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Advanced Vetronics Architecture for a Net-Enabled Combat Environment (ADVANCE) Technology Demonstration Human Factors Engineering (HFE) Definition Project

Human Factors Engineering Program Plan (HFEPP) Final Report

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Greenley & Associates

Contract Scientific Authority:
R.H. Chesney
DRDC Suffield

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Contract Report
DRDC Suffield CR 2006-225
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Advanced Vetronics Architecture for a Net-Enabled Combat Environment (ADVANCE) Technology Demonstration Project

Human Factors Engineering (HFE) Definition Project

Human Factors Engineering Program Plan (HFEPP)
Final Report

Completed by:

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DAVPM 8-4-4

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1 Introduction

This document is an Interim Report for a project entitled "The Advanced Vehicle Architecture for a Net-Enabled Combat Environment (ADVANCE) Technology Demonstration (TD) Human Factors Engineering (HFE) Definition Project. The purpose of this Interim Report is to detail the future Human Factors Engineering (HFE) components for the implantation stage of the ADVANCE TD project in a Human Factors Engineering Program Plan (HFEPP). Human Systems Integration (HSI) work elements are included in this plan. This report is submitted by Greenley & Associates Incorporated (G&A) of Ottawa, Ontario, Canada in support of Public Works and Government Services Canada (PWGSC) contract No W7714-030816 Task Number 2005-165.

1.1 Overview

The ADVANCE TD was implemented to design and evaluate a series of advanced vehicle concepts such as the integration of a multi-layered Vetronics network and a fully Active Suspension to exploit the potential of a Vetronics architecture in the network-centric battlefield of the Army of Tomorrow (AoT). The ADVANCE project is currently in its Definition Phase; this phase requires the development of a HFEPP to present the HSI activities to be completed in the future stages of the project. The HSI activities include: verification of user and technical requirements, analyses of crew functions and tasks, design input to the development of the Soldier Machine Interface (SMI), and the planning and conduct of experimental trials involving users to evaluate the proposed ADVANCE technologies. The plan also provides guidance for incorporating Training, Safety, and Health Hazards in the ADVANCE TD.

1.1.1 Background to the ADVANCE TD

Military vehicles include numerous electrical and electronic systems that are controlled and monitored by the crew. In current vehicles, system control and monitoring is facilitated by standalone user interfaces (UIs) that are specific to an individual sub-system. As vehicles became more complex, the number of standalone controls and displays has increased. Combat vehicles also include a variety of optical systems, which are used by the crew for driving, local situational awareness (SA), surveillance and target acquisition. Furthermore, recent net-enabled operations allow a considerable amount of information in relation to the crew's environment (e.g., own vehicle position, systems status, contact detection, etc.) to be available through both internal and external sources. Net enabled operations also allow information to be available to dismounts, other nearby vehicles, and the Command and Control (C2) system.

Modern vehicle systems integration (Vetronics) is based on distributed control and network connected sensors and communications systems which provide the ability to integrate all vehicle functions through a common Operator-Machine Interface (OMI). This interface is also exploited to support other combat functions including communications and command and control. However, the integration of information on a single OMI may become too complex for a crew member to efficiently operate, especially during high stress situations, as well as during sustained operations when the crew is fatigued.

To achieve the most simplistic OMI, the crew workstation and the OMI software must be designed with a comprehensive understanding of: crew characteristics, crew task requirements (e.g., priorities, schedules, times and type) and the operational environment. Requirements must be categorised and prioritized to develop simple and effective interfaces that will facilitate the crew in maintaining situational awareness and in rapidly responding to combat threats.

Furthermore, designing a common crew station can decrease individual training across multiple vehicle platforms for common functionalities.

Though the Vetronics architecture could potentially integrate a very large subset of components both on and off a vehicle platform, the resources and time available for the ADVANCE TD are limited. Therefore, some non-critical network functions will be emulated rather than implemented using actual hardware. The components that could feasibly lend themselves to emulation, while preserving the requirements of the demonstrator must be determined, along with their associated costs, schedule and integration risk.

1.1.2 Overview of the ADVANCE TD

The ADVANCE TD aims to demonstrate improved crew performance through a completely integrated multi-layered Vetronics network, whereby all subsystems are accessible from any node on a vehicle. System controls and displays may be integrated and shared among each crew member's workstation, and through the Land Command Support System (LCSS). Information from the Vetronics system may also be accessible from external platforms. The C2 system, other vehicles, dismounts and unmanned aerial and ground vehicles (UAVs/UGVs) may be able to receive data and commands through the Vetronics network. The project also aims to design a system that facilitates diagnostic and prognostic evaluation from the same interface ports to increase maintainability.

A secondary objective of the TD is to develop and integrate a fully Active Suspension to exploit the potential of the Vetronics architecture and to demonstrate the benefits of a stabilized and levelled platform.

This project will provide information to a number of ongoing Major Crown Projects, which have identified the requirement to conduct mobile surveillance and engagements from combat vehicles that are currently limited to static applications. It is envisaged that Active Suspension will significantly increase the effectiveness of the crew, while reducing the impact of vibration and mechanical shock on the vehicle and cargo.

The ADVANCE TD is not focused on designing technical solutions and crew interfaces for a single vehicle configuration. The project focuses on developing crew interfaces that can be readily adapted and reconfigured to a broad range of roles and vehicles, as well as to provide support to these roles and hardware configurations that may evolve over time. As a result, it must be determined which tasks will be required in a particular configuration. Furthermore, the workstation interface must be generic and adaptable to multiple functions through software re-configuration.

1.2 Aim

The aim of the HFEPP is to:

- Describe the overall Human Factors (HF) program for the implementation stage of the ADVANCE TD;
- Describe specific HSI elements within the program, including Human Factors, Training, Systems Safety (SS), and Health Hazards (HH); and
- Explain how the elements will be managed to provide timely input to influence the system design.

1.3 Scope

The HFEPP ensures that:

- System design is based on a user-centered *Mission, Function, and Task Analysis (MFTA)*;
- The design of the *Soldier Machine Interface* is based on user requirements and human performance requirements derived from the MFTA;
- The design of the *Soldier Machine Interface* is subject to evaluation through a combination of *User Groups, Field Demonstrations, Laboratory Evaluations,* and possibly *Virtual Simulation* throughout the project;
- The design of the *Soldier Machine Interface* is subject to evaluation by *Subject Matter Experts (SMEs)* after each significant iteration (i.e., build) of the system during the project;
- The evaluation of Active Suspension will include a combination of *User Groups* and *Field Demonstrations.*
- The *Measures of Performance (MOPs)* and *Measures of Effectiveness (MOEs)* used for evaluation of critical tasks are based on the MFTA;
- The *training material* provided to participants during the User Groups, Field Demonstrations and Laboratory Evaluations is based on the MFTA and on the system's design.
- *Personnel characteristics* are considered when identifying SMEs for the User Groups, Field Demonstrations, Laboratory Evaluations, and Virtual Simulation; and
- *Safety* and *Health Hazards* are considered throughout the development and design of the ADVANCE technologies.

The relationship between the activities described above is illustrated in Figure 1

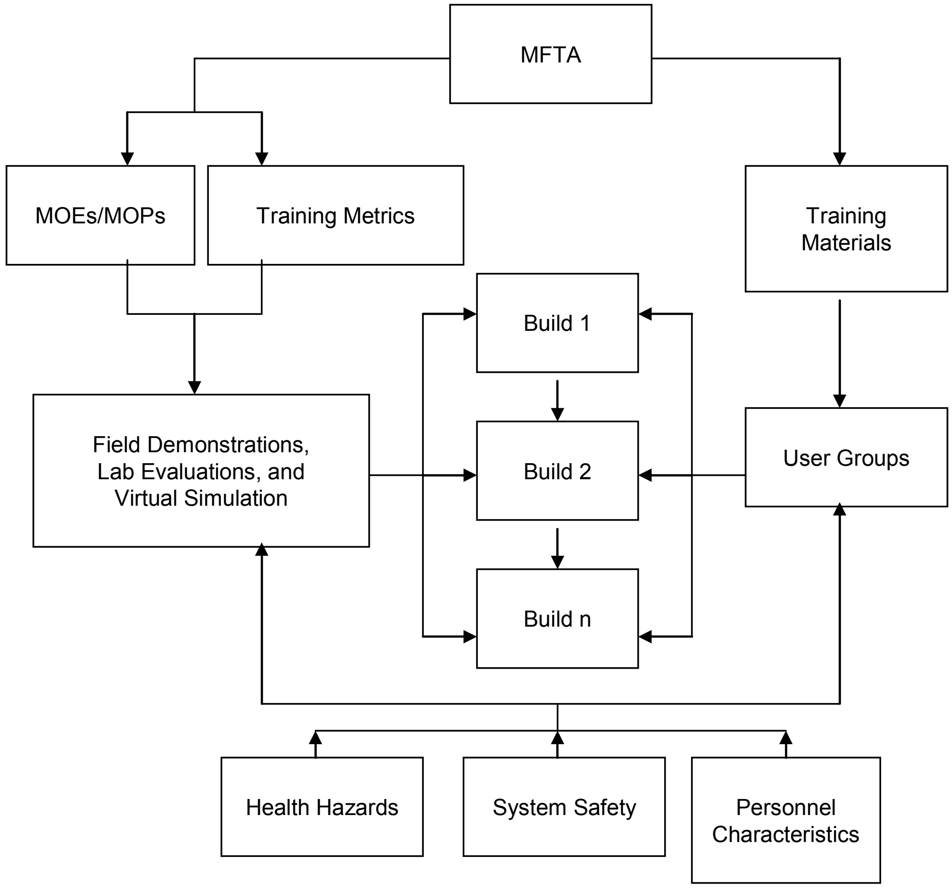


Figure 1 - Organization of Activities during the ADVANCE TD Project

1.4 Applicable Documents

- MIL-STD-1472F. *Human Engineering Design Criteria Standard*, 2003/12/05.
- MIL-HDBK-46855A. *Human Engineering Program Process and Proce*dures, 1999/05/17.
- MIL-HDBK-1908B. *Definition of Human Factors Terms*, 1999/08/16.

1.5 ADVANCE TD Reference Documents

- Espenant, M.., Scipione, A., Armstrong, J. & Brooks, J. (2006). *ADVANCE HFE Definition Project: Stakeholder Control Document Rationalization.* ADVANCE Interim Final Project Report to DAVPM 8-4-4.
- Espenant, M., Scipione, A., Armstrong, J. & Brooks, J. (2006). *ADVANCE HFE Definition Project: Experimental Plan.* ADVANCE Interim Final Project Report to DAVPM 8-4-4.
- Scipione, A., Armstrong, J., Brooks, J. & Espenant, M. (2006). *ADVANCE HFE Definition Project: Mission, Function, and Task Analysis.* ADVANCE Interim Final Project Report to DAVPM 8-4-4.

