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# Marine Corps Load Effects Assessment Program (MC-LEAP)– a standardized test methodology for dismounted soldier systems applicable for Norway?



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**Marine Corps Load Effects Assessment Program (MC-LEAP)  
– a standardized test methodology for dismounted soldier  
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## English summary

A soldier system is an integrated set of articles/components that soldiers wear, carry, consume or control to strengthen their individual capability and the capability of their fighting unit. The soldier equipment consists of many individual components and modules that must be seen and treated holistically, i.e. as a system. In practice this is a difficult task, which asks for new measures and tools for testing and evaluating the soldier equipment. It is not sufficient to optimize single components. To secure the soldier's ability to perform his or her mission, knowledge on how single components affect the soldier's ability when they are integrated into the rest of the soldier system is required. The US Marine Corps has developed a standardized test method that examines how soldier mobility is influenced by different equipment configurations. This test method, called MC-LEAP (Marine Corps Load Effects Assessment Program), has proven to be a very powerful tool.

This report is a summary of the information we received during a three day visit at the US Marine Corps. It starts by giving an insight into how the MC-LEAP, which is based on an obstacle course, is structured, the reasons for the choice of obstacles and course stations, and what the goal of this test method is. Moreover, the report describes what resources are required to own such an obstacle course, to carry out tests and to benefit from the results. To provide a better understanding of what MC-LEAP can be used for, examples of results of previously conducted trials are presented. MC-LEAP is in use in the US, Canada, and Australia. The UK has acquired a modified version of MC-LEAP.

Is the MC-LEAP a tool that also Norway should adopt?

To answer this question some clarifications are necessary. The report finishes by providing the questions that need to be clarified and shows different options as to how Norway could establish MC-LEAP for soldier system tests and evaluation.

## Sammendrag

Et soldatsystem er et integrert sett av artikler/komponenter som soldaten har på seg, bærer, forbruker eller kontrollerer for å styrke egen individuell kapasitet og kapasiteten til egen stridsteknisk enhet.

Soldatutrustningen består av mange enkeltkomponenter og moduler som må ses og behandles i en helhet, altså som ett system. Dette er en krevende oppgave som gjør nye tiltak og verktøy for testing og evaluering av soldatutrustning nødvendig. Det er ikke tilstrekkelig å optimere enkeltkomponenter. For å sikre soldatens evne til å utføre sine oppdrag kreves det også kunnskap om hvordan enkeltkomponenter påvirker soldatens evne når disse er integrert i resten av soldatsystemet. US Marine Corps har utviklet en standardisert testmetode som undersøker hvordan mobiliteten til soldaten er påvirket av forskjellige utstyrskonfigurasjoner. Testmetoden som kalles MC-LEAP (Marine Corps Load Effects Assessment Program), har vist seg å være et virkningsfullt verktøy.

Denne rapporten er et sammendrag av informasjonen FFI fikk under et tredagers besøk hos US Marine Corps. Den starter med å gi et innblikk i hvordan MC-LEAP, som baserer seg på en hinderløype, er bygget opp, hva som er bakgrunnen for valg av hindre og andre stasjoner, og hva målet med denne testmetoden er. Videre beskriver rapporten hvilke ressurser som er nødvendige for å etablere og drifte denne type hinderløype, for å gjennomføre tester og for å nyttiggjøre seg resultatene. For å gi en bedre forståelse av hva MC-LEAP kan brukes til, blir eksempler på resultater av tidligere gjennomførte tester presentert i denne rapporten. MC-LEAP er i bruk i USA, Canada, og Australia. UK har anskaffet en modifisert versjon av MC-LEAP.

Er MC-LEAP et verktøy som også Norge burde ta i bruk?

For å kunne besvare dette spørsmålet, er det nødvendig med en del avklaringer. Rapporten avslutter med å presentere hvilke spørsmål som må bli avklart og forskjellige alternativer for hvordan Norge kan etablere bruken av MC-LEAP for testing og evaluering av soldatsystemer.

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## Preface

The importance of optimizing the interrelation of all soldier equipment components has been a topic both in Norway and in NATO at least for a decade. And this topic will be even more important in the future with regard to NEC (Network Enabling Capabilities) [1].

This report looks at the potential of one specific soldier system testing tool, MC-LEAP, to treat and develop the soldier equipment as a system. MC-LEAP is a standardized obstacle course and provides a metric for soldier mobility. This obstacle course allows for building up knowledge about the influence of individual components integrated in a soldier system (equipment configuration) on soldier mobility.



# 1 Introduction

All equipment worn by a soldier, carries, uses or consumes is defined as soldier system [2]. When improving soldier capabilities with new components or further development of existing components one has to ensure that the overall performance of the soldier is also improved [3-5].

The soldier system is composed of many individual components and modules. Therefore, it is not sufficient to optimize single components. A holistic knowledge on how single components integrated into the rest of the soldier system affect soldiers' ability to perform their mission is absolutely necessary. This demands new measures and tools for testing and evaluating soldier equipment as a system.

