you about the subject, e.g. from a homepage. A click on one of the supplied surfaces gives you information about the use of a certain area. You can find 3D objects such as windmills or you can follow marked routes such as bicycle routes or scenic routes.

Skyline Project

Figure 38: Skyline Project for the County of North Jutland (click on picture to start simulator).

COWI has supplied the County of North Jutland with a Skyline 3D-model of the county, composed of a height model, draped orthophotos and supplied with building polygons from The National Survey and Cadastre Department. Everybody can go into the North Jutland County homepage, www.3d.nja.dk, and fly around in the county or you can key in an address and fly to the address in question.

3.0 MILITARY VR-PROJECTS

Military VR-projects are either ready-made bought simulators or research and development. Exceptions are VIKING GIS, and RTP 6.14 Virtual Environment in Military Decision Making mentioned below. Military research and development takes place at the Danish Defence Research Establishment (http://www.ddre.dk/).

3.1 HCI-Lab

The HCI-Lab at the Danish Defence Research Establishment is used for testing VR hardware and software. In 1999 the laboratory had the following hardware:

- Teranetix Blackbird XL Xeon
  - 2 x 3.06GHz Xeon 533 FSB
  - 2 GB ECC DDR memory
  - 182 GB hard disk
  - ATI FireGL X1 256 MB AGP Pro x8
- Assorted PC's
- Ascension's Flock of Birds
- V6 helmet
- I/O glasses
- Gloves
- Logitech Spacemouse

The laboratory has the following software:

- SuperScape
- Sense8
- Multigen Creator
- DI-Guy

3.2 F16 Flight Simulator

The F16 flight simulator is a readymade bought system from Hughes for the Air force. It consists of a mock-up of a cockpit standing in front of 3 screens as shown in Figure 39. The simulation is run on a Silicon Graphic's computer from a control room.

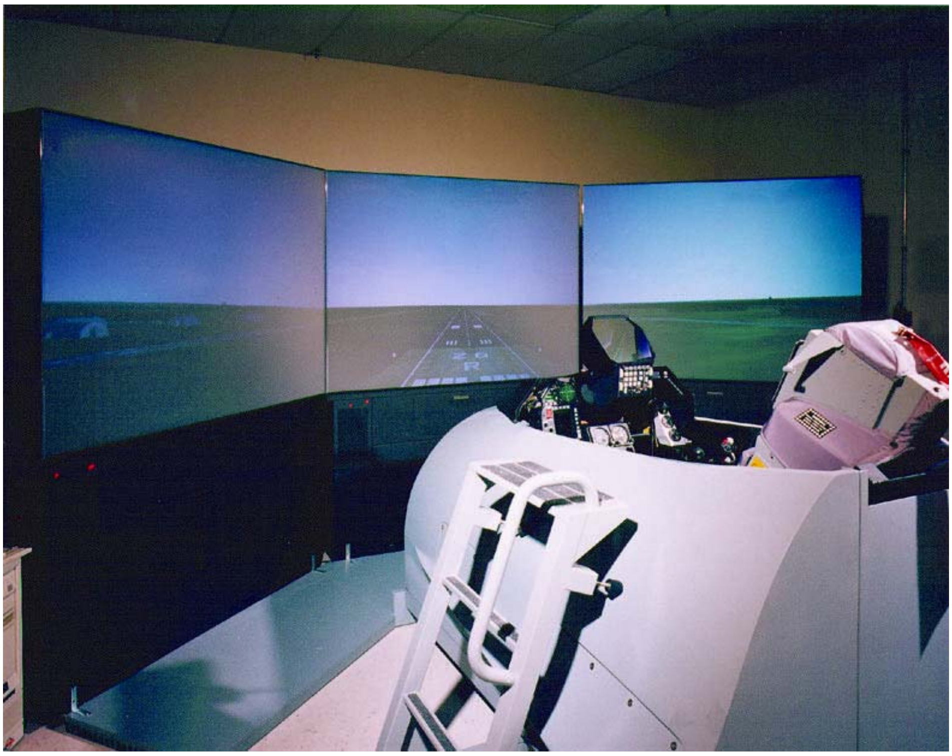

Figure 39: F16 Flight Simulator.

3.3 The Tank Simulator

The Tank simulator is a readymade bought system from Siemens (NL) and Simtech (Israel) for the Army. It is for shooting and battle exercises for platoon and below. The simulator has 4 40-foot containers. Three (3) of the containers have a technician room, a leopard 1A5 DK mock-up, a local instructor control panel, and a leopard 2A5 DK mock-up. The last container has a technician room, a central instructor control panel, and a report room with 12 seats. The set-up is shown in Figure 40 and Figure 41 show a picture from one of the containers.

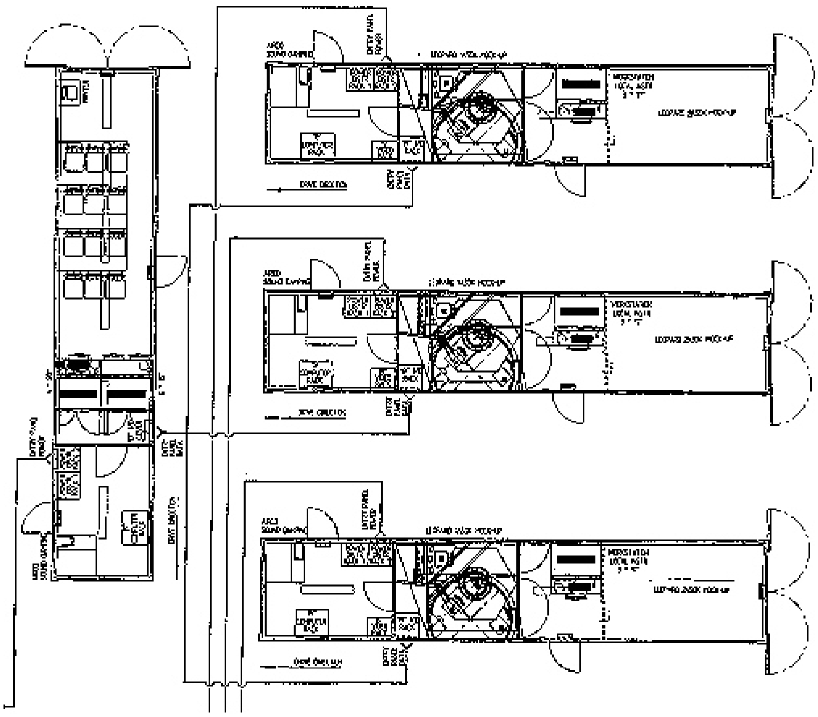

Figure 40: Tank Simulator.

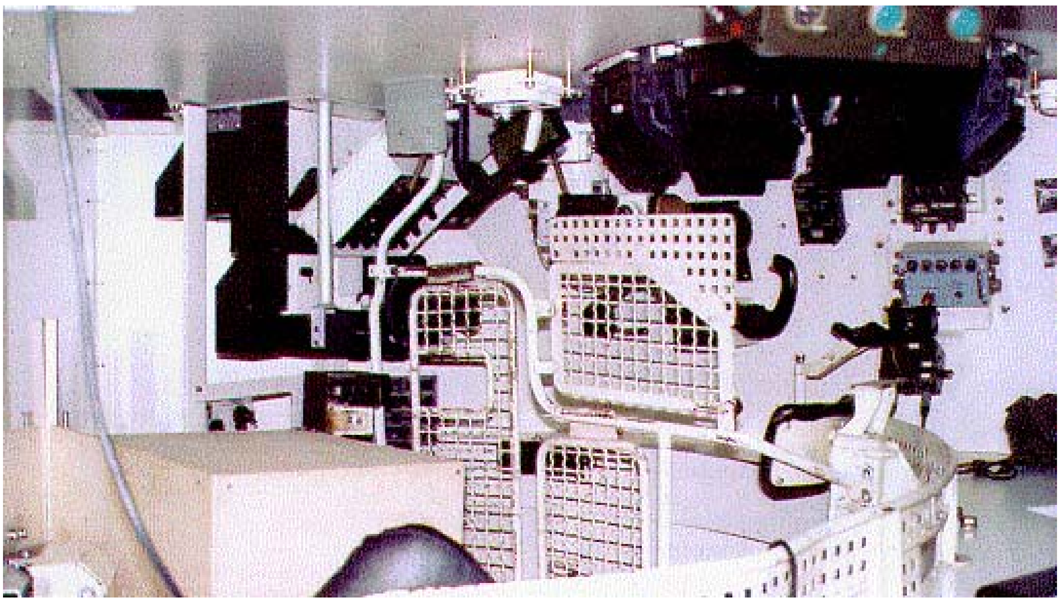

Figure 41: Tank Simulator.

3.4 Finished Projects

3.4.1 Tactical Trainer for a Group Leader

The tactical trainer for a group leader is a research and development project at the Danish Defence Research Establishment. It started 1998, and is a tactical trainer for education and training a group leader.

It combines a programmed simulation model with a geographical information system and a VR system and will have a speech interface. The duration is estimated to 5 years. The first prototypes are ‘Attack of mechanised infantry’. The conceptual model is pictured in Figure 42.

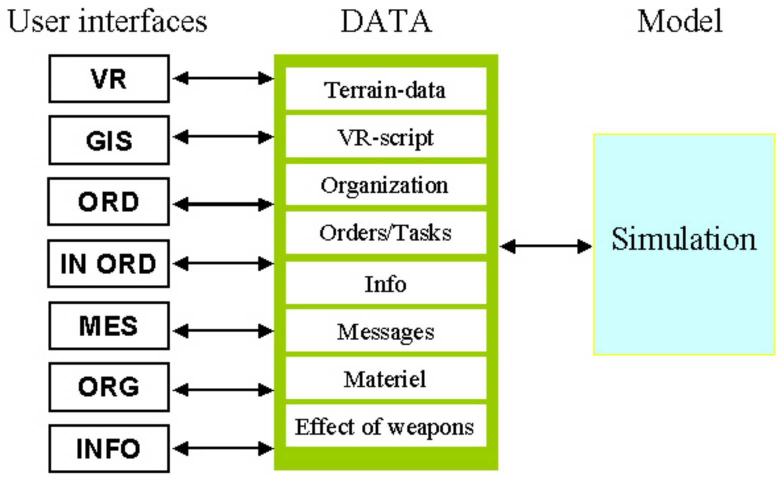

Figure 42: Conceptual Model.

The ordering of the soldier is done by voice. The VR part was developed in Superscape.

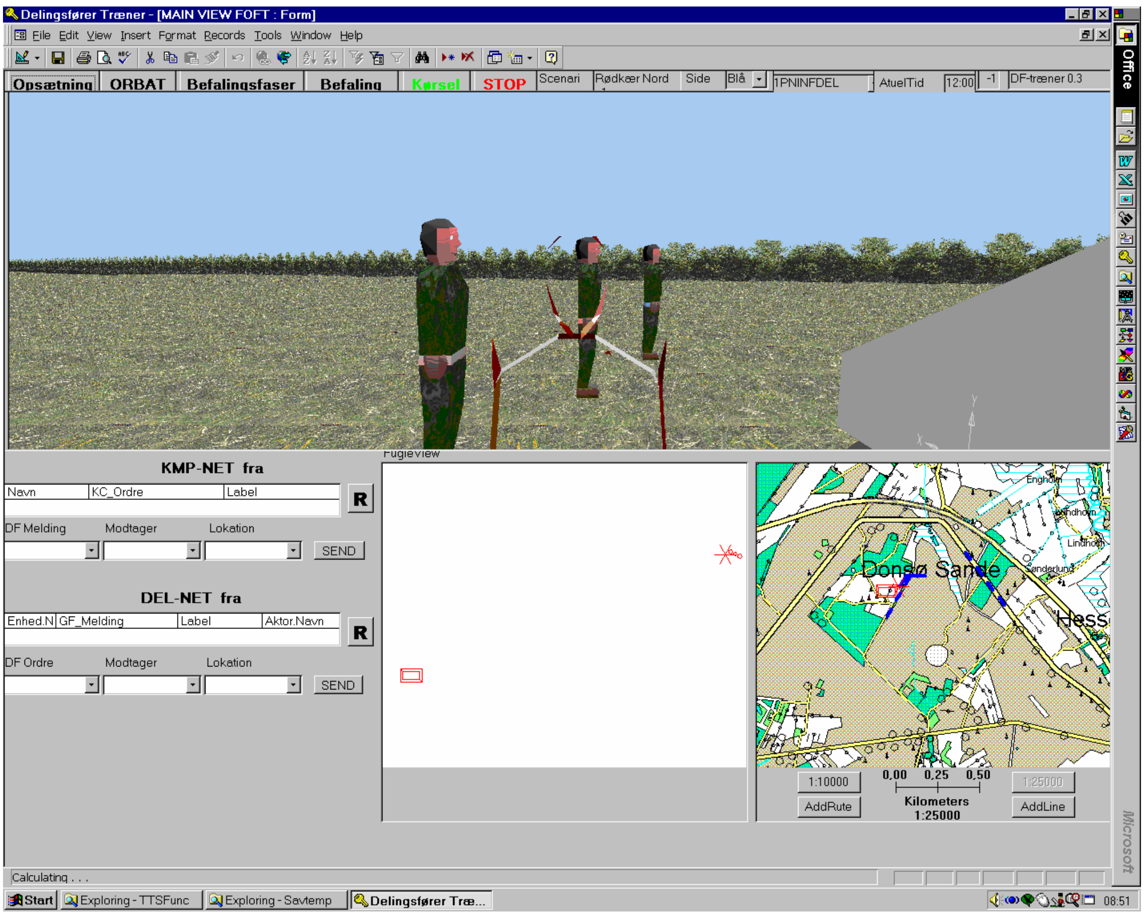

Figure 43: Screen Dump from the Tactical Trainer for a Group Leader.

The development of the VR in Superscape has stopped.

3.4.2 RTP 6.14 Virtual Environment in Military Decision-Making

The Western European Union (WEU) places contracts for research and development (R&D) projects under the European Co-operation for Long Term in Defence (EUCLID) programme. EUCLID's objectives are to provide European defence with basic technologies fully consistent with the aim of the Western European Armaments Organisation (WEAO) and to promote European industrial co-operation in R&D.

EUCLID consists of a set of Common European Priority Areas (CEPAs). CEPA 6 concerns "Advanced Information Processing and Communications". Within CEPA 6 the WEU is running a Research and Technology Project (RTP) number 6.14 entitled "Virtual Environment for military decision-making". The objectives of the RTP 6.14 project are to:

- Demonstrate the feasibility of using Virtual Reality (VR) techniques and a Virtual Environment (VE) in military decision-making in two functional areas: intelligence and logistics.
- Show how the military decision-maker's situational awareness is improved by using a demonstrator developed in the RTP.

The scope of RTP 6.14 is limited to decision-making at battalion and brigade levels during wartime and peace support operations on the (battle)field.

The RTP 6.14 project is being performed by an industrial team, led by Atos Origin (The Netherlands). Atos Origin's partners are IFAD (Denmark), INTRACOM (Greece) and DATAMAT (Italy). The industrial team is named "Military Applications for VE in Logistics and intelligence" (MARVEL). The demonstrator to be developed during the MARVEL project will be named the "MARVEL demonstrator". The client is the Western European Armaments Organisation's Research Cell (WRC). A Management Group (MG) of the Ministries of Defence of Denmark, Greece, Italy, and The Netherlands manages the RTP 6.14 project on the WRC's behalf. The Dutch Ministry of Defence leads the MG.

There are five Work Packages (WPs) in the RTP 6.14 project:

- *WP 0 Management and Integration*. The objective of WP 0 is to manage the project and to integrate the various components into the MARVEL demonstrator.
- *WP 1 Preparation Elements*. The objective of WP 1 is to prepare for the research and implementation phases of the project.
- *WP 2 Research Elements*. The objective of WP 2 is to perform research in the various areas that are relevant for the evaluation of VE for military decision-making.
- *WP 3 Implementation and evaluation of demonstrator*. The objective of WP 3 is to implement and evaluate a demonstrator supporting military intelligence and logistics decision-making for the land-battle domain using VE display and user-input devices.
- *WP 4 Presentation*. The objective of WP 4 is to communicate the technical results of the project to parties outside the MARVEL consortium.

The project finished June 2003.

3.4.3 VIKING GIS

Denmark, Norway, and Sweden have a joint project. They want to design a common new submarine that can be purchased for all three nations. In this project different studies are made. One of these is VIKING GIS. All the defence research establishments from the three countries participate in this study (which is the first common project between all three establishments).

The VIKING GIS is divided into two parts:

1) VIKING GIS, Part I
   a) Establishing a database describing available data and its sources and quality.
   b) Building a demonstrator to show how GIS can be used in the submarine.
2) VIKING GIS, Part II

3.4.3.1 VIKING GIS, Part I

The database will contain description of available digital and digitisable relevant marine geographic information from both civilian and military sources. An overview of future planed marine surveys shall be included. Special emphasis shall be given to the following parameters: depth, bottom characteristics, wrecks⁄objects, temperature and salinity or sound velocity profile, current, and acoustic and magnetic properties. The study shall include an assessment of data quality such as accuracy, resolution, and coverage. The database will have a graphical interface, where you can ask what information is available for defined areas.

A first version of a demonstrator package, named Concept Presenter (ConPres), shall be developed. Issues concerning modelling and visualisation of seabed terrain shall be addressed, especially evaluation of methods, technologies and functionality. ConPres shall demonstrate the use of GIS technologies for navigational purposes, more specifically:

1) Use of several types of marine geographical information such as seabed topography, sediment types, acoustic profiles and wrecks/objects;
2) Assess quality parameters as data resolution and data accuracy;
3) Illustrate compression and visualisation techniques for large amounts of data;
4) Use of sensor information.

ConPres is composed of individual, more or less coupled components as articles, pictures and software.

3.4.3.2 VIKING GIS, Part II

Second part of Viking GIS focus on the advantages of GIS for the Viking submarine. This part is not a visualisation project, but it specifies how GIS and visualisation can be used in the future submarine.

The study comprises internal GI systems, and only deals with external systems to an extent necessary for the overall information flow. The main emphasis is on the role of the submarine as a naval combat platform with advanced sensors. The work does not comprise detailed technical solutions or demonstrators. The work includes discussions of technology with respect to feasibility.

The main objective of the study is to explore the utilization of advanced GIS technology in a submarine for more effective and secure realization and completion of today’s and tomorrow’s missions. Emphasis is put on the exploration of the emerging GIS capabilities with other IT advances to meet the challenges of the 21st century battle space. The study is carried out using different perspectives of how GIS can be used in the following selected missions:

- Reconnaissance
- Special operation
- Mining and mine countermeasure

4.0 SUMMARY FOR THE DANISH VR PROJECTS

The previous sections have mentioned several centres involved with VR, and some of the VR projects going on in these centres. The table below is a summary. The hachure is centres, and the solid is projects. Red is military, and green is civilian. For each projects, the comments describe the type of project (divided into two categories), the techniques used (apart from VR) if any.

Table 1: Summary of VR in Denmark

(pink)	= Military
(green)	= Civilian
(hatched)	= Centre

NAME	ESTABLISHMENT	COMMENTS
HCI-Lab	Danish Defence Research Establishment	Testing VR software and hardware
Tactical trainer for a group leader	Danish Defence Research Establishment	R&D Simulation GIS Stopped
F16 flight simulator	The Air Force	Commercial Simulation GIS Completed
Tank simulator	The Army	Commercial Simulation Completed
RTP 6.14 Virtual Environment in Military Decision-Making	Atos Origin (Netherlands), IFAD (Denmark), INTRACOM (Greece), and DATAMAT (Italy)	Commercial, R&D Decision Support VR, GIS Concluded
VIKING GIS	Danish Defence Research Establishment, Norwegian Defence Research Establishment, Swedish Defence Research Agency	R&D (Study) GIS, 3D, (VR) Concluded
Centre for Pervasive Computing		Most of the work in the centre is organised as Research Projects involving both companies and universities
Center for Advanced Visualization and Interaction – CAVI	Centre for Pervasive Computing	3D Panorama Cinema TAN Holobench Virtual studio
VR Media Lab	University of Aalborg	Cave with 6 walls Powerwall (large flat screen) Panoramic screen (160° curved large screen)
Centre for 3DGI	European Regional Development Fund (ERDF), Aalborg University, the National Survey and Cadastre – Denmark, Kampsax A/S, and Informi GIS A/S	VR Media Lab

NAME	ESTABLISHMENT	COMMENTS
VR•C	The Technical University, UNI-C	TAN Powerwall (large flat screen) 3 n-vision DataVisor HiRes Head Mounted Display See-through (augmented reality)
FORCE Technology	FORCE Technology	Simulation(+VR+GIS)
Virtual Urban Planning	Aarhus University, Cadpeople, and COWI	Commercial, R&D Landscape, Decision Support VR, GIS
Visualization of the Cadiovascular System	CAVI, Aarhus University Hospital, and Systematic Software Engineering	R&D Medical VR
Digital Theatre – Hyperopticon	Aarhus University (Denmark), The Academy of Figurative Theatre (Norway), Studio di Progettazione (Italy), and CAVI (Denmark)	Commercial, R&D Entertainment VR
3D Experiences	Aarhus University and Zentropa Interaction	Commercial, R&D Entertainment + education 3D, interactive
3D Sound in 3D Space	Aarhus University and TC Electronic	R&D 3D sound in 3D models
Interfaces for 3D Applications	Aarhus University, Personics Aps, Systematic Software Engineering A/S, RoninWorks BV (Holland) and CAVI	Commercial, R&D VR, 3D
3D Image Processing for Cranium- and Brain-Surgical Planning and Simulation	CAVI, PET Centre	R&D Medical 3D Concluded
Digital, 3D Atlas of the Receptor Systems of the Human Brain	CAVI, PET Centre	R&D Medical 3D Concluded
Packaging Design	CAVI, Technical University of Copenhagen, Arla Foods	Commercial 3D Concluded
Landscape Visualisation	CAVI, Technical University of Copenhagen, Kampsax/Lundbeck	Commercial, R&D Landscape 3D Concluded
Architecture	CAVI, Technical University of Copenhagen, Arkitektfirmaet Schütze A/S	Commercial, R&D Architecture 3D Concluded
City Planning	CAVI, Technical University of Copenhagen, CF Møller/CADpeople	Commercial, R&D Architecture, landscape 3D Concluded
Virtual Set Activities / Ren Kagemand (Danish television show)	CAVI, Technical University of Copenhagen, Danmarks Radio	Commercial Entertainment VR Concluded
Beaching Museum St. George	CAVI, Technical University of Copenhagen, Jydsk Dykkerfirma (Diving firm in Jutland)	Commercial Architecture 3D Concluded

NAME	ESTABLISHMENT	COMMENTS
Family Factory	CAVI, the Danish Film School, Schule für Schauspiel-kunst “Ernst Bush” Berlin	Commercial, R&D Entertainment 3D Concluded
Digital Theatre	CAVI	R&D Entertainment 3D Concluded
Whizbang	CAVI	R&D 3D Concluded
Aarhus New Art Museum	CAVI, the art department Schmidt, Hammer and Lassen	Commercial Architecture 3D Concluded
CAVI Building	CAVI	Commercial Architecture 3D Concluded
Katrinebjerg Phase 1	CAVI	Commercial Architecture, landscape 3D Concluded
Katrinebjerg Phase 2	CAVI	Commercial Architecture, landscape 3D Concluded
Architectural Competition	CAVI, the architecture firms of Jørn Schütze	Commercial Architecture 3D Concluded
Project of Sonderborg	VR Media Lab, Cadpeople and COWI	Commercial Landscape
Aalborg University Campus Model	VR Media Lab	R&D Architecture
CAE and CFD into Virtual Reality (CCVR)	VR Media Lab	R&D Scientific
3D Airflow	VR Media Lab, the Department of Building Technology and Structural Engineering (also at Aalborg University), the Danish Institute of Agricultural Sciences, and the Royal Veterinary and Agricultural University	R&D Environmental, Scientific 3D
3-d Visual Data Mining	VR Media Lab	R&D Education, scientific 3D
Learning	VR Media Lab, Vestas and Zenaria	Commercial, R&D Education
Vestas	VR Media Lab	Commercial Education, architecture
Music House in Aalborg	VR Media Lab and the Danish National Research and Educational Buildings	Commercial Architecture VR Concluded

NAME	ESTABLISHMENT	COMMENTS
A Plan for New Housing Development	VR Media Lab, COWI	Commercial Architecture, Landscape VR Concluded
Highway at Holbæk	VR Media Lab	Commercial Landscape VR Concluded
Model of NOVI 3, 4, and 5	VR Media Lab	Commercial Architecture VR Concluded
Puppet	University of Aalborg	R&D Education VR Concluded
Staging of Virtual 3D-Spaces	University of Aalborg, etc.	Commercial, R&D 3D, VR, multimedia Concluded
Sound in Cyberspace	University of Aalborg	R&D Sound Concluded
Qualification of 3D GeoInformation	Centre for 3DGI	Commercial, R&D Landscape 3D, GIS
Queries for Navigation in 3D Models	Centre for 3DGI	Commercial, R&D Landscape 3D, GIS
3DGI Viewer	Centre for 3DGI	Commercial, R&D Landscape 3D, GIS
Interactive 3D Visualization of Projects	VR•C	R&D 3D
Scientific Visualization	VR•C	R&D Scientific
Network-Based VR Technology	VR•C	R&D VR Concluded
VR in Neuro Informatic	The Technical University	R&D Medical VR Concluded
Simulating a Combine Harvester	The Technical University	R&D VR, simulation Concluded
Ship Simulation	FORCE Technology	Commercial Simulation GIS
Skyline	COWI	Commercial Landscape GIS, 3D

As the table shows most projects can be categorised in the following categories:

- Landscape
- Architecture
- Decision Support
- Simulation
- Scientific
- Medical
- Entertainment
- Education

The categories are mentioned in the order of interest for the military.

The techniques are (apart from VR):

- 3D
- GIS
- Sound
- 3D sound
- Multimedia
- Hypermedia
- Real-time multi-modal communication
- Interactive TV
- Video

VR is a fertile research area in Denmark. The interaction between the military research and the civilian universities and research centres is improving. Several civilian research projects show great potential for military use.

Virtual, Mixed, and Augmented Survey – Germany

Thomas Alexander
FGAN – FKIE

1.0 INTRODUCTION

Augmented Reality (AR) and Virtual Environments (VE) have been introduced in the late 80s as innovative systems for displaying synthetic, computer-generated environments as if they were real. Various possible applications were identified soon, for instance: Product design, architecture, training, or teleoperation. But it turned out that computers' rendering power and display technology were too limited for a reasonable application then. The whole concept seemed to be a promising science-fiction topic that had come up too early for realization and practical use.

Nonetheless, technology evolved much faster. Less than a decade later, systems were powerful enough for first sample applications. Due to the huge demands on computing and rendering power (and resulting high financial expenses) they were just a small number of institutions doing research in this area. But again, it took only a short time until low-cost alternatives became available. The user community became much broader and, consequently, research and application activities were spread and intensified.

But while computing, rendering, and display technologies have made tremendous advance the design of the human-system-interface (HSI) did not. As a matter of fact, most systems still have to be run by special trained, qualified personnel, and most applications are often limited to passive presentations. The systems' interfaces are often prototypic and adapted from conventional two-dimensional graphical human-computer-interfaces. Interfaces remain limited to an extension of existing concepts without exploiting their real potential. A better integration of new concepts for training, for system design and for other future applications by including the capabilities of systems in an early conceptual stage would be desirable. For this, the HSI has to be ergonomically designed on different levels, including the pragmatic, semantic, syntactic, and even lexical level.

It turns out that the ergonomic design of HSI is an intensifying critical issue. The former NATO Research Task Group on *Human factors in virtual environments (HFM-021)* has identified Virtual Reality (VR) or Virtual Environments (VE) to be advantageous for a close, natural, and widely intuitive interaction by making better use of the human perceptive, cognitive, and motor capabilities. It defined VR *as the experience of being in a synthetic environment and the perceiving and interacting through sensors and effectors, actively and passively, with it and the objects in it, as they were real. VR technology allows the user to perceive and experience sensory contact and interact dynamically with such contact in any or all modalities.*

During its three years work it found that VE have developed into a useful technology for various applications. Most of them were found in product design, product presentation, education, training, and visualization of massive datasets. First experimental approaches of integrating VE in military education and training as well as mission rehearsal, support, and analysis were also identified (NATO RTA, 2001).

Potential future military applications of VE-systems identified in the areas of (NATO RTA, 2003):

- Human-system interfaces in materiel design (virtual prototyping).
- Command, control, communications, computer, intelligence, surveillance, reconnaissance (C4ISR).
- Telepresence, teleoperation and telemanipulation in reconnaissance, surveillance and target acquisition.

- Realistic and distributed simulation and training.
- Short-term mission preparation, including intelligent synthetic individuals and intended area of operation.
- Mission support as wearable, augmenting technology (including Mixed and Augmented Reality).

In 2003 the NATO Research Task Group on *Advances of Virtual Environments for Human-System-Interaction (HFM-121)* was established in order to update the actual state-of-the-art of Augmented, Mixed, and Virtual Environments (AMVE) and derive recommendations for the further development and application of this technology. Within this group, experts from Canada, Denmark, France, Germany, the Netherlands, Sweden, United Kingdom, and USA are exploring the potential of VE systems as an innovative technology for effective and efficient human-system interaction and to investigate system capabilities in the military domain.

First, a report on the actual state of research and technology within participating nations was compiled. The present technical report subsumes the German part of this compendium by giving an overview over research institutions with a primarily military focus, larger defensive projects including AMVE technology, and over civil applications of AMVE technology.

Generally said, in Germany AMVE research is spread across a diversity of civil and military agencies and institutions. Most military projects concerning AMVE topics are coordinated by the German Ministry of Defence and subordinate agencies. They are submitted to research institutions, academic institutes, and defence companies.

In this area, AMVE is not considered to be a high-level topic on its own. Instead, it always refers to special applications and larger defence program. A key domain is traditionally simulation in military education and training. Another domain is design of military materiel, especially in connection with visualization, ergonomic analyses and computer-aided design. Innovative approaches of applying AMVE technologies as an innovative HSI and for teleoperation also came up recently. These domains widely interfere with academic and civil research so that there is a close connection and exchange of knowledge with academic and civil research projects. *Dual-use* has become a common term for characterizing this sharing of results across domains.

This compendium summarizes current military projects including AMVE topics in Germany. Other activities in military simulation, for instance flight or tank simulators, were intentionally left out because they were not within the focus of the NATO RTG. Hence, a technology-based approach of differentiating between AMVE and traditional simulation will be given in chapter 7.1. This report includes three parts. First, studies and activities of institutional research and within defence industry are presented. Chapters 2, 3, and 4 handle this part. Second, main military projects are described briefly in chapters 5 and 6. Finally, in chapter 7, the results of a questionnaire survey on civil AMVE activities in Germany are depicted.

1.1 References

NATO RTA (2001): *What Is Essential for Virtual Reality Systems to Meet Military Human Performance Goals?* Meeting Proceedings RTO-MP-058. Neuilly-sur-Seine: NATO RTA.

NATO RTA (2003): *Virtual Reality: State of Military Research and Applications in Member Countries.* Technical Report RTO-TR-018. Neuilly-sur-Seine: NATO RTA.

2.0 RESEARCH INSTITUTE FOR COMMUNICATION, INFORMATION PROCESSING, AND ERGONOMICS (FGAN – FKIE)

T. Alexander

2.1 Areas of Interest

- Providing scientific and technical expertise for the German Ministry of Defence and subordinate agencies in the area of C4ISR and innovative HSI.
- Applied research in the area of human factors in military AMVE-Systems.

2.2 Current Research Projects

2.2.1 Applicability of AMVE Technology as Tactical Situation Display (TSD)

The general goal of this project is to develop recommendations for the applicability and usability of stationary and wearable AMVE-technology as advanced tactical situation display of C4ISR systems. The results are included into the development of different prototypes for such display systems. Examples of these are shown in Figure 2-1.

Figure 2-1: Powerwall TSD, Electronic Sandtable, Portable TSD for Dismounted Soldiers.

The designs take into account changes of demands on today's C4ISR systems. Within the scope of future scenarios there will be a high demand on detailed and actual information in C4ISR. It is often (and falsely) inferred that more information always leads to better tactical decision-making and higher mission success. High-tech data acquisition, transfer, and pre-processing will enable the military commander to collect a huge variety of diverse information about the current situation. But this massive quantity of information is also risky; especially in time-critical situations with tactical decision-making under stress relevant information is likely to be overseen. This leads to wrong decisions with far-reaching, sometimes fatal consequences. It can be avoided by making better use of the human perceptive, cognitive, and motor capabilities. AMVE technology can be applied here and is very promising already.

The human factors have to be considered as early as possible when designing and evaluating new display systems. Thus, detailed research on the display system itself, e.g. on characteristics of the display (stereoscopy, head-tracking, resolution, ocular stress) and interaction type (relative/absolute interaction, device, input signal gain) and their effects on human performance, as well as research on the kind of information visualization itself (possibilities for visualizing time tracks and uncertainty) are carried out within diverse projects in this field.