- Scipione, A., Armstrong, J., Brooks, J. & Espenant, M. (2006). *ADVANCE HFE Definition Project: User Requirements.* ADVANCE Interim Final Project Report to DAVPM 8-4-4.

1.6 Document Structure

This document is organized to reflect the Human Systems Integration components during the ADVANCE TD project including Human Factors, Safety, Training, Health, and Personnel. The project plan has the following structure:

- Introduction: Presents the background to the ADVANCE TD. This section also provides an overview of the scope and aim of the project plan, as well as the documents that were referenced during the plan's development;
- Human Factors: Human Factors support is categorized according to Systems Analysis (i.e., MFTA, MOE and MOP development), and the detailed design of the Soldier-Machine Interface.
- Safety and Health Guidance: Provides guidance to include safety and health considerations within the ADVANCE TD.
- Training and Personnel Guidance: Provides high-level training and personnel guidance for the ADVANCE TD.
- Test and Evaluation: Presents the required experimentation for the ADVANCE TD; this is not included as part of the HSI sections, since the experimentation incorporates both HF and technical evaluations;
- Schedule: Presents an overview schedule for the conduct of all HSI and experimental activities; and
- Acronyms: Provides the acronyms used in this report.

2 Human Factors

2.1 Human Factors in Systems Analysis

The following section outlines the effort related to the conduct of a MFTA to provide an initial definition of the function and tasks relevant to Armoured Fighting Vehicles (AFV) operations within the scope of the ADVANCE TD. The MFTA provides the framework for defining user requirements[1] and task performance requirements that should be used in the development of the Soldier Machine Interface and in the development of MOEs and MOPs. The MOEs and MOPs should be used in the Experimental Trials and Field Demonstrations to evaluate system performance.

An initial MFTA has already been completed for the ADVANCE project (Ref. 6). The MFTA was completed as an iterative process that was developed over a series of analyses conducted by a Human Factors team. In the context of the ADVANCE TD, the bulk of the analysis was derived from previous project experience in the AFV domain and from inputs provided by AFV Subject Matter Experts. The analysis considered the concepts defined as part of the Future Force Employment Concepts for the Army of Tomorrow timeframe (2010-2015), where the ADVANCE capabilities and equipment are projected to be fielded.

2.1.1 Mission Analysis

The objective of the mission analysis was to define the high-level goals that the ADVANCE technologies must satisfy. The mission analysis was used to:

- Fully examine the system application in each anticipated operational environment;
- Explore 'what-if' contingencies for various mission scenarios;
- Provide input into functional analyses to be utilised in the system analysis;
- Provide a framework for subsequent function and task analysis through the identification of mission scenarios; and
- Provide input into identifying the user community, including identification of user characteristics such as physical and cognitive capabilities, and clothing and equipment.

As part of the mission analysis, mission scenarios were developed to describe the intended operational roles of ADVANCE platforms as well as to provide justification for assigning equipment and capabilities as part of the overall employment concept. The mission scenarios describe the sequence of actions and events associated with the execution of a particular mission, which provide the foundation for building the functional and task analyses.

2.1.2 Function Analysis

Function analyses are conducted to divide the system into its component functions to which Operators, hardware, or software can then be allocated. Functions are broad categories of activities performed by the system, and all functions can be sub-divided into more detailed functions or levels. The detailed analysis of functions is necessary to determine system requirements, possible equipment, and human/equipment combinations, in order to effectively identify which functions should be performed by equipment and which functions should be

[1] An initial set of User Requirements has been completed for the ADVANCE Definition project (Ref. 7).

performed by Operators. The function analysis provides the framework for further task analysis to be completed, by breaking high-level functions into their lowest-level sub-components, in order to determine task allocation to an Operator, Maintainer, or to a system.

The foundation of the function analyses was derived primarily from previous AFV experience as well as through a review meeting held with ADVANCE stakeholders. An Abstract Functional Hierarchy was developed to provide a generic analysis and function flow. The Abstract Functional Hierarchy provides a high-level description of typical AFV operations and is not restrictive to a specific platform.

2.1.2.1 ***Functional Decomposition***

The function analysis utilizes a combination of narrative and graphical data to describe the AFV missions utilizing ADVANCE technologies. Missions are described as a series of distinct sections, each with its own hierarchy of tasks, but are related to each other in a logical and temporal sequence.

The objectives of the function analysis include provision of:

- A composite scenario which comprises the required breadth of AFV operational capabilities utilizing ADVANCE technologies; and
- Function flow diagrams for the composite scenario functions.

The functional decomposition was primarily derived from existing documentation, but was further extended to include net-enabled operations. Using the system or mission objectives as an initial starting point, the functional decomposition attempts to refine the objectives to the level of specific Operator tasks. Functions are broad categories of activities performed by the system, and all functions can be broken down or divided into more detailed functions or levels. The detailed analysis of functions is necessary to determine system requirements and identify which elements should be performed by the system and which element should be performed by the Operators.

An example of a function decomposition diagram is presented in Figures 2a, b, and c.

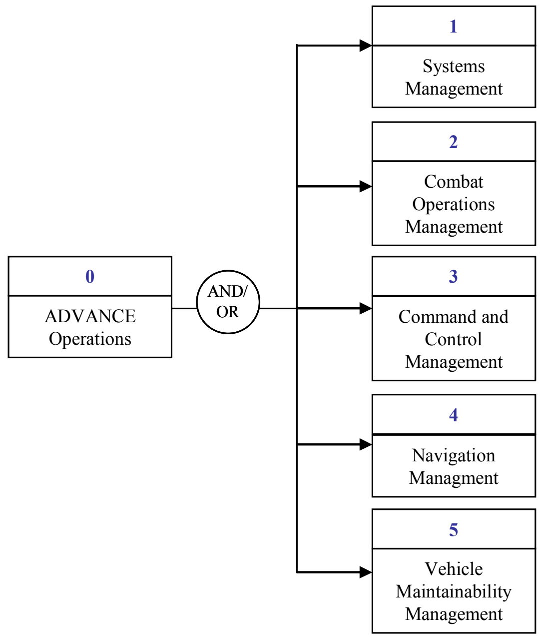


Figure 2a

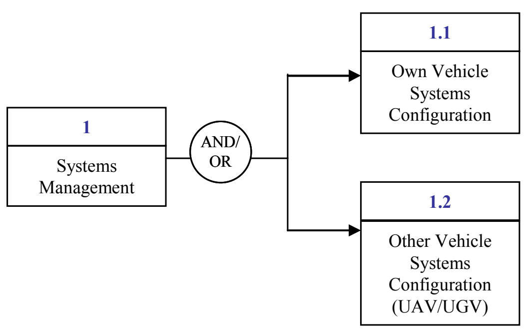


Figure 2b

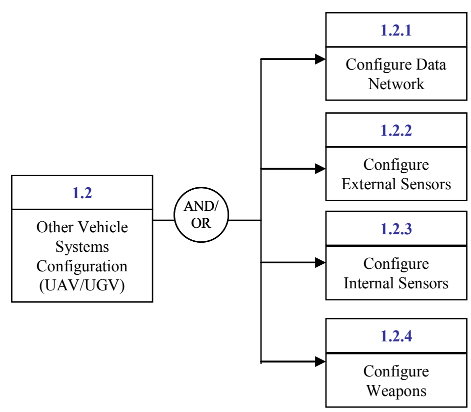


Figure 2c

Figures 2a, b, and c - Sample Functional Decomposition Diagram

*2.1.2.2 **Function Allocation***

The next step in completing the function analysis is to allocate each function to a crew member (e.g., Gunner, Crew Commander (CC)) or to a machine, or to the combination of both. The allocation of functions should be primarily derived from existing documentation and from a SME user group. Function allocation has not been completed as part of the ADVANCE Definition project. This allocation should be based on a set of criteria, weighing the relative merits of humans and machines as well as considering the pros and cons of automation.

2.1.3 Task Analysis

Due to the broad range of vehicle systems and capabilities that are implicated within the ADVANCE TD, it was beyond the scope of the current Definition project to either task analyse the full range of current systems or task synthesize future systems. A substantial body of AFV literature exists documenting platform specific behaviours and interactions that are of interest to the ADVANCE TD. Documented within this literature are results of task analyses specific to some of the platforms within the scope of ADVANCE. Thus, this body of literature has been assessed to determine the degree of relevance to the ADVANCE TD and to identify technologies currently lacking within the literature that will require further analysis.

The task analysis should build upon the mission and function analyses, as well as the function allocation, to create a systematic inventory of the tasks which can then be used to support subsequent SMI design, development and evaluation efforts. Tasks should be defined as perceptual, cognitive or manual behaviors that are required of a crew member to achieve a particular goal or function.

Tasks completed as part of normal, as well as degraded, modes of operation should be identified and examined with respect to: the knowledge, skills and abilities required completing the task; equipment requirements; task setting, time and accuracy requirements; and probable human errors and their consequences. The task analysis should be used to ensure that the SMI is compatible with the Operators' abilities as identified in the mission analysis.

2.1.3.1 ***Building the Task Inventory***

The allocation of information to respective tasks should be performed through a combination of methods including: subjective assessments by HF personnel; subjective assessments using SME personnel; and the utilization of existing HF task analysis resources (e.g., utilizing prior analyses of similar and related tasks). Tasks that are identified as "critical" (i.e., critical in relation to safety, mission effectiveness, efficiency, system reliability and/or cost) should merit a more detailed task analysis. The information that should be identified for each task should be sufficient to allow the design of the system to proceed. Examples of criteria to incorporate in the task analysis include:

- Operators: the crew member who will perform a specific task;
- Task type: discrete (i.e., one-off), repeating, or continuous;
- Task completion times: estimates of the time required for a crew member to successfully complete a task;
- Initiating conditions: the conditions that must be satisfied before a task can be initiated;
- Information required: the information required by a crew member to complete a task;
- Information available: the relevant information provided to, but not necessarily required by, a crew member to perform a task;
- Actions required: the actions a crew member performs in completing a task;
- Feedback required: the feedback required identifying successful completion of a task;
- Cognitive processing required: the mental processing required to complete a task;
- Decision requirements: the decision making-related aspects involved in completing a task;
- Knowledge requirements and knowledge level: the body of knowledge, usually factual or procedural, that makes it possible for a crew member to complete a task;
- Skill requirements and skill level: the capabilities required by a crew member to perform a task with ease and precision (also referred to as psychomotor-related activities);

- Ability requirements: the cognitive capabilities necessary to complete a task, usually requiring the application of a knowledge base;
- Communication and coordination: the method and content of communications amongst the crew member(s) and between the crew members and other parties (e.g., system, friendly forces) that is required to complete a task;
- SMI control requirements: the top-level characteristics of the interaction technologies that are required in order to accomplish a task;
- SMI display requirements: the top-level characteristics of the display(s) that are required in order to accomplish a task;
- Implications of Vetronics failure: the implication of a Vetronics System failure on task completion; and
- Implications of Active Suspension failure: the implication of an Active Suspension failure on task completion.