The requirement processes for dismounted soldier equipment is driven by the operational demands of the user together with the threat conditions. During the procurement process often only the fulfillment of the technical requirements for the single material components are tested and evaluated. This is most of the time not enough. To evaluate if an overall capability improvement could be achieved single components also need to be tested and evaluated together with the rest of the soldiers' equipment, i. e. integrated in the the soldier systems. Only by testing the new equipment in operational relevant configurations one can get a realistic understanding of the overall improvement of the soldiers' capability and identify drawbacks in interaction with the rest of the equipment. Integrated testing can be done in an operational environment. Such operational tests can be used to measure the effect of including a new component in a soldier system [6]. But they have limitations when it comes to repeatability and will often not give a clear understanding of what aspect of the new equipment actually improved or worsened the performance of the soldiers. To measure performance, to make the tests repeatable and to make a comparison of similar solutions possible the US Marine Corps developed a standardized test course, MC-LEAP.

The US Marines define their main capabilities as survivability, communication and mobility. In other words, the soldier has to be able to shoot, to communicate, and to move. Until the development of MC-LEAP measuring mobility could not be done in a standardized way.

MERS (Marine Expeditionary Rifle Squad) has the mission to manage the Marine Rifle Squad as a System. That means MERS has to coordinate the integration and modernization of everything worn, carried, used, or consumed by the rifle squad including integration of equipped Marines in mobile platforms.

MERS founded the Gruntworks Squad Integration Facility located on Camp Barrett at The Basic School, MCB Quantico, VA. The Gruntworks facility provides a venue to engineer, evaluate, and refine the capabilities and limitations of all equipment in development and under consideration for procurement and issue to the infantry squad (Section 4.1, [7])

This report summarizes the information provided by the MERS program manager, Mark Richter, during a three days visit at MERS at the US Marine Corps base in Quantico both by presentations, discussions and documentation.

A lot of this information is also content to “APPENDIX D: APPLICATION FOR INITIAL IRB REVIEW OF HUMAN SUBJECT RESEARCH; PROTOCOL/RESEARCH TITLE: Enhanced Technologies for Optimization of Warfighter Load (ETOWL) and Marine Corps Load Effects Assessment Program (MCLEAP).” [8]. Relevant sections are cited directly and written in italic (see below).

*In the case of fielded material solutions, threat conditions and operational user needs drive the requirements generation process which leads to material development, procurement, and fielding of infantry squad equipment. Unfortunately, information gathered from Marine Corps Lessons Learned and casual interviews have revealed that there can be a mismatch between the equipment worn by the infantry and the obstacles that they encounter during missions. For example, it has been reported that the equipment is inflexible, cumbersome, heavy and bulky which can make it difficult to navigate through narrow doorways, climb over obstacles, cross waterways, and conduct other routine tasks associated with the operational environment.*

*This study will utilize a novel performance battery course - Marine Corps Load Effects Assessment Program (MCLEAP) – to ascertain the effects of infantry equipment on mobility and determine how the equipment can be modified, integrated, or adjusted to better accommodate the infantryman. The course was developed from five years of surveying infantry Marines on the most physically demanding and common tasks they conducted during deployments to OIF and OEF. These data, along with other components of the study, will feed into the Office of Naval Research (ONR) sponsored Enhanced Technologies for Optimization of Warfighter Load (ETOWL) virtual Marine model that is being developed by Boston Dynamics and the University of Iowa.*

## 2 Marine Corps Load Effects Assessment Program (MC-LEAP)

The idea to use an obstacle course as a part of the soldier system test and evaluation process is based on the findings from lessons learned and casual interviews. It was found, that the equipment in use can be a hindering factor with regard to the obstacles soldiers meet in theater. The hindering itself is caused by the following three equipment qualities: weight, bulk and stiffness.

The developed standardized test course is called MC-LEAP and should serve as the methodology to characterize weight, bulk and stiffness of dismounted soldier equipment and provide a metric for mobility on the battlefield.

### **Soldier load, burden and the weight**

*What is “load” in this context? We would suggest that “load” comprises more than just weight. The independent variables of our load model (or Marine burden) include weight, bulk, and stiffness as they are key criteria known to affect combat movement performance and influence the physiological demands on the Marine. [9]*

The US Marine Corps has used MC-LEAP in different trials throughout the last couple of years and gained good experience with the test course which Mark Richter shared with us. Before we give a summary of MC-LEAP results, we will explain the test course and the execution of test trial in more detail. We start by describing the parameters measured by MC-LEAP, what the according MC-LEAP buildup looks like, and what the objectives of MC-LEAP are.

### **2.1 MC-LEAP – A standardized metric for mobility**

MC-LEAP is designed to measure a number of different performances which reflect the basic aspects of soldier mobility:

**Time:** *The MCLEAP can measure performance time needed to complete the entire circuit while simultaneously measuring the time it takes to traverse singular obstacles within the circuit itself.*

**Distance:** *A vertical jump test will record the height jumped by each participant as an indicator of leg power.*

**Load Handling Speed:** *The time to transfer horizontal loads and vertical load lifts will be recorded.*

**Shooting Performance:** *Using the Noptel target engagement system, the time to engage targets and shot accuracy and consistency (i.e. grouping) will be recorded.*

**Subjective Ratings:** *A series of Likert scale questions will be used in which participants will respond to a series of questions at a computer survey kiosk immediately following the course. Questions will require participants to rate the acceptability of each burden condition for flexibility, bulk, and weight, and their performance in terms of agility, speed, mobility, and overall fatigue.*

*Percentage of Body Weight: Percentage of body weight to load carried in relation to performance decrement will be recorded/calculated in order to define/update published standards.*

## 2.2 MC-LEAP layout

The layout of the course is shown in Figure 2.1. A picture of the obstacle course taken at the Gruntworks facility can be seen in Figure 2.2.