The results are integrated into prototypic designs of AMVE tactical situation displays for the tactical decision-making on different military commando levels, from operational to tactical command hierarchy.

2.2.2 Visualization of Massive Amounts of Abstract Data

The technologic and thematic development in the area of surveillance and intelligence is leading to growing amounts of inhomogeneous information and to changing analysis procedures. While in the past analogue radio networks allowed a clear distinction and localization of transmitting and receiving unit this is not possible with upcoming worldwide, distributed, digital communication networks. Especially with growing demands coming along with asymmetric warfare it is more important to sort out relevant information out of free-speech text messages, detect correlations to other messages, and to visualize the results of these pre-analysis in order to support the intelligence analyst.

Because of the huge amount of messages and the natural way of displaying information, it was decided to use AMVE technology as display. By integrating models of the human spatial processing memory general guidelines for visualizing inhomogeneous abstract information are being derived and implemented into a prototype display system. As shown in Figure 2-2, this system is scaleable from desktop-VR for today's use to a more sophisticated cooperative VE-system for future applications.

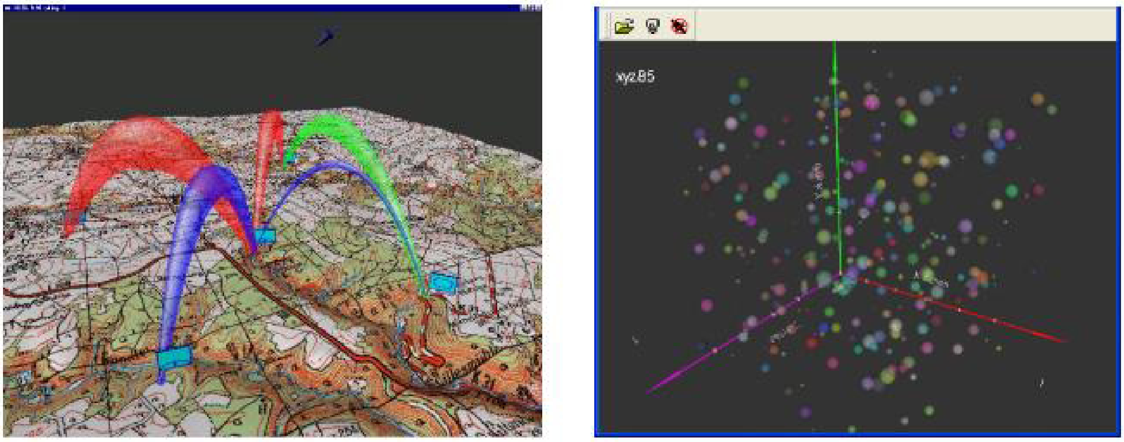

Figure 2-2: Information Visualization on Desktop Display (left) and Within an Immersive VE (right).

2.2.3 Infantryman of the Future

The Infantryman of the Future (Infanterist der Zukunft – IdZ) is a large project succeeding the Soldier 2000 and Soldier 2010 projects of the German Ministry of Defence. In a long-term approach, IdZ includes augmented reality technology to support the dismounted soldier with actual tactical information in his mission. Synchronously, the soldier collects data and enters it into a C4ISR system.

In cooperation with the central institute for medical service of the German armed forces (ZInstSanBw) a realistic scenario for determining performance tests and trials is to be built up. In this connection, a VE-system is used to create realistic scenarios and evoke physiological and mental workload.

2.2.4 Teleoperation of Unmanned Semi-Autonomous Vehicles

Remotely piloted vehicles (RPV: UGV, UAV, UCAV, UUV) are of growing importance for present and future military scenarios. The supervisory control of RPVs represents a cognitively highly demanding task for a human operator. To maintain required levels of situation awareness (SA) an operator must process and respond to multiple complex information streams in real-time. Therefore, the human-RPV-interface plays a key role in enabling an operator to effectively control an RPV with respect to mission requirements. AMVE-based user interfaces have the potential to overcome limitations of presently used

2D-interfaces. Significant amounts of information provided by RPVs, e.g. sensor data, includes georeferenced data, and can therefore take advantage from AMVE systems.

2.3 Results Achieved to Date

VE activities at FKIE/EFS have originally started with usability studies on VE for ergonomic workplace design and analysis. They were found to be advantageous for rapid prototyping applications. At a very early design phase, CAD-models of products could be visualized and examined as if they were real. Improvements were easily possible and the effects could be visualized immediately.

With respect to future tactical situation display a first prototype for applying VE technology, the Electronic Sandtable (ElSa) testbed, was designed and developed. Its concept is based on the sandtable metaphor, which models the working procedures of a traditional sandtable as used frequently in military tactical education. Geographic data and dynamic tactical situation data are stereoscopically displayed on a horizontal surface creating the illusion of a three-dimensional landscape. A self-developed software framework handles rendering. It facilitates rendering of common web3d-scenegraphs, geo-referenced C4ISR-data, and intelligence information on a heterogeneous computer clusters. Several experiments on the sandtable display system were carried out to optimize parameters of the viewing model and for interaction.

Because the original ElSa testbed was based on a rather (expensive,) bulky display technology, alternative displays with higher availability and mobility were built up recently. A low-cost approach uses the same software but a vertical projection surface with standard PC mouse and speech input for interaction. The setup is far more mobile and can be used for different types of command posts. It is based on today’s IT-technology and enhances standard tactical planning procedures – especially tactical situation presentations.

With the third system, which uses Mixed Reality procedures and is called MR-ElSa, mobility is even stronger enhanced. Wearable IT-technology and head-mounted displays offer a system’s applicability “in the field”. The system is to be used by small operational units just before the mission starts. Common software packages were included into the VE-framework and a prototype system has been developed und built up. Interaction procedures are currently being implemented for further research on HIS with this display.

2.4 VR R&D Laboratory

- Graphics / Rendering
  - SGI Onyx 2 InfiniteReality 2 Rack
  - Inhomogeneous COTS PC cluster, diverse NVIDIA Geforce graphics cards (permanent updates)
  - Xybernaut wearable computer
- Visualization
  - *Virtual Workbench* (stereoscopic horizontal projection) with CRT-projectors
  - *Powerwall* (stereoscopic vertical projection) with LCD-projectors
  - Diverse *Daeyang Cy-Visor* low-cost stereoscopic head-mounted displays (HMD) with self-developed “video see-through” option
  - Stereoscopic *Trivisio ARVision3D* HMD
  - *MicroOptical AV-1*
  - *NVisor SX*

- Input Devices
  - Electromagnetic *Ascension Flock-of-Birds Tracking System*
  - Diverse Interaction devices
  - Optical *ARTrack System*
  - *CyberGlove*
  - *Wacom Input Tablets*
  - *VOCON speech recognition*
  - *Space Mouse*

3.0 EADS DEUTSCHLAND GmbH, MILITARY AIRCRAFT

L. Vogelmeier

3.1 Areas of Interest

- Enhancement and customization of Virtual Environments (VE) for use in System Development with focus on Human-Machine-Interface (HMI) development and maintainability evaluations.
- Building up VE-based training devices with focus on procedure training for airborne systems and virtual flight training.
- Defining fields of applications for the operational use of VE in airborne systems and for airborne systems.

3.2 Current Research Project

3.2.1 Virtual Reality for Development, Manufacturing, Maintenance and Training

This project is a shared research project inside EADS N.V with EADS Deutschland GmbH, Military Aircraft in lead.

The main objective of this project is to enhance the VE-Technology to fit the special requirements for development, manufacturing, maintenance and training.

The project is divided into three main work-packages:

1) Realistic and Real Time Capable Light Simulation

The illumination of cockpit or passenger area of an airplane is of high importance for low workload of the crew and convenient travelling of the passengers. Many constraints for the illumination are pre-defined in early stages of development, for example by the basic geometry of the aircraft fuselage or the position of the windows and illuminating elements. Therefore, an early consideration of the illumination of the product is necessary for an efficient development process. To achieve and to keep development iteration cycles short, the use of computer simulation of the illumination is mandatory. Techniques must be found and implemented that provide a computer based light simulation that is comparable to the real world and enable interaction in real time.

2) Integration of Real and Virtual Humans into VE

It is essential to use computer-simulated data in a most efficient way to decrease time and costs for product development. For this reason it is necessary to find ways to merge human characteristics (of developer, operator, customer of the product) and computer data. The main aspect is to learn and understand how the human will act and sentence the future product. Two different concepts are required for this. The first is to simulate the person within the VE as an avatar, and the second is to integrate a real person into the VE. The use of avatars facilitates, for instance, the opportunity to generate test persons that are not available for ergonomic studies in reality, to simulate crowds, or to make assessments in dangerous environments without endangering real persons. Real persons are still required to give feedback about sensations like comfort or discomfort, to investigate stress, or to validate the data generated by assessments with the avatars.

3) Integration of Complex Simulations in VE

The objective of this work package is to control VE by complex simulations. The target applications are the simulation of a full functional aircraft cockpit for pilot training or for testing the Human-Machine-Interface (HMI) concept of the cockpit, to visualize the behaviour of crowds under special circumstances, e.g. the evacuation of an airplane after an emergency landing or the simulation of soldiers under combat situations. Therefore, large amounts of information must be exchanged between the VE-system, which provides visualization and interaction, and the simulation software, which generates and handles the underlying data.

3.3 Results Achieved to Date

- Successful integration of Virtual Reality in the cockpit development process for assessments of static cockpit geometry and layout, based on a mixed mockup system. First adoption of developed techniques in the Tornado program in 2002.

Figure 3-1: Virtual Cockpit.

- A first demonstrator model of a mixed mockup based virtual flight simulator (with restricted functionality) was implemented in 2000 and presented at several air shows. First prototype of complete cockpit simulation in VR was accomplished in 2003.

Figure 3-2: Mixed Mockup Flight Simulator.

- Evaluations of VE-based maintainability assessments with virtual prototypes have been performed. First adoption of defined methods will start in 2004.

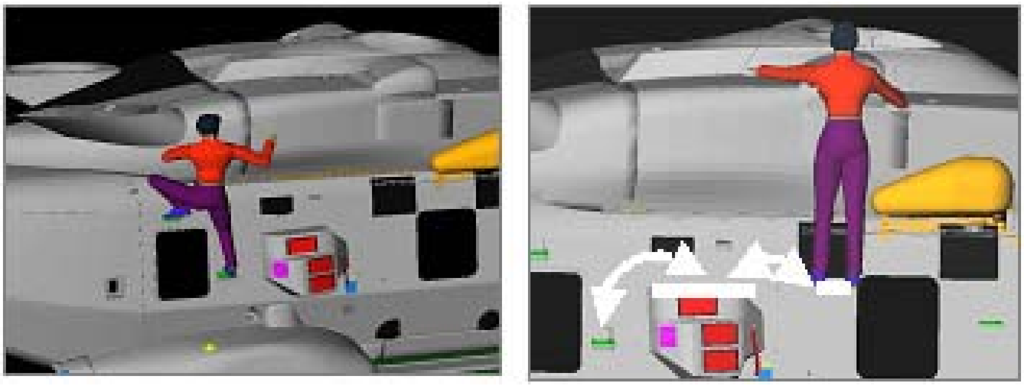

Figure 3-3: VR Maintainability Assessment.

3.4 VR R&D Laboratory

- Graphics / Rendering
  - SGI Onyx 2 InfiniteReality 2 Rack
  - Inhomogeneous COTS PC cluster, diverse NVIDIA and ATI graphics cards
- Visualization
  - Vertical Back Projection (active stereo, CRT-projector, One-Side-CAVE-Mode)
  - HMD *Kaiser XL50*
  - HMD *NVISION Datavisor HiRes*
  - 4-Side Cave (start of operation planned mid of 2004)
- Input Devices
  - Electromagnetic *Polhemus Fastrack System*
  - Ultrasonic *Intersense IS-900*
  - Optical *ARTrack System*
  - *CyberGlove*
  - *Flying Mouse*
  - *DaimlerChrysler speech recognition*
  - *Space Mouse*

4.0 IABG mbH (DEPT. "NETWORKED SIMULATIONS" AT MEPPEN)

F. Reiners

4.1 Areas of Interest

- Interoperability of simulation systems (interoperability between simulation systems alone and between simulation systems and other systems, e.g. C2-systems).
- Application of VE techniques (mainly improvement of user interfaces, e.g. for simulation systems).

4.2 Current Research Projects

4.2.1 Ergonomic Investigations with VR Techniques

The aim of this project is to find out if (and how) it is possible to use CAD data of combat vehicles of the German army for visualization purposes VE. This kind of visualization is considered to be very useful for the following reasons:

1) Ergonomic investigations (e.g. of the interior of a vehicle) can be done already in very early design phases, well before real prototypes are built.
2) The areas of free sight for the driver of the vehicle or for other persons, e.g. looking out of the hatches, can be examined, without the need for cumbersome and expensive measurements using the real vehicle.
3) The derivation of requirements for new military equipment can be supported enormously by coupling VE systems to simulations of the appropriate environment. For combat vehicles, this environment can be represented by combat simulation systems.

Usually, the direct use of CAD data for VE purposes fails, because the number of polygons that are needed for the proper description of the geometric extension of a vehicle is very huge, and an acceptable visualization e.g. in an HMD is not possible anymore. Instead, a significant reduction of the number of polygons is required.

The available CAD systems do not allow the automatic conversion of CAD data into formats that are used in VE systems. Therefore, in this project several steps were examined that are useful in performing this conversion. Figure 4-1 shows different sequences of steps that can be followed to reach this conversion.

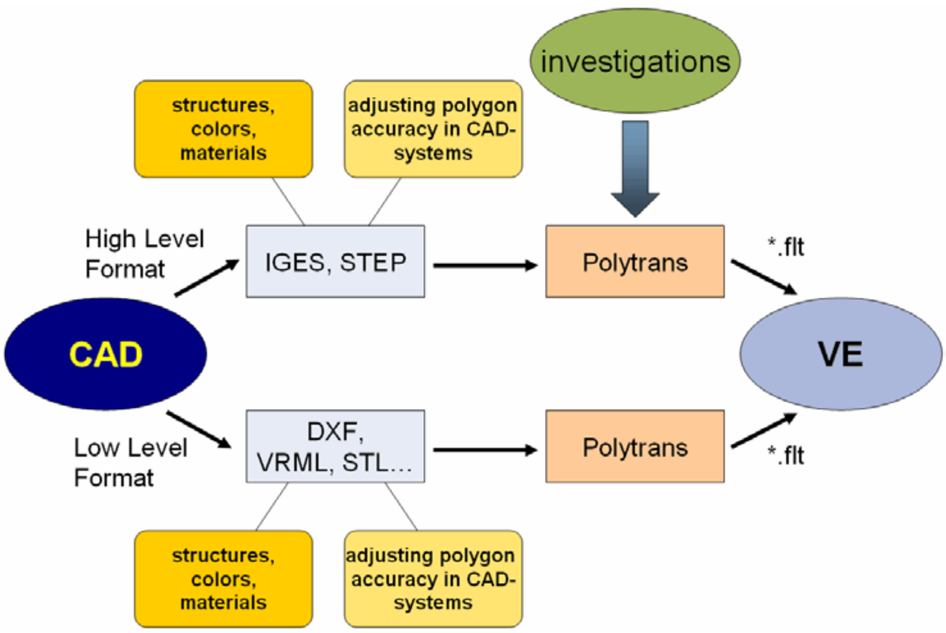

Figure 4-1: Possible Sequences for Converting CAD Data into VE Formats.

First ergonomic examinations of areas of free sight within the armored transport vehicle BOXER were done by using an HMD connected to either a mechanical or magnetic tracking system. Figure 4-2 shows a simulated view into the interior of a BOXER. The VE data have been derived completely from the CAD data as provided by the manufacturer of the vehicle.

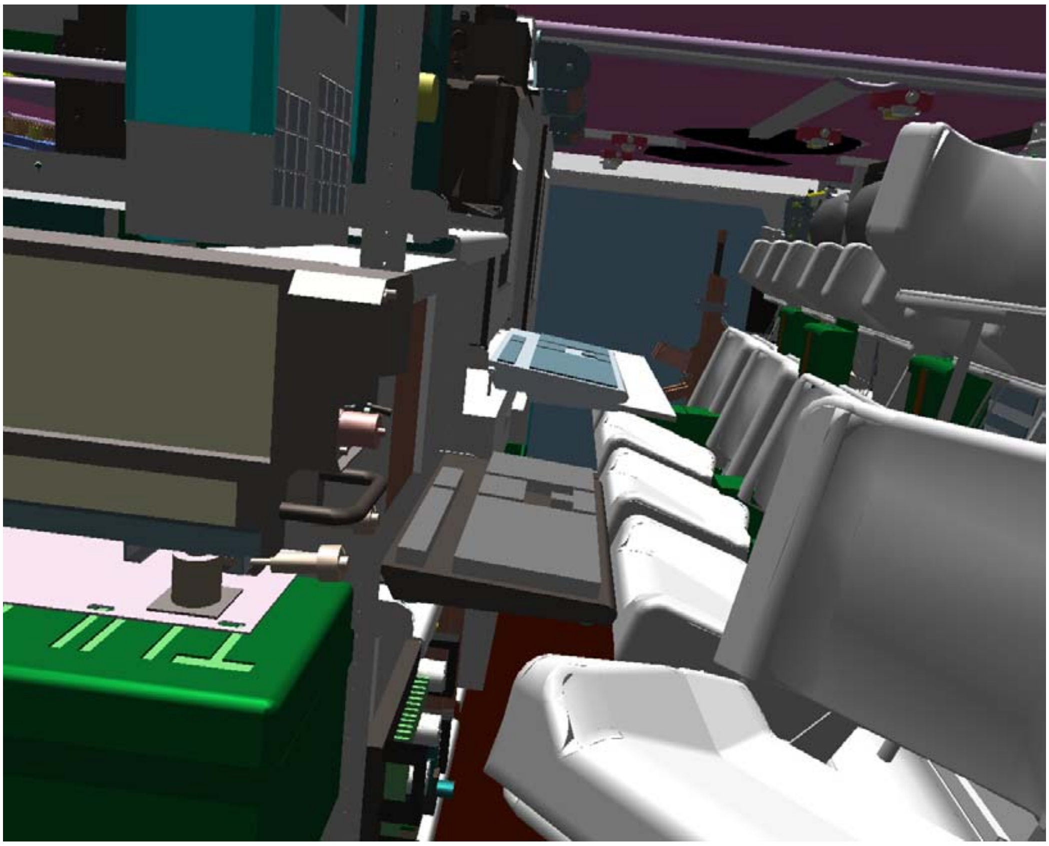

Figure 4-2: Simulated View into the Interior of a BOXER with VE Data Derived from CAD Data.

4.2.2 Coupling of VE-Systems with Combat Simulation Systems

As already mentioned above, it makes sense to join VE-systems with combat simulation systems. It was decided to perform this coupling in a two step procedure:

1) Coupling of an HMD to a driving simulator;
2) Coupling of the driving simulator to a combat simulation system.

In this study, available systems were used: An experimental, component-based driving simulator and the combat simulation system PABST 2000 by IABG.

An HMD can be seen as a special graphical monitor where the projection is dependant upon the position of the eye of the user captured by a tracking system. In the experimental driving simulator, it can be modified by keyboard inputs. The main focus of this experiment was to calculate the correct view shown in the HMD. This view depends on the right superposition of:

1) The position and orientation of the HMD (derived from the tracking system);
2) The position of the eye point, relative to the vehicle (derived from parameters of the driving simulator); and
3) The position of the vehicle within the synthetic terrain (derived from the combat simulation system).

Figure 4-3 shows an example of a picture as seen by the HMD, compared to the corresponding map of the combat simulation system.

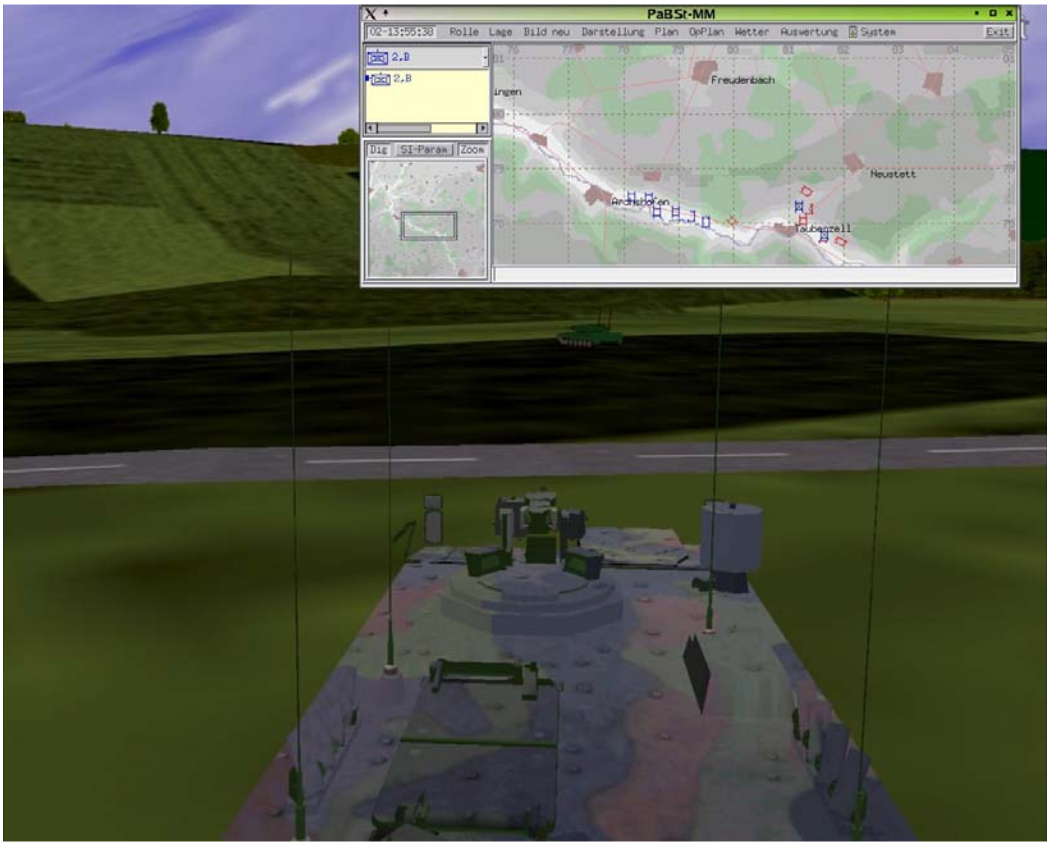

Figure 4-3: View into a Virtual Environment. The corresponding visualization of the combat simulation system PABST 2000 is shown in the insert.

4.3 VR R&D Laboratory

- Graphics / Rendering
  - PC, NVIDIA Geforce graphics cards
- Visualization
  - *Stereoscopic HMD NVISOR SX*
  - *Monitor*
- Input Devices
  - Electromagnetic *Ascension Flock-of-Birds Tracking System*
  - *Mechanical Shooting Star Technology ADL-1*
  - *Joystick*

5.0 CoCBT (KoCUA) – CO-OPERATIVE COMPUTER-BASED TRAINING FOR THE AMPHIBIAN M3

5.1 Background

CoCBT is a training device for the German Amphibian vehicle M3. The operational spectrum of this trainer covers driving practice on land and water including coupling manoeuvres, building bridge stumps and ferrying operations with large ferries. The instructor can control the exercise conditions by changing the variable parameters (e.g. wind, weather, water velocity, technical, and tactical incidents). Real crossing sites on the rivers Main and Weser have been used as a basis for the virtual exercise areas. A wide variety of wheeled and tracked vehicles can be used by the crossing troops.

The operation of the M3 amphibian requires the co-operation of several crews, for example when coupling amphibians to build a ferry. The previously available training tools, which are CBT program and digital teaching aid, were primarily designed for single-place training. However, a comprehensive amphibian training requires a team-oriented approach. CoCBT focuses on this approach. Figure 5-1 shows the setup of CoCBT.

Figure 5-1: CoCBT Amphibian M3 Training Facility.

5.2 Technology

The CoCBT Amphibian M3 training program facilitates single individual and team training. In a VE, which is implemented in a PC network, it is possible to train a team of up to four students in the operation of the amphibious vehicle M3. Consequently, CoCBT covers the complete spectrum of the amphibious training. The crew is able to exercise throughout the whole year, under controlled conditions, and independently from the otherwise mandatory availability of staff and equipment.

The whole virtual training situation is presented on three monitors with a 120° panoramic view. An additional, lower monitor is used to show the necessary handling functions (e.g. control stand). The crewmembers control the action by a PC-mouse, keyboard and the original master pilot (which is used for steering on water). The ferry commander gives hand signals, which are depicted by the system with the use of data gloves and a tracking system. An animated character presents the hand signals synchronously in the virtual world.

The CoCBT Training System consists of workstations with several PCs, which are linked to each other in a network. The educational network helps the instructor supervise the progress of the exercise.

For exercise assessment a recording system is available, which can be used for observing the training at any time. The recording also supports the instructor's follow-up of the exercise. The complete training system is based on a scalable technology, which allows for example, to add more workstations or to expand the panoramic view of the virtual world to 360°. This training platform can also be used in the future for other systems.

5.3 Delivery

The CoCBT training system was officially presented to the Armed Forces Engineers in Minden in December 2002.

6.0 ADVANCED AIR DEFENCE TRAINING SIMULATION SYSTEM (AADTSS) – VR STINGER TEAM TRAINER

6.1 Background

In the past, team training for the STINGER weapon system was done in stationary, large-scale dome trainers. Changing requirements, especially growing demands on mobility and transportability, made a modernization of the trainers and the application of new technology necessary. For the layout of the new trainers immersive VE-technology was utilized to allow a commander and a gunner cooperative training of STINGER handling. The system had to cover 350° horizontal and 130° vertical field of view, visualize multiple targets and effects and facilitate long-range aircraft detection and identification. In Figure 6-1 the system is illustrated.

Figure 6-1: VR STINGER Team Trainer.

6.2 Technology

The AADTSS simulator is integrated in an extensible container. Both, commander and gunner are equipped with Head-Mounted-Displays (HMDs) for visual display of the VE. For long-range aircraft detection/identification a high resolution was required and the HMD is capable of a maximum resolution of 1.280 x 1.024 pixels per eye. Because of better contrast and separation of surrounding light, the HMDs are without see-through option.

The team members have to co-operate with each other acoustically and optically, but due to the HMD they cannot see each other. By modeling both as avatars this problem was solved.

The commander's actions are tracked by an inertial tracking system, whereas the gunner is tracked by an optical tracking system. For safety reasons, both team members are encircled by handrails. This solution was necessary because of the HMDs without see-trough-option.

A further aspect was the database for training. The generation of databases is based on stereoscopic photos. It allows the generation of scenarios, targets and flight paths and is independent of the simulator. The system consists of one workstation, the stereo-camera-system and one control-PC.

6.3 Delivery

After an initial successful troop trial phase in 1997, a first system was delivered in 2000. A second system has been ordered from the German Air Force recently. Whereas the first system has been integrated into a mobile container, the second will be modified for inside building uses.

7.0 SUMMARY OF CIVIL AMVE RESEARCH

7.1 Background

Civil AMVE research activities in Germany are as multiple and manifold as in other countries. Most of these activities have their origin in computer sciences and computer graphics and are still positioned here. But recently, AMVE technology has become a tool for research in other areas and applications as well. This chapter explained the general background of civil AMVE research. Furthermore, the criteria for choosing participants in the survey, as well as the send and return of questionnaires are described.

7.1.1 General Background

Research on Virtual Reality (VR) and its applications started around 1980. VR was originally considered as an innovative visualization concept for system design and rapid prototyping. The premier goal of a natural interaction and an "intuitive" use made it a topic of ergonomics and human-computer-interaction at a very early state. Due to lacking performance it took several years until a reasonable use and application became possible. At first, among other reasons because of the expensive equipment required for research, only a relatively small number of institutions were on the topic. At that time VR turned out to be a highly innovative and technology-driven topic, which's true application areas were still to be determined.

Research was divided into then: On the one side there was application-oriented research (focusing on workplace design, medical applications, teleoperations etc.) and on the other side more basic, fundamental research on AMVE on its own (computer graphics, rendering etc.). With growing availability of VR equipment, a broad spectrum of academic, federal, and industrial institutions started work in this publicity topic. Today, the term VR has become widely used for each and everything, so that the term Virtual Environments (VE) has become more popular in the scientific world.

Due to higher technological demands, research on Augmented Reality (AR) and Mixed Reality (MR) came up slightly later. Both have been influenced and supported largely by the German automotive industry. A special goal is application of AR for development, production and maintenance of complex technical products.

7.1.2 Criteria for Choosing Participants

A main problem for setting up this questionnaire was to limit it to relevant activities in AMVE only. Traditional simulators, as frequently used by German automotive industry and research were intentionally left out. To distinguish between a traditional simulator on the one hand, and a VE-system on the other was difficult because both overlap widely and there is large parallelism between them.

At a first approach, VE is considered to be a part of simulation and not vice versa. It is well known that there are arguments for an opposite structure as well. Nonetheless, for this report the definition of VE given in the introduction and the notion within the scope of the RTG are strictly referred to. Thus, simulators were to be left out.

Likewise simulators, VE systems visualize synthetic, computer-generated databanks. Likewise simulators, VE evoke a feeling of being a part of the simulation. But unlike simulators VE simulate stimuli to a greater amount by means of special devices. In a simulator the direct surrounding of the user still remains the (real) original equipment (i.e. a cockpit of a flight simulator still is "real" just the outside view is virtual) while in an ideal VE system this would be simulated as well (i.e. by means of haptic feedback). For a VE system the synthetic part of stimuli is considerably larger than for simulators. Consequently, a closer user involvement (including head-tracking etc.) and special hardware is required.

Close user involvement is always subjective and object to vary largely between subjects. For this reason it seemed unpractical to choose it as main criteria. Instead, the specific hardware technology, which is more objective, was chosen to be the main criteria for identifying participants for the survey.

This –very technocratic– approach gave an opportunity to distinguish large-scale from small-scale research activities, because substantial research in AMVE still requires special devices (and expenses). We have chosen availability of head-mounted-displays (HMD), stereoscopic vertical or horizontal projection surfaces (Powerwall, Workbench), or special AMVE hard- and software as the participation criteria. This resulted into the participating institutions referred to in the following chapters.

7.1.3 Send and Return of Questionnaires

For this compendium available AMVE technology, application areas, and general areas-of-research were considered to be relevant. The questionnaire attached in the annex was sent out to 44 scientific and industrial institutions in Germany and 7 in Austria and Switzerland. As shown in Figure 7-1, 14 out of these were academic/university, 12 were federal and free research institutions, 13 industrial laboratories and 5 were developers of AMVE systems.

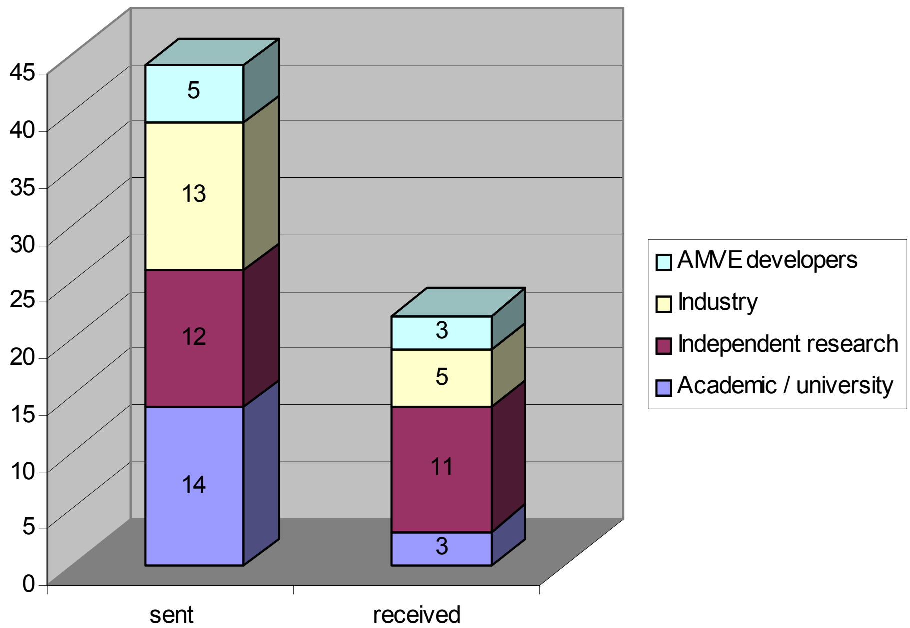

Figure 7-1: Questionnaires Sent and Received.

Twenty-two questionnaires (overall return rate: 50%) were returned. Three (14% returns) came from universities, 11 (92% returns) from federal and free research, 3 (60% returns) from AMVE system developers and 5 (38% returns) from industrial laboratories.

The results derived from the questionnaire returns are summarized in the following chapters. It has to be mentioned that more than a single response was possible at every question.