*2.1.3.2 **Task Flow Diagrams***

The task analysis also represents the sequences of activities through *task flow* diagrams. In a task flow diagram, all unique elements should be individually represented, such as:

- Crew members (e.g., CC) represented by triangles;
- Operations (e.g., search for contact) represented by squares;
- Decisions (e.g., engage contact) represented by diamonds; and
- Choices (e.g., and/or) represented as circles.

2.1.4 Mission, Function, Task Analysis: Future Work

As the ADVANCE TD is currently in the Definition Stage of the project, the MFTA requires further efforts to provide a detailed framework from which to evolve the user requirements documentation, define the operational roles for AFVs within the net-centric environment, and explore the impacts of Vetronics and Active Suspension systems on AFV operations. Significant involvement from the AFV operational community will be required to aid in the identification and definition of missing areas within the existing analysis. As the MFTA continues to be iterated throughout the design cycle, additional data elements will be included in the task analysis to support additional interface design and training, as well as to highlight issues for usability testing and human performance evaluation.

Further efforts are required to define mission scenarios that encompass operational roles and environments that extend beyond combat oriented operations to include activities associated with sustained operations (e.g., 72 hr operations), transitions from low to high threat environments and direct peace support roles that are not associated with active combat. The impact of ADVANCE technologies may not be adequately addressed without extending the current set of mission scenarios to this domain.

2.1.5 Development of Measures of Effectiveness & Performance

The test and evaluation phase of the project will require a series of measures, derived from the MFTA, in order to examine whether the ADVANCE TD technologies were successful at improving mission effectiveness and performance, such as:

- Improving information quality and timeliness;

- Improving battlefield Situation Awareness and workload;
- Improving Operator effectiveness; and
- Reducing vibration and mechanical shock on the vehicle, personnel and cargo.

Once the technologies and systems to be included in the vehicles have been determined, a User Group should be completed to identify the anticipated duty cycle and operational activities of the vehicle, which will facilitate the development of Measures of Effectiveness. Measures of Effectiveness are used to quantify the performance of the integrated system (i.e., human, machine and process) by describing the utility or value when using the system to meet mission goals. Typical MOEs may include Speed of Engagement, Survivability, Lethality, or Reliability.

2.2 Human Factors in Detailed Design

The initial Mission Analysis systematically identifies the anticipated AFVs' missions and operational environment within the context of ADVANCE technologies. The subsequent Function Analysis and Task Analysis systematically decompose the mission elements into functions and eventually into discrete tasks that are then assigned to Operators or are designated automated functions. The design of the Solder Machine Interface should be based on the identified task assignments, sequences, information, and action requirements. This development work should be conducted in an iterative manner in consultation with Subject Matter Experts to review design concepts. The design of the SMI should be described in a detailed SMI Design Document and SMI Style Guide.

2.2.1 Human Factors Organisation and Personnel

Figure 3 illustrates the HF Organisation and Personnel. The HF team should be integrated within the ADVANCE team, to ensure the proper communication flows are established and managed. This will facilitate the HF work, ensuring that the HF work properly aligns with the current stage of the ADVANCE project, and that the HF risks identified are integrated with the risks identified by the ADVANCE team.

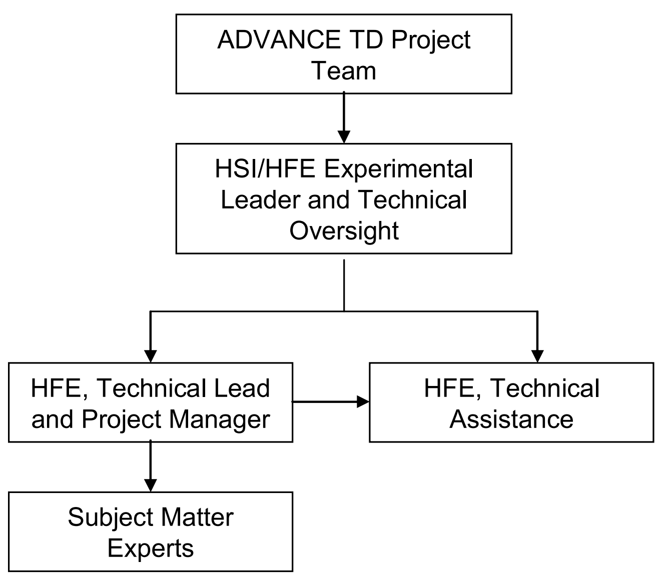


Figure 3: Human Factors Organisation and Personnel

2.2.2 Human Factors in the Engineering Design Cycle

Figure 4 illustrates the role of HF during the Engineering Design Cycle, from development of System Requirements through to System Validation. Each engineering design stage involves an iterative process that requires the conduct of HF activities to occur multiple times.

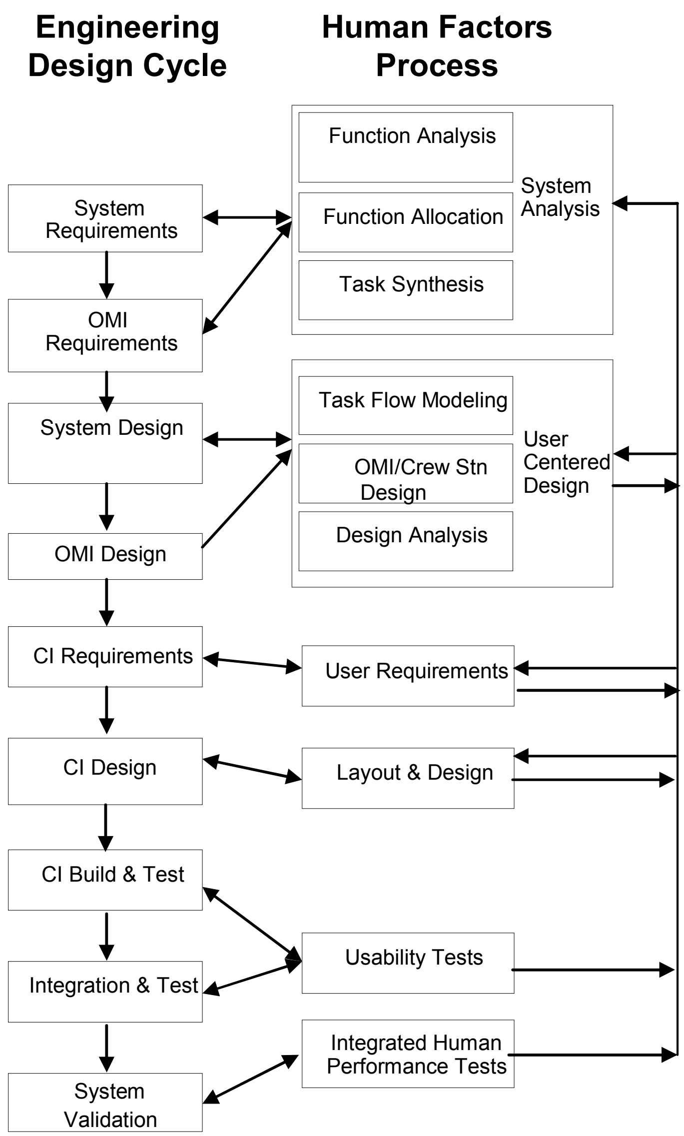


Figure 4: The role of HF in the Engineering Design Process

2.2.3 Human Factors in Soldier Machine Interface (SMI) Design

The design of the SMI will integrate the SMEs' knowledge about the tasks with established HF and OMI principles to identify the most effective user interface architecture, interaction approach, navigation, and screen designs to support the identified tasks, within the context of a net-enabled environment. The MFTA and the User/Performance Requirements should provide the framework for SMI development and design. Work elements that comprise this portion of the project include:

- Review of AFV literature for related HF issues;

- User groups with SMEs; and
- Analysis and Design of the SMI within the context of a net-enabled environment.

2.2.3.1 ***Shared Displays***

Past research in future armoured vehicle crew station design has identified a requirement to provide Operators with the ability to share tactical information between crew members. Due to the complexity of the modern battlefield and the requirement for crew members (especially in reducing crew platforms) to take an active role in determining vehicle tactics and interpreting the surrounding battlespace, it is critical that tactical information is easily accessible and that the representation of tactical information is maintained between Operators. Therefore, tactical information should be presented in a manner that enables Operators to easily access a dedicated tactical display, such as tactical maps and battle management systems, in a collaborative fashion to support shared situation awareness and effective decision making. Human Factors analysis should also incorporate the development, design, and evaluation of Shared Displays.

2.2.4 Human Factors in Physical Workstation and Workspace Design

The Physical Workstation and Workspace Design work should assess a Common Crew Station (CCS), evaluating the compatibility of the CCS with the intended user physical characteristics and capabilities, as well as integration with the existing interior layout and components of AFVs.

The current crew station design should be reviewed to assess the physical workspace and the necessary accommodations for the physical characteristics of the users, the equipment and the tasks. Physical accommodation should be based on anthropometric analysis using mock-ups and/or mannequin models.

The full range of anthropometrics (range of size, shape, and gender) of the crew members must also be considered, along with their clothing and equipment.

2.2.5 Human Factors Trade-Off Analysis

During HF design, the HF team may be required to conduct Trade-Off Analyses. The HF team may be required to compare and contrast different technologies to determine the best, or most suitable, kit to incorporate into the system design. Trade-Off analyses provide support for choosing to incorporate one piece of kit over another.

2.2.6 User Groups: Design Verification & Validation

Verification and Validation user groups with SMEs should be conducted to present, evaluate, the design of the SMI. The participants should be a representative sample of the anticipated user community (e.g., CCs, Gunners). This process elicits design feedback for iterative design-build-test loop.