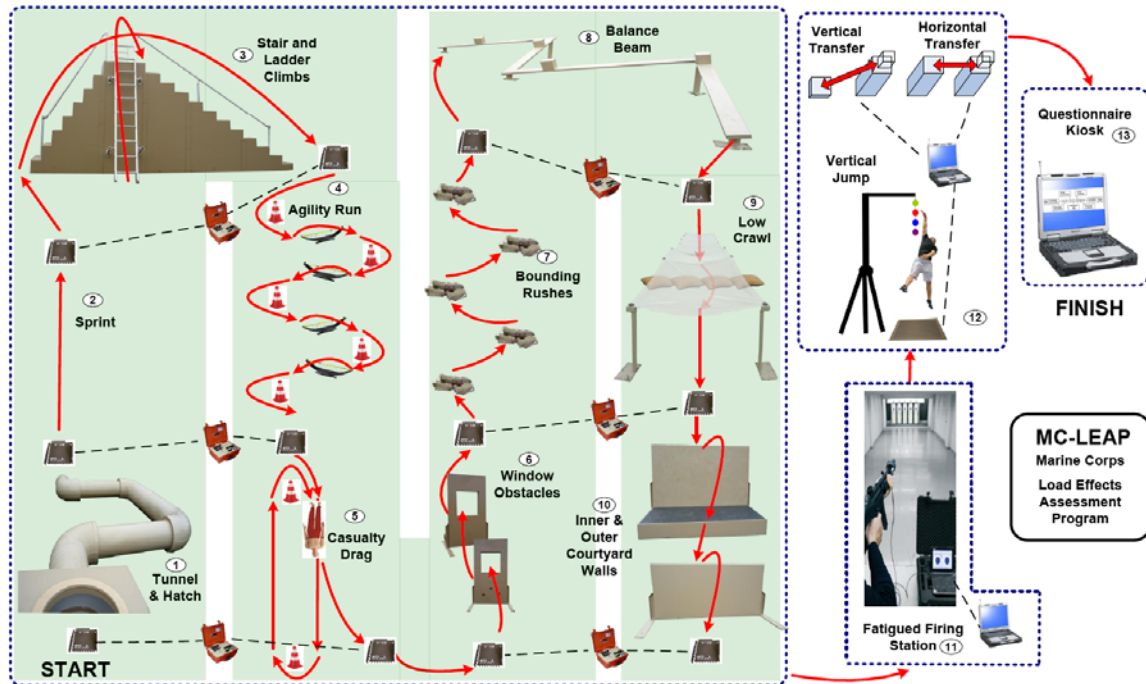


Figure 2.1 Sketch of the MC-LEAP test course



Figure 2.2 Picture of the MC-LEAP obstacle course

The obstacle course (Figure 2.1) consists of 10 tasks which are to be completed in the following order: tunnel and hatch, sprint, stair and ladder, agility run, casualty drag, windows, bounding

rushes, balance beam, low crawl, and walls. The individual obstacles and their utilization in the MC-LEAP set-up are described in Appendix A. But MC-LEAP consists of more than only the obstacle course. Performance data for four additional tasks are collected: firing range (station 11 in Figure 2.1), vertical jump, vertical weight transfer, and horizontal weight transfer (station 12 in Figure 2.1).

The last station of the course is a computer survey kiosk (station 13 in Figure 2.1). Here the participants are asked to fill out a questionnaire, where they are asked to provide ratings for various parameters and overall exertion required to complete the tasks with the respective equipment configuration on.

These activities are conducted in station 11-14, which will be described in more detail in Section 4.3.

### **2.3 Objectives**

MC-LEAP provides the ability to measure the performance of soldiers during operational relevant movements and tasks depending on load. Different equipment will affect the collected data on movement mechanics, time to complete events, physical performance attributes, observed performance, and after action reviews.

**The objectives of MC-LEAP were presented by Mark Richter as the following:**

- assess Marine combat performance under varying load conditions (weight, bulk, stiffness)
- develop a metric for mobility for use in requirements and acquisition processes
- provide essential guidance to infantry leaders to better understand the impact of different combat load decisions on the effectiveness of Marines in operations
- provide direction for the most promising areas and avenues for research and development to enhance mobility
- characterize the performance of Marines for a range of combat movements and tasks.

### 3 How to execute LEAP trials

Before conducting a test trial a lot of preparation and planning work needs to be done. This is not in the scope of this report. In the following section we will describe all the tasks and preparations which are necessary for the execution of the trial at the trial location.

To conduct the trial as effectively as possible, i.e. to be able to get an efficient number of participants running through the obstacle course on one day, a careful preparation has to be carried out in advance.

#### 3.1 Preparation of the trial area

The preparation of the trial area includes both the set-up of the MC-LEAP and the preparation of the soldier system equipment component configurations to be tested during the trial.