7.2 Technology

Technology is the backbone of each AMVE activity. Although it can be considered as widely available, technology development has not stopped, and technology trends are likely to affect more general trends in research. Technology includes the computing and graphic platforms, the display system and its modality (visual, acoustic, haptic), tracking systems, and special interaction devices. A further important aspect is software, e.g. operation system, rendering software, supported databank formats, and application-specific software.

7.2.1 Computing Platform

Recently, computing and graphics power of personal computers have tremendously increased. This resulted in growing utilization of PCs in AMVE laboratories. They have widely replaced the specialized, monolithic graphic workstations. Another effect of this development is that research activities and applications of VE technology have increased because of fewer required expenses, though still remaining cost-intensive. The results of the survey are shown in Figure 7-2.

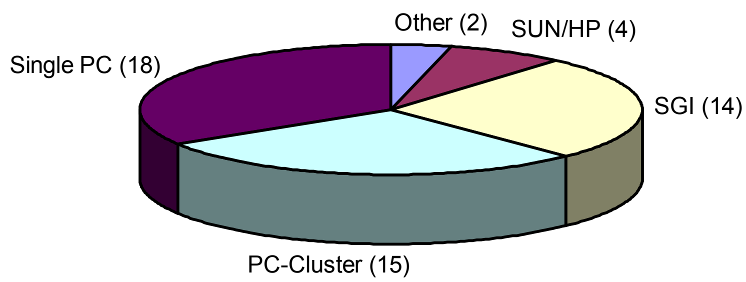

Figure 7-2: Computing Platform of AMVE-Systems.

Single PCs with high-end graphics cards are used in 18 AMVE institutions (82%). By connecting multiple PCs into a cluster, more graphics performance is available. Fifteen (68%) of the participants in this survey follow this direction. High-end graphic workstations from Silicon Graphics Inc. are a part of equipment of 14 institutions (64%). Four (18%) institutions use workstations from SUN or HP, respectively. For AR or MR topics a wearable PC is the most frequently used computer platform (2 cases, 9%). The application of PC increases to 21 laboratories (95%) if it is not differentiated between single or clustered PC. Consequently, all except for one single lab with a graphics workstation at least additionally use PCs in their AMVE-setups.

7.2.2 Visual Display

The visual display plays an important role for the applicability of an AMVE system because most of the environmental stimuli are perceived by the optical sense. Figure 7-3 shows the visual displays present at participating institutions.

As expected, most participants in this survey (15 cases, 68%) make use of monitor displays. Thirteen laboratories (59%) are equipped with HMDs which facilitate a total immersion into the VE.

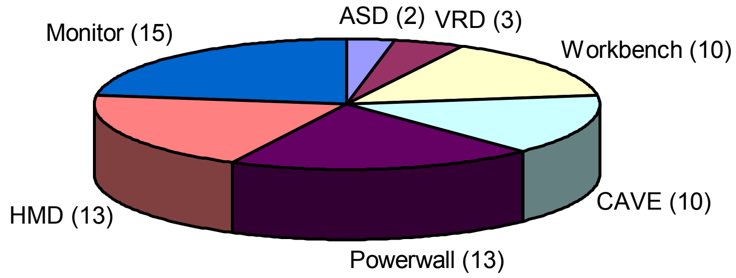

Figure 7-3: Visual Displays.

The diverse projection-based systems serve as visual display in 17 cases (77%). Most frequently a vertical projection surface is used (13 cases, 59%). Other projection-based systems (horizontal projection surfaces, and multiple surface projection systems) are each present in 10 laboratories (45%). These systems vary strongly in size (from 1 to 12 m) and number of projection planes (1 to 6).

In contrast to this, virtual retinal displays (VRD) (3 cases, 14%) or autostereoscopic displays (ASD) (2 cases, 9%) are only rarely found.

For projecting-based systems liquid crystal display (LCD) projectors are used most frequently (6 cases, 38% of projection-based systems). They facilitate a very bright presentation with high contrast and are relatively low-cost. Due to technical limitations they require a time-synchronous stereo-separation resulting in at least two projectors per projection surface. Cathode-Ray Tube (CRT) projectors which are used in 5 labs (31% of projection-based systems) work with higher framerate and allow time-alternating stereo-separation. Nonetheless, their projection is darker and they are usually more expensive than LCD projectors. Four labs (25% of projection-based systems) work with digital light processing (DLP) projectors that offer a higher projection quality. Three labs (21% of projection-based systems) use Direct Driven Image Light Amplifiers (D-ILA) with higher resolution and high brightness. Four participants using projection-based systems did not respond to this question.

Monitors and projection-based displays require glasses and devices for stereo-separation. These can be either time-alternating or time-synchronous. Time-alternating shutterglasses are usually found at monitors or when CRT-projectors are used. Twelve labs (55%) are equipped with these devices. In contrast to shutterglasses time-synchronous anaglyph (color) or polarization filter glasses are light-wear and cheaper. Polarization filter glasses are used in 15 labs (68%) while anaglyph glasses, which do not allow color presentation, are used in a single lab (5%) only.

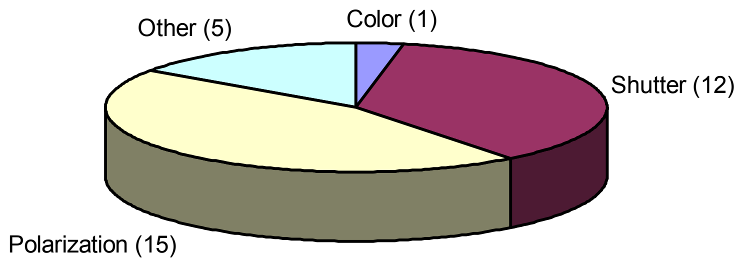

Figure 7-4: Devices for Stereo-Separation.

7.2.3 Acoustic Display

Multi-modality enhances the effect of immersion into the VE. For this, acoustic displays serve as an extension to visual displays. Acoustic displays are present in 15 institutions (71%). Nine labs (41%)

are equipped with stereo outputs and 8 (36%) use surround sound systems. Two participants in the survey have both available. Two institutions use other acoustic displays (binaural, 3D audio).

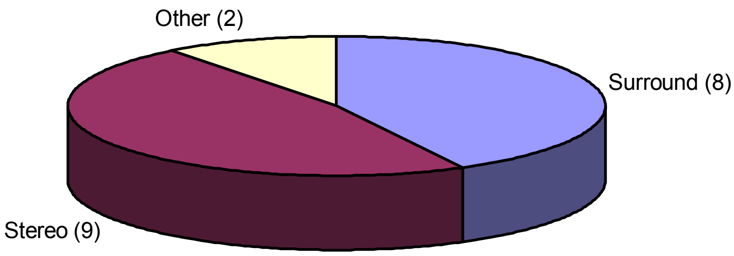

Figure 7-5: Acoustic Displays.

7.2.4 Haptic and Kinesthetic Displays

A further output modality used by AMVE-systems is haptics. Haptics is especially essential for fumbling, reaching, and grasping. A close, natural interaction with virtual devices becomes difficult without haptic feedback. Equipment for experimental haptic feedback is available in 10 institutions (45%), as shown in Figure 7-6. Mock-Ups made either from wood or other materials prepare a very accurate haptic feedback but are usually not very easy to modify. They are used in 5 labs (23%). Two participants (9%) make use of vibrating elements, and 1 (5%) use stepper motors or linkages. Four others (18%) possess PHANTOM devices that use stepper motors as well.

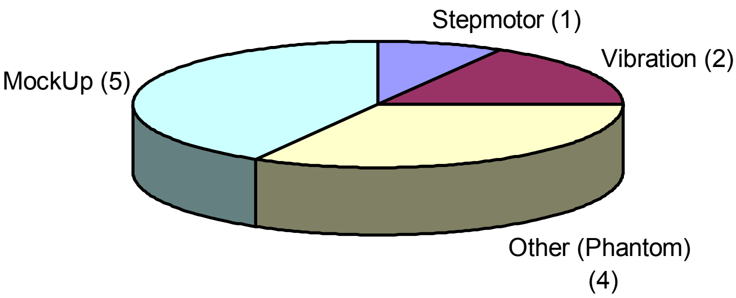

Figure 7-6: Haptic Displays.

Kinesthetics comprises the sensation of self-motion. It is implemented mostly by means of motion platforms, which simulate accelerating forces for the operator. Three labs (14%) are equipped with such motion platforms.

7.2.5 Tracking Systems

Receiving and processing operator inputs is obviously important for interactive systems. Tracking systems facilitate tracking of operator's view point position and orientation as well as the position and orientation of input devices. Tracking has to be real-time to minimize system lags and dizziness. Additionally, they have to be accurate enough to prevent display errors.

Figure 7-7 shows that electromagnetic tracking systems are widely used (16 cases, 73%), being followed by optical tracking systems (14 cases, 64%) and inertial systems (4 cases, 18%). Two labs (9%) make use of ultrasonic devices, and one possesses equipment for gaze capture. Two participants gave no answer to this question or do not make use of operator tracking. Again, the majority of labs rely on more than just one method. However, it is not clear whether methods are actively combined or just used for different setups.

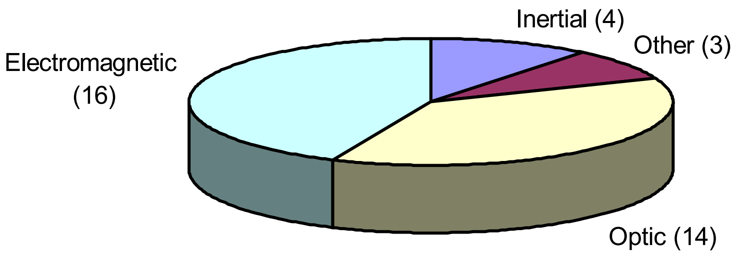

Figure 7-7: Tracking Systems.

7.2.6 Interaction Devices

Unlike conventional human-computer-interaction an intuitive, natural HSI requires special input devices. They vary between rather simple devices like mice or trackballs to highly sophisticated like 6-degree-of-freedom (6-DOF) controls or pointing devices. The proportions for the most common devices are shown in Figure 7-8.

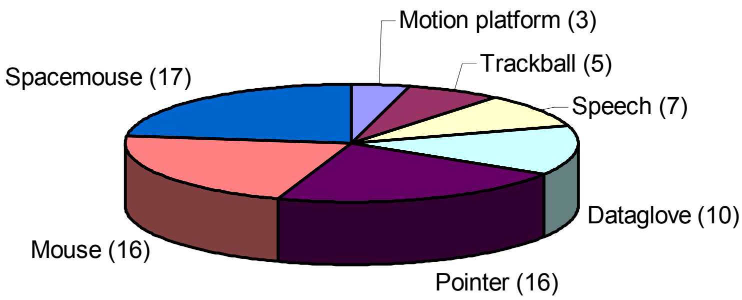

Figure 7-8: Interaction Devices.

Most frequently, a 6-DOF Spacemouse or comparable devices are used for 3D HSI (17 cases, 77%). Sixteen labs (73%) make use of conventional mice with just 2 degrees of freedom. The technologically identical trackballs are found in 5 labs (23%).

Pointing devices also requiring a tracking system are reported by 16 labs (73%). Five participants (23%) did not mention this devise despite have tracking systems available. This may hint at a misunderstanding of the question. Therefore, the actual percent of pointing devices can be considered as higher. Data gloves or derivatives make gesture input possible and allow a very natural pointing – simply with the hand gestures. They sometime include vibro-electric elements for haptic feedback (see according section 7.2.4). Ten of the participants' labs (45%) are equipped with these gloves.

Yet, all input devices facilitated a manual operator input – either by controlling a cursor, pointing, or gesture. Speech recognition facilitates acoustic and speech input and introduces a further modality. Speech input is usually combined with other interaction techniques like pointing. Seven institutions (32%) include speech recognition as a further input modality.

In addition to this, mixed mock-ups (see section 7.2.4) frequently use original input devices like knobs or dials as input devices. The Phantom device does not only serve for output, but also for input.

In addition to these commercially available products, several self-developed devices and innovative approaches are used. They include Cubic Mouse, JoJo, Easy2C and others. Special information about these innovative devices can be found on the websites of the according institutes.

7.2.7 Operating System

Hardware and devices described before are the backbone of the AMVE systems, but they would not operate without drivers and other supporting software. They are running on different operating systems. Figure 7-9 shows, that in 14 labs (64%) IRIX, the operating system for Silicon Graphics workstations is installed. The same amount uses LINUX operation system or Microsoft Windows. Only 2 labs (9%) run the UNIX operating system.

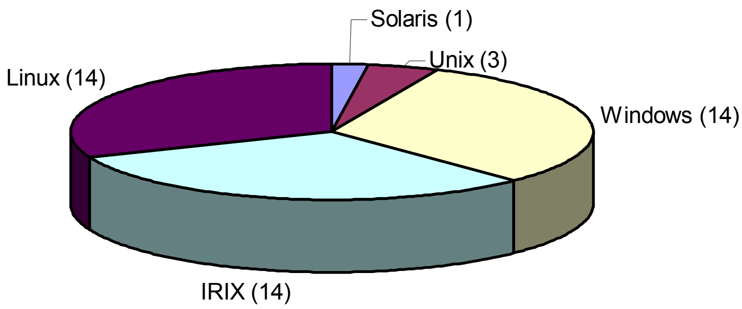

Figure 7-9: Operating System.

7.2.8 Visual Rendering Software

Visual displays and graphic computing hardware require a powerful rendering basis. The proportions of the most common rendering libraries or framework are illustrated in Figure 7-10. OpenGL (17 cases, 77%) is used most often as basis. Extensions of OpenGL, either self-developed or supplied, are implemented in 5 labs (23%). With SGI hardware platforms the software performer is present in 8 cases (36%). DirectX and derivatives serves as rendering basis in 5 institutions (23%).

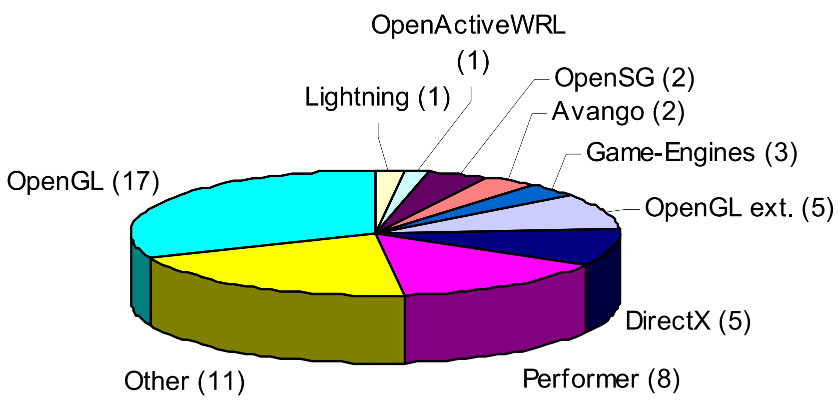

Figure 7-10: Visual Rendering Software.

Further and more specialized rendering software is just used by two labs (OpenSG, Avango) or just one lab (Lightning, OpenActiveWrl), which is usually the developing community of the rendering framework. Applications of rendering machines from game-engines were not reported.

7.2.9 Acoustic Rendering Software

Likewise visual rendering, there are special software frameworks for acoustic rendering as well. Six institutions (27%) report activities in acoustic rendering: 4 (18%) are using DirectX. 2 (9%) use OpenAL as more sophisticated acoustic rendering library.

7.2.10 Supported Data Formats

Virtual Worlds are usually not created online but stored in a special data format. The rendering software is capable to read this format and create a visual output out of it.

Answers in this section were very limited. The software of 5 institutions (23%) supports CAD data formats, and 3 (14%) support VRML as 3D modeling language. Other formats like inventor or Openflight etc. were just reported once. It has to be mentioned that the validity of these answers is not high because of a lot of missing answers (just 10 answers).

7.3 Areas of Application and Research

While hard- and software is the basis application and research gives insights into the actual purpose and intention of AMVE-systems. Due to the high flexibility of these systems, both topics have a broad spectrum. In theory, AMVE-systems can be applied to any possible application. In reality, there are several areas where the use of AMVE-systems is very promising and beneficial. In this chapter the relevant software modules for special applications, research and application areas are described. It is shown, that AMVE-systems, although still a research topics on their own, have changed into an application in recent years.

7.3.1 Application-Dependent Software Modules

Special applications require more specific software modules. These modules can be either single-stand modules, or they are a part of complex framework. In the questionnaire a rough structure of the main application-dependent modules was given. The result of the survey is illustrated in Figure 7-11.

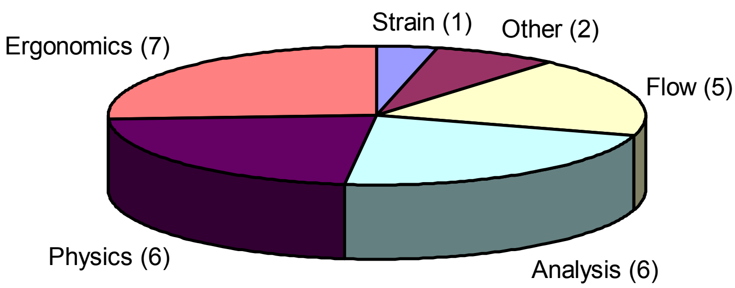

Figure 7-11: Application Software Modules.

For general analysis modules 6 institutions (28%) specified their software. Main modules were specific tools of Bool, CAD, BAF, VD2, ICEM/Surf, AVANGO, IDO Review, and others. Integrated physical libraries (5 answers, 23%) are ODE, Vortex, AVANGO, HAVOK 1.1. Modules for ergonomic analysis of workplace design are available at 7 institutions (32%). This comprises digital human models like Anthropos and RAMSIS as well as specific modules of VD2, AVANGO and IDO-Ergonomics. For CAD-Applications and general applications in manufacturing, strain analysis and analysis of flow are important. Five institutions (23%) answered this question positively. Available modules are within the AMVE-software libraries and packages EnSight, AVANGO, and Covise.

7.3.2 Areas of Research

Despite of upcoming real applications AMVE still remains a research topic and provides the infrastructure for research topics. Only two institutions (9%) did not respond to this question and are considered not to perform research activities in connection with AMVE. The frequency of other research topics is shown in Figure 7-12.

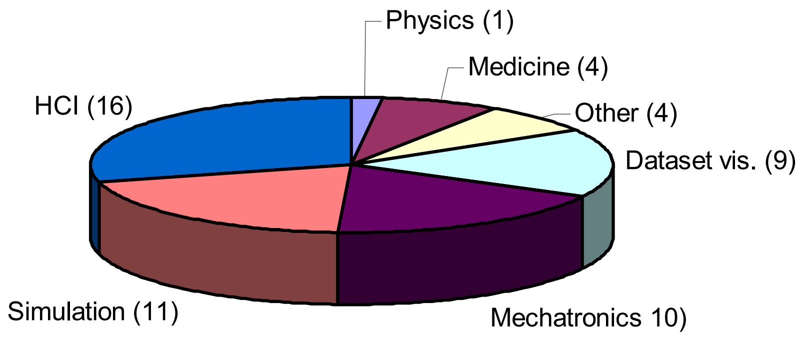

Figure 7-12: Research Topics.

According to this, the most frequent area of research is human-computer-interaction (16 cases, 73%). This meets the expectation because AMVE has been introduces as an innovative HSI and research in this area is required for optimal usability and application in manifold areas.

Other applications make use of AMVE technology as a tool. They are in the area of mechanical engineering / mechatronics (10 cases, 45%) and simulation (11 cases, 50%) of all kinds, but most frequently in combination with mechanical engineering. Nine institutions (41%) use AMVE technology for the visualization of massive datasets. In 4 labs (18%) medical applications of AMVE technology are the main focus. Applications in combination with other sciences like physics (1 case, 5%) or chemistry (no case) can be neglected. Further application areas (1 case per area) are architecture and modeling, storytelling, basic research in perception, and team training.

7.3.3 General AMVE Technological Development

In addition to research in more application-oriented areas, AMVE itself is being developed further on. This is necessary because of changing requirements for experimental setups and applications as well as changing technical capabilities. In total 16 institutions (73%) report activities in general technological developments. As shown in Figure 7-13, software development is the main goal of development. Six labs (27%) develop both, new software and hardware for AMVE. Two labs (9%) develop new hardware and 9 (41%) new software and software modules only.

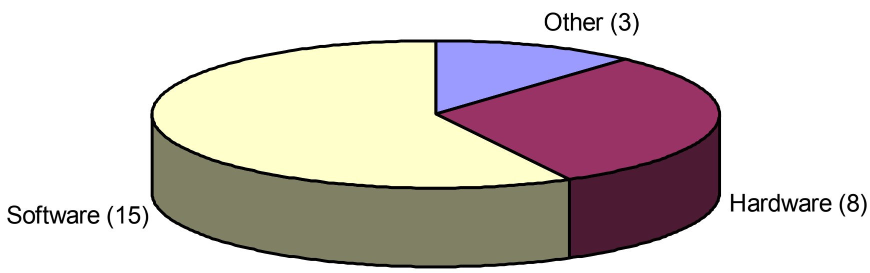

Figure 7-13: AMVE-Technology Development.

7.3.4 Product Design and Development

In product development AMVE technology is used primarily as a tool. In this case, AMVE provides infrastructure for developing a diversity of other systems. Figure 7-14 shows that most frequently industrial manufacturing processes, car manufacturing, and simulation (10 cases, 45%) are reported as application area. The following item, including 7 cases (32%), is product presentation. Five institutions (23%) use AMVE technology for application in architecture, aviation, and product design. Other applications areas are education and training in maintenance (1), automatisation (1), and military applications (1).

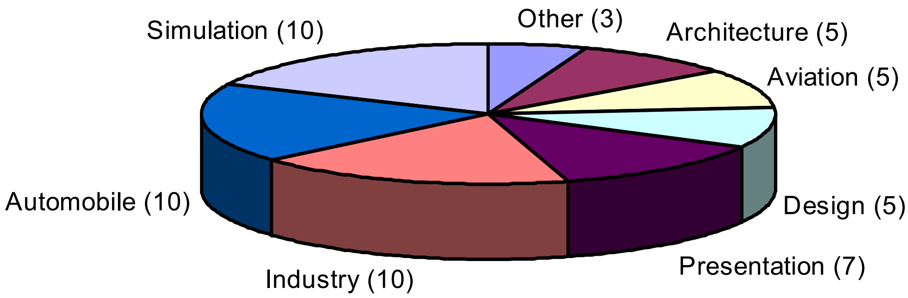

Figure 7-14: Area of Product Design and Development.

8.0 CONCLUSION

The report describes applications and research in institutions and within larger projects in Germany. Furthermore, a brief sketch of technological and thematic characteristics and trends for the civil sector is given. It shows that AMVE systems have evolved from a pure research topic to an application topic and that this trend is about to grow in future.

One obvious finding is the broad usage of PC systems for AMVE activities. Workstations are still used but even then PCs are used as an addition. The use of COTs hardware can be seen in display technology as well. Monitors are most often used, being followed by projection-based systems. Of course, the latter cannot be considered as commercially widely available, but they were strongly affected by dropping prices for LCD projection systems. Moreover, they do not have handling or comfort problems like HMDs. And they make team activities possible; something that is obviously impossible with a single HMD only.

As expected, visual presentation is more frequently present than acoustic or other modalities. However, acoustic is growing and available at several setups.

Tracking is widely done by optical or electromagnetic systems. Interaction devices are manifold and include simple as well as highly complex devices of various kinds.

With regard to software, Window, Linux and IRIX are most common. For acoustic or visual rendering most frequently self-developed software-frameworks or open-source software is used. They usually have benefits for specific applications but are variable enough to adjust them to others.

The main application area is ergonomics and within this, human-computer-interaction. Other areas are simulation, mechatronics, and visualization. Consequently, modules for physics, analysis of various kinds, and flow are available. Considering AMVE systems on their own, software is more often developed than hardware.

Most common application field is simulation, automotive and general industry, and product presentation.

In addition to the national findings, the NATO RTG has identified emerging technologies in one of its recent meetings. All of them will have effects on AMVE technology and its application. This includes:

- Vision (laser-based projection systems, small dome-projection systems, holographic displays, autostereoscopic displays)
- 3D-audio (new real-time software)
- Motion platforms (new pneumatic and electromechanic systems)
- Vibro-tactile elements (haptic feedback)

Seen from an international view, one of the main applications of AMVE technology still remains simulation and training. This is not observed in Germany, but is likely to develop with growing availability of AMVE-systems. This will result into more detailed modeling of the synthetic environment and the development of more realistic simulation environments. It also includes intelligent agents, i.e. behavior models, CGF, virtual combatants and their dynamic behaviors becoming a part of the training environment as well.

A further general trend is based on the falling prices of AMVE hardware. Increased computer power at low cost, wireless networks, shrinking of computer components, and better visual and auditory display systems are contributing to the maturation of these technologies. Potential applications in military operations, as well as training and system design are providing requirements that have spurred the technologies' development. Still most of the attention is drawn on the development of the technologies themselves. However, to be effective in military operations, the technologies must evolve into reliable systems that provide the information that their human users need to accomplish task objectives.

Compared to research on computer architectures, communication protocols, and display devices, there has been relatively little research on the perceptual requirements for displays, HSI issues from a human-factors point-of-view, design of effective training approaches, and measurement of human performance. The fundamental knowledge available today already indicates a large potential of AMVE technology for a broad spectrum of military applications, including: 1) dynamic, task-driven user interfaces for C4ISR systems; 2) telepresence, teleoperation, and telemanipulation in reconnaissance, surveillance, and target acquisition; 3) realistic, distributed military simulation and training; 4) mission preparation en-route, including intended area of operation; and 5) mission support as wearable, augmenting technology for individual operators.

Appendix A: Participating Institutions

We would like to thank the following institutions and persons for their participation and help in the survey.

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Volkswagen AG
PF 1511, VR-Labor
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Peter Zimmermann

A special thanks to

Leonard Vogelmeier
EADS Deutschland GmbH
81663 München

for providing us with chapter 3

and

Friedhelm Reiners
IABG Dept. "Networked Simulations"
Schiessplatz
49716 Meppen

for providing us with chapter 4.

Information considering chapter 5 (*Co-operative ComputerBased Training for the Amphibian M3*) is based on the internet domain of the project – http://www.kocua.info/.

- Contact for further information: Ray Sono AG Bremen, Otto-Lilienthal-Str. 8, D-28199 Bremen

Information considering chapter 6 (*Advanced Air Defence Training Simulation System*) is based on the www-homepage of EADS – http://www.eads.com/

- Contact for further information: EADS Defence and Security Systems, Business Unit Systems & Defence Electronics, 88039 Friedrichshafen

Swedish Projects

Jonathan Borgvall and Patrik Lif
Swedish Defence Research Agency

The Swedish part of this report focus on research within virtual reality in the military sector. Of course there is a lot of research conducted at different universities in Sweden but these activities are not included here. The military research work presented here includes the three military administrations, FOI – Swedish Defence Research Agency, FMV – Swedish Defence Materiel Administration, and SNDC – Swedish National Defence College. Some work is done at the military units but the main research effort within the virtual reality area within the Swedish defence organization is included within these three administrations.

1.0 FOI – SWEDISH DEFENCE RESEARCH AGENCY

The presentation bellow is different projects conducted at FOI which includes virtual environments.

1.1 Operator Site

The main aim of the project is to render more effective operator environments in complex systems by developing and adjusting operator supports that generate workload reduction and performance enhancement (Figure 1). The focus is on integration of operator supports characterised by being intuitive and thus requiring low degrees of human information processing. Experimental studies of visual, tactile and 3D audio displays are performed, including Human Factors evaluation and concept development for both manned and unmanned platforms.

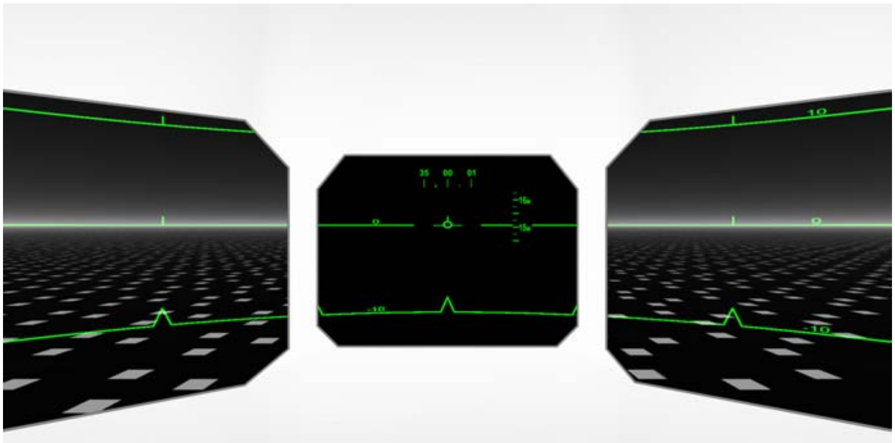

Figure 1: Example of Presentation that can be used during Low Visibility Conditions in Military Aircrafts.

1.2 Cognitive Overview

Every day there are numerous of important decisions made by decision makers in complex and dynamic environments. A leader of a rescue operation who is facing a major fire in a multi-storey building must act rapidly and accurately in order to cope with the situation. In another part of the world a taskforce is entering an urban area that has been occupied by terrorists. Somewhere else an air-traffic controller has discovered two airplanes that are on collision course and must decide how to handle the situation to prevent a disaster. All these decision makers are facing different kinds of problems that they need to handle in different ways. However, they all have at least one thing in common – they need to make important decisions in a dynamic environment – decisions that often are a matter of life or death.

Researchers all over the world work to find ways to help these decision makers. The technological advancement has created new opportunities. Today air-traffic controllers use two dimensional (2D) radar displays to monitor and guide air-traffic. In a similar way, the staffs that lead the taskforce usually have access to some kind of 2D command and control (C2) system that monitors the soldiers' movements. The technological development has now made it possible to present this kind of information in three dimensions, 3D. The question is if 3D presentation is better than 2D presentation, i.e. if it generates better decision making and better performance? The game industry uses 3D and the subjective effect is easy to see, but that does not mean 3D should be used for command and control (C2) systems too.

Research shows that 2D lead to better performance for some tasks while 3D lead to better performance in other tasks [1-3]. It is not easy to say when 2D should be used and when 3D should be used. One rule of the thumb is that 2D is good for tasks involving metric judgments and 3D is good to gain overall situation awareness (SA) [4]. SA is generated over time and is an important part of dynamic decision making. Reference [5] divides SA into three levels; perception, comprehension and prediction. The third level, prediction, is very important for dynamic decision making since the decision maker needs to be able to predict how a situation is going to evolve. At the Swedish Defence Research Agency (FOI) several studies relating to this problem has been conducted [1, 6-7].

In Military Operations in Urban Terrain (MOUT) it can be difficult to acquire and maintain good SA. In these environments threats can come not only from a close range but also from above. Enemies may hide behind a building and there may be snipers luring in a window or on a roof. Therefore, the commander of a MOUT needs a lot of support, probably 3D information, in order to make accurate decisions. One important question is if the commander should operate from a command vehicle where he is protected and has access to various decision supports? However, he is then taken away from the actual scene and that will most likely affect his SA negatively. Thus, there is a need to find a solution where the commander can use a C2-system and stay in the field where he belongs. It is also essential to find out what kinds of decision support the commander needs and if the information should be presented to him in 2D or 3D. The Swedish Defence Research Agency has developed a research platform to study these research questions.

1.2.1 A Research Platform: CoMap

The research platform is primarily developed for the military domain but it can easily be modified to meet the needs for the civil domain. The platform is called CoMap, Cognitive Map. The reasoning behind the name is that CoMap, besides a traditional 2D map, has a 3D map with some operational functionality which gives cognitive decision support for the operator. CoMap is constantly being developed in cooperation with possible end-users, e.g. the Swedish Military Combat School, MSS Kvarn. With its current functionality CoMap can be used as an information and decision aid during an exercise or as a planning- and evaluation-tool.

CoMap consists of three different parts; a 2D map, a 3D map, i.e. a 3D model of an urban area in Norrköping[1], and a toolbar (Figure 2). The toolbar consists of tools to create lines of approach, to place symbols and arrows to indicate for example own and enemy forces. The symbols are shown both in the 3D map and in the 2D map.

[1] This area was chosen because the Swedish Army Combat School, MSS Kvarn, uses this area for MOUT-exercises and it is possible to test the platform in cooperation with them.