The user groups should use varying degrees of simulation (paper, Power Point, interactive mockup, function sub-system, etc.) as the concepts and designs progresses. The user group sessions should involve structured presentation of the appropriate material, followed by structured and facilitated group discussion. Participants can complete questionnaires to record their perceptions of utility, ease of use, impact on future task performance, future situational awareness, and future workload, in addition to predicted impacts on ease of learning and skill development. Additionally, objective measures should be collected where the level of interaction with the users permit.

The user groups should be conducted at different stages of the SMI design development (i.e., after each detailed design build).

2.2.6.1 User Group Methodology

2.2.6.1.1 Participants

The User Groups should include approximately six SMEs; the SMEs should be representative of the anticipated user community.

2.2.6.1.2 Materials

The materials could include static or interactive PowerPoint slide decks or paper mock-ups of the SMI. The SMI could also be simulated using a standard desktop computer.

2.2.6.1.3 Review Process

SME feedback could be captured by a variety of techniques including: structured interviews, focus groups, and closed and open-ended questionnaires.

2.2.6.1.4 Reporting

A User Group Report should be developed to describe the methodology used to conduct the user groups, as well as the results, feedback and recommendations received from participants.

2.2.7 Subject Matter Experts

Subject Matter Experts will be required throughout the project to participate in User Groups, Field Demonstrations and Experimental Trials during the design, analysis, and validation phases of the project.

The SMEs should include:

- Light Armoured Vehicle (LAV) III qualified driver;
- Two full crews with Coyote experience, including Crew Commander, Surveillance Operator (SO), and Gunner; and
- Heavy Logistics Vehicle Wheeled (HLVW) driver (if required).

2.2.8 Human Factors Deliverables

During detailed design, the following deliverables should be provided:

- SMI Design document;
- SMI Style Guide;
- Function Flow Diagrams;
- Critical Task Analysis;
- Updated MFTA; and
- Updated User Requirements.

3 Safety and Health Considerations

Safety considerations identify the hazards and risks that occur as a result of system operation, including the contribution of human error and human reliability. The purpose of including safety considerations is to eliminate hazards during the design stage or to develop controls to maintain hazards at an acceptable level. The consideration of Health Hazards aims to eliminate, minimize or control both short- and long-term hazards to health that may occur as a result of system operation. The inclusion of health hazards consideration identifies whether the design features and operating characteristics of a system can create significant risks of death, injury, acute chronic illness, and disability, which can reduce job performance of personnel who operate, maintain, or support the system.

Examples of Systems Safety and Health Hazards considerations include:

- Safety of design and procedures;
- Human error and human reliability;
- Software and hardware failure modes;
- Total system reliability and fault reduction;
- Total system risk reduction
- Hazards induced by systems, environments or task requirements;
- Noise and vibration;
- User error and misuse of the system;
- Environmental conditions;
- Noise and vibration;
- Nuclear, biological substances;
- Heat and cold stress;
- Radiation; and
- Musculoskeletal impact.

System and Health concerns also include aspects of survivability (i.e. limiting the probability of personal injury, disability or death of personnel in their interactions with the system). This can include providing protection from attack, and reducing detectability, fratricide, system damage, personnel injury and cognitive and physical fatigue.

During the future phases of the ADVANCE TD, it is pertinent that potential safety and health concerns, if any, are identified, and that analysis of the safety risks are included in the overall Evaluation Plan.

The following mediums can be used to ensure safety in considered during design:

- System Safety Program Plan (SSPP): The SSPP describes the tasks and activities of system safety management and system safety engineering required to identify, analyze, and mitigate hazards by reducing their associated risks to an acceptable level.
    - The elements of the SSPP should be tailored for the purpose of a Technology Demonstration project. The SSPP should be integration with the Systems Engineering Management Plan and Process, and should be based on a tailored version of MIL-STD-882D: Standard Practice for System Safety (DoD, 2000).

- Health Hazard Assessment: The HHA systematically identifies and evaluates Health Hazards and evaluates proposed hazardous materials.

3.1 System Safety and Health Hazard Deliverables

The Safety and Health deliverables should include:

- System Safety Program Plan, including resulting documentation;
- System Safety Analysis; and
- Health Hazard Analysis.

4 Training and Personnel Guidance

During a Technology Demonstration project, the impact of the system design on the personnel who will operate and maintain the system (i.e., the users) should be determined at a high-level. This assessment draws substantially from HSI domains including HFE, Training and Personnel. The intent of this assessment is to provide an up-to-date assessment of the operations and maintenance personnel concept in relation to the personnel demands of the system and the projected personnel that are envisioned to be available for the system.

This should become an iterative and more detailed assessment that integrates information and analysis derived throughout the definition, design, development and testing phases.

The potential impacts can be extremely significant lifecycle cost drivers as a result of the introduction of new technologies, tactics, techniques, procedures, training and doctrine. They can impact at all levels including the ability to recruit and select future users, initial and continuation training, new military occupational categories and career progression changes. This integrated approach to analyzing the impact on personnel allows trade offs to be weighed and implemented to reduce unforeseen negative impacts on the total system cost and performance.

The two primary questions to be answered at this stage of the TD include:

- What will be the impact of the ADVANCE technologies on how the vehicle is crewed?
- What will be the impact of the ADVANCE technologies on how personnel are trained?
- Who are the types of personnel that will utilize the ADVANCE technologies.

4.1 Training and Personnel Deliverables

The Training and Personnel deliverables should include:

- Training Impact Analysis; and
- Personnel Impact Analysis.

5 Test & Evaluation

5.1 Overview

An initial Experimental Plan has been prepared for the ADVANCE TD (Ref. 5). Since the ADVANCE project is currently in the Definition Phase, the Experimental Plan was not intended to detail the exact trials to be conducted, but rather, focuses on providing a categorization of the experimental activities, as well as a high-level overview of the tasks that will be required to accomplish them. The plan outlines the methodologies and resource requirements, and relates the experimental activities to questions originally posed in the ADVANCE Stakeholder Control Document (SCD) (Ref. 4). The Experimental Plan provides suitable activities to answer all of the stakeholder questions; depending on the priorities of the ADVANCE TD, some of the recommended activities may not proceed.

5.2 Experimental Activities

The highest level activities were segregated by activity type and by the type of terrain or course required to do the activity. The following paragraphs briefly outline the rationale for each activity, the type of trials to be conducted, and the requirement for terrain or resources.

5.2.1 Static Technical Characteristics

5.2.1.1 Evaluation Requirements: Measure vehicle technical characteristics which do not require either vehicle movement or involvement of the crew. This includes such things as vehicle physical characteristics, capabilities of the suspension, and technical characteristics of vehicle systems (including the operator-machine interface).

5.2.1.2 Vehicles: A combination of the LAVIII and LAVII and suitable control vehicles will be required.

5.2.1.3 Terrain: This Activity can be conducted on any flat hard-standing area.

5.2.1.4 Equipment/Devices: Will require measurement equipment and specialized measuring devices, including a tilt-table.

5.2.1.5 Personnel: No crew are required except to move the vehicle to the Activity and between locations.

5.2.1.6 Human Factors: Will require a user group to determine operational parameters for some of the systems.

5.2.2 Short Course

5.2.2.1 Evaluation Requirements: Answer questions concerning vehicle systems performance under motion, where limited duration and very repeatable Trials are required. Trials are included for measuring vehicle speed, acceleration, and braking, measurement of the effect of Active Suspension on stabilization and absorbed power, and vehicle signature measurement.

5.2.2.2 Vehicles: Since all questions concern the effect of Active Suspension on vehicle performance, only the LAVIII (and suitable control vehicle) will be required.

5.2.2.3 Terrain: Three courses are required: pavement and two cross-country courses, with "extreme" and "moderate" roughness. The courses will be a straight line over at least 1 km.

5.2.2.4 Equipment/Devices: Will require measurement equipment and specialized measuring devices, and video equipment to record through-sight imagery.

5.2.2.5 Personnel: Crews will be required to drive the vehicle on the course accurately exactly as instructed by the test conductor to maximize repeatability between Trials and vehicles. Some of the Trials require a gunner to measure the effect of Active Suspension on tracking performance.

5.2.2.6 Human Factors: Crew questionnaires will be conducted to evaluate comfort and ease of task performance.

5.2.3 Slope Course

5.2.3.1 Evaluation Requirements: Measure the ability of Active Suspension to improve the vehicle's ability on side and forward slopes. Trials are included for static and moving slope capability considering Active Suspension levelling, including determination of a "best" mode of operation for the Active Suspension.

5.2.3.2 Vehicles: Since all questions concern the effect of Active Suspension on vehicle performance, only the LAVIII (and suitable control vehicle) will be required.

5.2.3.3 Terrain: Slopes of different steepness are required, which can be used in side and forward modes; large areas of constant slope would be preferred to allow repetition of tests given soil destruction by the vehicle.

5.2.3.4 Equipment/Devices: Will require equipment to measure slope. Ideally, the vehicle would be tested on a tilt table first to establish roll-over slope; however, in any case, safety equipment will be required to ensure no roll-over during the Trial.

5.2.3.5 Personnel: Crews will be required to drive the vehicle on the course accurately and smoothly as instructed by the test conductor to maximize repeatability between Trials and vehicles, and to maximize safety of the Trial.

5.2.3.6 Human Factors: Crew questionnaires or interviews will be conducted to gather subjective opinion of the vehicle characteristics during the Trial.

5.2.4 Manoeuvring Course

5.2.4.1 Evaluation Requirements: Measure vehicle automotive performance in non-linear motion, (i.e., manoeuvring; including Trials to measure steady-state and transitory turning, and to establish the most optimum mode of Active Suspension for manoeuvring.

5.2.4.2 Vehicles: Since all questions concern the effect of Active Suspension on vehicle performance, only the LAVIII (and suitable control vehicle) will be required.

5.2.4.3 Terrain: For the steady state Trials, a large hard-surfaced "skid pad" area is required. For the slalom Trials, a cross-country terrain equivalent to the "moderate" level of the short course will be required as well.

5.2.4.4 Equipment/Devices: Will require measurement equipment and specialized measuring devices.

5.2.4.5 Personnel: Crews will be required to drive the vehicle on the course accurately exactly as instructed by the test conductor to maximize repeatability between Trials and vehicles.

5.2.4.6 Human Factors: Crew questionnaires or interviews will be conducted to gather subjective opinion of vehicle characteristics during the Trial.

5.2.5 Obstacle Course

5.2.5.1 Evaluation Requirements: Determine the limits of vehicle capabilities on individual obstacles, including gaps and steps, and test the ability of the Active Suspension to enable novel mobility capabilities.

5.2.5.2 Vehicles: Since all questions concern the effect of Active Suspension on vehicle performance, only the LAVIII (and suitable control vehicle) will be required.

