Evaluation of Integrated AFV Fire Control and Defence Concepts in a Virtual Environment

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ABSTRACT

The development and evaluation of new Armoured Fighting Vehicle (AFV) Fire Control System (FCS), Defensive Aids Suite (DAS), and Soldier-Machine Interface (SMI) technologies has traditionally been done on actual vehicles. However, the space and technological limitations of the host vehicle pose significant design constraints, the control of an actual turret and weapons impose costly qualification requirements, and field testing is costly and subject to the availability of suitable ranges and weather conditions. These constraints can be minimised by the use of a virtual environment.

The Advanced Land Fire Control System (ALFCS) is an R&D project to develop, integrate, and evaluate advanced FCS, DAS, and SMI technologies. Capabilities being developed and/or evaluated include automatic target detection and tracking, high-accuracy laser warning, automatic defence, data fusion and exploitation, multi-spectral counter-measures, advanced multi-function displays, reconfigurable controls, and simplified state and mode control.

To evaluate these and other AFV technologies, a virtual environment capable of hardware- and man-in-the-loop simulation was developed. This virtual environment, the Armoured Vehicle Test Bed (AVTB), includes a 6-DOF motion platform driven by sophisticated vehicle models, computer-generated visual and infrared imagery, accurate high-fidelity models of the environment, and models of the sensors and counter-measures required by the FCS and DAS. The entire system is re-configurable, facilitating investigations into alternate host vehicle configurations. The ALFCS project includes extensive design input and evaluation by current armoured vehicle crews. A four-build spiral development process is being used to integrate increasingly-complex systems.

The paper presents an overview of the technical details of the ALFCS virtual environment, and of the FCS, DAS, and SMI technologies under development and evaluation. It details the results of user and technical evaluations of the second of four builds of the project, including the integration of automatic target detection and a basic Defensive Aids Suite. The tactical use of a DAS is also discussed, including the results of a concurrent operational research study.

ABOUT THE AUTHORS

Major Mark Espenant is Project Manager for a number of research and development projects including ALFCS and the DAS series of projects. Major Espenant has been a member of the Electrical Mechanical Engineering branch of the Army for 16 years. He has a BEng in Mechanical Engineering and an MSc in Military Vehicle Technology. He has experience in field maintenance, staff positions, training, and 5 years of project management.

Mr Kris Boyle is a Lead Systems and Software Engineer at Computing Devices Canada, suppliers of Fire Control Systems for a variety of Main Battle Tanks including the U.S. Abrams M1A1 and the U.K. Challenger 2. Mr. Boyle is involved with a number of armoured vehicle projects including ALFCS, DAS, and Vetronics. Kris has a B.A.Sc in Systems Engineering.

Mr Mike Greenley is the Human Factors Manager for ALFCS. He has over nine years experience providing Human Factors analysis, design support, and testing of complex information-based systems, including command and control systems, vehicle layout, AFV fire control systems, AFV full motion simulators, crew served weapons, navigation systems, and nuclear process control systems. Mr Greenley has a BSc and MSc in Psychomotor Behaviour from the University of Waterloo.

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INTRODUCTION

To survive on the battlefield, an Armoured Fighting Vehicle (AFV) must detect and neutralize a threat before the enemy can react. To do so, a future AFV will require quicker awareness of and reaction to threats, better first-round hit capability, improved terminal weapons effects, and improved defence without the mobility penalties associated with increased armour. This can be achieved through advances in fire control and defensive technologies, and improved integration and co-ordination of offensive and defensive capabilities and strategies. New technology is very expensive, however, particularly considering real reductions in military funding. It is critical to determine which new technologies provide the greatest increase in combat capability at the least cost.

The Advanced Land Fire Control System (ALFCS) project will assess improvements possible from new technologies. Concurrently, Operational Research studies will determine the effect of these improvements on battlefield effectiveness. This will help identify technologies that are effective and suitable for further development or for inclusion in future acquisition programs.

Objectives

The aim of the ALFCS project is to

"develop, demonstrate, and evaluate advanced technologies to improve engagement performance and survivability of a future AFV on the battlefield"

The project concentrates on the engagement time, from inter-visibility with the threat to its destruction or neutralization. It does not include battle management or digital mapping, or other fightability aspects; however, portions of these capabilities are included in ALFCS to give a representative crew workload leading up to and during an engagement.

ALFCS seeks to develop, integrate, and evaluate three key technologies:

- ***Fire Control System (FCS)*** - the integrated control of target acquisition and weapon aiming and firing functions;
- ***Soldier-Machine Interface (SMI)*** - the integration of controls and displays for efficient use by a human operator; and
- ***Defensive Aids Suite (DAS)*** - the integration of sensors, counter-measures, and a computer controller for automatic or semi-automatic response to a threat.