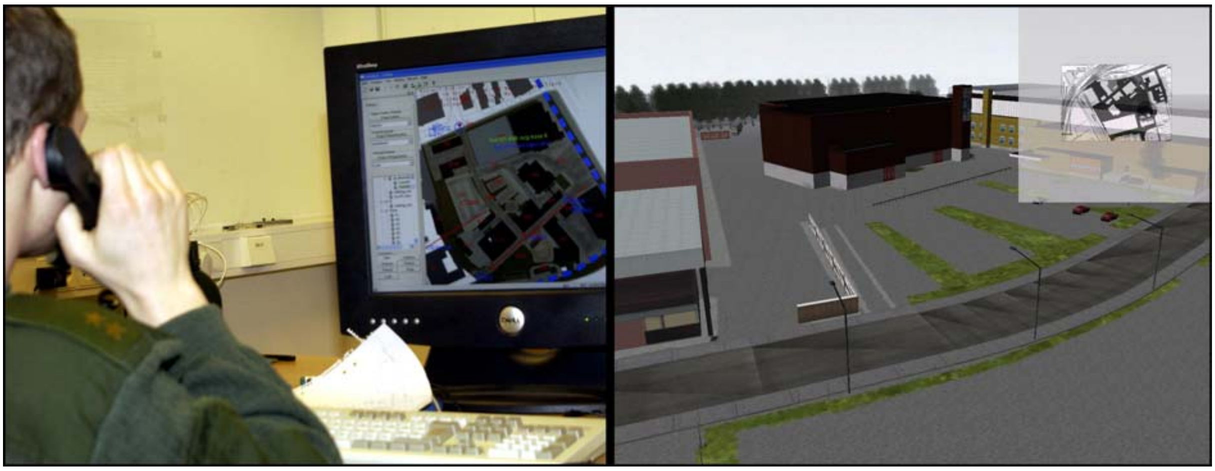

Figure 2: Left: A View of CoMap used by a Soldier in during a Real Military Exercise. Right: The 3D map used in CoMap.

The 3D map also has functionality that makes it possible to click in the model to get information about specific objects or to change field of vision to that specific place. The operator can move around in the 3D model and see it from different angles, e.g. it is possible to fly around and see everything from above or walk around on ground level. There are also tools to measure distances and to get line of sight analysis from certain positions, which can be valuable information in order to make accurate decisions. The operator can also use an overlay-function to show certain symbols and/or dispositions. CoMap can be used on more than one computer so if several computers are connected to a network an overlay can be sent to different operators within the network (Figure 3).

Figure 3: A Portable Version of CoMap used in the Field. The portable system is connected with a stationary systems of CoMap placed in away from the action.

[1] Andersson, P. and Alm, T., "Perception Aspects on Perspective Aircraft Displays". In *Displays, 24*, 2003, pp. 1-13.

[2] Bemis, S., Leeds J., and Winer, E., "Operator Performance as a Function of Type of Display: Conventional versus Perspektive." *Human Factors, 30*(2), 1988, pp. 163-169.

[3] John, M., Cowen, M., Smallman, H., and Oonk, H., "Use of 2D and 3D Displays for Shape-Understanding versus Relative-Position Task." *Human Factors, 43*(1), 2001, pp. 79-98.

[4] Haskell, I. and Wickens, C., "Two- and Three-Dimensional Displays for Aviation: A Theoretical and Empirical Comparison." *The International Journal of Aviation Psychology, 3(2*), 1993, pp. 87-109.

[5] Endsley, M., "Situation awareness in aviation systems." In: D.J. Garland, J.A. Wise and V.D. Hopkin (Eds.), *Handbook of aviation human factors*, pp. 257-276, MaHwah, 1999.

[6] Alm, T., Andersson, P., and Öberg, M., (2003). Evaluation of Monocular Depth Cues in 3D Aircraft Displays. *International Symposium on Aviation Psychology 2003*.

[7] Andersson, P. and Alm, T., (2002). Perception Aspects on Symbols and Symbol Relations in 3D Aircraft Displays. *Human Factors and Ergonomics Society 46th Annual Meeting*.

1.3 Future Soldier Concepts

Future soldiers, with ground mission as main task, can perform operations as a traditional army soldier, as sensor operator, an operator of unmanned vehicles, artillery commander, or operate other weapons, working with groups located at other places. The have to work with other soldiers and platforms to efficiently use different sensor and information. It is essential that the soldier can send and receive information about targets, hostile positions, and location of own forces. The soldier is very limited when it comes to carrying equipment, endurance, and energy supply the size of the equipment. It is of importance to understand the abilities the future soldier needs to have. Ability to perceive, assess the situation, and communicate perceived targets, or receive information from others, is probably the most fundamental ability. This ability must be preserved during different light conditions, different terrains, and all setting. The basic MSI question in this project is what demands that must be maid on the soldier's presentation equipment, to minimize distraction from the actual combat mission, and not to reduce his mobility. What size and where should the display be placed on the soldier? What kind of information should be available? Interaction principles with the display system will also be studied. Performance will be measured in terms of reaction times and direction understanding between the map and the reality, which leads to better situation awareness.

1.4 Operator Functional Status Assessment

The project develops measurement methods to quantify single operators and teams' mental workload, operative performance and situation awareness. The methods are developed in highly applied settings such as the operational environment of the Swedish Air Force, Army and Navy. The methods have been used to support tactics development, evaluate training regimes and design of new systems with complex man-machine interface problems. The project uses advanced statistical methods to combine online psycho physiological measures (both standard methods such as ECG, EPOG, EOG and new methods like NIRS and PPG), subjective rating methods, and objective measures (computer logs etc) to develop psychological models of human performance. The project studies the use of psycho-physiological measures to provide input to adaptive man-machine interfaces. The goal of the projects is to further develop measurement methods with high validity and reliability, which also are usable in applied settings such as real aircraft.

1.5 Computer Generated Forces and Human Behavior Models

During 2003, there have been two projects conducting research in Computer Generated Forces and Human Behavior modeling. Because of common interests and research activities the projects have had a close research relation with joint presentations and demonstrations. At the Division of Systems Modeling the focus has been on development of a joint library containing cognitive- and human behavior models for various tasks and applications, while at the Division of Command and control Systems the focus has been on development of cognitive models for individual infantry warriors. Both projects have common interests in methods of task analysis, AI-algorithms (path-finding, formation, etc), utilization of data from experiments and case-studies. Verification and Validation and implementation of behavior models for simulator systems. Both projects rely on their work to result in improved military simulation activities where many units need to participate.

There is evidence of an increased demand for computer generated forces and human behavior models for analysis and simulations within the M&S community, including a number of projects and applications at FOI. The research activities for this year, have been concentrated on studies and analysis of Performance Modifier Functions including prototype models used in simulations, design of a model library architecture, development of tools to aid in creation of behavior models and to integrate them into existing and future simulation frameworks and development of a database with physiological and psycho-physiological data to aid in development of human behavior models of individual infantry warriors.

1.6 An Analysis of CMMS Focusing on Knowledge Acquisition and Knowledge Engineering

CMMS is about conceptual descriptions and models of military operations.

It is the first level of abstraction when describing reality and aims to address characteristic details of the problem space. The concept of CMMS consists not only of conceptual models but also of tools for their development and reusability, a common library to store them, and standards for acquisition and integration of knowledge. Conceptual models are supposed to act as a bridge in the communication between modelers, system engineers, domain specialist and end users. The foremost reason for using conceptual modeling is to catch misunderstandings early in the development processes. The project's work during 2003 has focused on the concept of knowledge acquisition and knowledge engineering i.e. the KA/KE process. In conjunction to this, issues related to the problem domains; language and tools have been addressed. These three domains have a natural connection to each other in the way that they all are needed in order to map the early phases of the CMMS development process.

The part of KA is discussed thoroughly together with some methodologies for knowledge acquisition. The KE part describes guidelines on knowledge engineering in a similar manner while the language and tools chapters are only briefly discussed.

1.7 Methods for Producing High Resolution Synthetic Environments / Environment Models for Sensor Simulation

Models of the natural environment, environment models or Synthetic Natural Environments (SNE) have a central part in the M&S activities of the Swedish Armed Forces.

They form the common "playfield" where the simulated operations and interactions take place. Depending on the purpose, SNEs represent different environmental aspects for ground, sea and land operations (sometimes also space) across the whole spectrum of applications (armed combat, peace support operations, crisis management, etc.). The project "Synthetic Environments" has comprised of knowledge building concerning SNEs and studies and development of methods for constructing high resolution and detailed SNEs. A new standards proposal called SEDRIS has been studied and some tests have been implemented. A demonstrator in the form of a high resolution SNE for visual 3D real-time simulation has been produced using the developed methods. The project "Sensor Simulation" has comprised of knowledge building concerning SNEs for sensor simulation. Requirements for carrying out IR sensor simulation have been particularly studied. During the course of the activities, many successes and interesting results have been achieved. Methods have been developed to handle the different steps in the data production process. During the course of the project, even more applications for high resolution SNEs have been identified, both military and civilian.

1.8 Computer Generated Forces – Methods and Means

Modeling and Simulation, M&S, is a powerful tool that is used to support development of military concepts as well as training, studies and analysis of military operations in different environments. There are a number of important technologies that can be applied to military simulations. Computer Generated Forces, CGF, is one such technology.

CGF are used as Human Behavior Representations, HBR, of individuals or groups as operators or commanders in military simulations. Defence driven M&S is demanding more realistic HBR models in simulations. To confront the growing need of such models, the Swedish Armed Forces has sponsored a study of CGF development since 2001, conducted at FOI. The main purpose of the project is to construct a framework to support CGF development and to maintain a component based library of HBR models to be used in existing and future simulations.

1.9 Web-based HLA Federations and Simulations – Methods and Possibilities

Modelling and Simulation (M&S) is a vital part of the Network-Centric Warfare (NCW) concept, adapted by the Swedish Armed Forces (SwAF).

However, simulation model development, implementation, testing, and execution are time consuming and expensive processes. Hence, it is of great interest to combine the web and Internet technologies, and M&S in order to e.g. utilize the simulation models and computing resources more efficiently. This report presents the results from research conducted within the area of Web-based M&S. The project "Web-based HLA Federations and Simulations" was carried out during 2001 and 2002 on behalf of the SwAF. The main objective of the project was to investigate and study the benefits and advantages of the impact of networking technologies and distributed computing techniques on M&S for the SwAF. During the first year the potential of the combination of Web-technology and HLA federations, and Web-technology and legacy simulations was investigated. The focus of the project during 2002 was on component-based model development, distributed computing techniques, particularly Peer to-peer computing, and collaborative model development and execution. The results from the project confirm our preliminary assumptions regarding the advantages of combining networking technologies, such as Internet and the World Wide Web, and M&S.

We believe that the area has a great potential and will play a central role in the future NCW systems.

1.10 Mission Specific Mapping and Visualization

Task specific environment models of the area of operations are critical for e.g. mission planning, execution and after action review. In complex and rapidly changing environments such as urban areas, there is an increasing demand for updated and detailed environment information. With advanced sensors and sophisticated signal processing methods, this kind of information can be made available in a future network centric defence, enabling mission specific 3D models of areas of operation to be rapidly produced and distributed.

1.10.1 Data Acquisition

Future advanced sensors for reconnaissance and surveying provide data that enable reconstruction of the area of operations. For example, using a 3D laser and digital camera it is possible to obtain elevation data, intensity data, multiple signal returns and visual imagery.

1.10.2 Analysis and Data Processing

As a basis for generation of environment models of areas of operation, sub models area created using analysis and processing of sensor data.

1.10.3 3D Modeling of Areas of Operations

Mission specific 3D models of the areas of operations are produced using the generated sub models. The images on the previous page shows a detailed 3D model of an area generated using a ground elevation model, an orthophoto, 3D models of buildings and 3D models of single trees. The image below shows a model of the same area generated using only a digital surface model and an orthophoto (Figure 4).

Figure 4: The Image shows a Model of an Area Generated using a Digital Elevation Model, an Orthophoto, 3D Models of Buildings and 3D Models of Single Trees.

1.11 Applications of the New Swedish Dynamic Flight Simulator

1.11.1 Introduction

The Dynamic Flight Simulator (DFS) is a versatile high performance pilot training and research device (Figure 5). Technically it is a man-rated centrifuge combined with fully controlled and motor operated pitch and roll gimbals (2-axis) and a flight simulation system based on JAS 39 aircraft models and controls. A unique perception algorithm modeling the expected sensations provides a “realistic” flight experience and increased comfort since undesired sensations are minimized. A variety of operation modes allow traditional centrifuge training as well as extended or applied G-training. In applied G-training the pilot being in full control of a realistic environment is given meaningful tasks leading to more effective G-training.

Figure 5: The DFS Machine.

1.11.2 Dynamic Flight Simulation Requirements

Dynamic flight simulation can be described simply as a flight simulator that uses a human centrifuge as its motion base. DFS requirements arise out of a need to train high performance aircraft pilots to perform more effectively as they execute their flight missions and also from a need to study the human responses to acceleration with possible methods to increase pilot safety and effectiveness.

The DFS device then must be able to recreate the acceleration time histories that occur in flight and also provide the perception of flight motion so that training can be effective and so that research is applicable to the actual flight environment. Since the acceleration time histories include sustained acceleration, the DFS motion base must be a centrifuge with a reasonably large radius arm in order to minimize the disorienting effects of angular accelerations on the pilot vestibular system.

Time history requirements also mandate using a two-axis controllable gimbal system to support the gondola containing the DFS simulated cockpit, the pilot and the various simulator support systems. An important, perhaps non-obvious, feature is that the pitch axis, defined with the pilot facing tangential to the arm motion, must be supported within the roll axis gimbal. This allows the DFS to respond quickly to changes in the commanded linear acceleration vector. Finally, there must be a configurable control algorithm that can allow the DFS to be used to give the pilot the perception of flight or to give a researcher the ability to command accurate acceleration time histories in all axes.

1.11.3 Technical Description Flight Simulation System

The gondola (Figure 6) consists of permanent systems and configurable inserts. The training insert, a Gripen cockpit mock-up, can accommodate positioning of subject heart- or head level in the center of gondola. A separate insert for acceleration research is a turnable seat, which can be rotated or tilted in various angles.

Figure 6: Training Insert.

The flight simulation capabilities are based on:

- JAS 39 Cockpit mock-up containing real Aircraft hardware such as MB-seat, stick, throttle and Oxygen regulator.
- Aerodynamic model delivered by Saab (ARES). Current setup contains one weapon load, no fuel system simulation or ground handling.

- Head-up and head down display instrumentation. Head down software is a derivative of Saab glass cockpit (virtual front panel) from 1997. The software contains basic avionics- and weapon system functionality such as simplified IR and Radar modes and a choice of gun of missile.
- Visual out-the-window displays consisting of 3 monitors with a total field-of-view of approximately 90 degrees. The database is in Open Flight format and shows an area around Oakland CA.

1.11.4 Field of Application

The DFS has been developed for a wide field of applications such as:

- Pilot training and qualification
- Screening of pilot applicants
- Medical evaluation
- Research in Flight physiology
- Research in Spatial Disorientation
- Research in Man-Machine Interaction
- Development and testing of life-support equipment
- Aircraft equipment
- Evaluation of cockpit design approaches
- Tactical evaluation

1.12 ACES – Air Combat Evaluation System

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ACES – "Air Combat Evaluation System" is a research flight simulator specialized in within visual range (WVR) air-to-air combat. The system consists of two simulator cabins (pilot stations) and one instructor station. ACES is built around several pedagogical tools intended to make WVR-combat much easier to learn (Figure 7). ACES is a research simulator used for evaluation of pedagogical concepts of learning dogfight and to serve as a development simulator to demonstrate and evaluate the strengths of embedded pedagogical tools and online (real-time) analyses of important air combat flight parameters. During fall of 2004, ACES will be evaluated together with the FlygS (The Swedish Air Force Flight School). ACES will also serve as a concept facility for studying Forward Air Controlling. ACES will soon be linked to (FLSC) Swedish Air Force Air Combat Simulation Centre in Stockholm, for distributed simulation.

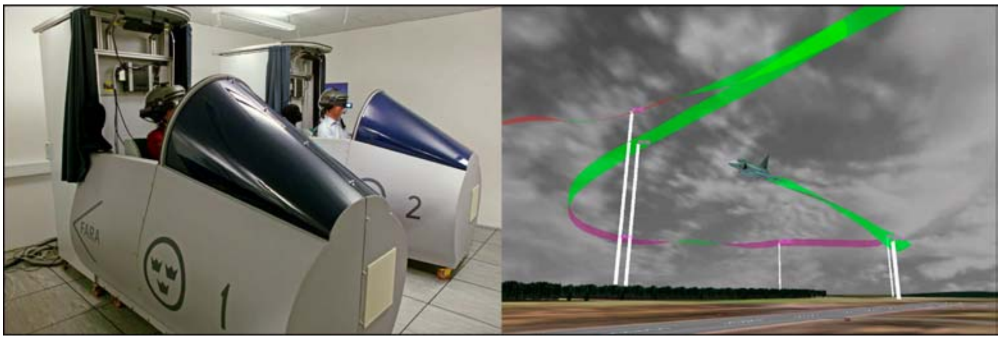

Figure 7: ACES Simulator and Example of Pedagogical Tool.

1.13 MOSART – A Platform for Integration of Research Results

Contacts: Mathias Tyskeng (E-post: mathias.tyskeng@foi.se), Tobias Horney, and Mikael Brännström

1.13.1 Overview

The primary objective of the MOSART project is to simplify integration of research results into larger simulations and demonstrators (Figure 8). Within the project, a modular software environment is developed which provides basic simulation functionality and enables an efficient integration of own and commercial software. The environment that is developed in the project is called MOSART Test-bed. The test-bed contains three main parts:

- Software for integration
- Basic features for simulation
- Integrated results from research projects

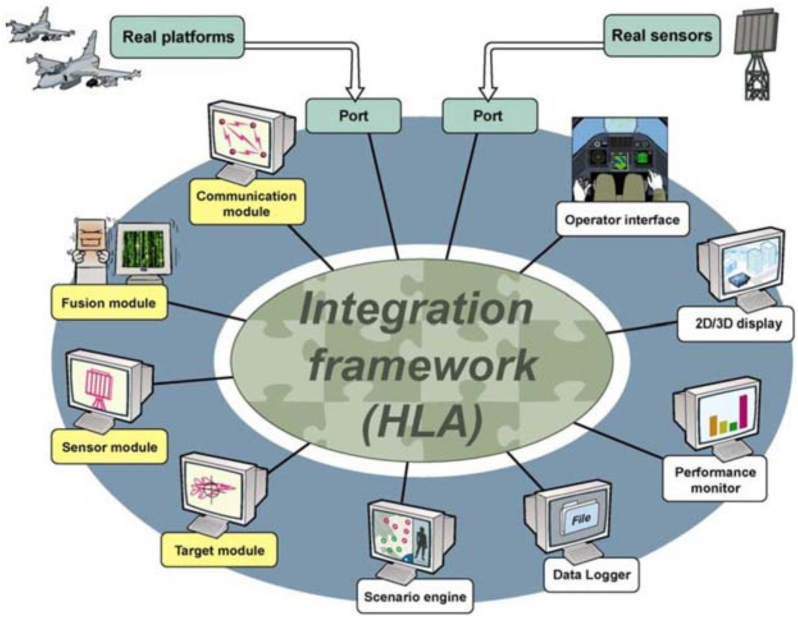

Figure 8: Overview of MOSART.

These main parts in the test-bed make it easier for research projects to evaluate results in a larger context by setting up more advanced simulations and demonstrators. This is accomplished by integration of the own research results, the basic features and other research results integrated in the test-bed. Through the development of the test-bed:

- Other research can be made more cost efficient.
- Greater opportunities for research collaboration is accomplished.
- Experience from integration of systems and data sources is gained.

1.13.2 Modules and Integration

The software for integration of modules decreases the complexity of developing large simulations and demonstrators, since the demand for user knowledge in the area of distributed simulation (High Level

Architecture, HLA) is minimised by the software. In the test-bed there are also a number of simulation support features, such as scenario editor and engine, visualisation in 2D and 3D, maps and high resolution synthetic environments, real sensor data, logging and scenario management. In addition, there are the modules that research projects have integrated into the test-bed, which can be reused by other research projects that wants to develop simulations and demonstrators.

In the figure below, screenshots from some of the modules in the MOSART Test-bed are shown. A) 3D visualisation and synthetic 3D environment B) Flames, simulation framework C) 2D visualisation D) IR sensor simulation module (Figure 9).

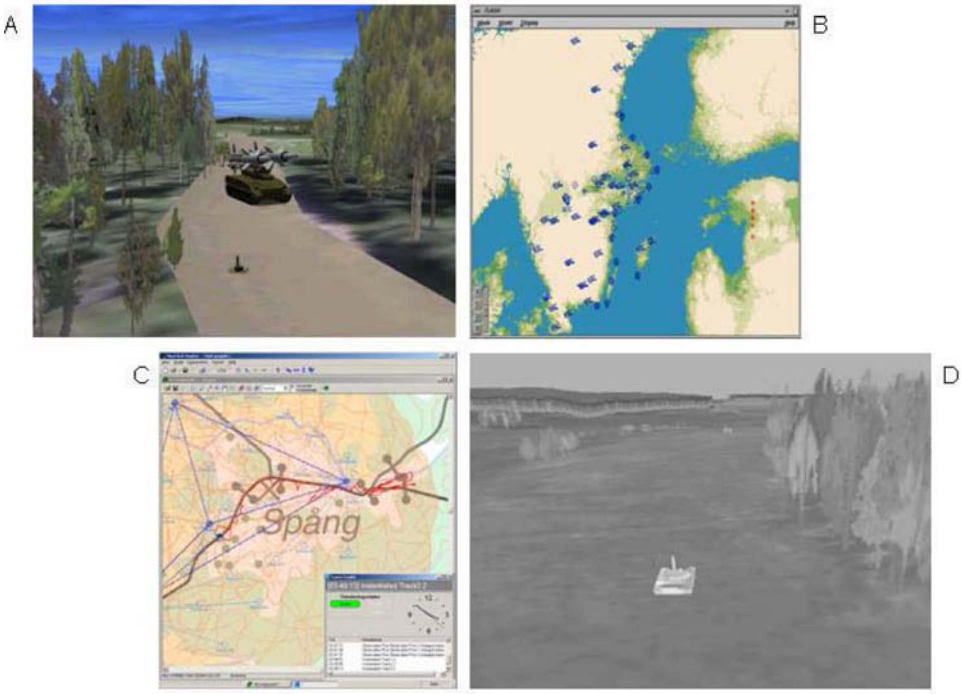

Figure 9: A) 3D Visualisation of 3D Environment; B) Flames, Simulation Framework; C) 2D Visualisation; and D) IR Sensor Simulation Model.

1.13.3 External Links

The development of the test-bed and the choice of HLA as the simulation mechanism, aim at accomplishing compatibility with similar environments in other organisations, e.g. the Swedish Armed Forces, FMV and the industry. This enables MOSART to be a link between FOI research and external collaborators, which in turn enable development projects to use research results. Today there is an established collaboration with DSO in Singapore, in which FOI and DSO develop compatible test-beds and perform common demonstrations.

1.13.4 Development

To maintain MOSART as an interesting environment for integration of research results, the test-bed functionality must be continuously improved. A coming development step is to introduce the possibility to use a service based approach for the modules in a demonstrator or simulation in order to be an active part of the development of a network based defence for the Swedish Armed Forces. Another important step for the test-bed is to create ports to real sensors and systems. By doing that, there is an option in the test-bed to mix real and simulated entities in a scenario and thereby be able to test future concepts and system configurations.

2.0 RESEARCH AT SWEDISH DEFENCE MATERIEL ADMINISTRATION

2.1 SMART-*lab*

Within the Swedish Defence Materiel Administration headquarter in Stockholm there is a unique laboratory environment installed for analysis and development of the Total defence. SMART-lab consists of around 2000 m^2 of projects rooms, offices and laboratories.

SMART-lab offers an advanced environment for its two main services. SMART-lab main service is Systems and enterprise analysis. SMART-lab also offers an arena for Technology demonstrators and C2 exercises.

SMART-lab has a focus of competence in System and enterprise analysis, Human to Systems interactions and Modelling and simulation. SMART-lab relies also heavily on partnership with the customers and other agencies for fulfilment of competent analysis team.

2.1.1 Systems and Enterprise Analysis

Within SMART-lab main service examples of different type of projects are Business and mission modelling, Organizational analysis and business development, Crisis management analysis, Process modelling of business and military operations and Analysis of future international military operations.

It is a wide range of different analysis projects with one thing in common. They all consists of analysis work done in the early phases of the acquisition process, before any procurement action of military systems, i.e. the work is mission centric. SMART-lab does not work with actual military platforms.

2.1.2 Technology Demonstrators and C2 Exercises

Within the area of using SMART-lab as an efficient information technology arena, customers often use SMART-lab for research and technology demonstration when requiring more advanced presentations.

The usage of SMART-lab as a Command and Control exercise arena has lately increased. During one of many exercises in SMART-lab the lab itself was refurnished and technically prepared to simulate a Command and Control Centre and its distributed Command and Control containers – as an actual field operation. Military personnel then trained and analysed different situations using a scenario and mission simulator for the exercise.

2.1.3 SMART-lab Technology Development

SMART-lab conducts technology development in Modelling and simulation in areas such as Simulation Based Acquisition, Verification, Validation and Accreditation, Conceptual modelling and in the arena of Commercial and defence gaming.

In the domain of Human to Systems interactions SMART-lab focus is on Perception of information and systems interaction, Command and decision support in distributed systems, Communications in a network based defence and Methods of evaluation.

More information at http://www.smart-lab.se.

2.2 SMART-lab VR-Projects

SMART-lab has supported some FMV projects that have a need of visualisation techniques for a cost-effective solution in the procurement cycle.

2.3 (2003-2004) SSG120 Armoured 120mm Mortar Project

SMART-lab is at the moment supporting the FMV Armoured 120mm Mortar Project. The support consists of preparing an evaluation of an industry produced 3D-model in the forthcoming Development Phase. The purpose of the evaluation is to perform a cost-effective development of a prototype. Evaluation sessions include both consumer and customer with their requirements and provide feedback to the developer. The evaluation will be performed from different views, e g Integrated Logistics Support (ILS) and Human to Systems interactions. A variety of VR-techniques will be used to meet the needs from consumer and customer.

2.4 (1999-2001) STRPBV90 Forward Command Vehicle, Ergonomics

There was a need to study new design concepts of the command and control version of the StrPBV90 to enable international duty. SMART-lab supported with the production of a virtual prototype of the chassis and turret, including all interior equipment (Figure 10). The 3D-model was used for stereoscopic visualization and simulation in the VR-tool "SmartScene". The purpose of the study was to examine ergonomic topics, test and present modifications of the design in 3D. The project team could view the model projected on a power-wall wearing stereoscopic shutter-glasses. For documentation of the used methodology in the project, a video film "VR-som verktyg" ("VR as a tool") was produced.

Figure 10: STRPBV90 Forward Command Vehicle.
3D-model: Peter Schyllberg och Björn Ramsell, FMV SMART-lab.

2.5 (2002-2004) Submarines of the Gotland, and Sodermanland Class, Half-Time Modification

To enable an efficient half-time modification and for testing of new design concepts of the submarines of the Gotland and Sodermanland class, the project needed 3D virtual models of the command and control room. CAD data from industry was converted to polygon models and adapted for stereoscopic viewing in the VR-tool "SmartScene". The 3D-models was painted and textured realistically (Figure 11). A number of design sessions were held at FMV and the project team evaluated different concepts projected on a power-wall wearing stereoscopic shutter-glasses. Animated video films and snapshots of the designs were rendered to act as presentation material.

Figure 11: Gotland Class Submarine Interior.
3D-models: Peter Schyllberg och Björn Ramsell, FMV SMART-lab.

2.6 (2003-2004) HMS Carlskrona, Half-Time Modification

There was a need to perform an efficient half-time modification of HMS Carlskrona. As the submarine project, 3D virtual models of the command and control room were produced for testing of new design concepts. The design concepts were evaluated by the project team and presented on a big screen with stereoscopic visualisation.

3.0 SNDC – SWEDISH NATIONAL DEFENCE COLLEGE

3.1 AQUA – Project

We present a prototype command and control system that is based on view-dependent co-located visualizations of geographically related data. It runs on a 3D display environment, in which several users can interact with view consistent visualizations of information. The display system projects four independent stereoscopic image pairs at full resolution upon a custom designed optical screen. It uses head tracking for up to four individual observers to generate distortion free imagery that is rendered on a PC based rendering cluster. We describe the technical platform and system configuration and introduce our unified software architecture that allows integrating multiple rendering processes with head tracking for multiple viewers. We then present results of our current visualization application in the field of military command and control. The command and control system renders view consistent geographical information in a stereoscopic 3D view whereby command and control symbols are presented in a viewpoint adapted way (Figure 12). We summarize our experiences with this new environment and discuss technical soundness and performance.

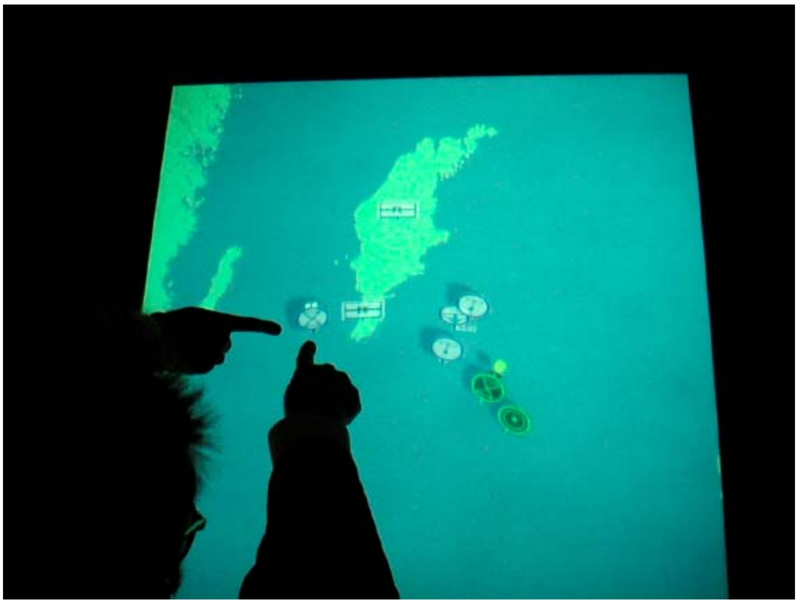

Figure 12: Two Users are shown Collaborating in the Multiple Viewer Display Environment.

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1.0 AREAS OF INTEREST

TNO Human Factors distinguishes the following areas of interest as regards augmented, mixed, and virtual environments for intuitive human-system interaction: mixed and virtual environment operations, tele-operations, command & control, and wearable augmented technology.

2.0 CURRENT RESEARCH PROJECTS

2.1 Mixed and Virtual Environment Operations

The goal of the projects in this area is realistic simulation and training of flying, driving, and dismounted soldier team operations (MOUT), and virtual prototyping of various designs, i.e., digital models of ship bridges, vehicles, offices, etc. Various projects are currently carried out in this area, using the facilities and technologies shown in Figures 1-5. Special attention is given to research into the determinants of presence and performance in mixed and virtual environments, focussing on team operations in urban terrain and using 'agent' and 'avatar' digital human models.

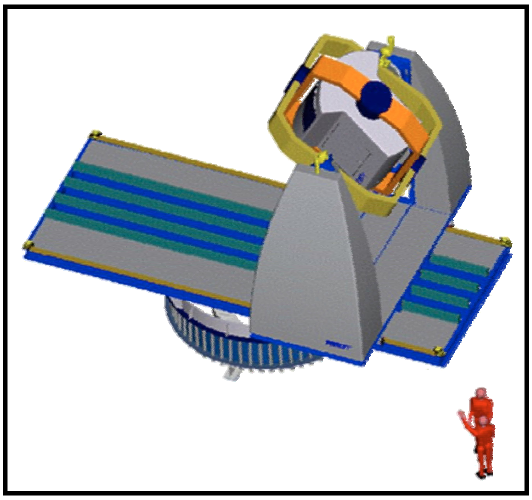

Figure 1: Desdemona, a 6DoF Next Generation Motion Platform for Spatial Disorientation Training and for Driving and Flight Simulation with Sustained G Capabilities.

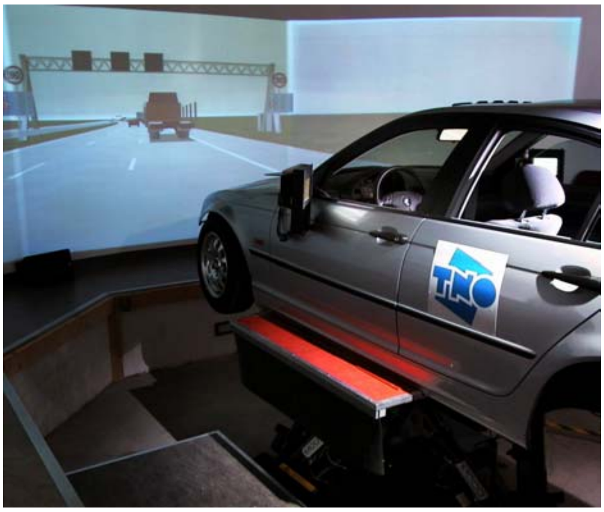

Figure 2: Moving-Base Driving Simulator.

Figure 3: Military Operations in Urban Terrain –
Subject immersed through head-mounted display.

Figure 4: Ship Bridge Virtual Prototyping.