5.2.5.3 Terrain: All Trials may be done on a small terrain area; however, individual obstacles must be constructed or available that can be varied until the limits of performance are reached, and must be strong enough to handle the weight of the vehicle. Obstacles constructed for the purpose at a test facility would be preferable.

5.2.5.4 Equipment/Devices: Will require only a measuring tape and recording equipment.

5.2.5.5 Personnel: Crews will be required to drive the vehicle on the course accurately exactly as instructed by the test conductor. They will be required to contribute to suggesting ways to increase the capability of the vehicle by use of the Active Suspension system.

5.2.5.6 Human Factors: No HF activities are required.

5.2.6 Obstacle Course

5.2.6.1 Evaluation Requirements: Measure and evaluate vehicle and crew performance parameters which require realistic vehicle motion, semi-realistic tactical scenarios, and a realistic representation of vehicle duty over a longer-distance course. Trials will include confirmation of vehicle vibration improvement, fuel and power consumption, crew and system performance evaluation, and determination of optimum Active Suspension modes for various tactical tasks.

5.2.6.2 Vehicles: Depending on the exact parameters to be included in the Trials, both the LAVII and LAVIII vehicles will likely be required. In some of the Trials a control vehicle will be required.

5.2.6.3 Terrain: The duty cycle from the LAV SOR is shown in Figure 5. A user group will be held to modify this duty cycle as desired for the Trials.

5.2.6.4 Equipment/Devices: Will require measurement equipment and specialized measuring devices.

5.2.6.5 Personnel: In some of the Trials, crews will be required to drive the vehicle on the course accurately exactly as told by the test conductor to maximize repeatability between Trials and vehicles. In other Trials, the crews themselves will be the subjects of the experiment, measuring their performance in using the vehicle systems and equipment.

5.2.6.6 Human Factors: Extensive HF involvement in this series of Trials, including conduct of user groups, measurement of crew performance and comparison to standard vehicle or methodologies, control of tactical scenarios, and administration of questionnaires and interviews. A user group will be conducted to identify and refine human tasks and consider optimum Active Suspension modes, and questionnaires and/or interviews will be conducted on system usefulness and usability and subjective impressions.

Distance (km)	Conditions	Speed (kph)
100	Primary or secondary roads	Average 80
60	Primary or secondary roads	Average 50
90	Trails or unimproved roads	Average 50
60	Medium (or gently rolling) cross-country	Average 50
4	Medium (or gently rolling) cross-country in reverse	Average 10
10	Medium (or gently rolling) cross-country, best possible speed	Minimum 50
2	Medium (or gently rolling) cross-country	Maximum 5
10	Marginal (severe) cross-country	Best possible
	Shallow ford three times	
	Ascend and descend 60% grade for 20 m five times	
	Stop, shut down for 30 min, start on 60% grade	
	Operation of vision devices and stabilization system for entire cycle	
	Engine operation for 20 hours/day	

Figure 5: Duty Cycle from LAVIII SOR

5.2.7 Virtual Simulation

5.2.7.1 Evaluation Requirements: Virtual experimentation will allow the evaluation of technologies that are not included in the real ADVANCE vehicle, or of capabilities that are not fully fleshed out. It will also allow the inclusion of trial conditions that may not be possible in the real environments, as well as completely replicable trials.

5.2.7.2 Vehicles: Real vehicles will not be required; however, the planning of the virtual experimentation must include trials comparable to those using real vehicles in order to validate the virtual environment results.

5.2.7.3 Terrain: Any terrain can be created, and should match as much as possible the real terrain, so as to make the results comparable to and able to be validated against the real vehicle experimentation.

5.2.7.4 Equipment/Devices: The primary requirement is for a suitable virtual environment. Given the limitations of the ADVANCE project, this will be an already-created simulation environment that must be modified as required to represent the vehicle characteristic and equipment and OMI desired for ADVANCE.

5.2.7.5 Personnel: Crews will be required to conduct all activities

5.2.7.6 Human Factors: Crew questionnaires will be conducted to evaluate comfort and task performance ease.

5.2.8 Constructive Simulation

5.2.8.1 Evaluation Requirements: Constructive simulation is effective at expanding the influence of technology performance on vehicle capabilities to higher organizational levels; the real or virtual experimentation at the vehicle level may show an increase in performance, and constructive simulation allows evaluation of the effects of this performance increase on a complete unit equipped with such vehicles. Constructive simulation is also used to conduct parametric analysis of system parameters at the vehicle level. There are different types of constructive simulation, including operational research wargames, in which large numbers of entities with specified capabilities interact with each other and simulated other forces, and task network modelling, in which models of all aspects of the vehicle and its systems are created, with the ability to rapidly conduct "what if" analysis of the effects of performance parameter changes.

5.2.8.2 Vehicles: Simulated vehicles with similar performance characteristics to the real (and virtual) vehicle Trials will be required.

5.2.8.3 Terrain: Any terrain can be included, primarily for its effect on the mobility of the simulated vehicles.

5.2.8.4 Equipment/Devices: Suitable constructive simulation environments will be required. It is anticipated that both a large-scale wargame and a task network model simulation will be required to evaluate the impact of all aspects of the ADVANCE technologies.

5.2.8.5 Personnel: Crews will not be required. There may be the requirement for information from a user group; however, this information would most likely be amassed from other user groups listed above and from the results of the real vehicle Trials.

5.2.8.6 Human Factors: Creating a task network model would be an HF activity, and HF input will be required to ensure that the scenarios and task requirements for the constructive models are consistent with the real and virtual work.

5.3 Experimental Trials

Annex A lists the experimental activities defined in Section 5.2, and defines the trials that must be conducted to completely answer the stakeholder questions. The information is arranged according to the following columns:

- Serial, Activity, Description and Trial: Each trial is given a serial number for future reference. The Activity and Description columns identify and describe the activity respectively, and the Trial column lists the overall parameter to be evaluated in each trial.
- Experimental Parameters: This column lists the detailed experimental parameters that must be evaluated during the trial. The remainder of the Experimental Plan must define how to define the parameters for experimentation, the methodology for measuring or evaluating the parameter, and the overall resource and other requirements.
    - There is some overlap between the activities. For example, absorbed power is measured in both the Short Course and Duty Cycle activities. In the Short Course, the power will be quantitatively compared between different types of terrain and between versions of the vehicle. In the Duty Cycle activity, the emphasis is on the effect of the vibration level (i.e., measured absorbed power) on crew and system performance. The results of the Short Course

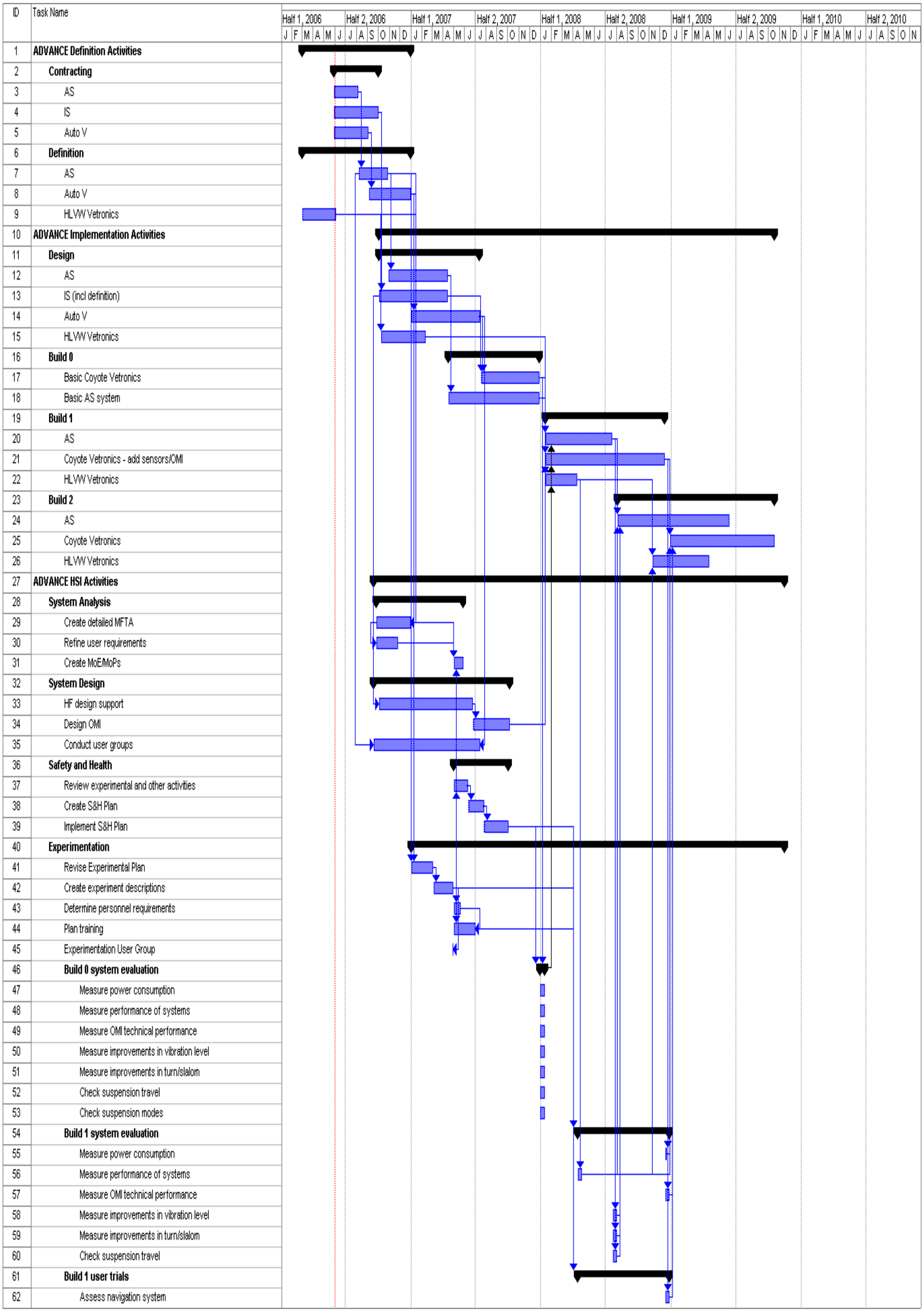
evaluation will be combined with those of the Duty Cycle to give a comparison matrix of terrain versus speed versus absorbed power versus performance.