MC-LEAP is a mobile system and it can be stored in two twenty-foot containers. Alternatively the MC-LEAP equipment could be stored in a forty-foot container, but this can cause complications during land transportation due to the large size.

##### 3.1.1 Set-up

The MC-LEAP should be set up outdoors on a grass field of 55 x 30 m<sup>2</sup>. To set up the obstacle course one should start at the corner of the tunnel and hatch obstacle. Relative to the position of this obstacle the other obstacles need to be set up according to the layout plan (Figure 3.1). All distances and angles need to be measured as exactly as possible to reduce the differences (uncertainties) when comparing results from different trials due to variations in the layout. This requires appropriate measurement equipment like measuring tape and universal surveying instrument.

Some of the obstacles are heavy and to reduce the number of people necessary to set up the course a suitable trolley is recommended.

The time taking system (Fitlight<sup>1</sup>) and shooting system (Noptel<sup>2</sup>) require at least one specialist each to set them up and to make sure that they are operational during the entire trial.

The experience of Mark Richter, confirmed by David Tack and Alison Kelly (Humansystems Incorporated (HIS), Canada), is that to set up MC-LEAP at least 5-6 people are necessary. With this amount of people the set-up will take 1-2 days.

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<sup>1</sup> <http://www.fitlighttraining.com/products/fitlight-trainer/>

<sup>2</sup> [http://www.noptel.fi/eng2/Sport/index.php?doc=2\\_products/2\\_sportii](http://www.noptel.fi/eng2/Sport/index.php?doc=2_products/2_sportii)



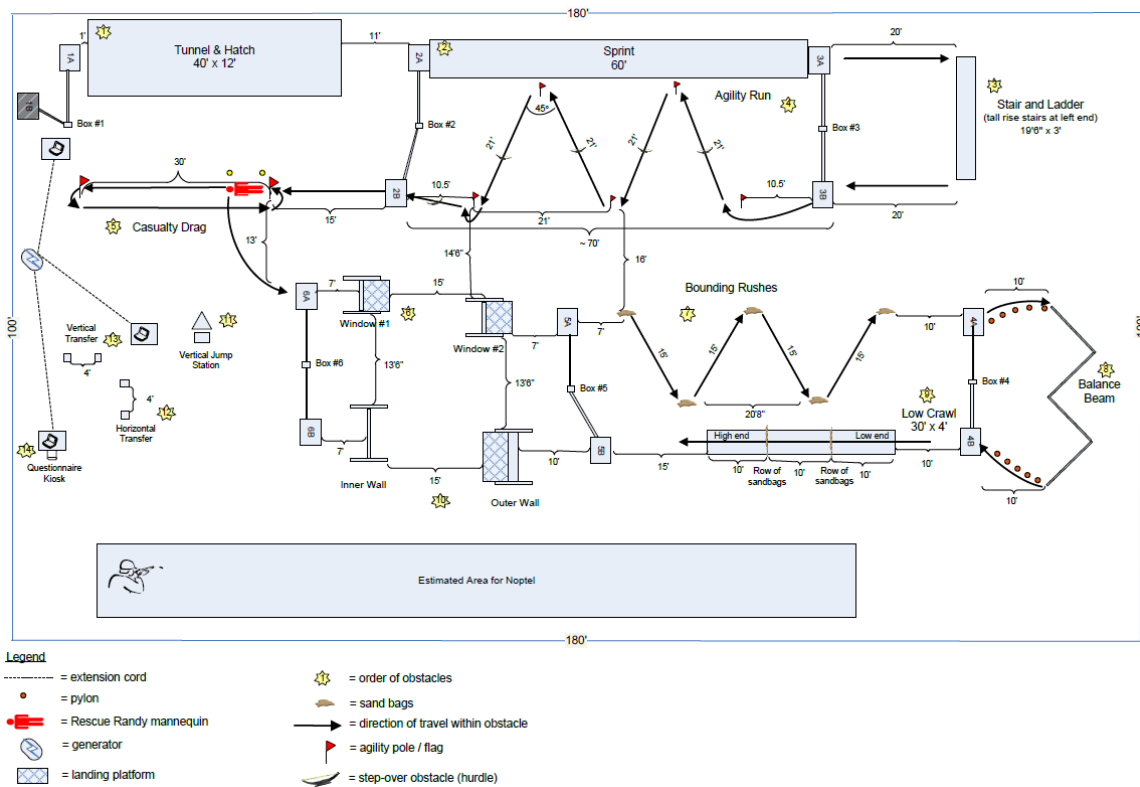


Figure 3.1 Sketch of the obstacle course with length and angle instructions

Due to safety reasons all obstacles have to be inspected and if necessary fixed, cleaned or, if wet, dried, before starting runs through the obstacle course.

### 3.1.2 Test equipment preparation

A MC-LEAP trial tests usually different configurations of equipment and involves a number of soldiers. This implicates that each participant of the trial needs to get the equipment in the right size.