Figure 5: Manipulation of Objects.

2.2 Tele-Operations

The goal of the projects in this area is intuitive control of remote ground and air vehicles (for tele-consultation: interaction of distributed subjects). Various projects are currently carried out in this area, using the facilities and technologies shown in Figures 6-10. Special attention is given to research into the determinants of presence and performance, focussing on the remote ground vehicle ('The General', Figure 6).

Figure 6: 'The General' Tele-Presence Enabled Unmanned Ground Vehicle (indoor version; at the left) and the Ground Control Station (at the right).

Figure 7: Unmanned Aerial Vehicle (UAV) Flying.

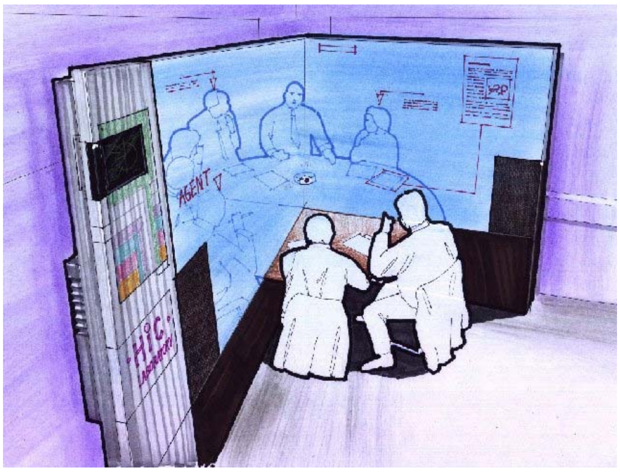

Figure 8: Tele-Conferencing – VIRTUE (Virtual Team User Environment).

Figure 9: Tele-Maintenance. At the left: a mechanic at work, providing a picture to the expert with a hand-held camera. At the right: an expert guiding the mechanic at a distance, communicating with video and duplex audio.

Figure 10: Tele-Medicine Body-Mounted Equipment.

2.3 Command & Control

The goal of the projects in this area is to develop and test new concepts of team organisation, human-system task integration and intelligent interfaces for efficient and effective command and control (example: Figure 11). Starting with a set of missions and tasks, the trade-off between task distribution, personnel qualifications and support concepts is analyzed. Modeling and simulation tools are used to analyze concepts and to monitor how workload is distributed over the personnel during a scenario.

Figure 11: Mock-up for the Landing Platform Dock 2 (Common Operational Picture).

Research on intelligent interfaces focuses on situation and operator state dependent adaptive interface concepts with integrated tools for information management and decision support. Concepts are implemented and tested in a new command & control workstation set-up called the Basic-T (Figure 12). It incorporates 3D perspective and stereo images of the tactical picture.

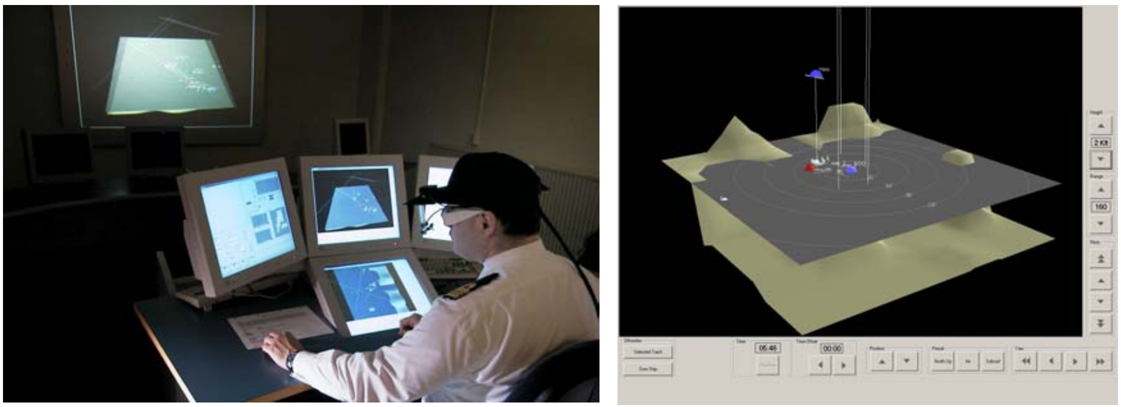

Figure 12: Basic-T (3D Tactical Picture).

2.4 Wearable Augmented Technology

The goal of the projects in this area is to provide situation awareness, communication and navigation for military and rescue services in the field. The deliverables are technology demonstrators, such as the tactile suit (Figure 13), prototype products, such as integrated headwear (Figure 14), and specifications (technical requirements enlightening human factors choices).

Figure 13: Pilot Wearing a Laboratory Version of the TNO Tactile Torso Display (TTTD), or Tactile Suit (in the back: a RNLAF Chinook Helicopter). This particular version of the TTTD contains twelve columns of five rows of vibro-tactile actuators, plus four more on shoulders and between the upper legs and the seat.

Figure 14: Example of Gen. 3 Integrated Head Based Systems (courtesy TNO).

3.0 RESULTS ACHIEVED TO DATE

Publications on the results achieved to date can be found in the section 'Literature prepared by researchers'. This section contains brief descriptions as regards the areas distinguished.

3.1 Mixed and Virtual Environment Operations

Basic research has been conducted on spatial orientation, navigation, and glove manipulation by subjects in various virtual spaces with a comparison to the equivalent real space. Virtual prototyping is implemented as a flexible and user-collaborative design method. The method has been applied to various workplaces, such as ship bridges, control rooms, and military vehicles.

Desdemona is under construction and is scheduled to be in operation at the end of 2005.

3.2 Tele-Operations

In the past a range of human factors aspects of unmanned (military) vehicles has been studied. The effort was focused on remote control of cameras, dealing with such issues as transmission delays and bandwidth limitations, situation awareness, and image augmentation. In more recent years, issues worked on have shifted to operator training, operator skills, ground control station design, automation design, human factors guidelines and standards, and manned-unmanned collaborations.

3.2.1 UAV Flying

Various interfaces to assist the operator were developed, and a series of experiments has been conducted. It was shown that the manual control of the camera of an unmanned aerial vehicle (UAV) can be difficult due to several factors such as time delays between steering input and changes of the monitor content, low update rates of the camera images, and lack of situation awareness due to the remote position of the operator and the small field of view of the camera images. Furthermore, if the UAV is controlled from inside an aircraft (moving operator), the operator has to deal with different frames of reference.

3.2.2 Tele-Presence Control Station

A new track is the work on tele-presence control stations. Intuitive (perceptual-motor) control of remote camera and possibly platform will free up the cognitive resources that are needed for performing the task at hand (e.g., acting in the remote environment, decision making, etc.). 'The General' is the first attempt to demonstrate this concept. It currently features immersive head-slaved stereo images and 3D sound, vibration sensations, body control of platform movement, and remote manipulator control. Special attention is given to research into the determinants of presence and performance in tele-operation settings.

3.2.3 Tele-Conferencing

VIRTUE (virtual team user environment) aims to create a multiparty meeting space where virtual and real worlds are seamlessly combined so that participants at different locations can have the impression that they are sitting next to each other and can work co-operatively. Experiments were carried out on the effects of shared background, stereoscopic vision and motion parallax, video and audio delays, and deviations in gaze direction on tele-presence. It turned out that tele-presence was not influenced by these variables. People have a high tolerance toward critical factors such as gaze deviations and delays. However, negative effects may appear under more critical circumstances and with more sensitive and more objective measures.

3.2.4 Tele-Maintenance

When knowledge, required for trouble-shooting at sea, can be supplied real-time but from a distance, problems, such as with the limited availability of specialists, and the high costs of maintenance, may be tackled. An experiment was performed with thirty subjects, in which an on-shore expert and an on-board mechanic fixed technical problems together. The results show that, in principle, the problems could be fixed, both by technical and non-technical mechanics, although it requires more time, communication and effort. Unfortunately, it is less safe.

3.2.5 Tele-Medicine

The tele-medicine project created opportunities to study an on-line mediated workplace involving a medic treating a patient, and a doctor at a remote site giving advice. Clinical experiments showed the effects of equipment and settings used, the mounting of the equipment, and the resulting conversation. A direct feedback tele-viewing system addressed the issues of delays and decreased image quality on telecommunication links.

3.3 Command & Control

Various new command concepts have been created and tested for the Dutch armed forces. With Basic-T as a testbed the different tools for information management and decision support have been tested for future application in the maritime environment.

3.4 Wearable Augmented Technology

3.4.1 Tactile Suit

The tactile suit can be viewed as a cockpit instrument, and ongoing research is establishing its value for navigation, hovering, threat warning, spatial disorientation countermeasures, communication, and other purposes. The same technology is also used for application on land (navigation support and threat warnings for drivers, infantrymen, blind people, etc.), underwater (divers), and in space (astronauts in the ISS).

3.4.2 Integrated Head Based Systems

Future soldiers will wear helmets in various degrees of encapsulation, as an optimization of protection, perception, and usability. Although information presentation is an important aspect (new type of non-obstructive head mounted display, high resolution on the move, restoration of 3D environmental sound while wearing hearing protection), the human factors integration is key to head based systems (design for a stable fit, weight and balance, scalability to head form, anthropometric variety, hearing protection, vision, facial recognition, quick conversion from grim to kind appearance). Head based systems replace a large number of equipment items while being fully compatible with the soldier system. Head based systems are a platform for additional functions such as instrumented vision, antenna's, breathing protection and climatization. Soldiers need for instance a day and night vision capability, that allows them to supervise, acquire targets, aim and shoot. Speed and accuracy compete for priority. Shooting comes in direct and indirect fire, demanding rather different aiming techniques. Though nothing is virtual at this, it is an outstanding example of the need for intuitive human system interaction. Procedures need not be different between day and night, sensor images need to combine so as to require minimal operation for switching. And there must be a smooth transition between searching and aiming, without losing the target. We found a practical solution that is economical and convertible to various military tasks.

4.0 COLLABORATIVE PARTNERS

TNO Human Factors collaborates with a large variety of national and international military and non-military organisations. Refer to www.tno.nl for more information.

5.0 LITERATURE PREPARED BY RESEARCHERS

This section contains a selection of the literature prepared by TNO-HF. Refer to www.tno.nl for more information.

5.1 Mixed and Virtual Environment Operations

5.1.1 Basic Research and Virtual Prototyping

Werkhoven, P.J. and Groen, J. (1998). Manipulation performance in interactive virtual environments. Human Factors, 40 (3), pp. 432-442.

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5.4.1 Tactile Suit

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5.4.2 Integrated Head Based Systems

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6.0 VR R&D LABORATORY FACILITIES AVAILABLE

Most of the technology used can be found in the new SimLab and the new Desdemona facility (Figure 15). The following facilities and technology are available:

Figure 15: TNO Human Factors SimLab and Desdemona Facility.

6.1 Mixed and Virtual Environment Operations

- Visualisation means (HMD, large screen projection, 3D-glasses)
- Moving base with an instrumented car or truck cabin
- Fixed base flight simulator
- Desdemona, a 6DoF motion platform
- Digital human models (agents and avatars)
- Body tracking (locomotion, gestures, etc.)
- Data glove (manipulation of objects)
- 3D sound

6.2 Tele-Operations

- Ground vehicle operations ('The General')
- Unmanned Aerial Vehicle flying
  Related technology
- Tele-conferencing / virtual team user environments
- Tele-medicine (consultation / tele-knowledge)
- Tele-maintenance (consultation / tele-knowledge)

6.3 Command & Control

- Basic-T
- Common Operational Picture mock-ups

6.4 Wearable Augmented Technology

- Integrated head based systems
- Tactile suit

Institutes in the UK Undertaking Research into Augmented, Mixed and Virtual Environments (AMVE) for Military Applications of Virtual Reality

Ebb Smith and Heather McIntyre
DSTL

1.0 INTRODUCTION

This report describes information gathered about institutes in the UK undertaking research into Augmented, Mixed and Virtual Environments (AMVE) for military applications of Virtual Reality. It also includes information on activities being undertaken in the civil sector that might be relevant to the military.

The information is described under three heading: UK Defence (Dstl/QinetiQ work), UK Academic Institutions, and UK Commercial Companies.

2.0 UK DEFENCE – SOME CURRENT PROGRAMMES

2.1 UK Mission Training via Distributed Simulation

Under the sponsorship of MoD a programme of applied research has been undertaken to explore the benefits to be gained from using networks of simulator, or Virtual Training Environments (VTEs), for aircrew collective mission training[1]. Use of networked simulation in this context has become known as Mission Training through Distributed Simulation (MTDS).

The original research remit was to investigate the technical issues associated with linking legacy and new generation military training simulators, to assess the potential for conducting aircrew collective training. The primary hypothesis was that training simulators could be connected together to provide a common synthetic battlespace capable of supporting the collective training needs of front-line combat ready aircrew.

MoD's research needs were founded in a growing interest in the potential of VE for training purposes. The big assumption was that by transferring certain tasks from the live training environment into the STE, the same level of operational effectiveness could be maintained but at less cost. Today this premise is as hotly debated as in the early 1990's. A balance between live and synthetic training has still to be determined. This is not surprising, as an optimal balance may not exist across the complete spectrum of operational training. It is a complex issue and the debate is likely to continue for some time yet. However some notional indication of the balance is undoubtedly a requirement when procuring any military equipment that requires a synthetic training component.

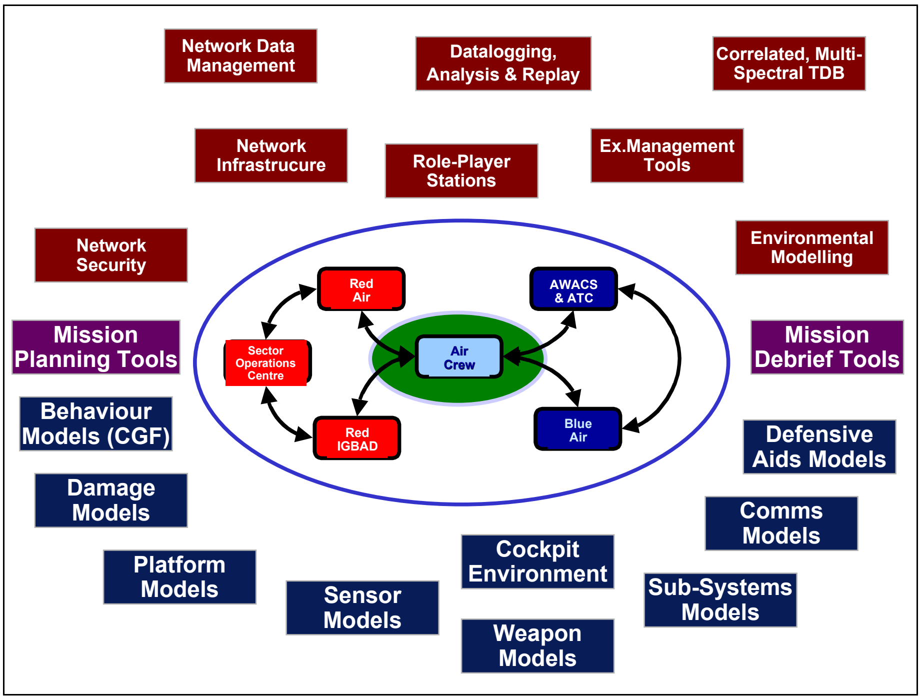
Despite the growing interest in STEs and the perceived potential for mission training via distributed simulation, a proven SE capable of providing collective training for front-line aircrew did not exist. Thus whilst this research activity had been structured in such a way as to enable some very focused technical studies to take place, it became increasingly obvious that the general hypothesis must be tested via empirical research methods. The research team therefore designed a series of practical experiments (trials), conducted under the banner heading of RAPTORS (Research into Aircrew Performance and Training

[1] 'Collective mission training' is defined as two or more teams training to interoperate in an environment defined by a common set of collective mission training objectives, where each team fulfils a different military role. NATO SAS-013 Study.

using Operationally Realistic Scenarios). To ensure that data obtained from these experiments was assessing genuine military training potential, the experimental subjects comprised front-line aircrew. A bespoke synthetic COMAO test-bed[2] was developed specifically to support the RAPTORS series of trials and comprised:

- A large package of aircraft (≈ 40) comprising
- Eight manned simulators flown by front-line aircrew
- A manned E3-D fighter-controller station
- Other friendly platforms represented by role players & computer generated forces (CGF)
- Hostile forces represented by two man-in-the-loop simulators, CGF & role players
- Complex tactical scenario, closely based on a real-world theatre
- Geo-specific location, targets, procedures, etc.
- Dynamically controllable threat environment
  - e.g. In-mission re-tasking of CGF
- War operations room and Exercise Management suite
- Planning, briefing and debriefing complex

The test-bed provided a comprehensive trainee-centric STE created over a secure simulation network that supported exercise, technical and tactical management of the scenario. The complexity of the RAPTORS COMAO environment is depicted below.



Schematic of the RAPTORS COMAO Environment.

[2] The test-bed was developed by DERA at the Bedford site. It is now a QinetiQ facility, although a limited number of components are customer owned.

To date the RAPTORS series of trials has comprised of Ebb and Flow (Feb 2000), SyCOE (Jan 2001), VirtEgo (Nov 2001) and SyCLONE (Feb 2003). Each trial has looked at different aspects of collective training from a technology and human factors perspective[3]. The current UK MTDS programme was initiated due to the success of these trials.

2.2 War Fighting Experiment (WFE)/Synthetic Environment (SE) Demonstrator and Training Strategy

The aim of this work is to create and demonstrate the tools and techniques to capture capability gaps and evaluate the effectiveness of Indirect Battlefield Engagement (IBE) equipment in realistic joint experimental settings. The core of the first year's work comprises two elements. The first of these is a training strategy study, which will address the overall collective training required across IBE. The second is the development of integrated live/virtual simulation techniques ("augmented reality") enabling a number of simulated attack helicopters to take part in a live exercise, for force evaluation and experimentation purposes. The second year is focused on developing an enduring live/virtual capability, by linking Synthetic Environments (SEs) with Area Weapons Effects Simulator (AWES), and broadening the extent of the IBE SE representation by bringing in a future ground-based indirect fire element.

2.3 Human Effectiveness (C2)

It is recognised that the challenge over the next decade will be to assist Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) mission specialists in exploiting the total range of data that will be made available to them whilst at the same time preventing them from becoming swamped with unmanageable information. The MoD customer requires a focus for the development of human factors policy for the use and exploitation of ISTAR assets, including the capture and promulgation of best practices on Human Computer Interaction (HCI) interface design and workload reduction. A primary objective is to determine the benefits of using: multimedia HCIs in Intelligence Databases and Image Product Libraries; touch screens and pressure sensitive pens in the exploitation task; speech recognition technology in populating intelligence reports and retrieving intelligence information; fusing intelligence products to increase the effectiveness of the exploitation task.

2.4 Improving the Representation of Human Variability in CGF

The aim of this research activity is to enhance the representation of Human Variability in Computer Generated Forces (CGF), taking factors such as stress, fatigue, cold, heat, night or day operations etc into account; thus making SEs more credible for users. The outcome of this work will be UK MOD's principal contribution to the development of the US OneSAF.

2.5 Realistic Synthetic Environments for Secure Command Information Service

This work aims to determine and demonstrate how an SE can be constructed to provide an intuitive environment for users to easily specify, develop and exercise, through the stimulation of a secure command system.

2.6 Automatic Extraction of 3D Information from Geospatial Data

Building on previous work, this study aims to automate, and reduce the time taken to extract (satellite) imagery data and create a new rapid and cost effective Synthetic Natural Environment (SNE) terrain

[3] The UK MTDS Capability Working Group was instigated after Trial VirtEgo. Trials Ebb and Flow and SyCOE were funded solely by the ARP. VirtEgo and SyCLONE were part funded by Headquarters Strike Command (HQSTC) and were designed to support both research and training objectives.

database generation, containing representations of true 3D features such as buildings and mountains. The work will open up the potential for using better SE for Mission Rehearsal.

2.7 Dismounted Infantry Virtual Environment (DIVE)

This work set out to exploit current and future modified games technology to develop a low cost, networked PC based system for supporting dismounted urban operations operational analysis. AS part of this research programme a training effectiveness trial was undertaken. The virtual environment was provided using a modification of the commercial PC-game HalfLife®. The aim of this trial was to investigate the utility of the DIVE environment as a training tool using an example of Urban Operations Training at Team and Section level.

This was assessed using a mix of subjective (questionnaire) self-assessment and Subject Matter Expert (SME) observation of comparable tasks executed in the live and virtual domain. Training transfer effect was observed in two groups of two teams who followed different progressions of live and DIVE training. A second comparison was made at Section level.

Overall, the trial achieved its aims in demonstrating that Synthetic Environments (SE) such as DIVE have a role to play in training some Dismounted Infantry roles. The following key results are of note:

- Additional evidence of close correlation of team performance, mission timings and outcomes in live and DIVE environments.
- No significant performance differences between teams following different DIVE and live training progressions at fireteam level.
- Indications of benefit of using DIVE to train at Section level.
- Strong subjective support from trial participants for the use of DIVE-type systems low-level command training applications and the benefit of playback-type After Action Reviews (AAR) enabled by DIVE.

2.8 Using SE in Support of Department of State Activities

This work focuses on the (short and long-term) application of SE tools and techniques to the MOD Department of State function in Military Assistance to Civil Authorities (MACA). The formulation and execution of effective policy in times of crisis is difficult due to the complex interplay between political and socio-economic factors. The tools to be developed and demonstrated would aid the formulation and execution of crisis management policy and offer a SE training tool for those involved in such crisis management.

The aims of this research are twofold:

- To identify areas where existing SE tools can be used for modelling MACA activities, identify where there is a gap in SE capability, or where SE technology is immature for MACA applications;
- Where SEs have utility, this programme will aim to devise a tool framework with appropriate interfaces to assist government departments in the formulation and execution of policy and planning in the MACA domain and research the underpinning architecture required to implement an appropriate set of training tools. The benefit of using SEs for MACA activities include the ability to explore alternative command structures, organisations and processes, support multi-agency training through distributed means with more effective AAR and provide decision support tools which can monitor crisis development as well as assist in resource and action planning.

2.9 Avatar Mobile Instructor

This work is investigating the Military use of Commercial Avatars (the embodiment of a human form within a SE) in the context of pre-deployment training. It aims to determine whether Avatars could provide effective training with the minimum demand for qualified manpower (training staff). This could allow for increased currency of information by taking training material content from a centralised data source. The programme will culminate in a demonstration of an Avatar based system providing a (re)configurable system in appearance and functionality terms.

3.0 UK DEFENCE RESEARCH FACILITIES

3.1 Human Factors Integration Defence Technology Centre[4]

Aerosystems International (AeI) has been awarded a contract by the MoD to establish the Defence Technology Centre (DTC) for Human Factors Integration (HFI). AeI will lead a consortium formed from leading industrial and academic groups which include MBDA Missile Systems, Lockheed Martin UK Ltd Integrated Systems, systems and software house SEA, VP Defence and the Universities of Birmingham, Brunel and Cranfield. The consortium will use virtual enterprise technology to link consortium members and a shared data environment to allow all HFI DTC Stakeholders access to the results of the programme.

3.2 The Applied Research Technology Demonstrator (ARTD)

The Applied Research Technology Demonstrator (ARTD) has been constructed to test and evaluate new, emerging technologies in an enclosed, simulated battle environment. Essentially it is a ‘plug-in-and-play’ unit, where armed forces, MOD representatives and their industry suppliers can test new technologies by seeing how well they perform in real scenarios, played out in a computer simulated environment.

The facility itself is a series of rooms that can be linked to one another, partitioned to create separate working areas, or opened up to create virtual battle spaces. Units can be added or omitted as desired. State-of-the-art computers can stage any given scenario and even newly designed systems can be added to the simulation mix.

As a member of the Combined Federated Battle Laboratory (CFBL), a consortium, developed between the US, NATO, Australia, Canada, New Zealand and the UK, ARTD is now part of a wide network of similar facilities in friendly countries. It can operate 24 hours a day if necessary, linking with these other nations’ facilities over secure links, broadening the scope of research now available to the UK MOD.

3.3 Battlespace Management Evaluation Centre (BMEC) – British Aerospace

The joint MoD/Industry partnership known as NITEworks (Network Integration Test and Experimentation works) will use the BMEC as a hub for linking other MoD and industry battlelabs together to explore network centric warfare. Other industry battlelabs include those at Dstl (the ARTD) and QinetiQ. Other companies have also been asked to identify facilities that could potentially link to the overall NITEworks programme.

4.0 UK ACADEMIC INSTITUTIONS

Many UK Universities are involved with research into Virtual Reality and Augmented Environments. The main universities carrying out work of interest are:

- Cardiff University

[4] http://www.hfidtc.com/hfidtc/index.htm

- Hull University
- Loughborough University
- Nottingham University
- Royal Military College of Science (Shrivenham and Cranfield University)

4.1 Cardiff University

4.1.1 C-HIVE – Cardiff Human Interfaces and Virtual Environments Laboratory[5]

Researchers in the C-HIVE focus on two primary areas of virtual environments (VEs; virtual reality worlds): (a) experimental investigations of the interface between people and VE systems (human-computer interaction), and (b) the use of VEs to investigate other, real-world problems. All of the research is multi-disciplinary.

4.1.2 Published Literature

Ruddle, R.A., Huddart, S.A., and Jones, D.M. (1999). *Interaction in Immersive Virtual Environments: Rotating Objects with an Instrumented Prop.* Proceedings of the Human Factors and Ergonomics Society 43rd Annual Meeting, pp. 1214-1218.

Ruddle, R.A., Payne, S.J., and Jones, D.M. (1999). *The Effects of Maps on Navigation and Search Strategies in Very-Large-Scale Virtual Environments.* Journal of Experimental Psychology: Applied, 5, pp. 54-75.

Ruddle, R.A., Payne, S.J., and Jones, D.M. (1999). *Navigating Large-Scale Virtual Environments: What Differences Occur Between Helmet-Mounted and Desk-Top Displays?* Presence: Teleoperators and Virtual Environments, 8, pp. 157-168.

4.2 Hull University

4.2.1 Hull Immersive Visualization Environment (HIVE)[6]

HIVE provides state-of-the-art visualization, interaction and computing technology and related support for both University departments and industry, and is dedicated to helping researchers and industry make effective use of emergent technologies.

HIVE Facilities:

- Stereoscopic vision (using immersive workwall or desktop PC's)
- Virtual and augmented reality
- Virtual prototyping
- Collaborative design reviews
- Development of virtual environment trainers
- Simulation of urban development and terrain
- Scientific and medical visualization

[5] http://www.cf.ac.uk/psych/ruddle/C-HIVE/

[6] http://www.hull.ac.uk/hive/index.htm

- Scene capture and reverse engineering using stereo cameras, motion tracking, CMM
- Haptic interaction with visualizations
- High performance computing

Computer Science Staff around the VisionStation.

4.3 Loughborough University

4.3.1 AVRRC – Advanced VR Research Centre[7]

The Advanced VR Research Centre undertakes research in the area of immersive and pervasive computing environments. Specific applications for the research involve engineering and scientific visualisation. The multi-disciplinary research undertaken by the Centre is underpinned by in-depth investigations involving the associated human factors issues. For example: Development of intuitive GRID working environments and Improving remote visualisation across GRID architectures.

The AVRRC employs a range of specialised facilities including:

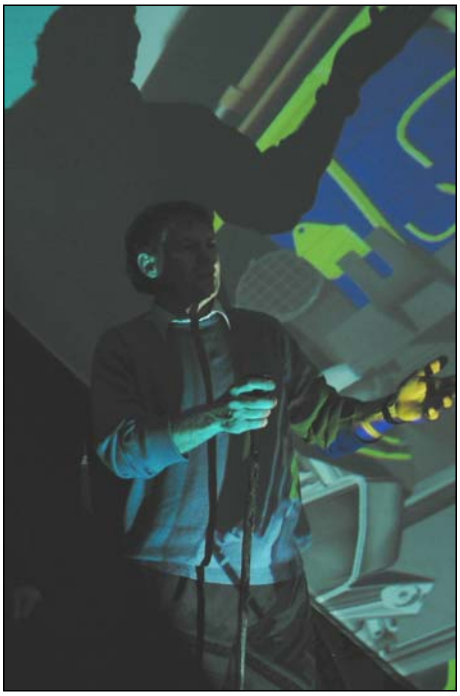
- Panoramic Reality Centre
- 5M Vision Dome®[8]. Thus is a fully immersive multi-user, single projection Virtual Reality environment for interactive space development. Upon entering the VisionDome, users are completely drawn into a fully immersive 180 degree hemispheric screen. The tilted screen is positioned so as to fill the users' field-of-view, creating an incredible sense of immersion. Users experience vivid images that take on depth via the unique optical system. The VisionDome is further enhanced by an environmental sound system. Users of the VisionDome do not have to wear head mounted displays, stereo glasses, or other restrictive devices. The VisionDome can be used for multi-user, multi-sensory display for simulation, training, design, engineering, product display, energy exploration & production, education, medical services and entertainment. A second slightly smaller Vision Dome is also available and can run in conjunction with the 5M Vision Dome.

[7] http://www.avrrc.lboro.ac.uk/

[8] http://www.avrrc.lboro.ac.uk/Visiondome_facility.html

- Immersive Wall
- SmartSpace
- AccessGrid – currently undergoing testing
- Wearable Computing Environments

Inside the VisionDome.



Loughborough University is also undertaking an extensive research programme which is focussing on developing an understanding of the complex human factors issues behind augmenting the real world with virtual information. This work links with their research on wearable computing systems and the University has been conducting extensive research in the field of Augmented Reality as a means of improving the cognitive performance. Much of this work is funded by the UK Ministry of Defence.

4.3.2 Recently Published Literature

Stedmon, W., Kalawsky, R.S., Moore, P.M., Aung, M., Purcell, J., Reeh, C., and York, T., *"It's not what you wear, it's how you wear it: Human Factors of Wearable Computers"*, Centre for Human Sciences, Defence Evaluation and Research Agency, UK, IFC Research Group, Advanced VR Research Centre, Loughborough University, UK.

Stedmon, A.W., Kalawsky, R.S., Hill, K., and Cook, C.A., *"Old Theories, New Technologies Developing Guidelines for the Cognitive Ergonomics of Augmented Reality",* Paper accepted for presentation at the IEA 2000/HFES 2000 Congress. July 30th- August 4th, 2000, San Diego, California.

JTAP Project 305, *Human-Computer aspects of Virtual Design Environments*[9].

Sony Glasstron Augmented Reality Head Mounted Display.

4.4 University of Nottingham

4.4.1 COllaborative Virtual ENvironments – COVEN[10]

COVEN was a four-year project (1995-1999) focusing on the development of a computational service for teleworking and virtual presence. The overall objective of the project is to provide the facilities needed to support future cooperative teleworking systems. The project is a unique endeavour that brings together expertise on communications infrastructures; computer supported cooperative work; virtual reality (VR) and animation to provide support for a European wide distributed virtual environment (VE). This virtual environment will enable groups of geographically disparate users to work together by inhabiting common information spaces. Partners in this work were:

- Arax, Division Ltd.

[9] http://www.avrrc.lboro.ac.uk/JTAP305introd.html

[10] http://www.crg.cs.nott.ac.uk/research/projects/Coven/

- EPFL – Swiss Federal Institute of Technology
- Integrated Information Systems Ltd.
- KPN Research
- Lancaster University
- Swedish Institute of Computer Science
- Thomson-CSF – Laboratoire Central de Recherches
- TNO Physics and Electronics
- University College London
- University of Geneva – Mira Lab
- University of Nottingham

4.4.2 Structured Evaluation of Training in Virtual Environments (STRIVE)[11]

A review of existing case-studies on VE training applications (VETs) was carried out to: examine the type of training applications and VR systems being considered; the state of development of these applications; and results of any evaluation studies. From this review it was seen that the type of VETs being explored involved the training of navigation skills or psycho-motor skills. However generally these applications had been 'proof-of-concepts' and little evaluation had been performed. Of the evaluation studies that existed, generally usability issues with the systems had confounded the results. Therefore it was felt that desktop VR would be the most appropriate system to focus on, as it has fewer of the side effects associated with other systems. Furthermore desktop VR has been highlighted as the most popular VR system because it requires very little initial investment.

In order to perform a structured evaluation, existing theories of training and evaluation were reviewed. It was clear that evaluation was inter-linked with the development process of a training application, therefore using these theories, a framework for developing VETs was suggested. This framework examined the stages of proposing, specifying, building and evaluating VETs. Then using this framework, two VETs were developed to be examined. There were a number of conclusions that were drawn from these experiments. In particular this work highlighted the many areas in the development process of an effective VET that still need addressing. There are still tools to be developed for evaluating VETs and much more evaluation studies required from academia and industry to input information back into the development process. Therefore VEs are still in their early stages but it is possible to recognize the gaps in the development process that need to be addressed before implementation.