Approach

Development and evaluation of FCS, DAS, or SMI technologies would normally occur in a real AFV; however, this has several disadvantages. In ALFCS, the FCS and the DAS controller are real components, but they are being tested and evaluated using a high-fidelity virtual environment, capable of man- and hardware-in-the-loop simulation. Using this virtual environment, called the Armoured Vehicle Test Bed (AVTB, see Figure 4), creates several key advantages for an R&D program like ALFCS:

- ***Host Vehicle Configuration*** - The AVTB is completely re-configurable, which allows the modeling of any current or future vehicle, and avoids the physical and technological constraints of a real vehicle. This also allows an emphasis on SMI aspects and a greater possible range of technical investigation.
- ***Component Robustness*** - Lab-based ALFCS components do not have the same mounting and cooling requirements as they would in a real vehicle, and so are less expensive and quicker to build.
- ***Safety*** - The FCS does not control actual gun or turret equipment, so no qualification testing is required;
- ***Design Responsiveness*** - Due to lower robustness and qualification requirements, and constant user input, the design is easier

and faster to change.

- ***Field Testing*** - A wider range of field testing conditions and tactical scenarios is possible than with a real vehicle, and all testing is completely reproducible.
- ***Cost*** - Due to the elimination of field testing and simplified design requirements, the virtual approach is significantly less expensive.

Using hardware-in-the-loop simulation to develop and evaluate a real system forces the imposition of significant constraints on the development process. It is critical to distinguish between the "truth" information created for the virtual environment, and the sensor inputs the FCS would receive in a real vehicle. In the ALFCS program, the engineering design of the FCS and AVTB is kept completely separate. Different teams work on the two sub-systems, to ensure there is no collaboration on the solution to design problems. It is also critical that all aspects of the AVTB undergo rigorous validation.

Development Process

ALFCS is being developed using a spiral process of four "Builds". The Builds increase in functionality and complexity over the four-year program (see Figure 1). Build 2, incorporating Automatic Target Detection and Tracking (ATDT) and Defensive Aids Suite (DAS) capabilities, is now complete and the design phase for Build 3 is in progress.

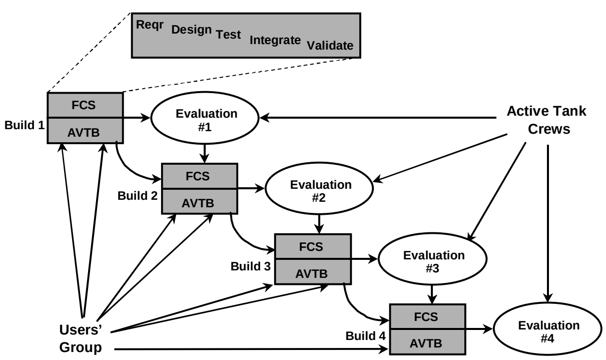

Figure 1 - ALFCS Development Process

Canadian armoured personnel are consulted regularly as part of the design process. At key points in the development cycle the Users' Group provides input to the design process, and Active Tank Crews do formal system performance evaluation at the end of each Build.

Operational Research Study

Early in the ALFCS program an OR Study was done to determine the relative effects of improvements in accuracy and speed of engagement on the survivability of an AFV equipped with ALFCS. The study, using the software *Janus*, was designed to indicate where the emphasis should be placed in ALFCS development. The results clearly showed that improving engagement time had a much more significant effect on AFV survivability than did a corresponding increase in accuracy.

Further OR studies will be done later in ALFCS to verify the impact of improvements in performance.

TECHNICAL OVERVIEW

Figure 2 shows the key components of the AVTB and FCS that make up ALFCS, with arrows showing the flow of information between components.

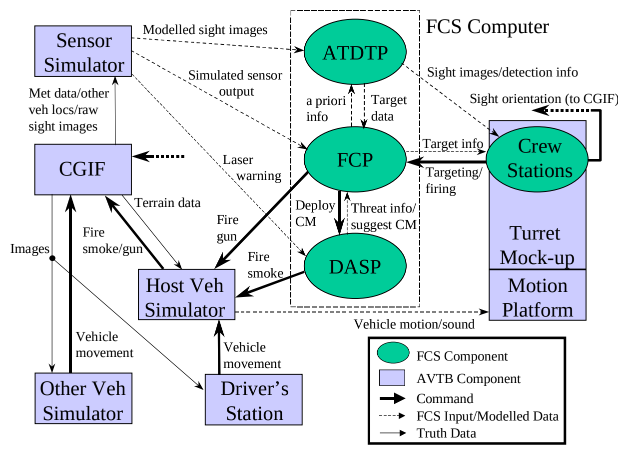

Figure 2 - ALFCS System Components

Fire Control System

The ALFCS FCS is a real component that could, with suitable testing and militarization, be installed in an AFV. It acts on the various simulated inputs, which are both physically and logically representative of real equipment. The FCS includes ATDT, improved ballistics models for predicting the flight of the round, Line of Sight/Line of Fire coincidence determination, a modeled battlefield combat identification system, and diagnostic and calibration functions. The FCS is composed of an FCS Computer, two Crew Stations, Fire Control Sensors, and an integrated DAS capability.