During a trial participants run through MC-LEAP with random orders of the equipment configurations. This poses the challenge that the equipment needs to be available in the right configurations, sizes, and at the right time for each participant. This can be assured by laying out the equipment for each participant close to the start of the obstacle course. A lot of this work has to be done in advance of a trial day (test interval) as the time period between the start for two participants will not be longer than at maximum 10 minutes. In addition, the person responsible for the equipment also has to make sure that everyone is using the right equipment and that it is put on in a proper way.

## 3.2 Human volunteers

The MC-LEAP test trials depend on an efficient number of well-trained military volunteers.

### 3.2.1 Number and requirements

The number of required participants in a trial depends both on the number of configurations to be compared and the number of required test runs for each configuration. Generally a volunteer will not do more than two runs a day to ensure sufficient rest time for restitution, ensuring meaningful data. Hence, a volunteer is needed for example for 4 four days if the goal is to test 8 different configurations. MERS uses usually about 25 volunteers during a one-week period.

The volunteers should be well-trained soldiers who know how to conduct the different obstacles which reflect common military tasks.

Furthermore, the preferable number of participants depends on the desire to cover for example various age groups, a cultural variability, an anthropometric variability, and/or different experience levels.

### 3.2.1 Briefing and training runs

Before the trial the participants are briefed and get time to get familiar with the MC-LEAP.

During the in-brief the following information is provided:

- background information on the MC-LEAP program
- goals and aims of the experimentation protocol
- safety brief
- MC-LEAP orientation on obstacles and its accessory test stands
- information about all objective and subjective measures that will be collected and the acceptability rating scale along with the rules for the questionnaire completion
- signing the photograph/video release form (if necessary)

Subsequent to the brief the participants will be asked to walk through the MC-LEAP course and get movement instructions for each obstacle. Then they are given time to practice the course with up to 5 training runs. One of these training runs can be conducted with a loaded configuration. This should ensure course understanding and correct manipulation of stations and provide the participants from continuing to learn how to traverse the course during testing.

## 3.3 Data collection

As described in Section 3.1 a number of different performances are measured during a MC-LEAP trial.

### 3.3.1 Trial run stations

#### 3.3.1.1 Anthropometry and Range of motion station

Once the training runs are completed and the participant has rested enough he can get equipped for the first trial run. At the Anthropometry station the participant will be checked and measured

ensuring his diameter does not exceed the safe dimensions for traverse of the tunnel. Otherwise the tunnel has to be bypassed for that particular equipment configuration.

Range of motion measurements should be taken to evaluate the influence of the different equipment configuration on the flexibility of the soldier in comparison to an unencumbered baseline (boots, t-shirt, utility pants). The measured motions are (Figure 3.2):

- Trunk forward flexion
- Trunk lateral flexion (standing)
- Trunk rotation

The trunk rotation and the trunk flexion are measured in degrees. The sit and reach distance will be measured in centimeters.



*Figure 3.2 Range of motion measurements will be taken using a combination of a goniometer, a Wells and Dillon Sit and Reach apparatus, inclinometer, and a digital level.*

### 3.3.1.2 Obstacle course – combat movements

The participant moving as fast as possible through the obstacle course is followed by a researcher walking along besides him to provide reminders of the correct course path and proper procedure, to observe the volunteer for any signs of unsafe levels of fatigue or exhaustion, and to watch for any safety concerns. Besides that, the researcher is also able to note any special influences/effects on the participants' movement through the course caused by the respective equipment configurations. No more than two volunteers will be permitted to be on the course at the same time. This will prevent them from passing/colliding into one another as well as avoid the attention of researchers and safety monitors from becoming too divided. The measured times both for the completing the entire course and the individual obstacles are stored for each participant.

The run through the obstacle course takes between 5-8 minutes, depending on the equipment load.

### 3.3.1.3 Rifle shooting

*The system works by emitting an infra-red LED light towards the target upon the rifle being fired. The light is reflected back to the optical receiver by prisms mounted on the target and the software converts this to a target score. The targets are mounted 150 feet away from the firing line (Figure 3.3).*

*To execute, the Marine will be instructed to pick up the rifle and approach the firing line and take a tactical kneeling position. Upon the command “Fire” (given by the researcher), the Marine is given 15 seconds in which to complete 5 shots. He must aim for the center of the target. After 15 seconds have elapsed, if the 5 shots have not been taken the researcher will command “Cease Fire” and no further shots will be permitted.*



Figure 3.3 Set-up of the Noptel targets.

### 3.3.1.4 Vertical jump

Jump heights, both maximum jump height and average jump height for three jumps, are stored in meters.

*The jump station (Figure 3.4) consists of a rubber mat with an embedded sensor attached to a laptop. A set of 6 differently colored tennis balls suspended from a rope serve as targets to facilitate goal setting for each jump. When the Marine jumps, the sensor measures the time off the mat, and computer software converts that time to a jump height and lower limb power. In order for this calculation to occur, the participant’s body mass (body weight + clothing + gear) will be taken and entered prior to the jump testing.*