4.4.3 Recently Published Literature

Stedmon, A.W. and Stone, R.J. *Re-viewing Reality: Human Factors of Synthetic Training Environments,* International Journal of Human-Computer Studies Vol. 55, No. 4: 675-98, October 2001.

4.5 Royal Military College of Science at Cranfield University

4.5.1 Flight Deck Officer Training[12]

Currently the British Royal Navy Flight Deck Officers (FDO) are trained at RNAS Culdrose, Cornwall, England. Although their training is shore-based, they make extensive use of real simulation, learning to

[11] http://www.virart.nottingham.ac.uk/Projects_STRIVE.htm

[12] http://www.rmcs.cranfield.ac.uk/ssel/train.htm

direct real helicopters onto a landing area. If, however, the weather conditions restrict aircraft flights or aircraft are unavailable, then the training makes use of a virtual simulation system. The current FDO training simulator at RNAS Culdrose requires another person, typically the instructor, to fly the helicopter, in response to the signals given by the trainee.

The FDO Training Simulator.

This RMCS project was an investigation into the use of virtual reality to improve the current simulator. It was envisaged that in such a system the trainee will be wearing a head mounted display (HMD) through which he is presented with the view as seen on the flight deck of a sea-going vessel (e.g. frigate). Using two three-dimensional trackers the hand movements of the trainee were monitored and computer software determined the signal that the user is giving. Once the type of signal had been determined it was fed directly into the dynamics model of the helicopter, which would then respond. Thus if the move left signal was given the helicopter would move to the left. This would remove the instructor from actually flying the helicopter and allow him to concentrate on his main task of instructing. In addition such a system would allow for more than one trainee to be trained at a time and would allow all of the benefits of computer-based training to be applied.

4.5.2 Parachute Training

The Parachute Training Simulator allows a trainee parachutist to gain experience in the handling of a parachute while immersed in a virtual world. The current application runs on a PC, running Microsoft Windows. It was built using Superscape's VRT product. Using a head-mounted display (HMD), the trainee is presented with a view of the world as they descend from an altitude of 3000ft. The use of the HMD allows the user to look in any direction thus giving a complete field of view that would not be possible, or too costly, with a monitor or projection system. The brake toggles used by a parachutist to control their descent are modelled by means of two joysticks that are interfaced to the serial ports on a PC. These inputs control the dynamics model of the parachute.

The Parachute Training Simulator – 1.

It is the aim of the trainee to manoeuvre themselves, using the brake toggles to traverse a course of control gates that an instructor has placed in the virtual world and to land at a specified location.

The Parachute Training Simulator – 2.

The simulator allows for a variety of malfunctions in the operation of the parachute:

- Line twists
- Line bunched together
- End cells closed (slider up or down)

- Streamer
- Canopy damaged
- Canopy distortion

This allows the trainee to become familiar with the recognition of good and bad canopies and the procedures that should be followed in the event of a malfunction.

The trainee's control inputs and flight path are recorded for review after landing, giving the instructor the option to explain any incorrect actions taken.

Initial testing of the simulator by experienced and student parachutists has shown that it offers potential benefits for parachute training.

It is hoped that the future work will:

- Extend the modelling to allow for different canopy types.
- Improve the visual sub-system allowing for greater depth perception, weather effects and day/ night capability.
- The ability to use real-world terrain.
- Improve the input device mechanism so as to have greater range of movement.
- Incorporate the simulator into a network to give the ability for team training.

4.5.3 Recently Published Literature

Smith, J. and Steel, J., *"The Use of Virtual Simulation for Dismounted Infantry Training",* NATO Modelling & Simulation Conference, Royal Military College of Science, Shrivenham (RMCS), England, October 2000.

Sastry, V., Trott, E., and Steel, J., *"A Virtual Environment for Naval Flight Deck Operations Training",* NATO Research & Technology Organisation Meeting Proceedings: MP-058, March 2001.

Hollis, Dr. J.E.L., Meinertzhagen, Maj. R.D., and Lai, Maj. N., *"Application of Virtual Reality Technologies to Communications",* IEE Conf. Pub., 1997, IPA97.

Brent, Maj. P., *'Networked Virtual Reality for Dismounted Infantry,'* RMCS July 1998.

Ourston, D. and Reece, D., *'Issues Involved with Integrating Live and Artificial Virtual Individual Combatants'*, SAIC Stricom.

Hutchinson, Maj. N., *'The Simulation of Dismounted Infantry'*, RMCS, 2000.

Clarkson, Maj. M., *'Low Cost, 3D, Interactive Networked Training'* RMCS 1998.

Jones, Maj. I.*, 'Desktop Dismounted Infantry Trainer A Proof of Concept Demonstrator'*, RMCS 1999.

Percival, Maj. A.E., *'Distance Estimation in Virtual Environments'*, RMCS 2001.

Bosher, Maj. P. *'Training Transfer in Environmental Awareness from Virtual Environments',* RMCS 2001.

4.6 University of Surrey

4.6.1 Synthesising Human Motion for Virtual Performance

Recent research has achieved automatic reconstruction of realistic 3D models from surface measurements of static objects and environments. Currently captured object models are represented as dense unstructured polygonal meshes. Direct application of unstructured meshes for computer generated imagery is prohibitively expensive. The proposed research addresses the automatic reconstruction of functional models that are optimised according to the requirements of a particular application. Functional requirements include realistic and efficient representation of the development of techniques to enable automatic reconstruction of functional models of real objects suitable for realistic computer generated imagery. Applications include realistic object modelling for virtual environment, animation and Internet transmission. In particular application of this research will be based on existing expertise in capturing 3D models of complex organic objects and internal environments.

4.7 School of Computer Science Information Technology

4.7.1 The Realisation and Utility of Persistence in Collaborative Virtual Environments

The design and authoring of a collaborative virtual environment is normally distinct from its activation and use. For example, completed virtual worlds are made available as fixed definitions (e.g. world description files) which are used repeatedly to create distinct instantiations of active virtual worlds. This project will investigate the implementation and utility of collaborative virtual environments for which design, creation, publishing and use are not differentiated and are available to all participants. This builds on the proposer’s PhD work in the area of large-scale collaborative virtual environments, which include the implementation and ongoing testing of the MASSIVE-1 and MASSIVE2 CVE systems. From a distributed systems’ perspective, the project will identify and employ system and programming facilities to implement persistent virtual worlds. These will be integrated with an existing virtual reality system or tool kit. From a human factors perspective the project will make one or more such worlds.

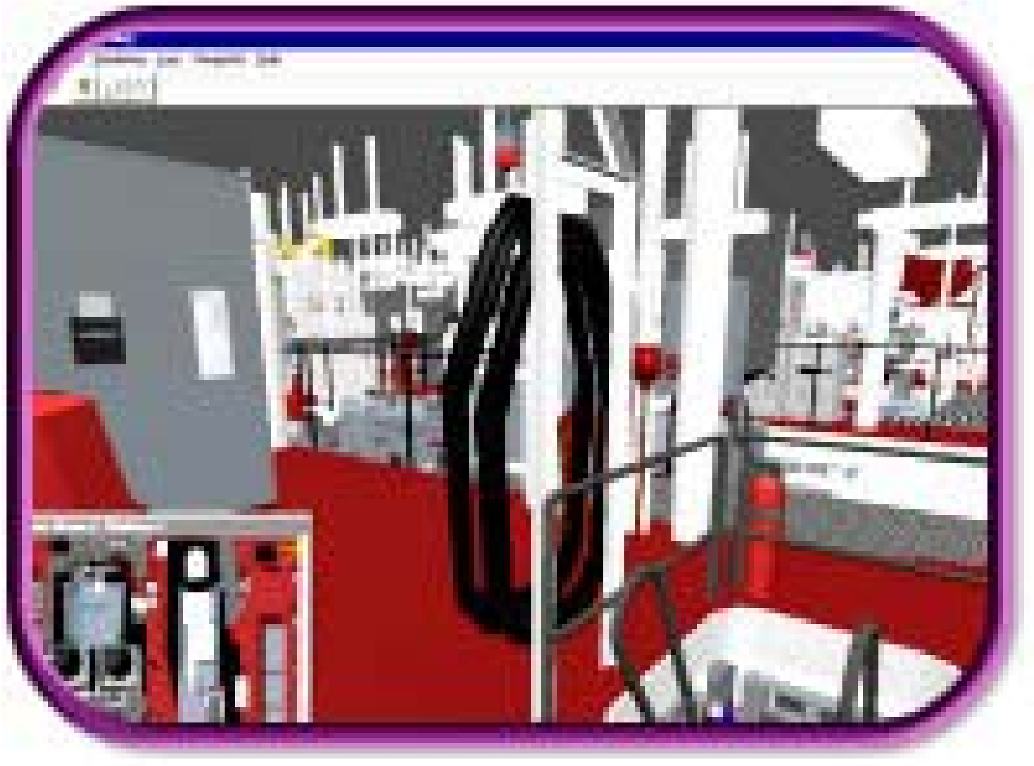
5.0 UK COMMERCIAL COMPANIES

5.1 Facit – A Division of TWG Ltd.[13]

Facit are developers of Sense8 virtual reality authoring software, building commercial visualisation applications for a wide range of industries including retail, education, construction and engineering. Augmented Reality (AR) is a growing area in their virtual research. Augmented Reality can be integrated into a number of different industries as a turnkey solution. Current AR users include Academics, Medical, Entertainment, Military Training, Engineering Design, Robotics and Telerobotics, Manufacturing and Consumer design. Facit aim to bring a solution to industries looking at the implementation of Augmented Reality into their current research projects. They have had success in supplying AR Head Mounted Displays and also the solution of constructing personalised AR unit from products currently available within the IT market.

In addition they supply simulators for the defence market which includes large-scale operations planning and mission rehearsal to part-task training, using a blend of VR and multimedia. Multiple students can familiarise themselves simultaneously with complex systems, vessel or craft layout, maintenance tasks, fault-finding, repair and refit.

[13] http://www.facit-vr.co.uk/defence_simulation.htm



Augmented Reality for Familiarisation of Vessel Layout.

5.2 Advanced Interactive Solutions Ltd.[14]

AIS work in partnership with large system integrators and strategic partners to deliver comprehensive training solutions. AIS integration of simulation technology and readiness certification through advanced information systems is ideally suited for readiness assurance for military forces. In April 2003 AIS announced the sale of a new computerised training simulator to the UK MoD. The UK MOD has purchased an AIS P3000 Live Fire PRISim™ System. The system will be used for close-quarter battle training and counter-terrorist training and provides highly realistic use-of-force training that develops the skills required for personnel armed with both lethal and non-lethal weapons. Flexible deployment options allow training to be delivered at fixed facilities or at any off-site location.

The PRISim™ platform produces exceptionally realistic video-based environments for all aspects of firearms handling including marksmanship, decision-making, and tactical strategies and uses broadcast-quality DVD technology.

[14] http://www.ais-sim.com/casestudies_military.htm

Firearms Training Handler.
(http://www.ais-sim.com/news_press_releases_060703.htm)

Sim Room.

5.3 Inition Ltd.[15]

Inition deliver bespoke solutions to clients, having years of experience working with the following technologies:

- Virtual Reality
- Stereo Visualisation
- Interactive Art & Visuals
- Systems Integration
- Web 3D, Bespoke Application Development

5.4 Maelstrom Virtual Productions Ltd.[16]

Virtual Reality training and simulation environments have been built in the fields of medicine, energy, architecture, and Military.

5.5 Virtual Reality Centre at Teesside Ltd.[17]

The company is involved in image generation, visualisation and training simulations. It creates PC-based and internet off-line visualisation and training packages for various industries. Their products include:

The Hemispherium® – a 6m dome using 7 projectors to give a full 180° field of view and driven by a 3 pipe Silicon Graphics IR2.

The Hemisperium®.

The Auditorium – a 7m wide Cylindrical Display using 3 Projectors to give a 140° x 45° Field of View.

[15] http://www.inition.co.uk/

[16] http://www.maelstrom.com/military.htm

[17] http://www.vr-centre.com/

The Auditorium.

5.6 cueSIM (ex-Motionbase)

Originally developed by Motionbase plc at Bristol, production is now by cueSIM at Bedford. QinetiQ acquired Motionbase in 2002 and formed cueSIM. The company has access to the simulation expertise of its owner organisation, the UK company QinetiQ plc that deals in R&D for the UK Ministry of Defence. This may be particularly important in aspects such as multi-player networking and the use of Computer Generated Forces (CGF). Their products include:

- VANguard multi player simulators: VAN stands for Virtual Air Network and this range of devices is designed to be coupled together for mission training exercises. A modular design is employed and types from desktop to motion-based Full Flight Simulators are available. Facilities include DIS, HLA and CGF.
- RTAVS simulation: This stands for Real Time All Vehicle Simulation and includes DIS/HLA compliance and compatibility with many COTS components. RTAVS is essentially a software architecture that allows hardware to be rapidly implemented.
- Motion platform: CueSIM Maxcue 6-DoF electric.
- Explorer dynamic flight simulator: This includes a compact flight simulator cockpit shell mounted on an electric motion platform. The display system comprises three of the company’s collimated monitors.

cueSim Dynamic Flight Simulator.

5.7 Pennant Training Systems Limited (PTSL)[18]

5.7.1 Virtual Aircraft Training System (VATS)

This is a computer-based classroom training system for aircrew and maintainers.

Features include interactive training, maintenance and diagnostics, aircraft systems emulation with faults, test equipment and LRU change.

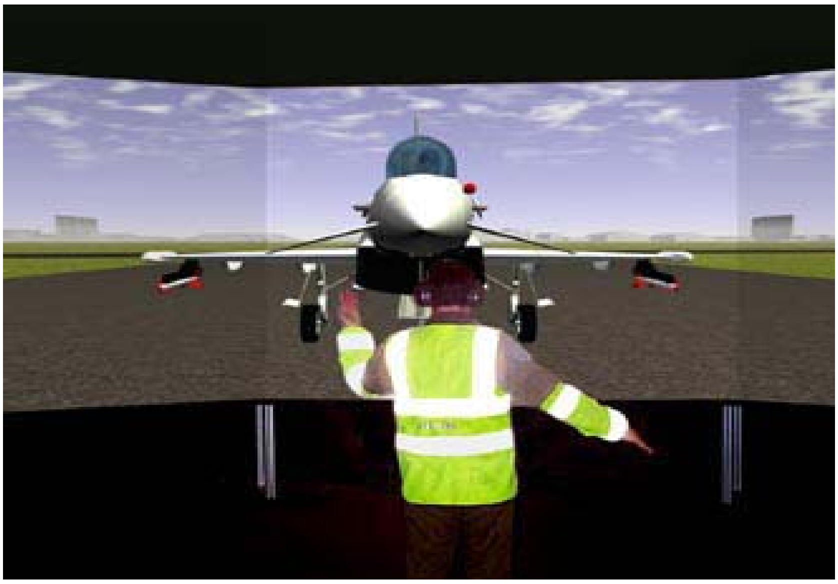
The Virtual Aircraft Training System.

[18] http://www.pennantplc.co.uk

5.7.2 Synthetic Environment Procedural Trainer (SEPT)

The Royal Air Force has adopted the very latest development in Virtual Reality to enable training of recruits in marshalling and ground handling of aircraft. The trainer, known as the Synthetic Environment Procedural Trainer (SEPT) is in service at RAF Cosford where, after classroom instruction on the required skills and safety procedures, students consolidate their learning through practical experience on the SEPT. This is an ideal preparation ground for the real situation where the marshaller must give clear and positive direction to the aircraft pilot.

SEPT is a complete procedural trainer providing high fidelity, real-time, computer generated images of an operational airfield with realistic visual and aural representations of operational aircraft, general airfield activities, buildings and vehicles. Central to the SEPT's capability is the high-fidelity visual system with its wide field of view (FOV). The aircraft visual is integrated into the SEPT computing system that contains an aural-cueing database, synthetic airfield database and Instructor operating facilities.



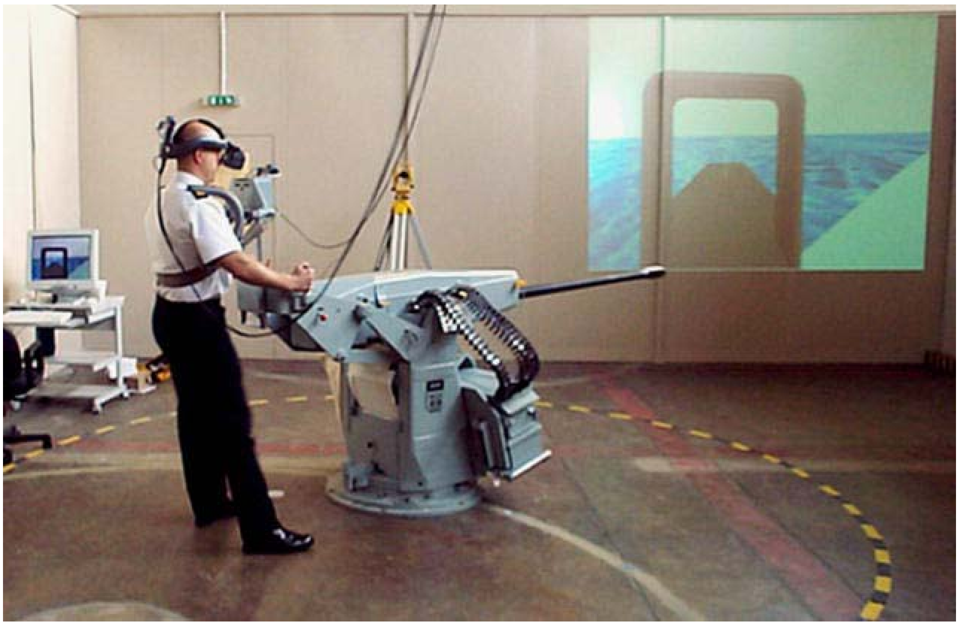
The Ground Marshalling Training Simulator.

The visual database is projected onto a wide-angle screen in front of the trainee who is then able to conduct the Marshalling and Ground Handling of Aircraft, in an immersive environment. This enables the trainee to progress from a theoretical base into the practical environment and instills confidence in undertaking the task for real.

5.8 Virtalis – Naval Virtual Reality Close-Range Gunnery Trainer (CRGT)[19]

Virtalis employs an experienced team of software, hardware, electronics, human factors and design specialists. They form partnerships whatever type of work is needed, be it a short commercial feasibility study, an in-depth technology review, a concept demonstrator or a full-blown visualisation system.

[19] http://www.vrweb.com/



The Virtual Reality Gunnery Trainer.

Human Factors Issues in the Use of Virtual and Augmented Reality for Military Purposes – USA

Stephen Golberg
US Army Research institute

PAPER 1 – AIR FORCE RESEARCH LABORATORY – MESA, AZ

PAPER 2 – ARMY RESEARCH INSTITUTE (ARI)

PAPER 3 – NAVAIR ORLANDO TRAINING SYSTEMS DIVISION

PAPER 4 – NAVAL POSTGRADUATE SCHOOL

PAPER 5 – NAVAL RESEARCH LAB (NRL) IN VR

PAPER 6 – U.S. ARMY RESEARCH, DEVELOPMENT, & COMMAND (RDECOM) SIMULATION & TRAINING TECHNOLOGY CENTER (STTC)

Paper 1 – Air Force Research Laboratory – Mesa, AZ

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1.1 AREAS OF INTEREST

- Enabling the DoD vision of achieving training transformation.
- Fulfilling the Air Force's Distributed Mission Operations vision by providing capabilities to train airmen to meet Combatant Commanders' requirements.

1.2 CURRENT RESEARCH PROJECTS

1.2.1 Distributed Mission Training (DMT)

DMT is a shared training environment comprised of live, virtual, and constructive simulations allowing warfighters to train individually or collectively at all levels of war. DMT allows multiple players at multiple sites to engage in individual and team participation to full theater-level battles. It allows participation, using almost any type of networkable training device, from each weapon system and mission area. Additionally, computer-generated, or constructive, forces can be used to substantially enhance the scenario. This combination of live, virtual, and constructive environments allows nearly unlimited training opportunities for joint and combined forces from their own location or a deployed training site.

1.2.2 DMT Air

DMT for aircrew complements flying training by providing capabilities to gain knowledge, skills, and experience for infrequently practiced tasks and missions. Since DMT is not constrained by airspace limitations or by number of aircraft available, pilots and controllers can learn to conduct complex missions in high-threat environments focusing on enhancing the individual and team skills required for mission success.

Training Systems Technology Research: USAF F-16 pilots and AWACS controllers participate in training research exercises using the F-16 DMT testbed at AFRL/HEA in Mesa, AZ. Pilots ranging in experience from Mission Qualification through Weapons School use the testbed to enhance their skills. Research is focused on developing training strategies that emphasize specific training needs and include validated measures of performance to track progress. In addition, coalition training research exercises are conducted using real-time, secure links to defence laboratories in Canada and the UK. US, Canadian, and British warfighters use DMT to plan, brief, fly, and debrief simulated composite force, coalition missions.

High-Resolution Visuals: The full field-of-view visual displays currently used in the F-16 DMT testbed provide high levels of immersion into the synthetic environment but lack the resolution required for within-visual-range air combat and close air support missions. Research is in progress to increase resolution in immersive displays to eye limiting (20/20 visual acuity) resolution. The objective of the 20/20 Immersive Visual Display System for the DMT-Aircrew program is to develop, integrate, and demonstrate a high fidelity visual display system for flight simulators. This Air Combat Command (ACC) Category 1, Advanced Technology Demonstration will significantly enhance the visual system for fighter simulators such as the F-16 by developing and integrating technologies that will improve the resolution of the simulated visual and sensor imagery while reducing the overall cost of the image generation and display system. This display system will provide bright, high-resolution (20/20 acuity) imagery wherever the pilot looks. The resulting system will eliminate the need for target projectors that restrict the number of high-resolution targets that can be displayed or channel the pilot's attention to specific areas within the scene. In addition, this display system will improve the pilot's perception of size and distance over real-image displays. This Advanced Technology Demonstration is scheduled for completion in FY 05.

The approach for achieving the objective is through contracted efforts to design, develop, and deliver:

- High resolution, full color laser projectors capable of displaying over 10 times the number of pixels currently displayed by high resolution projectors; and
- High performance, low cost image generators based on commercial technology that can provide high resolution visual and sensor imagery at 60 HZ.

The Next Threat System: Constructive (computer-generated) entities are a vital component of DMT. Constructive entities serve as both friendly and threat aircraft and provide an Integrated Air Defense System incorporating missiles, radars, and a command network. TNTS is an object like electronic warfare environment system designed to be HLA compliant. The design purpose of TNTS is to accurately depict Electronic Warfare considerations in distributed mission training.

Distributed Training Network Guard: Opportunities for team and inter-team training using DMT are limited by the different levels of security required by different systems. The Distributed Network Training Guard will greatly enhance DMT and Distributed Mission Operations (DMO) by allowing distributed simulations to interoperate at their native classification levels. DTNG will expand the range of possible scenarios exploited by DMO, and further enable warfighters to "train the way we fight" in a distributed, secure, high-fidelity, full-mission training synthetic battlespace. The DTNG is a Category I Advanced Technology Demonstration program that delivers a capability to transfer data between High-Level Architecture (HLA)-based distributed simulation networks executing at multiple security levels, thereby providing a critical element in realizing the full potential of the DMO concept. The operating component of the DTNG is a physical, real-time automated network guard that supports real-time two-way data transfer between HLA simulation federations operating at different security levels. The parameters for this guard are set pre-mission via a standalone interface that provides the security and federation domain experts with a tool to develop and review reclassification rules that govern the transfer of objects, attributes, interactions, parameters, and the execution of cross security-level, Run-Time Infrastructure operations for cross-federation object models. These rules can be Boolean "yes/no" rules, or more sophisticated guising or sanitizing rules. For example, a filtering rule may zero out, clear, or null the data values of attributes, sub-attributes, parameters and subparameters. Guising or sanitizing rules allow these attribute or parameter values to be changed within the constraints of the data type. For example, an F-22 operating within the high-side federation could be guised to appear as an F-15 on the low-side federation.

Space: DMT is not limited to aircrew training. A major goal of the DMT – Space R&D program is to develop and demonstrate a variety of technology delivery and performance support options that will provide faster, better, cheaper, seamless training and mission performance support. Another goal is to facilitate integration of products from this effort into our Distributed Mission Operations synthetic battlespace permitting space and missile operations that include the capacity to provide performance support and training to new operators within the context of mission planning and rehearsal. This work provides the scientific and technology foundation for future large-scale research for distributed training and rehearsal technologies for Space and Missile Operations. More specifically, we plan to collect into a database the operational requirements for space and missile operations mission rehearsal and training as well as specify alternative science and technology solutions to address identified needs.

Air and Space Operations Center: In 2000, the Air and Space Operations Center (AOC) was designated an official Air Force weapon system. This designation levied a requirement to develop a comprehensive training program for AOC warfighters from initial qualification through advanced and continuation training. The Air Force recognized that AOC training was previously accomplished on-the-job in an ad-hoc fashion. The goal of the current research effort is to ensure that AOC training methods and technologies provide the operators with the training required to employ the AOC as an effective warfighting instrument. AFRL/HEA is working with ACC/DOY and AFC2ISRC/DO to gain access to AOC subject matter experts to define the mission essential competencies (MECs), and knowledge, skills, and experiences required to develop an expert AOC warfighter. MEC definitions are also needed if AOC crews are to be "certified" for operations.

Security Forces: The objective of Security Forces DMT research is to develop, demonstrate, and evaluate a computer-driven, simulation capability to support training in command and control of USAF security forces. The S&T value resides in three areas: research and development of realistic computer-generated forces to serve as stimuli for decision-making, development of simulation training scenarios to support learning objectives underlying mission essential competencies, and collection/analysis of empirical data to determine usability and training value.

1.2.3 Night Vision Training System (NVTS)

The goal of the NVTS program is to produce high fidelity, deployable, low-cost, NVG simulation that will enable mission training, preview, and rehearsal whenever and wherever necessary. NVTS is a research and development effort that will continue development and transition to users. The NVG imagery is based upon the modeling of the unique two-dimensional NVG effects such as halos, gain response based on an accurate characterization of goggle sensitivity, gain, resolution, color, and field of view. The imagery is presented through a head tracked CRT-based display mounted in an actual NVG shell. This approach allows for the correct eye-point for all crewmembers. Each display requires at least one channel of imagery. The three-dimensional world incorporates high-resolution material-classified imagery, and accurate per-texel radiometric response of surface reflectance and aspect. The current approach results in a single database which will support completely correlated visible and multiple sensor simulation.

1.2.4 Uninhabited Aerial Vehicle Synthetic Task Environment

AFRL/HEA's Mesa Research Site has established a Performance and Learning Models Lab (PALM Lab) with the mission of conducting empirical research and creating computational process models for understanding human performance and learning. Architectures for developing computational process models of human behavior in dynamic, time-critical environments have only recently reached a state of maturity that makes them useful in a military modeling context. Computational process modeling provides value in both basic research on human behavior representation and processes, and also in applied research on technologies for improving warfighter training. Broadly stated, our objectives in the current PALM Lab basic research program are to (1) advance the state of the art in computational process modeling of human-system interaction in dynamic, time-critical environments of relevance to the warfighter, and (2) transition products and lessons learned both to the scientific community and to applied research involving warfighter modeling. In pursuing these objectives, our first goal is to develop a computational process model representing the behavior of an Uninhabited Air Vehicle (UAV) operator. This model is being developed with the Atomic Components of Thought-Rational (ACT-R) human behavior modeling architecture. ACT-R has evolved into an embodied cognitive architecture that provides theory-based mechanisms for representing perceptual inputs, cognitive processes, and motor actions, making it useful for modeling interactive tasks like operating a UAV.

In summary, PALM Lab researchers are using and advancing the state of the art in human behavior representation. Results of these efforts will lead to an improved scientific understanding of modeling idioms and representational assumptions useful in accounting for behavior in complex, dynamic, time-critical domains.

1.3 RESULTS ACHIEVED TO DATE

1.3.1 Distributed Mission Training (DMT)

DMT research efforts at AFRL/HEA incorporate both enhancements to VR/VE technologies and development of training strategies and interventions that take advantage of these technologies.

1.3.2 DMT Air

Training Systems Technology Research: These efforts are focused around the specification of Mission Essential Competencies (MECs) for a selected group of warfighters such as F-16 pilots. MECs along with specifications of required knowledge and supporting competencies describe the capabilities expected from warfighters that are required to accomplish their missions. MECs are derived from detailed interviews with subject matter experts and are used to define the objectives for any training event. Using MECs as the foundation, training syllabi have been to develop individual and team air combat skills for different sets of training objectives and levels of experience. DMT Air Training Effectiveness research has expanded to focus on coalition air operations through establishment of international cooperative research agreements with Canada and the UK and with Australia. Coalition, composite force training missions have been conducted with forces located in Mesa, AZ, Toronto Canada, and Bedford, UK.

Products developed this year include:

- Procedures and analysis tools for crew, team, and individual cognitive task analysis methods
- Mission Essential Competency specification for Air-to-Air, Air-to-Ground, AWACS, and SEAD Coalition MECs for Air-to-Air, Air-to-Ground and AWACS
- Validated competency-based syllabi for Air Combat DMO
- Knowledge- and skill-based learning and performance assessment tools
- Automated grade sheet mission evaluation metrics

- Scenario-based performance assessment methods
- Mission planning and analysis tools
- Cost-benefit training utility trade-off models
- Tools for career field education and training management and reshaping

1.3.3 High-Resolution Visuals

Products developed this year include:

- Assessed line rate and antialiasing effects on aspect recognition using legacy testbed visuals
- Integrated and evaluated MetaVR PC-IG in DMT testbed
- Assessed low altitude cueing in PC-IG / M2DART for altitude, velocity, and heading tasks
- Completed initial system resolution and antialiasing research
- Assessed spatial and temporal properties of COTS displays
- Developed digital interface for high-resolution, laser projector
- Demonstrated 5120 x 1024 real-time imagery on high-resolution, laser projector
- Demonstrated monochrome holographic collimating display
- Upgraded high-resolution, laser projector to full-color using prototype red laser

The Next Threat System: TNTS has been developed in two versions. The ground version runs on a PC and provides EW simulation for distributed simulation exercises. The airborne version is a mini computer, rack-mounted system that taps into the aircraft's signal bus and provides EW simulation to on-board displays. The airborne system has been installed and tested on an MC-130P aircraft. Specific attention is paid to accurately implementing sensor scanning and target detection in realistic situations. Sensor modeling is designed to be true to real world performance in the guise of beam pointing. Beam pointing in the TNTS is true to the description in EWIR. TNTS detection and tracking is allowed only within the beam of the sensor as the sensor scans (as applicable) and not based on presence with a scan volume. The utilization of "real world" clutter is limited by the data base used to describe the terrain in the scenario data base. Local area clutter is to be specified by the scenario database using, initially, DMA surface codes to describe the clutter reflectivity and the correct geometry to correlate its effect. Currently, such clutter is constrained to the terrain under the target or the terrain at the point of contact between the beam and the surface. Other basic considerations include the initial implementation of ECM effects.

Distributed Training Network Guard: On 20 February 2003, the Air Force Research Laboratory, Warfighter Training Research Division (AFRL/HEA) in Mesa AZ, successfully demonstrated the capabilities of the DTNG via a live, real-time demonstration. Attendees included more than 90 DoD and DoD contractor personnel representing many of the 33 mission training centers that make up the DMO community. In addition, system program offices including ASC, ESC and SMC, and Navy and Army representatives attended the event. News of the successful demonstration piqued the interest of Mr. William Davidson, SAF/AA, who subsequently visited the site on 22 May 2003 to view a demonstration of the DTNG and to discuss the future challenges of the program. Thus far, the DTNG has been a success and the Category I Advanced Technology Demonstration is expected to be closed by mid FY04. Beyond the ATD, the DTNG will transition to the MLS testbed at Det 4, Theater Aerospace Command and Control Simulation Facility, Kirtland AFB NM, for certification and accreditation as well as operational test and evaluation. Det 4 has been designated as the DMO Center of Excellence by the CSAF and was chosen to lead the implementation of the DMO concept. AFRL will work directly with Det 4 to provide continued support for the DMO concept and development of the DTNG. On 16 July, the DTNG was briefed to the Top-Secret and Below Interoperability Guard Review Board at the Defense Intelligence Agency (DIA). AFRL was notified that DIA will sponsor DTNG for Certification and Accreditation. Det 4 is expected to achieve Certification and Accreditation for DTNG by Mar of 04.

Space: Satellite Operations Simulator (SOpSIM). The Satellite Operations Simulator (SOpSim) concept offers the first system-selectable space operations training system, scalable to a given training environment. Utilizing high fidelity visual representation and an astrodynamically correct model serving as the engine for the simulation, SOpSim brings to the space operator a never before available visually and astrodynamically correct space operations mission training and rehearsal tool. Leveraging the DMT concept and technology, space operations personnel can now train individually, as an entire console crew, and up to an entire Space Operations Center (SOC). SOpSim is an innovative PC-based simulator that addresses the mission training and rehearsal of space operations. Utilizing SOpSim, space operations trainers can mitigate risks historically inherent with satellite operations training. Having never before had a dedicated training system, satellite operations training was the burden of on-the-job training with live mission systems. SOpSim eliminates the risk associated with this by taking the training off line, and removing the billion-dollar mission platform from the process. SOpSim can now train operators on traditionally high-risk satellite maneuvers in the low risk environment of high fidelity simulation. This coupled with the first visualization of the satellite operations significantly enhances the element of training transfer.