FCS Computer. The FCS Computer manages the activities of the fire control system. It incorporates a Fire Control Processor, an ATDT Processor, a DAS Processor, and analog and digital interfaces.

Crew Stations. An extensive Human Factors engineering effort is integrating equipment, controls, and tasks, to significantly improve crew performance during an engagement. The Crew Station includes an LCD flat-panel sight display and tactical panel (see Figure 3), control panels with programmable buttons, and multi-function control handles.

Figure 3 - Crew Station

Sensors. In a real system, the sensors are part of the FCS; in this case the inputs to the FCS must replicate the information supplied by the sensors. The sensor models are part of the virtual environment in the AVTB.

Defensive Aids Suite. A real computer controller is integrated with the ALFCS FCP and SMI, and interacts with a modeled laser warning receiver and multi-spectral screening smoke grenades.

Armoured Vehicle Test Bed

The AVTB is a full-motion virtual environment to allow demonstration and evaluation of the FCS and SMI (see Figure 4). The aim of the AVTB is to make the FCS and crew believe they are on the battlefield by accurately reproducing FCS sensor inputs and sound, motion, and visual cues.

Figure 4 - AVTB

Computer-Generated Imagery Facility. The Silicon Graphics 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 must be 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 (slightly less than 1g) 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 crew member. This capability enables efficient crew debriefing, precise evaluation of the SMI aspects of ALFCS, and objective evaluation of FCS performance.

Human Factors Engineering

A key to meeting the aims of ALFCS is extensive human factors analysis during the design and evaluation process. Human Factors engineers have input into all aspects of ALFCS, including tasks in functional analysis, SMI design support, workload modeling, Users' Group and lab evaluations, and applied human factors research.

RESULTS OF BUILD 2

New Features

Several of the features included in Build 2 are new to ALFCS or to the Canadian armoured corps. This section outlines these features and presents conclusions about their functionality. The SMI aspects of these and other ALFCS features are presented in the following section.

Auto Target Detection and Tracking. Several algorithms for ATDT have been developed, including *contrast detection* and *motion detection*. A stabilization algorithm is also being developed for cross-country operation. For Build 2, problems with the stability of the motion detection algorithm prevented its use, so ATDT was implemented with only the contrast algorithm.

Targets detected by ATDT are indicated on the sight display as diamonds, with the target nearest the reticule indicated by an open square (see Figure 5). Pushing the "Track" button on the control handles causes the sight to move to and track the nearest target. When the target is being tracked automatically, the "Aim Point Bias" feature adjusts the aim point on the target by pushing a button and moving the control handles.

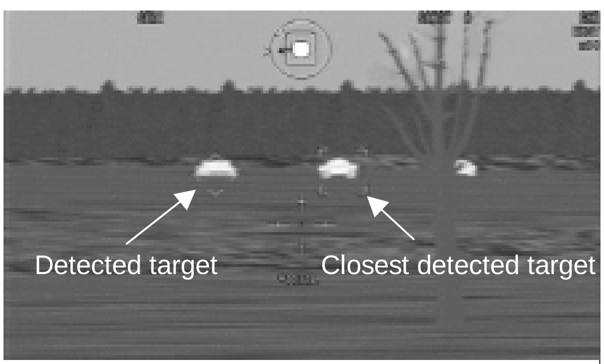

Figure 5 - Automatic Target Detection

The Build 2 ATDT implementation had some problems:

- The contrast algorithm picked up targets, but also tree lines and other areas of high contrast.
- The ATDT smoothly tracked the target, but the gun did not always smoothly follow the ATDT due to a problem with the control loop.

Although ATDT could not find targets that were invisible to the eye, it frequently was able to do so faster. It was also much faster than a human operator in moving the point of aim onto the nearest target, particularly on a moving target. Typically, the crews would use "Track" to move the reticule onto the target, then see how well it tracked. If ATDT tracked the target well, they would fire while in AutoTrack. If not, they would revert to manual tracking.

In general, ATDT was seen by the evaluation crews as having great promise if it can do a better job of discriminating targets from terrain, and reliably provide a stable track of moving targets. The motion detection algorithm will be installed for Build 3, and the control equation between the ATDT and gun-control equipment will be refined.