- Statistical Analysis Requirements: To ensure that the results of this experimentation are valid and can be used for making decisions concerning future acquisition programs, statistical analysis should be used as required. This column indicates the requirements to ensure valid results.
- Resource Requirements: Each Trial will require different resources in terms of personnel, equipment, and measuring devices. An overview of the resource requirements is shown in Section 5.2; this column in the table lists resource requirements in greater detail. This part of the Experimental Plan will require the most additional detail in future planning (i.e., in creation of the Test Descriptions).
- Vehicles Required: This column lists the real vehicle requirements to conduct the relevant trial.
- References: Each trial is intended to fulfil the requirement to answer one or more of the questions raised in the Stakeholder Control document (Ref. 4). Annex B of the SCD lists the methods of answering these questions; this column refers back to the SCD, such that each trial in the Experimental Plan can be traced to the original Stakeholder question. This column also contains references on experimental techniques or standards that should be considered.

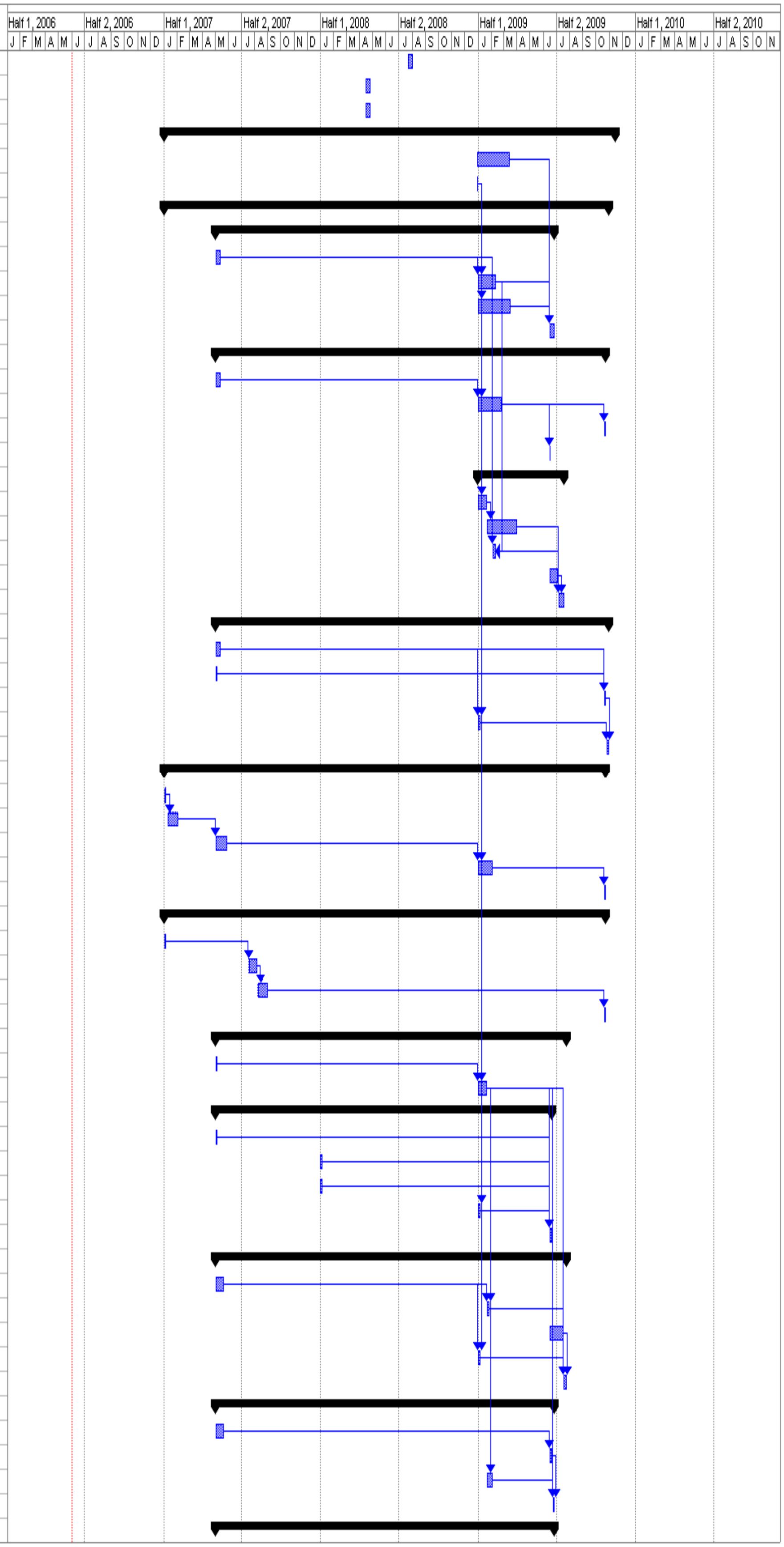
6 Schedules

Figure 6 provides a draft overview schedule for the preparation and conduct of all HSI and Experimental activities during the ADVANCE project, including experimentation. The main activities have been related to the major definition, design, and development stages of ADVANCE. The experimental part of the schedule includes activities in three stages, according to the three builds of ADVANCE development. The bulk of the experimentation is done at the end of Build 2, when all ADVANCE Vetronics and Active Suspension functionality in all three vehicles will be in place; lesser amounts of experimentation are planned for the completion of Builds 0 and 1. The primary goal of the Build 0 and 1 experimentation is to identify if system performance is showing improvement from the baseline with each build, and to have user feedback on the first version of the OMI.

The current experimental schedule has activities with placeholder lengths and, in some cases, start dates. Once the technologies and detailed integration schedule are known, the experimental schedule can be refined.


ID
Task Name
Half 1, 2006
Half 2, 2006
Half 1, 2007
Half 2, 2007
Half 1, 2008
Half 2, 2008
Half 1, 2009
Half 2, 2009
Half 1, 2010
Half 2, 2010
1 ADVANCE Definition Activities
2 Contracting
3 AS
4 IS
5 Auto V
6 Definition
7 AS
8 Auto V
9 HLVW Vetronics
10 ADVANCE Implementation Activities
11 Design
12 AS
13 IS (incl definition)
14 Auto V
15 HLVW Vetronics
16 Build 0
17 Basic Coyote Vetronics
18 Basic AS system
19 Build 1
20 AS
21 Coyote Vetronics - add sensors/OMI
22 HLVW Vetronics
23 Build 2
24 AS
25 Coyote Vetronics
26 HLVW Vetronics
27 ADVANCE HSI Activities
28 System Analysis
29 Create detailed MFTA
30 Refine user requirements
31 Create MoE/MoPs
32 System Design
33 HF design support
34 Design OMI
35 Conduct user groups
36 Safety and Health
37 Review experimental and other activities
38 Create S&H Plan
39 Implement S&H Plan
40 Experimentation
41 Revise Experimental Plan
42 Create experiment descriptions
43 Determine personnel requirements
44 Plan training
45 Experimentation User Group
46 Build 0 system evaluation
47 Measure power consumption
48 Measure performance of systems
49 Measure OMI technical performance
50 Measure improvements in vibration level
51 Measure improvements in turn/slalom
52 Check suspension travel
53 Check suspension modes
54 Build 1 system evaluation
55 Measure power consumption
56 Measure performance of systems
57 Measure OMI technical performance
58 Measure improvements in vibration level
59 Measure improvements in turn/slalom
60 Check suspension travel
61 Build 1 user trials
62 Assess navigation system

ID	Task Name
63	Assess AS modes
64	Preliminary evaluation all OMI devices
65	Preliminary evaluation all user functionality
66	**Build 2 Experimentation**
67	Refine pers and trg requirements
68	Organize experimental requirements
69	**Measure Static Technical Characteristics**
70	**Weight/CG**
71	Document required loading configurations
72	Acquire equipment for loading/ballast
73	Acquire/arrange scales/crane
74	Conduct weight/CG measurements
75	**Interior space**
76	Determine methodology
77	Acquire/train on equipment
78	Measure Coyote interior
79	Measure LAV AS interior
80	**Suspension characteristics**
81	Investigate tilt-table availability
82	Determine suitable side-slope terrain
83	Obtain ballast
84	Instrument for power consumption
85	Measure characteristics
86	**Power requirements**
87	Document operating/duty conditions
88	Determine battery limitations
89	Instrument for power current/voltage
90	Acquire/set up automatic recording system
91	Measure power usage
92	**System performance**
93	Determine list of installed equipment
94	Determine performance characteristics
95	Determine evaluation methods
96	Acquire test equipment
97	Conduct evaluations
98	**OMI technical performance**
99	Identify new devices on vehicle
100	Determine human performance characteristics
101	Determine evaluation methods
102	Conduct evaluations
103	**Conduct Short Course Evaluations**
104	Identify and recce courses
105	Lay out courses as required
106	**Speed/absorbed power/acceleration**
107	Review SAE vibration limits
108	Install 6 DoF accelerometer
109	Install logger
110	Prepare crew questionnaires
111	Conduct evaluations
112	**Weapon/sight stabilization**
113	Determine tracking task
114	Set up target
115	Instrument sight head?
116	Prepare CC questionnaires
117	Conduct evaluations
118	**Braking**
119	Determine instrumentation requirements
120	Instrument vehicle
121	Set up course
122	Conduct evaluations
123	**Signature**