Air and Space Operations Center: In FY03 AFRL/HEA's research team developed and defined the first set of MECs and specifications of Knowledge, Skills, and Experiences for warfighters in the Combat Operations and Combat Plans Divisions of the AOC. In FY04, we will use this as a framework to assess the current state of training in the AOC community. Through a series of closely administered surveys we will identify existing gaps in the current training with respect to the defined MECs required for operators in those divisions. This will provide a basis for Air Combat Command to determine Continuation Training requirements and impacts to Mission Qualification Training and Initial Qualification Training. Additionally, this will allow us to develop competency-based, instructionally-principled training scenarios for simulation-based training for AOC warfighters.

Security Forces: Developments in the past year include:

- Obtained letter of support for R&D from HQ USAF/XOF and HQ ACC/SF.
- Conducted training needs analysis with participation of 46% of active duty security forces officers; direction of security forces for air base defense identified as high-need training area.
- Coordination with subject matter experts accomplished at the 99th SFS/GCTS (ACC), 37th TRG (AETC), and the Air Mobility Warfare Training Center to develop baseline capability.
- Baseline simulation capability developed, demonstrated, and evaluated for usability and model validity at 96th SFS/GCTS and 37th TRG.
- Input from field evaluations used for spiral development of revised capability.
- Revised simulation capability demonstrated and evaluated for usability and model validity at 96th SFS/GCTS and 37th TRG.
- Presentations and/or technology demonstrations delivered to HQ USAF/XOF, Force Protection Battlelab, Air Force Security Forces Center, and all major command security forces directors.

- Presentations and technology demonstrations delivered to HQ AFRL/CV, HQ AFRL/XPH, SAF/AQRT, OSD/DDR&E, ARI/IFRU, and US Military Academy.
- Developed and submitted a proposal for evaluation of simulation technology as a means of security mission preview; submitted proposal to AEF Battlelab, Force Protection Battlelab, and Wing Commander at AL Udeid Air Base.
- Independently developed and submitted an Education and Training Technology Application Proposal (ETTAP) for field evaluation of SecForDMT to the 37th TRG.
- Effort underway to obtain support from HQ USAF/XOF for operational, test, and evaluation to determine training value.

Night Vision Training System (NVTS): The physics based approach used in NVTS has been adopted by the USMC for the Night Attack Harrier (AV-8B) simulators, the USN F-18 DMT, the USAF F-16 Mission Training Center and, National Training Center as well as Weapons Systems Trainer and Unit Training Device programs. The system as developed for use in Night Vision Goggle (NVG) training research at AFRL/HEA includes a correlated photographic and material-classified database covers 380 nautical miles by 420 nautical miles of the Nellis AFB training rang derived from multi-spectral satellite imagery, aerial photography, material spectral response data, and Digital Terrain Elevation Data. The NVG sensor simulation uses a physics-based approach to provide an accurate in-band, radiometric response for the NVG gain and special effects (such as halos). It senses at aperture radiance as defined by the reflectance and aspect of the material-coded texel under illumination. As the illumination level and angle change in the simulation, the amount of light reflected from each texel to the viewpoint changes in real time, providing directional lighting effects. Selected combat effects have recently been modeled and include several types of explosions, missile trails, flares and tracers. All of these effects include near- and in-view effects for haloing, gain, and noise. High-resolution helmet-mounted displays present the simulation to the user. These displays incorporate miniature cathode ray tubes (CRTs) mounted inside NVG shells to provide the same form, fit, and function of actual NVGs, with the same weight and center of gravity as the NVGs being modeled. The CRTs use the same phosphor as current NVGs in order to provide the same color and decay characteristics. Current Helmet Mounted Displays have a display resolution up to 1700 pixels by 1350 lines, non-interlaced, refreshed at 60Hz. A Phase II Small Business Innovative Research program is developing a Helmet Mounted Display to support the Panoramic Night Vision Goggle. The Introductory NVG academic courseware is in use by the USAF, USN, and USMC. The NVG Instructor's course is required for all USAF NVG instructors.

Uninhabited Aerial Vehicle Synthetic Task Environment: AFRL/HEA researchers have designed and implemented a Synthetic Task Environment (STE) for the Predator Uninhabited Air Vehicle (UAV). This STE includes a high-fidelity simulation of a UAV operator station and provides a first target domain for HEA's computational process modeling of human behavior. With continuing basic research funding from AFOSR, PALM Lab scientists are now using this STE as a research testbed. Efforts to model the behavior of the UAV Operator have centered on basic maneuvering – foundational skills required for controlling the aircraft. Later in the research program, after validating the basic maneuvering model against performance data, eye movement data, and verbal protocol data from subject matter experts, efforts will turn to extending the model's capabilities. Eventually, it will represent the behavior of an operator completing a simulated reconnaissance mission.

1.4 COLLABORATIVE PARTNERS

Combat Air Forces:
- Air Combat Command
- USAFE
- PACAF
- AF Reserve
- Air National Guard

Air Education and Training Command
Air Force Office of Scientific Research
United States Air Force Academy
Aechelon Technology, Inc.
SDS International, Inc.
McDonald Research Associates
Lockheed-Martin
L3 Communications
Boeing
Evans & Sutherland
Silicon Light Machines
Fire Arms Training Systems
Northrop Grumman
Simulation Technologies, Inc.
Solipsys
Mak Technologies
Metrica, Inc.
Micro Analysis and Design
Aptima, Inc.
Cubic Defense Systems
Surface Optics Corporation
Diamond Visionics
Stottler Henke, Inc.
Adacel Technologies, Ltd.
The Group for Organizational Effectiveness
Defence R & D Canada
Defence Science and Technology Laboratory (UK)
Defence Science and Technology Organisation (AU)
NATO Research and Technology Organization
Army Research Institute/Infantry Forces Research Unit
Defense Advanced Research Projects Administration
Navair – Orlando
Office of Naval Research
Army Research Institute
National Research Council
US Joint Forces Command
Chandler-Gilbert Community College
Maricopa Community Colleges
University of South Florida
University of Central Florida
University of Georgia
Arizona State University
University of Tennessee
Texas A & M University
Colorado University – Boulder
Oklahoma University
University of Dayton Research Institute

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1.6 VR R&D LABORATORY FACILITIES

1.6.1 F-16 DMT Testbed

The F-16 testbed consists of four high-fidelity, F-16 Multi-Task Trainers (MTTs) equipped with full field-of-view Mobile, Modular Displays for Advanced Research and Training (M2DART) visual display systems, two AWACS Air Weapons Controller stations, a control and observation console, constructive threat generation systems, data recording systems, performance assessment systems, and two replay/debrief systems.

Each M2DART consists of nine, rear-projection screens faceted around the cockpit providing the full field of view for an F-16 pilot. The screens provide xx ft-L of brightness with yy:1 contrast. Out-the-window imagery for two of the cockpits is provided by SGI Reality Monster Computer Image Generators (CIGs). Out-the-window imagery for other two cockpits is produced by Personal Computer (PC) based CIGs. These CIGs manufactured by Aechelon Technologies, Inc. and SDS International Inc. provide comparable imagery to the Reality Monsters using commercial, off-the-shelf PC hardware. The control and observation console consists of ten, large display screens that show the forward view and selected cockpit information from all four F-16s together with a plan-view of the engagement and radio communications. Cockpit displays, radio communications, and the plan view are recorded for replay in one of two debrief facilities. Using the debrief systems, instructors can replay, fast-forward, and rewind recorded scenarios while zooming in and out of the plan-view displays.

1.6.2 Night Vision Training Laboratory

The laboratory facilities include an NVG simulation development system comprised of an SGI Onyx and a PC image generation system, a psychophysics human factors laboratory, a precision equipment measuring lab including a variety of NVIS measuring and testing equipment, a multi-media courseware development system and specialized cameras for collecting NVG imagery, an NVG academics training facility including two eyelanes, a multi-media classroom, a terrain model board and associated NVG instructional materials. The academic training facility is located at Luke AFB.

1.6.3 High Resolution Visual Displays Laboratory

Unique Facilities:

- Dedicated M2DART Visual Testbed
- Laser Projector Lab
- PC-IG, projector, and display test lab
- PC-IG systems from a variety of vendors
- Collimating and retro-reflective displays
- Head-mounted display facility (under development)
- DMT testbed available for follow-on training effectiveness studies

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2.1 AREAS OF INTEREST

- Use of VR/VE for dismounted Infantry training.

2.2 CURRENT RESEARCH PROJECTS

Virtual Environment Research for Infantry Training and Simulation. The objective is to develop, integrate, demonstrate, and evaluate technologies, techniques, and strategies for using virtual simulations for individual, leader and small unit training, mission rehearsal, concept development, and test & evaluation. Emphasis is being placed on developing the capability within Virtual Environments to conduct night, MOUT (Military Operations in Urban Terrain) and contingency operations. The more recent experiments have also examined instructional strategies and training interventions unique to training teams in distributed VEs.

2.3 RESULTS ACHIEVED TO DATE

Initiated a program of experimentation to investigate behavioral sciences issues in the use of VR for military training in 1992. Following an initial analysis of the task requirements for dismounted soldier training, and a review of previous VR training research, four experiments were conducted to investigate interface effects on the capabilities of participants to perform simple tasks in VR. Variables investigated included the type of control device, amount of task practice, stereoscopic vs. monoscopic helmet-mounted displays (HMDs), and type of display device (monitor, Boom, or HMD). Three experiments were performed that addressed the effectiveness of VR for teaching route and configuration knowledge of large buildings, and the transfer of this knowledge to the real world. The results of these experiments led to a program of basic research on distance estimation in VR. The next phase of the research investigated the use of VR to represent exterior terrain for training both land navigation skills (identifying landmarks and learning routes) and terrain knowledge. Finally, research was conducted investigating the use of VR for training more complex tasks. This included experiments examining the effects of self representation on performance, the training of two-person hazardous materials teams, and distributed team training in underway. Overall, the program has conducted 16 experiments involving over 600 human subjects. Knerr 100 et al. (1998) provides an overview of the results of the first phase of the program (1993 – 1998), along with recommendations for the use of VR for dismounted soldier training.

Beginning in 1999, increasing emphasis within the program is being placed on the development of technologies and techniques for the training of Infantry leader tasks. In 2000/2001 we developed and released for free a new library called the Virtual Environment Software Sandbox (VESS).

2.4 COLLABORATIVE PARTNERS

- US Army Simulation Training and Instrumentation Command
- US Army Research Laboratory, Human Research and Engineering Directorate
- US Army Research Laboratory, Computer and Information Sciences Directorate
- US Naval Air Warfare Center Training Systems Division
- University of Central Florida Institute For Simulation and Training

2.5 LITERATURE PREPARED BY RESEARCHERS

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2.6 VR R&D LABORATORY FACILITIES AVAILABLE

- Silicon Graphics Workstations including an Onyx Reality Engine Rackmount System (3 Graphics Pipes, 8 CPUs, 12 RMs, MCO), an Onyx RealityEngine Deskside (4 CPUs, 4 RMs, MCO), an Onyx RealityEngine Deskside (2 CPUs, 2 RMs) a Crimson RealityEngine Deskside (2 CPUs, 4 RMs, MCO), an Octane (2 CPUs. OCO), and several High Impact, O2, Indy, and Indigo Systems.
- Evans and Sutherland ESIG 2000 dual channel image generator
- SIMNET 8-channel image generator and M1A1 Tank Simulator
- Numerous Networked PCs
- Virtual Research V8 HMD (2)
- Virtual Research VR4 HMD (3)
- Virtual Research Flight Helmet (2)
- VPL EyePhones
- Fake Space Labs, high resolution 2-color BOOM
- CrystalEyes (4)
- Howlett CyberFace II
- Ascension Flock of Birds tracker, extended range with 8 sensors
- Ascension Flock of Birds tracker, extended range with 2 sensors
- Ascension MotionStar tracker, extended range with 16 sensors
- Polhemus trackers with multiple sensors (3)
- LogiTech Acoustical trackers (2)
- Crystal River Convolvotron
- IST ChordGloves™ (4 pairs)
- IST VE Motion Treadmill
- Mirage Display System
- Auto Cad
- Alias
- ElectroGIG
- GMS
- GRASS
- MultiGen
- Neo Visuals
- S-1000
- Strata Vision-3D

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3.1 AREAS OF INTEREST

- VEs for the acquisition and use of spatial knowledge
- Haptics (virtual touch and feel), cross-sensory display substitution, depth perception
- Modeling of individual differences in spatial cognition at the individual and team level
- Effectiveness of VE technology for small team training; tracking technology
- Locomotion methods in VE
- 3D spatial sound

3.2 CURRENT RESEARCH PROJECTS

3.2.1 Virtual Technologies/Environments (VIRTE) Demonstration I; Expeditionary Warfare Combat Vehicles and Craft

This program is developing a series of interoperable, deployable combat simulations that support training, mission planning, and rehearsal in Expeditionary Warfare. By using PCs, and maximizing the use of Government-owned software, the simulations will be deployable, inexpensive, and easy to maintain.

The three Expeditionary Warfare Platforms that were developed are the Landing Craft, Air Cushion (LCAC), the Expeditionary Fighting Vehicle (EFV) (previously known as the Advanced Amphibious Assault Vehicle (AAAV)), and the helicopter. Each of these platforms offers unique simulation and training challenges. The goal of the program is to demonstrate Human-centric designs that meet a variety of challenging goals. VIRTE simulations will be able to form a federation using DoD's High-Level Architecture (HLA) and interact in a highly complex synthetic environment consisting of realistic weather (rain, wind, fog, etc.), ocean environment (wave height, sea state, surf zone, etc.), man-made features (buildings, obstacles, craters, etc.), and other vehicles.

3.2.2 Virtual Technologies/Environments (VIRTE) Demonstration II; Close Quarters Battle for Military Operations in Urban Terrain (CQB for MOUT)

VIRTE Demonstration 2 is developing the technologies and infrastructure to allow Marines and Seals to interact with the virtual environment in a more realistic and natural manner than is currently possible.

By tracking the entire body, instead of just the head and the weapon, the avatar in the virtual world will be much more realistic. Advances in Head Mounted Displays (HMDs) will allow greater immersion and improved realism. The simulation infrastructure will allow much more natural interaction with the virtual world. For example, a Marine or Seal will be able to kick open doors, move furniture with his body, and observe realistic, physics based weapons effects.

Today's infantry must quickly adapt to diverse situations, from high-intensity warfare to peacekeeping missions, functioning in small teams and with increasing physical, emotional, and intellectual demands. Due to reduced live training opportunities, VIRTE will need to provide a level of visual, audio, and haptic fidelity that has not been available in a single synthetic exercise. Warrior acceptance of such advanced training technology will require detailed effectiveness data developed, collected and analyzed by a thorough human centered design process, with continuous user input into spiral developments, then tested in training transfer studies.

3.3 RESULTS ACHIEVED TO DATE

3.3.1 VIRTE Demonstration I, Combat Vehicles and Craft

VIRTE Demonstration I developed three unique interoperable Expeditionary Warfare simulations in FY 02 and FY 03. They share a common networked synthetic battlespace, but they are very different in their technologies and applications. The three Expeditionary Warfare platforms that were chosen are the Landing Craft, Air Cushion (LCAC), the Expeditionary Fighting Vehicle (EFV) (previously known as the Advanced Amphibious Assault Vehicle (AAAV)), and the helicopter. The VELCAC uses a gaming engine (Gamebryo) to develop high fidelity virtual cockpit for all three crew positions. The architecture allows a single crew to train in their position and supports team training of the entire crew. The VEEFV uses a medium fidelity mockup of the interior of the vehicle and provides gunnery and team training. The same software can be used for Embedded Training and also supports laptop operations. The VEHELO uses a Chromakey approach and a HMD to combine a low fidelity physical mock up with the virtual world. It also supports a laptop configuration.

3.3.2 VIRTE Demonstration II, Close Quarters Battle for Military Operations in Urban Terrain (CQB for MOUT)

A prototype testbed has been developed at NRL and it has been used to test and integrate component technologies. A government-owned, PC based, HLA compliant, game quality simulation infrastructure has been developed and demonstrated. A government-owned 3D spatial sound software package has been developed and integrated into the simulation architecture. Real-time control by an individual, using only their body, of a virtual avatar has been demonstrated. Various methods of locomotion in VE have been tested. Magnetic, passive optical, and active optical tracking systems have been tested and integrated. The new PhaseSpace tracking system is the result of an ONR funded SBIR.

3.4 COLLABORATIVE PARTNERS

- ONR (Office of Naval Research)
- NPS (Naval Post Graduate School)
- NRL (Naval Research Laboratory)

- ARI (Army Research Institute)
- U.S. Army Program Executive Office for Simulation, Training and Instrumentation (PEO STRI)
- U.S. Army Research Development and Engineering Command (RDECOM)

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3.6 VR R&D LABORATORY FACILITIES AVAILABLE

NAVAIR Orl

Prototypes of VELCAC, VEEFV, VEHelo, and ISMT-E are available for demonstration.

NRL

VIRTE Demo 2 prototype using VICON tracking system; PhaseSpace Tracking System.

NPS

See section 7F for details.

Paper 4 – Naval Postgraduate School

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4.1 AREAS OF INTEREST

The MOVES Institute's mission is research, application, and education in the grand challenges of modeling, virtual environments, and simulation. Specialties are 3D visual simulation, networked virtual environments, computer-generated autonomy, human-performance engineering, immersive technologies, defense/entertainment collaboration, and evolving operational modeling.

4.2 CURRENT RESEARCH PROJECTS

4.2.1 3D Visual Environments – Technical Director: Dr. Don Brutzman

NPS has been instrumental in standardizing the extensible 3D (X3D) graphics specification, collaborating with the Web3D Consortium, ISO, and WWW Consortium to produce a synthesis of the Virtual Reality Modeling Language (VRML) and the Extensible Markup Language (XML) to exploit X3D graphics for Web-based viewing of 3D scenes. The addition of geospatial representations, humanoid animation, DIS networking capabilities, advanced 3D rendering, computer-aided design interchange, and other capabilities makes 3D graphics and visualization broadly available on the Web.

In scenario authoring and visualization for advanced graphics environments (SAVAGE), we have built sophisticated open-license military models in X3D as part of the SAVAGE project. Dozens of students have contributed high-res models for ships, aircraft, submarines, land vehicles, robots, humanoid behaviors, environmental effects, etc. The SAVAGE archive is a multiple-CD set documenting over 700 military models, scenarios, theses, etc.

Autonomous underwater vehicle visualization is also a MOVES concern. NPS provides sophisticated capabilities in modeling and visualizing oceanographic data collected by underwater robots. With Office of Naval Research (ONR) sponsorship, we have participated in fleet battle experiments to assess minefield-clearance by robots, and translate telemetry and communicate messages to the global Command-and Control System (Maritime) mine-warfare environmental-database-analysis library.

In XML for operations orders, we can auto-generate large-scale VEs corresponding to regional (and potentially theatrical) operations. This new capability can be communicated via existing message circuits, but for actual deployment, a common vocabulary with common semantics is needed; NATO's battlespace generic hub (BGH) appears a good candidate for such a model. We are showing how BGH can be expressed in XML for modeling joint and coalition tactical scenarios. This work is seen as necessary for enabling worldwide battlespace presence, monitoring, and visualization. Applications to homeland defense and assessment of the effects of weapons of mass destruction provide further challenges.

DoD modeling and simulation (M&S) must identify and adopt transformational technologies of direct tactical relevance to warfighters. The only software systems that composably scale to worldwide scope utilize Web technologies; therefore an extensible Web-based framework offers promise in scaling up M&S systems to benefit training, analysis, acquisition, and operational warfighters. We are defining an extensible modeling and simulation framework (XMSF) to exploit Web-based technologies. Government, academic, and industrial experts are working under investigators from the Naval Postgraduate School, George Mason University, SAIC and Old Dominion University. XMSF is a composable set of standards, profiles and recommended practices for Web-based modeling and simulation. XML-based markup languages, Internet technologies, and Web services will enable a new generation of distributed M&S applications to emerge, develop and interoperate. The precepts of XMSF are:

- Web-based technologies applied within an extensible framework will enable a new generation of M&S applications to emerge, develop and interoperate.
- Support for operational tactical systems is a missing requirement for such M&S applications frameworks.
- An extensible framework of XML-based languages can bridge forthcoming M&S requirements and open/commercial Web standards, while supporting existing M&S technologies.
- Compatible, complementary technical approaches are now possible for model definition, simulation execution, network-based education, network scalability, and 2D/3D graphics views.
- Web approaches for technology, software tools, content production and broad use provide best business cases from an enterprise-wide (worldwide) perspective.

4.2.2 Networked Virtual Environments – Technical Director: Dr. Don Brutzman

MOVES continues research in networked virtual environments through NPSNET-V, a platform for investigating new concepts in related design. It features composable components, and can be extended at runtime; it is graphics-standard agnostic, and can use entirely new network protocols loaded at runtime. It has been used to test new ideas in interest management, security, and dynamic extensibility.

Cross-format schema protocol (XSFP) is a technique for saving XML data in binary format. XML data can be read by many platforms, but it is verbose, storing all data as strings. XSFP uses XML in bandwidth- or storage-constrained environments, increasing processing speed in data-intensive XML documents. MOVES is developing DIS libraries in many contexts (e.g. Java, X3D, and browser plugins), and describing DIS protocol in terms of XML and XSFP.

4.2.3 Computer Generated Autonomy – Technical Director: John Hiles

In 2002, the MOVES Institute established the Center for the Study of Potential Outcomes to employ our connector-based, multi-agent systems (CMAS) concept and cognitive science in modeling terrorist behaviors. The first project of the center is Project IAGO.

Project IAGO (integrated, asymmetric, goal organization) aims to develop a conceptual model and prototype implementation of a cognitive model of the decision-making and dynamic behaviors of terrorists. The object is to develop an anti-terrorist tool for intelligence analysts, enabling them to explore a complex, hyper-dimensional space of terrorist capabilities and possibilities in a social space, with potential for identifying infrastructure vulnerabilities and detection/prevention opportunities. This work also explores benefits and limitations in applying the CMAS concept, n approach conceived by MOVES professor John Hiles and inspired by the information exchange and -processing techniques that have evolved at the cellular level.

Initially, IAGO will construct a prototype cognitive model for exploring terrorist behaviors, in three phases:

- **Phase 1: Demonstration Model.** Initial design and implementation to generate software components that capture fundamental CMAS concepts of tickets, connectors, and templates. Lessons from phase one provide the software foundation for phase-two activities.
- **Phase 2: Proof-of-Concept Model.** This phase produced an initial prototype implementation of mental blending, a cognitive-psychological model of creative thought in which perceptions and concepts are combined under the guidance of generic problem-solving mental spaces and goal motivations to create cognitive blends (see cognitive training agents below). Development is ongoing to yield more complex blended spaces from the initial mechanisms.
- **Phase 3: Domain Demonstration**. The next phase is application and demonstration of the blended-mental-space modeling approach to represent influences and dynamics in forming terrorist behaviors leading to decisions and actions and to show the potential of the approach as a useful model for analysts. Early work with experts has resulted in a characterization of decision elements influencing terrorist behaviors. This information enables formulation of initial generic spaces and goals for interplay with an information stream, to produce behaviors comparable to real-world actions.

While our funding for IAGO was small in FY2002, the project shows great promise. In 2002, the Defense Threat Reduction Agency contracted with the MIIS Center for Non-proliferation Studies for a literature review of existing terrorist-behavior models. Two-hundred-and-sixty-five models were studied, and IAGO emerged in the top ten.

Cognitive training agents are also under intensive research. In January 2003, the MOVES computer-generated autonomy team reached a milestone. Using a multi-agent system combined with CMAS technology we developed over the last three years, we demonstrated that our software could do what cognitive psychologists call cognitive blending, producing cognitive-integration networks. That is, our software was able to create new knowledge in situ based on what it was doing and what it wanted to accomplish. Until this time, advanced multi-agent work has only been able to demonstrate the ability to adaptively explore problems with intent and purpose. Software blending means that multi-agent software can now be built to answer questions such as, “What do you know?” “How do you know that?” or (most importantly for training), “What are you doing?”

In the next year, we intend to extend these experimental results to create adjustable cognitive training agents that will add new capabilities to training. The cognition of these agents will be built-in and applicable to a range of applications. Specialization will take place outside these capabilities (for example, a specific application will require specific input and output routines (sometimes referred to as input and actuator suites), and an application-specific set of meta-data packages that we call generic spaces, which would describe the types of cognitive operations needed in that particular area).

Training software equipped with cognitive-training agents could ultimately take on the following capabilities:

- Training involving competition with virtual opponents would add adversaries that adapt, deceive, and could explain what they were doing and why.
- Training for tasks not involving problem solving could self-adjust to press students to their limits of understanding, then offer explanations of their boundaries and what additional work might expand them. In this and the following training applications, cognitive training agents guide the training software rather than act as adversary.
- Training for problem solving where innovation and discovery are demanded could continually alter the situation to keep it open and freshly challenging.

Not all training software would benefit from these properties. But important benefits can be derived from software that adapts and incorporates discoveries into knowledge that it produces as it goes.

4.2.4 Human-Performance Engineering – Technical Director: Dr. Rudy Darken

We find two fundamental barriers to achieving the transformation in training the CNO has called for: (1) the cost of simulation for training is too high, and (2) the development cycle from mission-need to product is too long. Low-cost simulators and the bringing training to the fleet swiftly will have an immediate impact on the individual warfighter. HPE has been focusing on these issues through the VIRTE program to develop high-fidelity deployable trainers.

Our work includes the development of a Chromakey- augmented training environment, whereby the near-field cockpit of a helicopter is captured with a camera and mixed with a simulated "out the window" view, allowing inexpensive reconfigurable training to occur. Similarly, we are developing a "suitcase" simulator for close-quarters battle for the second phase of VIRTE, miniaturizing as many components as possible to facilitate shipboard usage. This will be integrated with our forward-observer trainer towards a full spectrum combined-arms training capability. A common theme is the use of open standards and computer gaming technologies to increase performance while driving down development costs. All simulations for training developed in our laboratory undergo thorough testing both in house and in the fleet to determine their value in transfer of training.

As a part of DARPA's augmented-cognition (Aug-Cog) program, MOVES is researching a context machine to "improve the performance of the human-machine symbiosis by an order of magnitude or greater," thereby contributing to Aug-Cog's goal of improving warrior/computer interactions, advancing systems-design methodologies, and re-engineering military decision-making at a fundamental level. MOVES is exploring the computer science behind creating a system able to determine a situation's context and thereby assist in accomplishing its goals. Using a game engine to simulate real-world inputs and provide a means of output, MOVES has built a prototype system and continues research into the artificial intelligence and other factors required to determine context and act upon it.

In addition, MOVES has evaluated the training effectiveness of a damage-control trainer built at University of Illinois, Urbana-Champaign. We evaluated the system on surface-warfare officers stationed at NPS to understand the efficacy of the system in training DCAs. We expect to present our findings at ONR Workshop in May. Funding for HPE has been provided by ONR, N61M, DARPA, and the FAA.

4.2.5 Immersive Technologies – Technical Director: LCDR Russ Shilling, USN

The immersive technologies directorate met major milestones in 2002. The goal has been not only to apply virtual environment and video-game technology to training tasks, but also bridge the gap between these technologies and the operational- warfare environment.

First, technologies were advanced for the development of a sourceless postural tracking system using magnetic and inertial sensors to accomplish full-body tracking in a virtual environment. The unique and exciting part of this technological advance centers on a tracking device only slightly larger than a quarter. Patents for this device are measured the physiological impact of VE technology and emotion/arousal on cognitive abilities in a training task.

Finally, using the student-built cave system and other visual technologies, we are combining entertainment techniques, video-game technology, and advanced display design to solve problems associated with information management in network-centric warfare tasks, especially in command and control (video games routinely use various strategies to allow players to track and manipulate hyper-dimensional data within game play).

We will see if some of these same strategies can be applied to helping planners, analysts, and operators track multi-dimensional data sets associated with the fusion of large amounts of tactical data from different sources in a live warfare setting. At the same time, we will be examining game engines and editors to see if traditional methods of war gaming might be better implemented or improved using game-engine technology. Results of this research will be presented at ForceNet in April 2003.

4.2.6 Evolving Operational Modeling – Technical Director: LCDR Alex Callahan, USN (ret)

The technical directorate for evolving operational modeling became established as the configuration manager for the naval simulation system (NSS), an analytical model with unique capabilities for representing network-centric warfare.

The directorate coordinated efforts between SPAWAR Systems Center, San Diego, developers and testing agencies to ensure the quality of delivered versions, and continued to nurture a broad base for operational analysis across government, military, and commercial interests, with NSS as the focal point.

Evolving Operational Modeling obtained tasking in several key areas of NSS employment, including analysis of alternative platforms for the multi-mission aircraft program. The directorate prepared draft curriculum materials for a new course, applied combat modeling, providing insights into the application of combat models (using NSS as the exemplar) to military operational analysis.

The directorate led a working group of faculty from operations research and MOVES to review the combat modeling curriculum at NPS. As a result of these efforts, existing combat modeling courses have been revised, greater infrastructure has been provided for the war-gaming analysis course, and a school-wide wargaming policy and advisory committee has been established to revitalize application of warfare gaming across multiple disciplines.

4.2.7 Defense/Entertainment Collaboration Creative Director: Alex Mayberry

The MOVES Institute has been in the press continually with our *America's Army* project (see Appearances, below). *Newsweek* has toasted "the legendary Naval Postgraduate School" in the aftermath of *AA* and its success, and we will soon be in *Newsweek* again.

AA has engendered much faculty and master's-student interaction, yielding several completed theses this year, and has brought NPS much positive media attention. It has inspired the CNO to task the Naval War College's strategic studies group (SSG) to perform a study on the utility of massively multi-player gaming as the basis for the development of future large-scale M&S systems. That study reports out to the CNO in July 2003. The MOVES director gave a presentation on the project to the SSG in December 2002 for that study. The last two SSG plenary meetings have discussed massively multi-player gaming.

AA is highly approved by the sponsor for its transformation of Army recruiting. As of the 3rd of September 2003, there were 2M+ registered players of *AA,* with 1.3M+ having completed basic combat training in the game. Over 218M+ game missions have been completed, and some 100K gaming hours per day are played.

To understand the dividends of the game from the US Army perspective, a look at traditional recruiting is in order. The army spends $2B (two billion) per year to attract and enlist 120,000 recruits (80,000 army, 40,000 national guard). That's $16,666 per soldier.

Twenty percent (or 24,000) of these recruits drop out during basic combat training with the excuse that the army was not what they expected and combat training was not for them. With them goes $400M in wasted recruiting expenditure. In addition, the army has spent $75K each for training; thus, the army's loss per annum from this dropout group is $2.2 billion.

America's Army cost $7M to build over the first twenty-four months, a tag equivalent to that of 420 recruits who wash out (if we count recruiting costs alone). If the game encourages only 120 potential waverers to stick with it, it's broken even, counting recruiting and training costs. And of course, if it attracts those who would not otherwise have considered an army career, it's worth $92K apiece.

The Army estimates *AA* has the potential to save some $700M-$4B per year. With respect to recruitment, actual results won't be known for four or five years, when the current raft of thirteen- and fourteen-year olds will be old enough to join. The hope is that through realistic role playing and exploration of a soldier's job, the important work of the military will be among the options that compatible young men and women will consider when planning a career.

Improvements are continually made. By August 2003, occupations within the game will include infantry, medic, engineers, RSTA/Scouts, and Special Forces:

- Medic/91W & combat lifesaver: Four missions, from AIT at Brooke Army Medical Center through an STX under field conditions. These missions are pass-fail and enact expert information on combat lifesaving. This training conveys lifesaving information applicable to the population for homeland defense. One mission will incorporate training to recognize the symptoms of nerve agent as well as immediate self- and buddy-aid for nerve-agent casualties (funded by FORSCOM).
- Special Forces: Several missions to replicate the Robin Sage exercise as apart of SFAS with emphasis on land navigation and escape and evasion. These missions will qualify players to enter specialized S.F. training and be assigned in multiplayer S.F. missions.

New units and weapons added into *AA:*

- Stryker: the Stryker debuted in May in a transport- and support-by-fire role within a new online, multiplayer mission. Coverage of the SBCT within the Game expanded throughout the summer of 2003.

- TACOM-ARDEC is funding incorporation of the objective individual combat weapon (OICW) and the shoulder-launched multipurpose assault weapon/bunker-defeat munition (SMAW-D) into the game.

Having a successful online game inside the MOVES Institute is like having your own particle accelerator. Lots of proposed applications and interesting research are coming in the door.