Defensive Aids Suite. Build 2 includes a basic DAS, consisting of:

- a Single Card Processor from Tracor Aerospace;
- modeled multi-spectral smoke in six banks of 60 degrees each, covering the front 240 degrees of the vehicle (see Figure 4); and
- a modeled Laser Warning Receiver based on the HARLID$_{TM}$ laser detector, with +/-1 degree resolution in azimuth and 180 degree coverage (see Figure 6)[1];

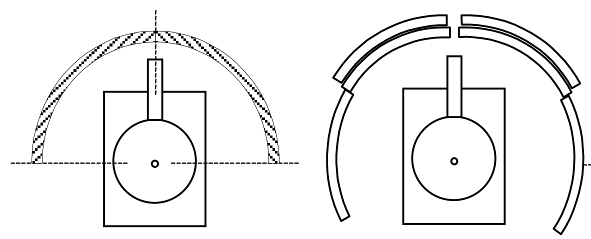

Figure 6 - LWR (L) and Smoke (R) Coverage

The DAS responds to a threat in three modes:

- Manual - a warning tone sounds over the intercom, and the threat direction is indicated in the sight display (see Figure 7). The crew can push "Align" to align their respective sights/gun to the threat. Pushing "Salvo" fires the bank of smoke closest to the threat.

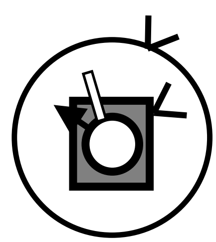

Figure 7 - DAS Indicator showing two threats

[1] 180 degrees was a limitation of using a single SCP; 360 degrees would be required in a real system

- Semi-auto - as above, plus the commander's sight is automatically turned to the threat direction and his ATDT turned on. The gunner can use "Align".
- Automatic - as above, plus the optimum bank of smoke is automatically discharged.

The Lab Evaluation of DAS was very positive. Crews surprised themselves by deciding they liked having a system to automatically protect them if necessary. The Usefulness and Ease of Use ratings for DAS were very good, quite unusual for a brand-new concept. Objective survivability data showed that, in all combat scenarios, the vehicle was much more likely to survive with DAS active.

Automatic was the preferred mode for offensive operations, due to the likelihood of being lased by a threat you don't see. Semi-auto was preferred for defence, when crews were more concerned about giving away their position. There were no situations in which they preferred Manual mode.

The smoke is modeled in 6 banks, doubled in the frontal arc, to avoid having to rotate the turret to fire smoke in the direction of the threat. Of course, the nearest available bank may not be optimum, particularly if the dischargers have not been replenished. This could be solved by invoking automatic turret rotation; however, crews are unanimous that they don't want to lose control over the gun in (potentially) the middle of an engagement. This could also be solved by using a mini-turreted smoke dispenser.

The modeled $HARLID_{TM}$ laser receiver is among the best performers in the world. Interestingly, however, there were times when even +/-1 degree of threat resolution wasn't good enough, particularly in a narrow field of view. If the target is not in the sight picture when the sight finishes automatically slewing to the threat, significant time may be required to find it.

Two-Person Turret/Panoramic Sight. ALFCS has a commander's panoramic sight, which is stabilized and capable of independent 360 degree rotation. For most Canadian crews involved in the evaluations, this was their first experience with hunter-killer operation, which gives much greater autonomy to the gunner. In addition, with only two crew members in the turret, the necessary tasks had to be reallocated between them. These changes in task allocation and roles have had significant effects:

- The requirement for crew coordination is greater than in a conventional turret, and the rank division between commander and gunner less obvious. This has resulted in recommendations about training requirements and, potentially, changes to crew rank structure.
- The division of tasks could results in greater crew loading. This demands increased emphasis on Human Factors, with careful consideration of the task flow and methods to automate or simplify tasks.

The panoramic sight requires a means of indicating to the crew the location of the gun and commander's sight relative to the hull. This is provided on the crew sights by the icon shown in Figure 7. Crews have been very enthusiastic about this icon, and would even like to see it on their current tanks without panoramic sighting!

Relaxed View Sights. A typical AFV has optical sights, requiring the crew to brace against hard-mounted brow-pads. Unlike with brow-pads, the ALFCS relaxed view sight displays (see Figure 3) do not appear to degrade crew detection and engagement performance, even during extreme cross-country motion. In addition, the full range of protective clothing and equipment (cold weather or NBC gear) can be worn without performance degradation.

Integrated Control Panel. All displays and controls for the advanced fire control system (including autoloader, ATDT and DAS) are integrated in a single control panel. Early in the project the panel contained 47 buttons, not including DAS. Through the spiral design process, with structured user participation, the SMI has continually been refined to support the critical user task flow during engagement and threat response sequences. As a result, the current panel contains only 39 buttons, *including the new DAS functionality*.