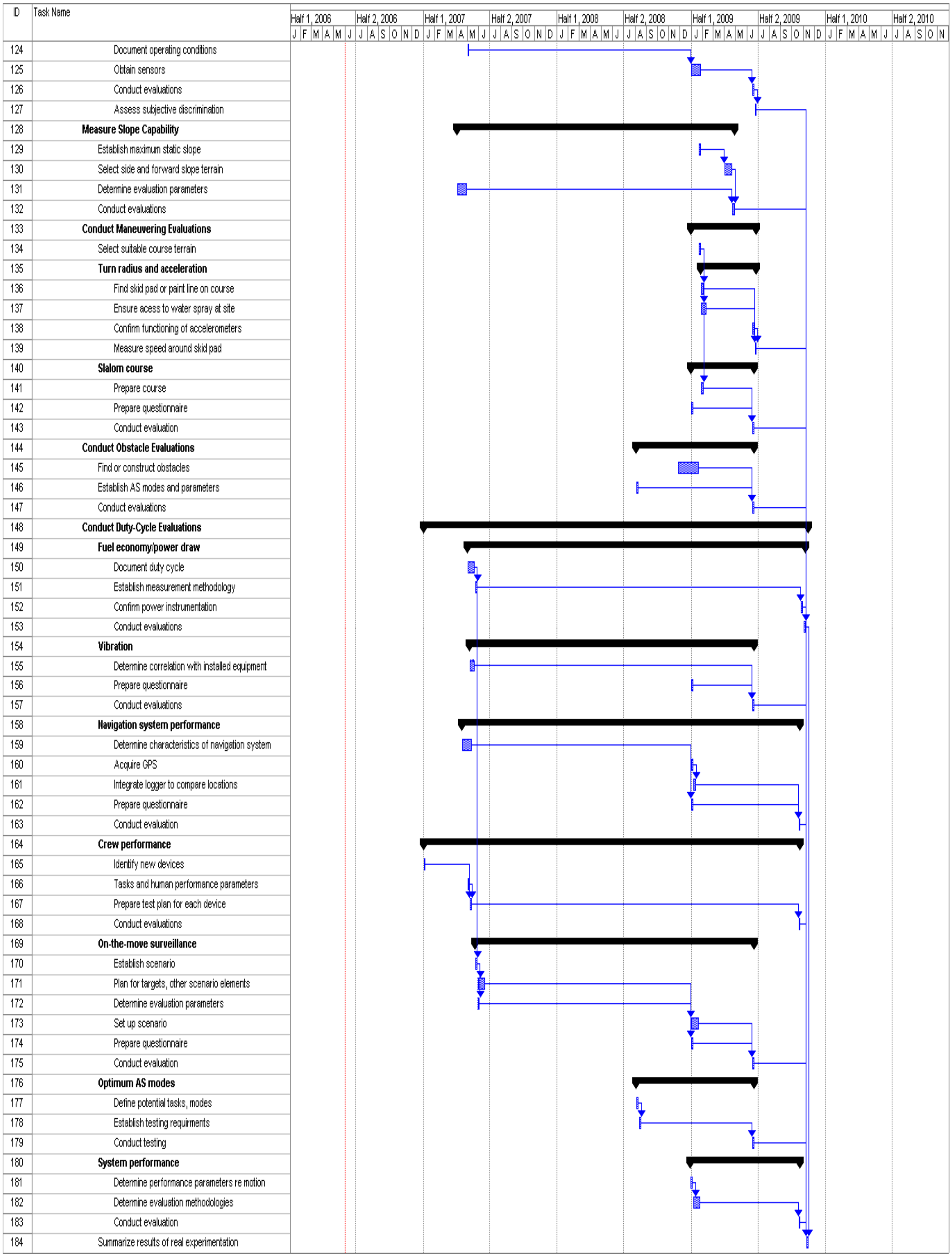


Figure 6: Draft overview schedule for the preparation and conduct of HSI and Experimental activities

7 Acronyms

ADVANCE	Advanced Vehicle Architecture for a Net-Enabled Combat Environment
AFV	Armoured Fighting Vehicle
AOT	Army of Tomorrow
C2	Command and Control
CC	Crew Commander
CCS	Common Crew Station
G&A	Greenley & Associates Incorporated
HF	Human Factors
HFE	Human Factors Engineering
HFEPP	Human Factors Engineering Program Plan
HH	Health Hazards
HLVW	Heavy Logistics Vehicle Wheeled
HSI	Human Systems Integration
LAV	Light Armoured Vehicle
LCSS	Land Command Support System
MFTA	Mission Functions Task Analysis
MOEs	Measures of Effectiveness
MOPs	Measures of Performance
OMI	Operator Machine Interface
PWGSC	Public Works and Government Services Canada
SA	Situation Awareness
SCD	Stakeholder Control Document
SME	Subject Matter Expert
SMI	Soldier Machine Interface
SO	Surveillance Operator
SS	System Safety
SSPP	System Safety Program Plan
TD	Technology Demonstration
TNA	Training Needs Assessment
UAVs	Unmanned Aerial Vehicles
UGVs	Unmanned Ground Vehicles
UIs	User Interfaces

Annex A: Experimental Trials

Serial	Activity	Description	Trial	Experimental Parameters	Statistical Analysis Requirements	Resource Requirements (Terrain/Crew/Eqpt/Time)	Vehicle(s) Required	SCD Reference
1-1	**Static Technical Characteristics**	Measurement of technical parameters of vehicle or installed equipment relevant to the ADVANCE TD	Weight	• Weight of vehicle • Height and longitudinal location of CG • Variation of CG location with different loading conditions and vehicle configurations	• Nil	• Conduct user group to confirm number of crew in vehicle, select loading for experiment. Include possible variations in vehicle configuration and vehicle type • Acquire equipment including personal, weapons, ammo, (simulated where necessary) etc. • Require scales to accept 8 wheel stations, crane or hoist to hang vehicle to measure vertical CG location. • Testing time for experiment = 2 days	• LAV IIIAS	• TM-8 • HE-10 • DQ-3 • LAVIII manual
1-2			Interior Space	• Internal volume change • Usability of available volume	• Nil	• Determine methodology for internal volume measurement – ultrasonic, manual, CAD, etc. • Measure or calculate actual available volume, compare with standard vehicle. • Assess if any of the internal volume is practically unusable, including anthropometric assessment. • Testing time = 1/2 day	• LAV IIIAS • Coyote Vetronics • Control vehicles	• TM-9
1-3			Suspension	• Min/max suspension height	• Nil	• Can conduct levelling trials largely	• LAV III AS	• TM-10

Serial	Activity	Description	Trial	Experimental Parameters	Statistical Analysis Requirements	Resource Requirements (Terrain/Crew/Eqpt/Time)	Vehicle(s) Required	SCD Reference
			characteristics	• Time to change height up/down • Range of auto-level angles laterally and longitudinally • Time to auto-level – max Left to max Right • Compensation for unbalanced loading • Confirm that individual wheel stations can be raised. • Duration that suspension settings are maintained without power (Dependant on height or weight?) • Power draw of the suspension system • Entry/departure angles		on flat ground, then confirm “auto-level” on sloped terrain. Ideally, all trials could be done on a tilt-table. • Require ballast, human or otherwise, for unbalanced loading • Maintenance of setting may not require experimentation if suspension “locks” in location without power draw. • Measure peak and instantaneous power consumption while carrying out tests. • Directly measure entry/departure at different suspension heights. • Testing time = 1 day		• TM-11 • TM-5
1-4			Power requirements	• Silent watch time with various systems operating, including AS on/off, power management system on/off, etc.	• Nil	• Conduct user group to determine appropriate operating systems for different conditions, and duty cycle for equipment (turret traverse, etc) that is operated sporadically, including emergency conditions. • Determine technical limitations of power storage (batteries) – level to which to draw to for	• LAV IIIAS • Coyote Vetronics • Control vehicles	• TM-11 • MFTA-4 • DQ-4

Serial	Activity	Description	Trial	Experimental Parameters	Statistical Analysis Requirements	Resource Requirements (Terrain/Crew/Eqpt/Time)	Vehicle(s) Required	SCD Reference
						experiment. • Measure current draw and battery voltage over time until limit reached. • Testing time = depends on length of capability (3 days?).		
1-5			System performance	• Time to boot systems - shortcuts to improve? • Accuracy • Speed • Reliability • Latency • Throughput/bandwidth	• Possible requirement to determine minimum repetitions	• Also see 6-8 for testing on moving vehicle. • Determine list of equipment and systems to be installed in ADVANCE vehicle. • For each system/item, determine desired performance characteristics, and determine method to evaluate. • Measure boot time of all installed systems. • Testing time = depends on installed systems and test parameters	• LAVIIAS • Coyote Vetronics	• TM-12 • TM-13 • TM-15 thru TM-18 • DQ-5
1-6			OMI Technical Performance	• Objective evaluation of technical characteristics of new devices (volume, noise reduction, etc – as opposed to human-based evaluation). Specific parameters to be defined.	• Nil	• Identify new devices that will be on ADVANCE vehicle. • For each device, determine important technical characteristics for human performance. • Testing time = depends on range of devices and parameters for test.	• Coyote Vetronics	• TM-17 • HE-8

Serial	Activity	Description	Trial	Experimental Parameters	Statistical Analysis Requirements	Resource Requirements (Terrain/Crew/Eqpt/Time)	Vehicle(s) Required	SCD Reference
2-1	**Short Course**	Set courses on pavement and two levels of cross country to evaluate effect of AS and determine the optimum AS modes.	Speed	• Max speed based on limiting factor(s): ○ Crew ride and driver control (subjective) ○ Absorbed power or SAE acceleration limits	• Crew rotation • Minimum repetitions	• Instrument vehicle to measure 6 DoF acceleration. • Determine applicable SAE limits. • Do runs with increasing speed, measure accelerations, calculate absorbed power. Stop when crew limit reached. • Use crew questionnaires for comfort and task completion ratings and task performance measurement • Compare SAE limits to observed ratings vs absorbed power. • Testing time = 4 days	• LAVIIIAS • Control vehicle	• TM-3
2-2			Absorbed Power	• Peak/integrated over specific duration at same speed	• Nil		• LAVIII • Control Vehicle	• TM-4
2-3			Acceleration	• Straight-line acceleration over fixed distance	• Nil	• Measure elapsed time over fixed distance. • Use accelerometers to measure time/distance curve. • Testing time = 1 day	• LAVIII • Control Vehicle	• TM-3
2-4			Weapon/sight stabilization	• Ability to maintain sight on target (subjective) • Objective stability	• Crew rotation • Minimum repetitions	• Using available sighting system set tracking task on target parallel to course. • Do at increasing speeds. • Either instrument sight head with 6 DoF accelerometers or mathematically extend from hull. • Do video capture of sight imagery for post-hoc analysis. • Use crew questionnaires to	• LAVIII • Control Vehicle	• TM-4

Serial	Activity	Description	Trial	Experimental Parameters	Statistical Analysis Requirements	Resource Requirements (Terrain/Crew/Eqpt/Time)	Vehicle(s) Required	SCD Reference
						capture subjective ease of tracking. • Testing time = 3 days		
2-5			Braking	• Stopping distance • Optimum AS mode • Degree of dive – effect on crew • Oscillations or other negative effects	• Nil	• Measure stopping distance from increasing speeds. • If different AS modes, vary – anti-dive, etc. Anti-lock on/off? • Testing time = 1 day	• LAVIII • Control Vehicle	• TM-6
2-6			Signatures	• Acoustic signature • IR signature during and after movement • EMI	• Nil	• Select and obtain sensors – IR camera, sound pressure level, others depending on requirements. • Determine operating conditions for test – different speeds, silent watch, cross-country vs roads. • Determine suitable background. • Assess subjective differences in IR signature – ability to recognize. • Testing time = 2 days	• LAVIII • Control Vehicle	• TM-7 • DQ-4
3-1	**Slope Course**	Measure automotive performance on slopes of different terrain, to evaluate effect of AS and determine the optimum AS	Side-slope	• Max static slope • Performance on side slope • Effect of AS leveling	• Minimum repetitions	• If available (see 1-3 as well), use tilt table to establish maximum static slope. • Locate suitable slope at approximately 75% of max slope • Determine evaluation parameters (degree of understeer, side/rotational slippage, speed?), assess AS on/off/modes. • Test ability of vehicle to traverse	• LAVIII • Control Vehicle	• TM-2 • FT-1