Many related training applications using the *AA* code base as a starting point are being considered. We have funding from one project that's using *Operations* for treaty verification pre-planning, and an Air Force group is looking at funding a training level within the game that will deal with force protection.

Infantry soldiers at Fort Benning are using *Operations* before setting foot on the real range. Also, the Army's objective force is having us integrate prototypes of their new weapons systems into *Operations* to evaluate their potential utility. We are building special levels of the game for the Special Forces, both for recruiting and SF training.

We have strong interest from Commander Naval Surface Forces Pacific in our building a game for material-assessment training. They have approved both proposal and schedule and are raising funding for the project. One extraordinary possibility, raised by the undersecretary of defense's office, is massively multiplayer (MMP) gaming. The *AA* project is being looked at both as a model of how such an effort could be carried out within government and as possible starting point for a MMP project. The work involved might include the procurement (or development) of a government-owned game engine capable of full-spectrum combat modeling and large-scale inter-operability integration, as well as a programming interface for modeling individual and organizational behaviors and stories.

An additional goal would be a rapid prototyping interface to the MMP that would allow any mission to be put together nearly overnight.

4.3 RESULTS ACHIEVED TO DATE

- In 3D visual simulation and networked virtual environments, we have created the extensible modeling and simulation framework (XMSF), an effort cited as the most important strategy for connecting DoD modeling and simulation to C4I systems.
- Our terrorist behavior-modeling effort, Project IAGO, is listed among the top ten in a DTRA survey of two hundred and sixty five models.
- Our Chromakey augmented training environment has been deployed to helicopter squadron 10 (HS-10) to study its utility in flight navigation training.
- Our achievements in immersive technology include a pending patent for our inertial tracker. Sounds we and LucasFilm's Skywalker Sound recorded, of an LCAC for a Marine Corps training VE, were used for a hovercraft in the movie *Minority Report.*
- Our *America's Army* is the fastest-growing online game ever, and has won or been runner-up for several best-game-of-the-year awards. The project is cited as a transformational model for turning the PC game into a communications medium and demonstrating how innovative projects can succeed within DoD. *AA* is expected to save $700M to $4B annually and has inspired the CNO's strategic studies group to consider massively multi-player gaming for combat modeling; other defense agencies are pursuing similar studies. The game is the first successful defense/entertainment collaboration, as spelled out in the National Research Council report, "Modeling and Simulation – Linking Entertainment and Defense."

- We have applied techniques from VE and entertainment to enhance comprehension of complex tactical information in "live" command-and-control settings. We showed that radio, radar, air-traffic control, and possibly UAV communications could be improved using spatialized cues over headphones, presenting results at the ForceNet 2003 conference.

We support our students through courses and funded research directly related to our mission. Our projects provide DoD- and DoN-relevant thesis topics for officer students. Funded projects indicate serious interest in our research and educational abilities. In FY2002, MOVES had $11.4M in reimbursable funding. As of mid-FY2003, we had some $12M in reimbursables (forty-four accounts from thirteen sponsors).

MOVES has expanded greatly, currently employing sixty-eight faculty and staff. Students working in institute projects increased from forty to sixty-eight, hailing from twelve curricula (MOVES, CS, OR, IT, IS, NSA, IW, meteorology, ME, ECE, UW and C4I); see theses on our website.

4.4 COLLABORATIVE PARTNERS

4.4.1 Civilian

4.4.1.1 Academic

- Boston College
- California Polytechnic State University
- Carnegie-Mellon University
- California State University, Monterey Bay
- Clemson University, Department of Psychology
- ENIT, France
- George Mason University
- Georgia Tech, Modeling and Simulation Research and Education Center (MSREC)
- Institut National de Recherche en Informatique et en Automatique, France (INRIA)
- Miami University
- MIT Lincoln Laboratories
- MIT Research Laboratory of Electronics (RLE)
- Old Dominion University, Virginia Modeling, Analysis, and Simulation Center (VMASC)
- Queens University, Kingston, Ontario
- University of California, Berkeley, Center for Design Visualization
- University of Central Florida, Department of Industrial Engineering
- University of Central Florida, Institute for Simulation and Training
- University of California, Santa Cruz
- University of Newcastle, Newcastle-upon-Tyne
- University of Virginia
- University of Wisconsin

4.4.1.2 Corporate

- Bios Group
- Boeing
- Dolby Emergent Designs
- Epic Games
- John Mason Associates
- Lucasfilm Skywalker Sound
- Lucasfilm THX
- Microstrain
- MITRE
- Potomac Institute
- Science Applications International Corporation (SAIC)

4.4.1.3 Non-Profit

- Center for Naval Analysis
- Fraunhofer Center for Research in Computer Graphics
- High Performance Computing Center, Maui
- Institute for Defense Analysis
- Monterey Bay Aquarium Research Institute (MBARI)
- Monterey Bay National Marine Sanctuary
- Sea Grant
- S.E.A. Lab Monterey Bay

4.4.2 Military and Federal

4.4.2.1 Air Force

- Medical Command, San Antonio

4.4.2.2 Army

- Army Research Office
- Assistant Sec. Army for Manpower & Reserve Affairs
- Office of Economic & Manpower Assessment
  - Sponsorship: OEM Analysis, US Army Training Analysis (TRAC Monterey), US Army Training and Doctrine Command (TRADOC), US Army Operational Test Command, Fort Hood (USAOTC)
- US Army Operational Test and Evaluation Command (OPTEC), Fort Hood
  - Sponsorship: High-resolution database creation

4.4.2.3 Marine Corps

- Marine Corps Combat Development Command (MCCDC)
  - Sponsorship: Adaptive Exploration of Agent-Based Command and Control Simulations
- Marine Corps Combat Development Center Training and Education Command (MCCDC TECOM)
  - Sponsorship: Scenario authoring and visualization for advanced graphical environments (SAVAGE)
- Detail Marine Forces Pacific
- Training & Education Command

4.4.2.4 Navy

- Chief of Naval Operations, CNO-N6, Space Information Warfare Command and Control Directorate
  - Sponsorship: SimSecurity, a distance-learning and virtual laboratory for information assurance
- Commander, Helicopter Anti-Submarine Wing, Pacific Fleet (CHSWP)
- Commander, Submarine Development Squadron TWELVE
- HS-8 – Helicopter Anti-Submarine Squadron EIGHT, FRS
- HS-10 – Helicopter Anti-Submarine Squadron TEN, FRS
- Naval Aerospace Medical Research Lab
- Naval Oceanographic Office
- Naval Postgraduate School Distance-Learning Resource Center
  - Sponsorship: Joint-Combat Modeling Class (MV/OA4655)
- Naval Postgraduate School Institutionally Funded Research Program (NIFR)
  - Sponsorship: Scenario authoring and visualization for advanced graphical environments (SAVAGE). Detail
- Naval Sea Systems Command, Advanced Systems & Technology Office
- Naval Submarine School
- Naval Research Laboratory
  - Sponsorship: Automatic determination of safest routes for aircraft in enemy radar environments
- Navy Modeling & Simulation Management Office, N6M
  - Sponsorships: NPSNET-V: an architecture for constructing scalable, dynamically extensible, networked virtual environments
- NPSNET-V: DBP, vrtp for adaptive XML-based streaming of 3D behaviors and X3D
- Navy Toxicology Detachment, Wright
- Patterson Air Force Base
- Space and Naval Warfare (SPAWAR) Systems Center, San Diego
  - Sponsorship: Joint Simulation System (JSIMS) Marine Corps amphibious operations modeling

- Naval Undersea Warfare Center, Newport (NUWC)
  - Sponsorship: Scenario authoring and visualization for advanced graphical environments (SAVAGE). Detail
- Naval Air Warfare Center, Training Systems Division (NAWC-TSD)
- Office of Naval Research
  - Sponsorship: Immersive audio
- Office of Science and Development (OSD)
- Defense Advanced Research Projects Agency (DARPA)
- Defense Modeling & Simulation Office (DMSO)
  - Sponsorship: Scenario authoring and visualization for advanced graphical environments (SAVAGE). Detail
- Defense Threat Reduction Agency (DTRA)
  - Sponsorships: DIS-Java-VRML, STRP and HLA/RTI gateway for physically based battle-damage assessment
- Scenario authoring and visualization for advanced graphical environments (SAVAGE).
- Federal Aeronautics Administration
  - Sponsorship: VIRTE (Virtual Technologies and Environments)
- National Aeronautics and Space Administration (NASA Ames)
- National Reconnaissance Office
  - Sponsorship: NPSNET-V: an architecture for constructing scalable, dynamically extensible, networked virtual environments
- National Science Foundation
  - Sponsorship: Virtual Vaudeville
- Office of the Director, Operational Test & Evaluation
- Office of the Secretary of Defense, Extensible-Markup Language Message-Text Formats (XML-MTF) working group
  - Sponsorship: Generic hub: auto generating and distributing shared virtual environments for US and Allied operations orders using XML and X3D
- US Joint Forces Command Joint Experimentation Directorate (USJFCOM J9)

4.4.2.5 Foreign Military

- Bulgarian Military
- Czech Republic Military

4.5 LITERATURE PREPARED BY RESEARCHERS

4.5.1 Theses and Dissertations

Arisut, LTJG Omer, Turkish Navy. "Effects of Navigation Aids on Human Error in a Complex Navigation Task." MS in MOVES, 2002.

Aronson, MAJ Warren., USA "A Cognitive Task Analysis for Close Quarters Battle." MS in computer science in cooperation with MOVES, 2002.

Back, LT David, USN. "Agent-Based Soldier Behavior in Dynamic 3D Virtual Environments," MS in MOVES, 2002.

Brannon, LTCOL David, USMC and Villandre, MAJ Michael, USMC. "The Forward Observer Personal Computer Simulator (FOPCSIM)." MS in computer science in cooperation with MOVES, 2002.

Calfee, LT Sharif, USN. "Autonomous Agent-Based Simulation of an AEGIS Cruiser Combat Information Center Performing Battle Group Air Defense Commander Operations," MS in MOVES, 2003.

Campbell, LT James, USN. "The Effect of Sound Spatialization on Responses to Overlapping Messages," MS in operations research in cooperation with MOVES, 2002.

Desypris, LT Georgios, Hellenic Navy. "Enhancement of Learning Process in Web-based Courses Using Combined Media Components," MS in computer science in cooperation with MOVES, 2002.

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Paper 5 – Naval Research Lab (NRL) in VR

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5.1 AREAS OF INTEREST

There are three main Virtual Reality (VR) facilities at the Naval Research Laboratory. The first, the Immersive Simulation Laboratory, is directed by Dr. Jim Templeman and focuses on exploring Human Computer Interaction challenges and techniques for enhancing immersion (Templeman, Denbrook & Sibert, 1999). The second facility, the Virtual Reality Laboratory, is directed by Dr. Lawrence Rosenblum and focuses on many of the technical aspects attendant with using VR as well as Augmented Reality. The third facility, the Warfighter Human Systems Integration Laboratory (WHSIL), is co-directed by LT Joseph Cohn and Dr. Roy Stripling. The focus of this facility is on developing and evaluating VR tools for supplementing training within the US Navy-Marine Corps, including the development of novel methodologies for detecting, assessing and enhancing performance. These latter two facilities will be discussed in greater detail in the following sections.

5.2 CURRENT PROJECTS: WHSIL

5.2.1 Creating Effective First Person Training Tools: Evaluating Locomotion Interfaces

Despite the potential advantages, several practical limitations of VR systems challenge their utility as training tools. One significant limitation is the method by which individuals control their movement within the VR. The optimal control method for training purposes would allow the user to move through the VR by performing identical movements in the real-world. Such a system would thus enable the trainee to experience first-hand and with true fidelity, the speed, intensity, and precision of movements required to perform the real-world operations. For vehicle based applications, such as flight or tank simulators, this mapping of real to virtual interfaces is fairly straightforward. System developers need only copy those elements of the real cockpit, together with their functionality, that are deemed necessary for training purposes. On the other hand, for non-vehicle based applications, such as those that enable individual infantrymen to train combat operations in an urban setting from a first person perspective, this mapping is anything but straightforward. Ignoring the more complex question of how best to recreate virtually the many sensory stimuli experienced in the real world, a more basic question is simply one of practicality. In vehicle based applications, movement is effected through a proxy, the cockpit instrumentation, whereas in a first person application, movement is effected directly through the individual. While it is a relatively simple task to create virtual, active, models of vehicle interfaces, it is an extremely complex task to do so for the 'human' interface.

There are numerous surrogate control methods which may address this problem. The simplest involve using keyboard entries or a high degree of freedom joystick (i.e., one capable of supporting a wide range of movements including body rotation and translation with independent control of head orientation). At the other extreme, full-body optical tracking enables real movements to be tracked and translated by the VR system either into identical movements in VR (e.g., ducking, peaking around corners, and head or body turning), or into the movements that these 'physical gestures' are meant to represent (e.g., walking-in-place interpreted as walking forward in VR). Intermediate solutions also exist, which, for example, combine real-world orientation tracking (through inertial or optical trackers) with joystick controls for translation. While conventional wisdom suggests that greater fidelity will translate into enhanced training impact, this notion is seldom put to the test and in reality this likely depends on the specific training application as well.

The WHSIL facility is conducting a series of experiments intended to provide a fundamental understanding of the mapping between control system 'fidelity' and the training impact for tasks common to CQB in urban terrain. Rather than test every system available, we have selected representative systems from either end of the extreme. This approach was adopted based on the assumption that if no differences between these extremes were found, then the intermediate solutions would not, in principle, be different either. While it is likely that each control interface may have an impact on the breadth and/or quality of training, it is both necessary and useful to evaluate operator performance capabilities with the designated control systems in a simplistic setting first. If a given system is found to be unable to support roughly the same precision of user movement, then further comparisons become moot.

5.2.2 Multi-Modal Sensory Integration for Training Transfer

Given that VR systems supporting urban ops will be required to provide a much more robust set of sensory information, it is crucial to develop a comprehensive model of multimodal integration in support of enhancing the degree to which VR training enhances real world performance. Within such a framework, one can start to pose research questions in an effort to more fully characterize a comprehensive model for multi-modal sensory integration in support of training transfer. The ultimate goal is to explore these relationships using conventional training transfer studies, combined with a 'sensory knockout' paradigm, in which different levels and types of sensory stimulus are varied, leading to a better of understanding of the relationship between multi-modal sensory integration and training transfer.

Two efforts are currently being pursued. The first focuses on Haptic information – the form of sensory stimulation acquired through collisions with objects (Caldwell, 2000; Durlach & Mavor, 1995). Most VR training simulations essentially ignore the haptic domain, relying instead on the visual domain and to a lesser extent, the auditory one, to provide trainees with the range of information typically encountered in the real world. This approach has been favored in part due to limitations of current technology. Haptic interfaces must render any number of a wide range of sensations (e.g. force, vibration, texture etc) while minimizing restrictions on movement, a synergy of requirements that has yet to be achieved. Currently, haptic interfaces are extremely bulky, have significant latencies, and fail to capture the range of frequencies/amplitudes typically encountered in real world settings.

Yet, haptic cues play a critical role in supporting fully immersive VR systems: during a single training exercise, trainees may repeatedly contact walls, furniture and other objects as well as each other. Additionally, given the un-naturally narrow field-of-view HMD displays currently available, haptic information is even more essential for making the user aware of where, when, and what kind of contact is made with virtual objects outside of their limited field-of-view. In the real world, these collisions provide trainees with critical information that ultimately supports their mental model of the environment; in the virtual one, which lacks these cues, the mental model is consequently much poorer. When supported, training systems in which the haptic information is coupled with visual information show great promise (Merril, 2000). When absent, the lack of multiple-modality information adversely affects the degree to which the VR training enhances real world performance (Cohn, Burns, Helmick & Meyers, 2000; Birch and Bitterman, 1949; Paivio, 1991). Thus, there is great training potential for developing a method for providing this information during immersive VR training.

The system under development will provide haptic information in a manner that is both sensorally meaningful and in synchrony with other virtually represented information modalities. The device will minimally encumber the wearer, who will already be required to wear an HMD and other devices. It will fit comfortably on a range of body sizes and be quick and easy to put on and to take off. It will also be mechanically robust, operating over a range of environmental conditions (temperature, humidity, excessive use) and should not require overly-burdensome power supplies. Finally, the system should provide a flexible application programming interface for device control.

Auditory cues also play a pivotal role in providing trainees with comprehensive training experience (Greenwald, 2002). In order for such cues to be salient when integrated into a VR system, they must be delivered in such a fashion as to preserve both the spatial and temporal qualities of the 'real' cues (Brockhurst, 1995). Since the information extracted by the human auditory system is dependent on the structure of the individual's receiving organ, models supporting the transmission of these stimuli are typically developed based on individual Head Related Transfer Functions (HRTFs) (Kistler and Wightman, 1992). Yet, this is often a laborious exercise, requiring specialized equipment and hours of data collection from each individual. Moreover, a wide range of individuals are expected to utilize these VR systems. In order to support the level of independent operation necessitated by current training needs, a new approach is mandated. This approach must be validated both in terms of the *technology*, as well as the *level of performance enhancement* attributable to the inclusion of this modality. Current research focuses on developing and validating techniques for rendering spatialized audio cues quickly and effectively.

5.2.3 Alternative Visual Displays

Personnel training and mission rehearsal are costly, logistically demanding, and potentially dangerous. VR training systems hold the potential to solve these problems, but have so far fallen short on their promise, in part, because the technologies are seldom truly low-cost or well suited for true deployment. Or, when they are designed to be minimally costly and maximally deployable, the trade-offs made to obtain these gains come at the expense of the types of training that they can support.

High-end VR systems rely on high-fidelity HMDs which alone can cost more than $20,000 each. Even at these high costs per unit, however, these devices offer poor peripheral vision, which may impair the training value for many applications. High-end VR systems also rely upon complex tracking technologies to maintain consistency between the user's movements and movement within the VR. In addition to high cost and fragile calibration procedures, these systems generally demand a large footprint for effective operation. An alternative high-end approach is the use of CAVE technologies. Based on rear-projection systems and advanced tracking technologies, these systems eliminate the problem of limited peripheral vision, however, they remain high-cost, and actually increase the system foot-print. Low-end VR systems can be as simple as desktop displays or single screen projection systems. They offer much lower costs, much smaller foot-prints, and are generally easier to use. However the trade-off for these gains is the lack of an immersive experience, which may impact their training effectiveness for many tasks important to the Navy and Marine Corps.

A largely unexplored middle ground is the use of small-footprint 'wrap-around' video display systems. Such systems may be based on low-tech solutions such as multiple front-projection screens, or a single wrap-around (circular) front projection screen. These systems provide fully immersive experiences with maximal support for peripheral vision and require only one degree of freedom tracking to determine the orientation of the user. These systems are potentially very deployable and easy to use as well. Wrap-around video display systems may thus be ideal for training military tasks that require 360° situational awareness, such as dismounted urban operations and forward air observers. At the time of this writing, the WHSIL facility has plans to pursue a rigorous evaluation of the training values of two different wrap-around video display systems. Experimental evaluation will be made within the context of training for MOUT operations as a model for training in dismounted operational tasks in general. Final assessment of training value will occur within the context of a real-world training transfer experiment and will include an assessment of system deployability (based on system cost, cost to transport, ease of use, and size of footprint).

5.2.4 System-Independent Measures of Team Performance

The primary goal of developing *any* training system is to provide a level of training that translates to enhanced performance on the types of real world tasks being simulated. The principal benefit that VR systems have over real world training is that they offer instructors the chance to train situations that would be too hazardous or too costly to actually practice in the real world. On the other hand, there is currently a lack of effective team performance models, theories, and metrics, which could predict a priori how effective a training system will be before it is actually implemented, as well as inform future development efforts. Further, there is a void of empirical studies that demonstrate team training transfer from VR systems. Given the increasing reliance on VR training systems in military environments, there is a critical need to identify methodologies for the objective measurement and assessment of individual and team performance to ensure that training systems are effective at facilitating the development and maintenance of targeted training objectives and lead to transfer of training back to the operational environment.

Current measures of team performance suffer from a heavy reliance on discrete, subjective (i.e. trained observer) ratings or discrete objective outcome measures. Consequently, these measures may be considered 'derivatives' of true information and, as developed, reveal little about the dynamic processes through which teams respond, evolve and develop. Using the paradigm of Urban Operations, in which small teams ($n \leq 4$) are tasked with a common goal, the members of the WHSIL facility are pursuing numerous methods, stochastic and deterministic, for calculating optimal team behavior in a wide range of settings, including those of imperfect information. This is because maximizing team performance is the key to quantifying team performance across the board, insofar as the behavior of any non-optimal team may be rated by its resemblance to that of the optimizing team.

In control theoretic terms, at each point in time a given team has a set of choices available to it, corresponding to its "control variables." The actual physical changes that result from these control variable decisions determine the spatial, time-dependent characteristics of the team, known as the "state variables." Since a team's primary task is to strategize based on the options available to it and its foes, a team's goal can be reinterpreted in this context as determining its control variables optimally as functions of the state variables. We categorize the wisdom, level of optimality of a respective team's control variable functions by means of a game-theoretic payoff function. In order for a team to be optimal, it must maximize or, depending on the construction, minimize its payoff function over the domain of control, space variables. In addition, the theory assumes initial values for these differential equations, i.e., that at each point in time one has knowledge of all of the state variables involved and that he can thus input the solutions of the differential equations to predict future values. While this is the case in situations of perfect information, in many military and other "games," there is a critical shortage of knowledge regarding enemy position, firepower, and other vital state variable values. Importantly, the hypotheses herein have wider implications beyond the improvement of existing training regimens. Insofar as they engender an algorithm for optimal combat performance, applications of differential game theory ought to play a pivotal role in any attempt to create automaton warriors. Indeed game-theoretic notions have been utilized in applications of artificial intelligence to related fields.

5.3 VR LAB

5.3.1 Mobile Augmented Reality

Many future military operations will occur in urban environments. In principle, many of the difficulties in these environments can be reduced through providing individual combatants with better situation awareness. The Battlefield Augmented Reality System (BARS) is investigating new ways of delivering situation awareness in real-time to the individual combatant in the field. Rather than hold a laptop or PDA, the user wears a see-through head mounted display and a wearable computer. The position and orientation of the user is tracked and graphics are rendered directly in the display, providing heads-up and hands-free access to information. Research in the Virtual Reality Laboratory (VRL) is focused on the issues of developing effective representations, user interactions and hybrid tracking techniques.

5.3.2 Uncertainty Visualization

The "Visualization of Battlefield Uncertainty" is focused on visualizing and analyzing the impact that environmental uncertainty has on active acoustic detection schemes used for ASW target state prediction. Acoustic transmissions, which are used for detecting targets, are subjected to environmental conditions such as internal waves, thermal currents, varying degrees of soil densities (when bouncing off the sea bottom and sea mountains) and surface scatter. Estimates for the environmental conditions are translated into environmental uncertainties such as transmission loss, reverberation level and bounce absorption. These environmental uncertainties are used to better predict locations and headings of targets. The project's emphasis is to develop display and analysis techniques that exploit the underlying characteristics of the multi-value, multivariate environmental uncertainties so that the researchers developing target state estimations can better understand the impact of the environmental uncertainty estimates. Rich-content and easy-to-understand display tools were developed to convey the environmental uncertainty data to research statisticians. Advanced visualization hardware including a 4-wall immersive room was utilized to provide an analysis environment for the researchers to study the statistics. The future direction of the project is to extend the tools and develop capabilities for appropriate end-users (e.g., sonar operators) that allow for early detection and prosecution of threats.

5.3.3 Multi-Modal Interaction

The Interoperable Multi-Modal Interaction and Display System (IMMIDS) system is developing the capability to control several C2 system interfaces with a multi-modal combination of the naturalistic input modalities of speech and gesture. The interfaces include (1) a 2D map-based interface, where the user gestures with a 2D digital pen on a tablet computer, (2) a 3D map-based virtual reality (VR) interface, where the user gestures with a 6 degree-of-freedom tracked flightstick, and (3) a mobile, wearable augmented reality (AR) system, where the user gestures using head orientation, eye gaze orientation, and arm pointing gestures. Typical examples of the types of commands which the system can recognize include: (1) "phase line red <indicate line with ink, or outdoors with pointing gesture>", (2) "there is a sniper in this building <indicate

building with ink mark, or outdoors by pointing>", "mine field <indicate area with ink, or pointing gesture>". Interacting in a naturalistic, multi-modal manner will yield a number of advantages. First, naturalistic input modalities bring the level of abstraction of the human-machine discourse closer to that employed when humans talk to each other. This can reduce the training necessary to use the system, and it can facilitate pervasively-aware interfaces, where the system tracks human-human discourse and provides information relevant to the conversation. Second, multi-modal I/O has a number of advantages over uni-modal I/O. Among the most compelling is mutual disambiguation; this is the property where one modality can correct interpretation errors in another modality. Studies have shown that this property can reduce recognition errors by 45%. Another advantage is that a single modality can be employed when appropriate; for example, gesture only when silence is needed, or voice only when the hands are occupied.

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5.6 WHSIL FACILITIES AVAILABLE

- Four networked, high-end immersive systems
  - Four NVIS Head Mounted Displays
  - Two tracking systems:
    - PhaseSpace Optical Tracking Systems (8 cameras per system)
    - Eight InterSense InterCube2 inertial trackers (2 Cubes per system)
- One Single Screen projection system
  - HP LCD projector
  - Hit Detection System
- Numerous PCs
- Two Kaiser Head Mounted Displays

5.7 VR LAB R&D LABORATORY FACILITIES AVAILABLE

- Immersive Room (CAVE)
- Responsive Workbench
- ORAD DVG 8 nodes Cluster
- SGI ONYX Workstations
- Numerous multiprocessor PCs
- Trackers:
  - Ascension Flock of Bird medium range (magnetic)
  - Ascension Motion Star (wireless)
  - Polhemus Magnetic Trackers
  - InterSense IS900 Trackers (ultrasonic – inertial)
  - Dynasight Optical Tracker
- 6 DOF Motion Stage 0.01 mm 0.1 deg accurate
- Optical See-through displays:
  - Stereo Sony Glasstron
  - Mono Sony Glasstron
  - Stereo Video See-through
  - Microvision Retinal-scanning display

- CyberGrasp/Cyberforce hand and arm force feedback device
- Phantom Haptics Display
- Plasma Screens
- Quantum 3D Termite Wearable Computers
- A variety of Wearable computers / equipment / modules
- Ashtech Differential Kinematic GPS (3DOF position)
- ADU5 6DOF GPS tracker (6DOF position and orientation)
- Video capture and editing hardware

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6.1 AREAS OF INTEREST

Training Simulation Technologies (TST) for Homeland Security – This research area includes the Virtual Emergency Response Training System (VERTS), Dismounted Infantry Semi-Automated Forces (DISAF), Individual Combatant Virtual Simulation, and the Massively Multi-Player Simulation for Asymmetric Warfare Science and Technology Objective (STO).

6.2 CURRENT RESEARCH PROJECTS

6.2.1 Virtual Emergency Response Training System (VERTS)

This program focuses on developing a simulation capability to train First Responder, Civil Support Teams (CST), and Incident Commanders on tasks required to deal with a weapons of mass destruction incident. The VERTS suite consists of fully immersive and desktop simulators for live trainees networked together with a semi-automated force application (SAF). The suite also includes medical simulation capabilities. CST members would be able to train medical tasks on a Human Patient Simulator (HPS).

6.2.2 Dismounted Infantry Semi-Automated Forces (DISAF)

DISAF was developed to add Dismounted Infantry to the virtual battlefield in a realistic fashion. The Infantry capabilities of simulations such as SIMNET SAF and ModSAF have been limited to the low-fidelity viewpoint of tanks. The primary focus of DISAF has been the development of tactical behaviors for Individual through Squad level operations. DISAF is based on the OTB SAF architecture. DISAF includes support for Military Operations in Urban Terrain (MOUT) and rural terrain operations. Most of the DISAF behaviors are based on validated military Combat Instruction Sets (CISs). A database development process was developed to generate Compact Terrain Database (CTDB) Multiple Elevation Surface (MES) structures from visual database files. DISAF supports ‘c7’ terrain with MES capabilities. DISAF provides an enhanced 2D Plan View Display (PVD) to support display of MES buildings and new Individual Combatant (IC) icons.

6.2.3 Individual Combatant Virtual Simulation

This research initiative focuses on overcoming the critical challenges for dismounted soldier simulation by building on the previous efforts in the development and use of virtual simulations. RDECOM is currently working to enhance the capabilities of the Soldier Visualization Station (SVS). The SVS is a PC based, high fidelity, virtual simulation system developed to serve as a training simulator for the small unit leader with a focus on Military Operations in Urban Terrain (MOUT). An acoustic tracking system is used to identify the position/posture of the immersed soldier. The tracking system recognizes sensors located on the weapon and hat worn by the soldier. The SVS operates from a rear-screen projector, a standard PC, and low-cost software. Features include real-time 3D graphics, directional audio, and a unique user interface into the virtual battlefield. The SVS enables the realistic and effective integration of an individual participant into a networked simulation.

6.2.4 Massively Multi-Player Simulation for Asymmetrical Warfare

STO OBJECTIVE – Conduct research and generate technology needed to perform large-scale (massively multi-player (MMP)), persistent (long term), distributed simulation environment operations in support of asymmetric warfare training. Technology will allow Joint and Army Special Operations Battle Staffs and the Psychological Operations Community to engage and counter simulated asymmetrical and conventional warfare operations, interactively, in varying urban settings and realistic scenarios.

The Army lacks a high-level training and analysis capability for long duration, asymmetric missions such as multi-year anti-terrorist operations in Afghanistan and the Philippines. Current training opportunities are focused on conventional warfare and are limited to short duration missions. The objective of this research is to develop a large-scale, persistent, distributed simulation environment to train users for asymmetric threats and conventional warfare in a large theater of operation. The research will also focus on developing tool sets to construct the physical environments and to setup the conditions (economy, religions, social structures, etc.) within those environments. Weapons of Mass Destruction, terrorists' actions, crowd & hostage situations, peacekeeping, psychological operations, and civil affairs will be possible interactions faced by the users. Users will interact with and against numerous people in the environment not against scripted computer intelligence. Armed Forces will be able to engage in such simulation environments anytime, anywhere via the Internet and other communication interfaces. Transition objective is to use the software as a potential front-end simulation driver to a WARSIM / OneSAF exercise.

6.3 RESULTS ACHIEVED TO DATE

- Developed the prototype virtual simulation identified by the VERTS Operational Requirements Document (ORD).
- Transitioned DISAF capabilities to the One Semi-Automated-Force (OneSAF) team for incorporation into OTB 2.0.
- Developed the prototype Individual Combatant virtual simulation identified by the Program Manager Ground Combat Tactical Trainer (PM GCTT) as a likely candidate to satisfy the requirements of Soldier CATT.

6.4 COLLABORATIVE PARTNERS

- Army Research Institute (ARI)
- Army Research Laboratory (ARL)
- Program Executive Office Simulation Training and Instrumentation (PEO STRI)

- Fort Benning Dismounted Battlespace Battle Lab (DBBL)
- Special Operations Command (SOCOM)
- Maneuver Support Center (MANSCEN)

6.5 VR R&D LABORATORY FACILITIES AVAILABLE

- Soldier Visualization Station (Stand up and workstations)
- Mixed Reality MOUT experimental facility
- Various virtual systems that rely on a wearable computer for image generation
- Massively Multiplayer Environment

REPORT DOCUMENTATION PAGE

1. Recipient's Reference	2. Originator's References	3. Further Reference	4. Security Classification of Document
	RTO-TR-HFM-121-Part-I AC/323(HFM-121)TP/62	ISBN 92-837-1136-X	UNCLASSIFIED/ UNLIMITED

5. Originator
Research and Technology Organisation
North Atlantic Treaty Organisation
BP 25, F-92201 Neuilly-sur-Seine Cedex, France

6. Title
Virtual Environments for Intuitive Human-System Interaction – National Research Activities in Augmented, Mixed and Virtual Environments

7. Presented at/Sponsored by
The HFM Panel as a Compendium to the Final Report – TR-HFM-121-Part-II.

8. Author(s)/Editor(s)	9. Date
Multiple	December 2005

10. Author's/Editor's Address	11. Pages
Multiple	280

12. Distribution Statement
There are no restrictions on the distribution of this document. Information about the availability of this and other RTO unclassified publications is given on the back cover.

13. Keywords/Descriptors

AMVE (Augmented, Mixed and Virtual Environments)
Augmented reality
Emerging technologies
Human factors engineering
Human systems interaction
Information processing
Information systems
Information transfer
Man machine systems
Military applications
Military research
Research projects
Simulation
Software development
Technology assessment
Virtual reality
Visualization technologies

14. Abstract

Augmented, Mixed and Virtual Environments (AMVE) are new paradigms and media that provide a realistic training environment and a natural human-system interaction (HSI). This report is an extensive compendium on the military organizations, activities and projects in this field. More than 100 different activities and their interrelationships are described in detail, making this report a source of information for interested persons, researchers and managers in this field.

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