As an example, the control array for the autoloader has evolved from 11 to 7 buttons, while significantly streamlining the task flow associated with start up, switching weapons and ammunition in battle, and shut down (see Figure 8). In addition, novel display feedback has been integrated in the sight display to continually keep the crew informed of weapon status.

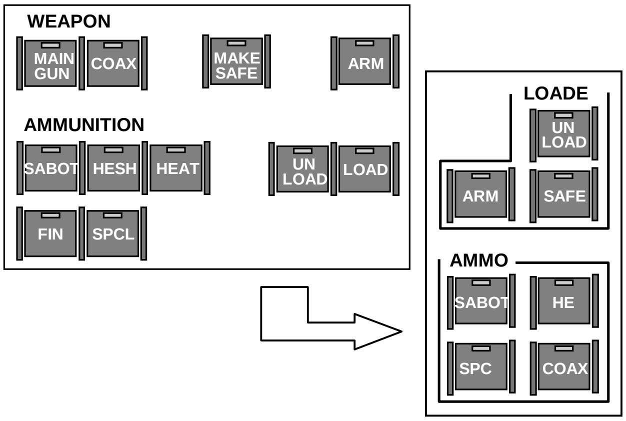

Figure 8 - Autoloader Before (Left) and After

Multi-Function Control Handles. With the ALFCS control handles, the crew can operate critical features without removing their hands from the handles. The arrangement of controls has evolved throughout the project, with the latest version providing access to Override, Auto Track, Lase, ATDT Aim Bias Adjustment, Mag Selection, and View Other (see Figure 9). The priority and location of these devices is based on critical task demands, established through task flow analysis, and confirmed in user trials. User response to the location and operation of the switches has been very positive; however, the control handle response characteristics require tuning to meet user requirements for fine aim and manual tracking capability.

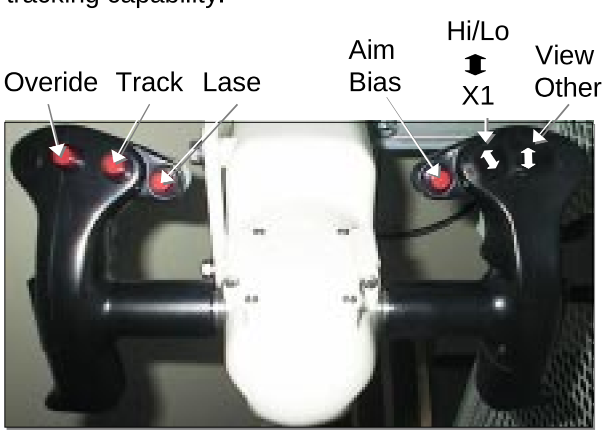

Figure 9 - Multi-Function Control Handles

Override and View Other. These features are provided to improve the efficiency of the hunter-killer team:

- Override. Normally the commander is in control of his sight and the gunner in control of the Line of Fire (LOF). The commander presses "Override" to take control of the LOF, and the gun (and gunner's sight) automatically moves to coincidence with his sight in elevation and azimuth regardless of sight magnification. He can then relinquish control to the gunner to complete the engagement.
- View Other. Either crew member pushes "View Other" to view the other's sight image. While using View Other, the crew member's sight stays in its previous location.

The crews find these features essential to the speed of a hunter-killer engagement. If the commander finds a target first, he normally calls it to the gunner while simultaneously pushing "Override". Once the commander verifies that the gunner is on target, he leaves him to shoot while he looks for other targets. This is much faster than "talking" the gunner onto a target by reference to terrain features.

If the gunner finds a target, he calls it to the commander, who pushes "View Other" to confirm the target and order the gunner to fire. View Other is also useful for designation of arcs of fire or other tasks that require one of the crew members to indicate a feature in the sight image to the other.

Image Enhancement. The visual or infrared sight image is electronically enhanced for greater clarity. Figure 10 shows a typical image before and after noise reduction and image enhancement.

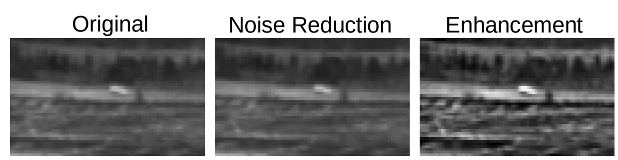

Figure 10 - Effect of Image Enhancement

Technical Results

ALFCS is using many different technologies to create the virtual environment, and to develop and test the new FCS features and SMI. The following paragraphs detail conclusions about the technical suitability of the technologies used and the results of their integration.