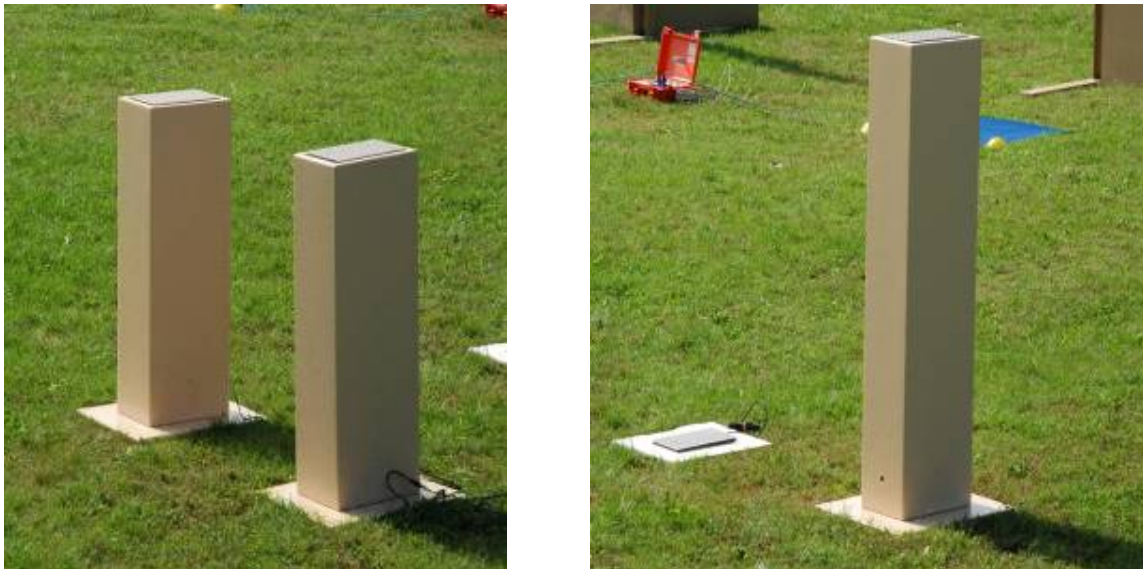


Figure 3.4 Jump Station.

### 3.3.1.5 Load handling

The times for sets of vertical and horizontal lifts are measured and stored. Times will be indicated in seconds.

*There are two components to the weight transfer station: horizontal transfer (Figure 3.5, left) and vertical transfer (Figure 3.5, right).*



*Figure 3.5 Horizontal (left) and Vertical Transfer (right) Stations.*

*The horizontal lift platforms are 48”<sup>3</sup> from the ground, and a 30 lb<sup>4</sup> ammunition can is used as the lifting load. The vertical platform is 68”<sup>5</sup> from the ground and a 30 lb ammunition will be used as the lifting load for the vertical transfer. For both the horizontal and vertical transfers, six lifts (with back and forth being considered one lift) are to be performed, and the time it takes to complete this set of six lifts is recorded.*

### 3.3.1.6 Survey kiosk

The survey kiosk consists of a stand-alone computer where the participant is filling in a one-page questionnaire. It is used to record the soldier’s self- assessment scores for mobility, speed, agility, maneuverability in confined space, exertion, and physical comfort.

*The Marine will be presented with the screen (Figure 3.6). He must fill in his participant number and condition, as well as an answer for each of the seven questions before the “Submit” button becomes active.*

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<sup>3</sup> 48 inch = 120 cm

<sup>4</sup> 30 lb = 13,61 kg

<sup>5</sup> 68 inch = 173 cm

**MERS Combine - Questionnaire**

**Instructions**  
On a scale of 1 to 7, with 1 being Completely Unacceptable, 4 being Borderline and 7 being Completely Acceptable, please rate your acceptability of the following..

**Identification**  
Enter Participant # [ ] Select Condition [ ]

**Question 1**  
The flexibility of the test condition  
○ 1    ○ 2    ○ 3    ○ 4    ○ 5    ○ 6    ○ 7

**Question 2**  
The bulk of the test condition  
○ 1    ○ 2    ○ 3    ○ 4    ○ 5    ○ 6    ○ 7

**Question 3**  
The weight of the test condition  
○ 1    ○ 2    ○ 3    ○ 4    ○ 5    ○ 6    ○ 7

**Question 4**  
Your agility while wearing the test condition  
○ 1    ○ 2    ○ 3    ○ 4    ○ 5    ○ 6    ○ 7

**Question 5**  
Your speed while wearing the test condition  
○ 1    ○ 2    ○ 3    ○ 4    ○ 5    ○ 6    ○ 7

**Question 6**  
Your mobility while wearing the test condition  
○ 1    ○ 2    ○ 3    ○ 4    ○ 5    ○ 6    ○ 7

**Question 7**  
Your overall fatigue while wearing the test condition  
○ 1    ○ 2    ○ 3    ○ 4    ○ 5    ○ 6    ○ 7

Comments (Used 0 of 500 allowed characters) [ ]

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Figure 3.6 Example of the subjective Questionnaire used during MC-LEAP trials.

### 3.4 Data handling

#### 3.4.1 Collected data

During a trial a number of different objective and subjective data are collected. The data collection methods are explained in Section 3.3. In addition some information about each individual participant should be collected.