Serial	Activity	Description	Trial	Experimental Parameters	Statistical Analysis Requirements	Resource Requirements (Terrain/Crew/Eqpt/Time)	Vehicle(s) Required	SCD Reference
		modes.				straight, sideways, 45 degree lines up/down. • Testing time = 3 days (requirement for significant safety measures)		
3-2			Forward slope	• Max slope for start • Optimum AS mode on steep hills • Best sustained speed on long grade	• Minimum repetitions	• Require series of steep hills (LETE?), and/or quite steep dirt hill, plus longish constant grade (public roads). • Measure max speed in various modes on long hill. • Test starting ability on hills of increasing steepness if available – if not, measure degree of wheel slip. • Testing time included in 3-1	• LAVIII • Control Vehicle	• TM-2 • FT-1
4-1	**Maneuvering Course**	Measure automotive and obstacle performance on	Turn radius and acceleration	• Minimum-speed turning radius • Lateral acceleration • Effect of “leaning” vehicle in turn	• Nil	• Require large “skid pad” area of asphalt/cement, with circle painted of appropriate diameter. • Drive vehicle around circle as fast as possible in dry and wet, with AS setting several angles of vehicle roll. • Record subjective impressions from vehicle drivers/CC. • Record minimum turning radius at very slow speed. • Testing time = 1 day	• LAVIII • Control Vehicle	• TM-5

Serial	Activity	Description	Trial	Experimental Parameters	Statistical Analysis Requirements	Resource Requirements (Terrain/Crew/Eqpt/Time)	Vehicle(s) Required	SCD Reference
4-2			Slalom course	• Speed of maneuvering through course • Effect of suspension height/leveling • Degree of body roll • Operator comfort and confidence ratings • Optimum AS modes	• Crew rotation • Minimum repetitions	• Prepare slalom course using cones on different terrain types. • Measure time to complete course, using different AS modes (anti-lean, lean into turn, ?) • Measure roll, etc using accelerometers. • Use questionnaire to assess subjective impressions of security, handling, comfort and confidence. • Testing time = 1 day	• LAVIII • Control Vehicle	• TM-6
5-1	**Obstacle Course**		Gap crossing	• Max gap	• Nil	• Would best be done at a facility created for this purpose such as the old LETE; the ability to vary the step height and gap would otherwise be difficult considering the vehicle weight. • Determine measured max capabilities in previous vehicle testing and start with that • Use “commanding” of suspension at different stations • Testing time = 1 day	• LAVIII • Control Vehicle	• TM-5
5-2			Step climb	• Max height of step	• Nil		• LAVIII • Control Vehicle	• TM-5
5-4			Tip-toeing	• Ability to avoid specific spot on the terrain	• Nil	• Mark location on the ground; try to run vehicle over the spot without touching a wheel. • Assess manually or (if available) automatically. • Testing time = 2 hours	• LAVIII • Control Vehicle	• TM-5

Serial	Activity	Description	Trial	Experimental Parameters	Statistical Analysis Requirements	Resource Requirements (Terrain/Crew/Eqpt/Time)	Vehicle(s) Required	SCD Reference
6-1	**Duty Cycle**	Vehicle runs multiple laps of a duty cycle typical of real operation, to evaluate effect of AS.	Fuel Economy	• Mileage on different terrain/integrated over duty cycle • Power draw of suspension system	• Nil based on extended duty cycle	• Define duty cycle and test terrain. • Define required runs for statistical significance. • Run vehicle through duty cycle with and without AS. • Use measured amount of fuel or amount to fill tank. • Measure peak/instantaneous power draw during runs. • Testing time = 1 week (including all other "duty cycle" tests.	• LAVIII • Control Vehicle	• TM-1 • DQ-4
6-2			Vibration	• Absorbed power - peak/integrated over duty cycle • Subjective effects of vibration on crew at different absorbed power levels and in different terrain types and speeds (ie, does "absorbed power" correlate to crew comfort. • Crew task performance measures	• Crew rotation • Minimum repetitions	• See 2-2, use same procedure. • Correlate human tasks on installed equipment (will depend on equipment, see 1-5) with runs at different speeds/absorbed power. • Relate to SAE standards • Testing time included in 6-1.	• LAVIII • Control Vehicle	• TM-4 • HE-9
6-3			Navigation system performance	• Reported vehicle location from navigation system • Refresh rate • Requirement for crew information	• Nil	• Compare navigation system accuracy to hand-held GPS. • Measure refresh rate, determine • Use questionnaire to assess refresh rate suitability, measure. • Testing time included in 6-1	• Coyote Vetronics	• TM-14 • MFTA-3
6-4			Crew	• Effectiveness of new devices (LSAS, crew viewing, warning	• Crew rotation • Minimum	• Identify new devices that will be on ADVANCE vehicle.	• LAVIIIAS • Coyote	• HE-1 thru HE-

Serial	Activity	Description	Trial	Experimental Parameters	Statistical Analysis Requirements	Resource Requirements (Terrain/Crew/Eqpt/Time)	Vehicle(s) Required	SCD Reference
			performance	devices, sensors, Vetronics integration, etc)	repetitions	• Conduct user group to identify specific tasks and human performance parameters relevant to new devices or capabilities. • Conduct testing as required. Include subjective assessment of usability (readability, ease of use, usefulness, etc, as well as objective (task based) human/system performance tests. • Compare to current method, with and without AS • Testing time = 1 wk (in addition to 6-1)	Vetronics • Control Vehicles	7 • MFTA-2
6-5			On-the-move surveillance	• Ability to observe targets on the move without being detected • Effectiveness improvement from being able to do surveillance on move	• Crew rotation • Minimum repetitions	• Ability to track targets tested in 2-4. • Establish surveillance scenario, including move between surveillance locations, stealth, surveillance tasks • Conduct scenario, determine ability of vehicle to do on-move surveillance, and assess improvement in overall crew and system performance from being able to do on the move. • Compare with/without AS • Testing time included in 6-1/6-4.	• LAVIIIAS	• HE-1

Serial	Activity	Description	Trial	Experimental Parameters	Statistical Analysis Requirements	Resource Requirements (Terrain/Crew/Eqpt/Time)	Vehicle(s) Required	SCD Reference
6-6			Optimum AS modes	• Modes of the AS that are most useful for different tactical tasks	• Nil	• Conduct user group to define desired tasks, discuss potential AS modes. • Review results of previous testing. • Determine requirements for testing to establish most useful mode. • Testing time = depends on requirements.	• LAVIIIAS	• MFTA-1
6-7			System performance	• Accuracy • Speed • Reliability • Latency • Throughput/bandwidth	• Nil	• Also see 1-5 for static testing. • Determine list of equipment and systems to be installed in ADVANCE vehicle. • For each system/item, determine desired performance characteristics, and determine method to evaluate. • Testing time = depends on installed systems and test parameters, likely included in 6-1/6-4.	• LAVIIIAS • Coyote Vetronics	• TM-12 • TM-13 • TM-15 thru TM-18 • DQ-5
7-1	**Virtual Simulation**		Crew performance	• Effectiveness of new devices in motion environment – including: ○ more complete or sophisticated representations of current devices	• VV&A of simulation and models • Crew rotation • Minimum repetitions • Depending on	• Determine devices and capabilities to be represented, and level of fidelity and integration into simulation and OMI. • Create models and capabilities, including AS model. • Expand scenarios and tasks from	• Nil	• HE-1 thru HE-7

Serial	Activity	Description	Trial	Experimental Parameters	Statistical Analysis Requirements	Resource Requirements (Terrain/Crew/Eqpt/Time)	Vehicle(s) Required	SCD Reference
				○ Other postulated devices not implemented in the ADVANCE vehicle. ○ Capabilities under more challenging or more replicable conditions	evaluation	6-4 and 6-5 for use in the virtual environment. • Create test plan including comparisons (design studies), measurements of human/system performance, etc. • Testing time = depends on capabilities and testing required, perhaps 2 weeks.		
7-2			Optimum AS modes	• Modes of the AS that are most useful for different tactical tasks		• Include in definition of model capabilities (for AS) in 7-1. • Incorporate in test plan. • Testing time = included in 7-1.		• MFTA-1
7-3			Vibration	• Level of crew comfort and performance at different absorbed power inputs, with wider range of vibration levels and suspension characteristics.		• Replicate testing from the field, concentrate on areas considered to be problematic for human performance or comfort. • Testing time = possibly included in 7-1.		• TM-4 • HE-9
			Sight Stabilization	• Objective evaluation of crew's ability to maintain sight-line at different vibration levels. • Engagement and gunnery performance; ability to fire on the move under varying conditions		• Replicate vibration results from 2-1/2-4. • Crew assigned pointing task, measure peak, RMS variation in deviation from desired pointing direction. • Testing time = included in 7-1.		• TM-4
8-1	**Constructive Simulation (OR**		Logistics planning	• Impact of maintenance, manning, and logistics requirements on availability	• VV&A of model • Minimum repetitions	• Create OR model of larger force equipped with vehicles with ADVANCE capabilities.	• Nil	• Nil

Serial	Activity	Description	Trial	Experimental Parameters	Statistical Analysis Requirements	Resource Requirements (Terrain/Crew/Eqpt/Time)	Vehicle(s) Required	SCD Reference
	and TNM)			and battlefield effectiveness of the force		• Use presumed RAMD data from OEM or from testing, and logistics requirements from OEM. • Testing time = 2 weeks?		
8-2			Battlefield Effectiveness	• Effectiveness of force equipped with vehicles with ADVANCE capabilities		• Use OR model from 8-1, including combat function capabilities. • Assess LER or other parameter with different vehicle capabilities. • Testing time = included in 8-1?		• Nil
8-3			AS Performance	• Capabilities of AS system		• AS contractor creates model of the AS system. • Conduct analysis of the performance of individual capabilities and compare to the results from other trials.		• CS-2
8-4			OMI Assessment	• Effectiveness of OMI		• Model vehicle systems and crew interfaces using Task Network Model. • Assess variations in performance parameters, differences in system capabilities or availability, etc.		• All

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