Hardware-In-The-Loop Simulation. Using a simulated environment to evaluate and prove concepts brings a number of advantages to the system design and development process, as listed on page 1. However, including the target hardware in the simulation loop brings a number of constraints to the design process:

- Interfaces between the target hardware and the simulated components must be considered carefully, as it is not always possible to simulate the exact physical characteristics of a component. This requires implementing the interface in a manner that is representative of the interface and of the data being transferred across it. The design team must ensure that the interface does not provide additional information or a relaxation of requirements that could allow the target hardware to perform in a manner that would not be possible in the final configuration.
- Control loops between the target hardware and the simulation must be paid particular attention. It is not always possible for the simulated components to react in the same time-deterministic manner as would a real component. This is due to the fact that the simulation generally runs in a non- or near-real-time software environment such as Unix.
- Capabilities of the target hardware with which the users are already familiar must be implemented to a fidelity level that allows the user to accept them as the real thing; otherwise, acceptance of new features can be seriously affected. For example, users have complained that the control handle response is not as good as real systems they are currently using, which has impacted their acceptance of the system as a whole.

Build 2 included a perfect example of the advantages of hardware-in-the-loop simulation. Technical difficulties precluded integration of the DAS Single Card Programmer CCA. The decision was made to simulate this component rather than delay the build evaluation. Due to the simulated environment, it was possible to implement this in a manner that did not require any changes to the software or hardware of other components. The evaluation proceeded as originally scheduled, including evaluation of the DAS functionality, even through the CCA had been removed from the target hardware. On a system that was not being evaluated through simulation, this situation would have resulted in significant delay to the evaluation, and significant costs associated with rescheduling a field trial and delays in the project.

Man-In-The-Loop Simulation. Consulting the final users of a system in the design process is not new. However, man-in-the-loop simulation allows the users to experience how the system operates under a wide range of expected conditions, and the design team to evaluate the advantages and disadvantages of features under the conditions in which they would actually be used.

This has had the advantage in ALFCS of showing that simple system concepts can sometimes provide greater benefits to user performance than more complex ones. An example is "View Other", which allows one crew member to view the sight image of the other. This was a very simple capability to implement in the system, but provided a significant improvement in user performance. The man-in-the-loop approach also ensures the system will only include capabilities that the end users regard as useful, which has the potential to reduce the final cost of a developed system.

Simulation Technology. The experience of ALFCS has been that simulation technology is generally mature, but has required additional effort to make it fit a ground vehicle environment.

The availability of terrain databases of sufficient fidelity to represent the visual and physical aspects of a simulated moving vehicle is limited. For realism in the ground environment, the visual database must provide a higher level of detail at shorter ranges than is required for other applications. There also must be sufficient detail at medium ranges to allow the users to judge the distance of objects that are presented. ALFCS also provides simulated vehicle motion through the visual terrain, and the correlation of the vehicle ride and the visual presentation of the terrain type is critical.

There is a natural tendency to try to improve the fidelity of a simulation so it appears exactly like the real thing, particularly when used for training purposes. The use of a simulator in evaluating design concepts, however, allows this requirement to be relaxed to some degree. It is important to implement the simulation to a level of fidelity that allows concepts to be effectively evaluated, without spending additional manpower and hardware resources on a higher fidelity level that provides little or no additional data.

The selection of simulation system components is critical to the time, effort, and success of the system. ALFCS has focussed on using, rather than developing, simulation technology, allowing effort to be expended in areas directly related to program goals instead of creating an infrastructure to support system development. The two key simulation components are:

- SGI Onyx2 InfiniteReality. This industry-standard platform for visual simulation has proven well-suited to project goals. It has the processing capability to support most of the simulation modeling, as well as providing the required visual fidelity for crew sight images and additional views to allow the simulated vehicle to be maneuvered in the terrain. Additional processing capability is being added to implement increased simulation fidelity and functionality for later builds.
- Fokker Control Systems Motion Platform. The electrically-driven 6-DOF platform has proven well-suited to ALFCS needs. It easily supports the payload of the turret mockup while providing the requisite range of motion and acceleration to provide realistic motion cues. The platform incorporates front-end processing that allows the ALFCS simulation to provide the desired mockup accelerations, the platform processor controls platform movement to result in those accelerations being felt by the users inside. This has removed the need for the simulation software to directly control the platform.

Human Factors Results

A key part of ALFCS is the creation of a new SMI to improve the crew's ability to effectively perform battlefield tasks. The enhanced SMI integrates the displays and controls for a number of subsystems in support of a two-person crew with autoloader.

To date, the ALFCS design has been evaluated in four User Groups and two Lab Evaluations. In combination, this has provided about 87 Crew Days (one Crew Commander-Gunner pair spending 8 hours at the ALFCS site) of experience with the design, of which approximately 67 Crew Days has included simulator trials.

The following paragraphs detail results of the Human Factors activities, and conclusions concerning SMI techniques, interface technologies, and the impact of advanced systems on crew structure, training and doctrine.