#### Information about participants

In order to be able to understand and analyze the trial results it is important to know the characteristics of the test population. Therefore the following background information should be collected for each participant prior the trial:

- Age
- Rank
- Years of service
- Pre-existing injury (-ies)
- MOS (Military Occupation Specialty)
- Billet
- Number of deployments
- Self-reported equipment size

In addition some anthropometric measurements should be taken:

- Height
- Weight
- Chest circumference

- Torso length
- Waist circumference

### 3.4.2 Data analysis

The collected data along with the information about the participants can be analyzed and presented in many different ways. The data analysis will depend on the aim of the trial and the questions asked. There is no standard data analysis and hence there is no ready to use analysis tool available. MERS gets the data analysis done at US Army Research Institute of Environmental Medicine (USARIEM).

The preferred data analysis has to be defined for each trial independently and is a time consuming task.

### 3.5 Personnel needed to conduct a trial

The validity of a MC-LEAP trial depends on a sufficient number of volunteers, which need to be trained soldiers. This again requires a sufficient execution of a trial. There will always be uncontrollable issues, like the weather condition, which make the conduction of the trial impossible during time periods. However, it is in the responsibility of the trial staff to secure that all trial equipment and instrumentation is functional at all times. Therefore the following manning for a trial is recommended by Mark Richter (Table 3.1).

*Table 3.1 Recommended manning for a LEAP trial*

Task	Number of persons
'Fit and issue'	1-2
Noptel (shooting) station	1
'Human performance' station	1
'Range of motion' station	1-2
Time taking system (Fitlight)	1
Runner (follows the participant through the course)	1-2
Doctor/medical staff	1
Research monitor	1
One additional person	1
<b>minimum number of persons</b>	<b>9</b>

## 4 Already existing results and lessons learned

Australia (AUS-LEAP) and Canada (CAN-LEAP) have adopted MC-LEAP with the exact same setup. During the last years all three countries have conducted LEAP trials. Mark Richter shared the experiences and lessons learned from these trials with us.

In this section we present some of the results from the initial phase of human performance studies for the Office of Naval Research's "Enhanced Technologies for Optimization of Warfighter Load (ETOWL)" program given in [8].

### 4.1 Trail results

The US Marine Corps tested different orders of load in a trial conducted at Camp Lejeune in the initial phase of the human performance study for the Office of Naval Research's "Enhanced Technologies for Optimization of Warfighter Load" program. MC-LEAP was used to evaluate the effect of eight load order configurations on Marine mobility performance. The results are described in reference [9]. Here we only give some examples of what kind of results MC-LEAP can provide us with.

All the recorded data can be used as statistical basis for answering different questions concerning the influence of the equipment on the mobility of the soldier as well as to check the validity of the achieved results with respect to the volunteer population.

The following USMC load orders were tested in a balanced, repeated measures design (Table 4.1).



Table 4.1 Load orders testes during the initial phase of the human performance study for the Office of Naval Research’s “Enhanced Technologies for Optimization of Warfighter Load” program

<b>CONDITION A</b> 21.9 lbs (≈ 10 kg)	<b>CONDITION B</b> 35.5 lbs (≈ 15 kg)	<b>CONDITION C</b> 49.7 lbs (≈ 23 kg)	<b>CONDITION D</b> 56.4 lbs (≈ 25 kg)
<b>Base Uniform:</b> <ul style="list-style-type: none"> <li>• Uniform FROG Top</li> <li>• Uniform FROG Bottom</li> <li>• Glove, FROG</li> <li>• Undershorts</li> <li>• Combat Boots, with Laces</li> <li>• Socks, Boot</li> <li>• LightWeight Helmet with pads (only some helmets have NVG bracket)</li> <li>• M16A4 with RCO, GripPod, and Vickers 2 Point Sling</li> </ul>	<b>Improved Modular Tactical Vest (IMTV)</b> <ul style="list-style-type: none"> <li>• Yoke</li> <li>• Throat protector (done up)</li> <li>• Low back protection</li> <li>• Cummerbund</li> </ul>	<b>Front/Back ESAPIs:</b> <ul style="list-style-type: none"> <li>• Front and Back ESAPI Pouches</li> <li>• Front and Back ESAPI Plates</li> </ul>	<b>Side ESAPIs:</b> <ul style="list-style-type: none"> <li>• Side ESAPI Pouches</li> <li>• Side ESAPI Plates</li> </ul>
<b>CONDITION E</b> 75.0 lbs (≈ 34kg)	<b>CONDITION F</b> 75.0 lbs (≈ 34 kg)	<b>CONDITION G</b> 76.5 lbs (≈ 34 kg)	<b>CONDITION H</b> 79.4 lbs (≈ 36 kg)
<b>Full Assault Load:</b> <ul style="list-style-type: none"> <li>• Weighted M-16 Mags (6)</li> <li>• Double-mag pouches (3)</li> <li>• Grenade Pouches (2)</li> <li>• Blue body grenades (2)</li> <li>• IFAK</li> <li>• Dump Pouch</li> <li>• Groin Protection</li> <li>• PRC-153 Radio + Pouch</li> <li>• Hydration System filled with water</li> </ul>	<b>Repeatability Test:</b> <ul style="list-style-type: none"> <li>• Same condition as E.</li> </ul>	<b>NVG:</b> <ul style="list-style-type: none"> <li>• PVS-14 + case</li> </ul>	<b>Groin Protection:</b> <ul style="list-style-type: none"> <li>• Protective Undergarment (PUG)</li> <li>• Protective Overgarment (POG)</li> </ul>

In Figure 4.1 the time to run through the MC-LEAP course for the eight different load orders and the time for three individual obstacles are shown. The influence of the different equipment configurations on the times needed for individual obstacles can provide additional information on e.g. motion restrictions.