Project Success Factors. Human Factors is an integral part of the ALFCS “user-centred” design methodology. The user-centred methodology has contributed toward a number of project success factors, including:

- Enhanced Customer Relations. Frequent interaction with the user community allows the engineering team to resolve requirements and design issues. This has reduced demands on project managers from DND and industry to debate and resolve such issues.
- High User Buy-In. Human Factors team interaction with AFV crews in the field, at simulator training exercises and live fire gun camps, and during project user groups and lab evaluations, has resulted in a high level of support for ALFCS in the AFV community.
- Human Systems Integration (HSI). HSI is the technical process of integrating human engineering, manpower, personnel, training, systems safety, and health hazards in a materiel system to ensure safe, effective operability and supportability. HSI principles are being fully applied within a Simulation-Based Acquisition context, allowing doctrine, crew task distribution, and training to be optimized.
- Valid Performance Measurement. The ALFCS Lab Evaluations use realistic operational scenarios based on AFV community input and analysis of their training operations. This range of input has ensured that participants relate to the evaluation, and that the selected performance measures are based on sources in AFV and human factors literature.

Enhancements of Task Performance. A number of the SMI features have enhanced human task performance. The support these features provide to the crew can be categorized in the following areas:

- Improved crew communication, co-ordination, team task flow, and situational awareness is provided by the capability of the commander to Override the gunner's control of the Line of Fire, the View Other feature that allows either crew member to view the other's sight picture, and the Line of Sight/Line of Fire icon at the top of the sight picture that allows each crew member to orient themselves in relation to the hull and to each other (see page 5 and 7, Figures 7 and 9). The combination of these features reduces the time for a Commander to orient a Gunner to a new target and, to a greater extent, reduces the time for a Commander to confirm a Gunner-detected target and provide the direction to engage.
- Automation of challenging tasks with the ATDT system and DAS features. While ATDT

requires further refinement to meet its potential to help the crew, it currently has high utility for the user in tracking moving targets. On the other hand, DAS allows the crew to detect and immediately orient to a threat vehicle, a task which a human is incapable of performing in the timeline required.

- <u>SMI integration and enhancements of complex operating systems</u> has been realized through the relaxed view sights, integrated control panel, and multi-function control handles. These allow the crew to perform more tasks quicker and with less effort by concentrating their attention on critical items and simplifying necessary control manipulation.

Performance Measurement. Engagement speed and accuracy is objectively measured during User Groups and Lab Evaluations using an integrated Performance Monitor. The automatic measurement of speed and accuracy data has permitted continual comparison against project goals and against the engagement performance of other NATO systems (based on firing table data), providing the design team with the information required to focus on design enhancements. For example, Figure 11 illustrates a decomposed engagement timeline for a Static Own Vehicle (SOV) – Moving Target Vehicle (MTV) engagement. The largest portion of the timeline is from Detection of the target to 1st Lase; this time

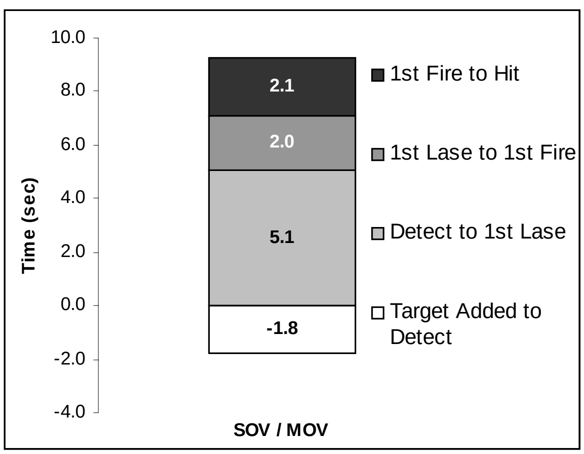

Figure 11 - Engagement Timeline Data

can be improved through control handle tuning and improvements to the ATDT system to help the user get the cross hairs on the target faster (which would decrease Lase to Fire time as well). Therefore, control handle tuning and ATDT system development will continue to be a focus for the project.

User Acceptance Measurement. "Usefulness" and "Ease of Use" are subjectively rated by questionnaire during trials. This provides a metric of future user acceptance of the ALFCS design, and aids in design decisions (for the following examples, see Figure 12). The positive impact of Override and View Other on task performance is cross validated by high utility and ease of use ratings. Some features, such as ATDT, are consistently rated as having high utility but low ease of use, which emphasizes the need to focus on ATDT in future build cycles. Other features, such as DAS Manual Mode are rated as low utility and low ease of use and are therefore candidates for deletion from the system. Finally, there are areas such as control layout or the design of the DAS SMI which are consistently high in utility and ease of use, allowing the design efforts in these areas to relax, and validating the user-centred design process to date.

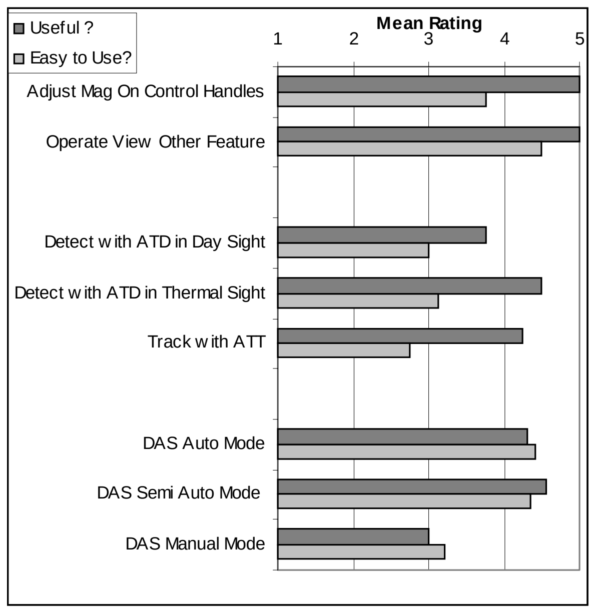

Figure 12 - Example User Acceptance Ratings

Doctrine, Training, and Crewing. Evaluation and measurement of the new features in a simulated environment has permitted insights into issues beyond SMI design, and has resulted in a number of lessons about simulation-based design and evaluation from a human factors perspective.

Evaluations of the advanced FCS in a two-person turret with autoloader show that the introduction of such a system changes crew roles. The gunner acquires increased responsibility to manage the gun and ammunition (compared to a three person turret with loader), increased responsibility in target detection and identification, and increased responsibility in determining the end of an engagement (with hunter-killer drills). The gunner is also required to understudy the commander more, and be available to support command, control, communications, and navigation as required, in addition to "fighting the tank". In combination, these changes suggest an increased future gunner training requirement, and potential changes in rank level to go with the added responsibility.

The ALFCS program has required the development of drills, doctrine, and a training program in parallel with the design. This has permitted evaluation of future concepts in the simulator that would otherwise be very difficult. The simulated environment permits extensive evaluation that would not be possible in other ways, but in a development program there is also increased variability that demands cautious comparison between trials. For example, each set of enhancements to the FCS and the AVTB alters the configuration of the environment, the visual conditions, terrain, enemy vehicle behaviour, and own vehicle behaviour. However, this variability can be accommodated in the experimental design by ensuring that "like" conditions occur. Integration of MODSAF enemy force modeling in future versions of ALFCS will introduce more complexity in these areas, with focus necessary on being able to "repeat" scenarios between crews for comparison.

It is also important to control for changes in doctrine. For example, executing one evaluation with narrow arcs of responsibility for the test vehicle, and then doubling those arcs for future trials, make FCS design comparisons difficult. Controlling for these changes is important, while continuing to support the positive aspects of being able to continually evaluate enhancements to all aspects of the hardware, software, training, and procedures.

FUTURE FEATURES

There are two remaining builds in the ALFCS program, in which the existing features will be added to and refined, and the fidelity of the virtual environment improved. In particular, the following additions will be implemented:

- Other types of ammunition in addition to the current sabot, which involves amending the ballistic solutions and the simulation of the rounds.
- Manual range selection, in addition to the current laser.
- Surveillance capabilities that will automate the scanning of an area and immediately move the turret to pre-defined points.
- A wide-angle viewing capability that will simulate a camera scanning 180 degrees, for good heads-down situational awareness.
- An improved and enlarged terrain database for a greater range of possible tactical scenarios.
- A simulated battlefield combat ID system. The main purpose of this feature is to add suitable complexity to the engagement timeline.
- Use of the second display screen for a tactical panel with vehicle calibration and diagnostics, and limited navigation and tactical information. Future development will also include a moving-map.
- Three "other vehicle" stations for live operation of other vehicles on the battlefield, which could be enemy vehicles or the other members of an ALFCS "troop".

CONCLUSION

The ALFCS project relies heavily on simulation to develop and evaluate advanced fire control and defensive technologies. The first 2 1/2 years of the program, through the second of four builds of a spiral development process, have shown that the distinct advantages theorized for the use of human- and man-in-the-loop simulation are paying significant benefits.

Evaluation of the key AFLCS technologies has been very successful. Fire control enhancements, particularly in the soldier-machine interface, have resulted in significant improvements in crew effectiveness and engagement speed. The defensive aids suite has been very well accepted by evaluation crews, and has demonstrated significant gains in vehicle survivability.

The remainder of the ALFCS program will concentrate on improvements to fire control and simulation technologies already implemented, and on more precisely quantifying the effect of the key technologies. This, and the potential use of the ALFCS platform for other research and development programs, promises an exciting future for the Canadian Army R&D program.