The agility run is mainly influenced by the weight load (Figure 4.1 c)).

However, the time distributions for the Tunnel and Hatch obstacle, reveals condition G being significantly different to E, F and H ( $p \leq 0.1$ ) (Figure 4.1 b))[9]. The equipment weight for

condition G and F is the same. Taking a closer look at the equipment configurations for G, E, F and H suggests that the PVS-14 bag used in configuration G slowed the soldiers down in the tunnel.

The results for the Window obstacle show significantly longer times for condition H ( $p \leq 0.05$ ) (Figure 4.1 d)) [9]. This condition included the addition of PUG/POG protective garments that provide protection to the groin and pelvis. This additional equipment may have caused mobility restrictions in the hip joints and pelvis.

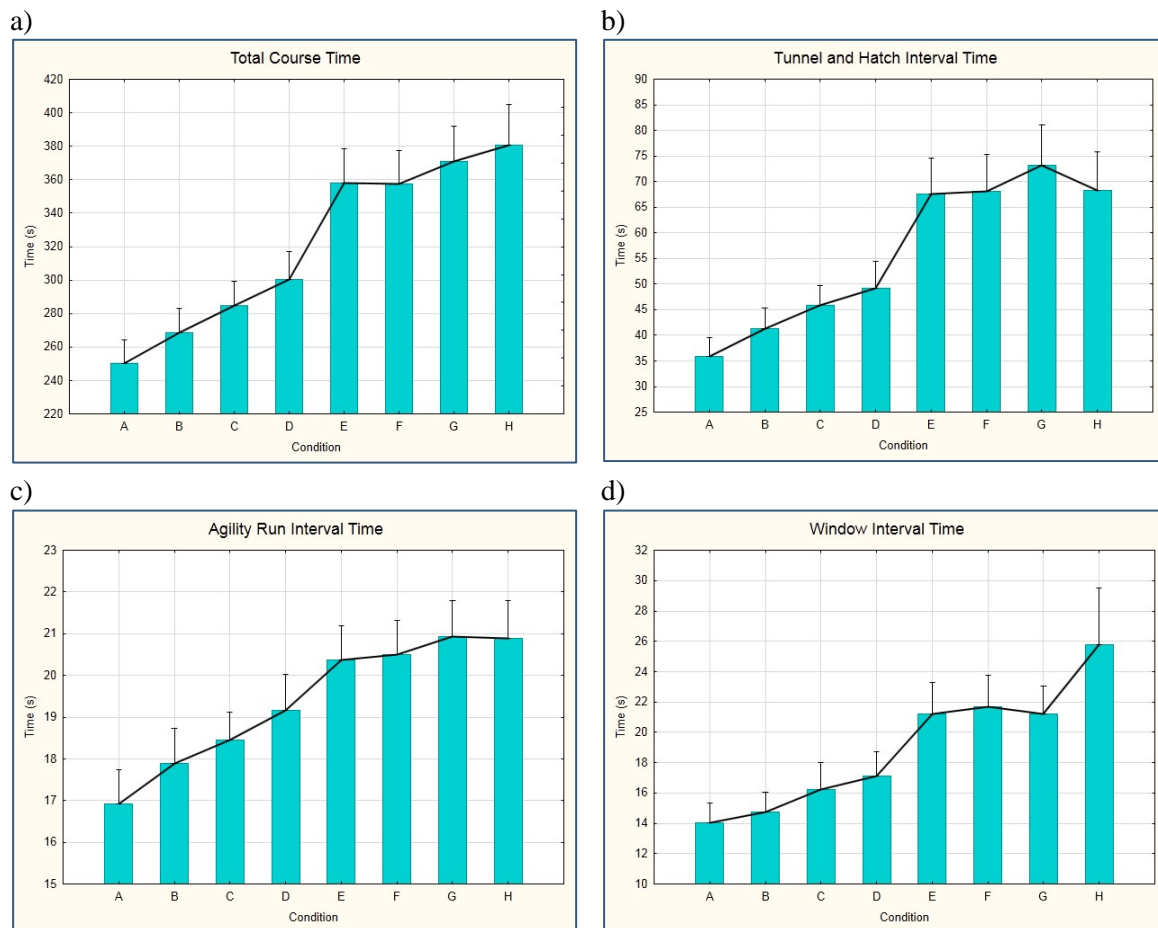


Figure 4.1 a) Average total course time by load condition  
 b) Average Tunnel and Hatch obstacle performance  
 c) Average Agility Run obstacle performance  
 d) Average Window obstacle performance

Figure 4.2 shows some more general results justifying that choice of participants does not lead to biased results.

Obstacle course performance (total course time) was compared to participant body mass according to the percent of body mass represented by each load order condition (Figure 4.2 a)). A statistically significant correlation was identified between percent body mass and total course

time, although the correlation was only moderately strong ( $r=0.56$ ) suggesting that load weight, relative to body weight, only partially explains course performance times.

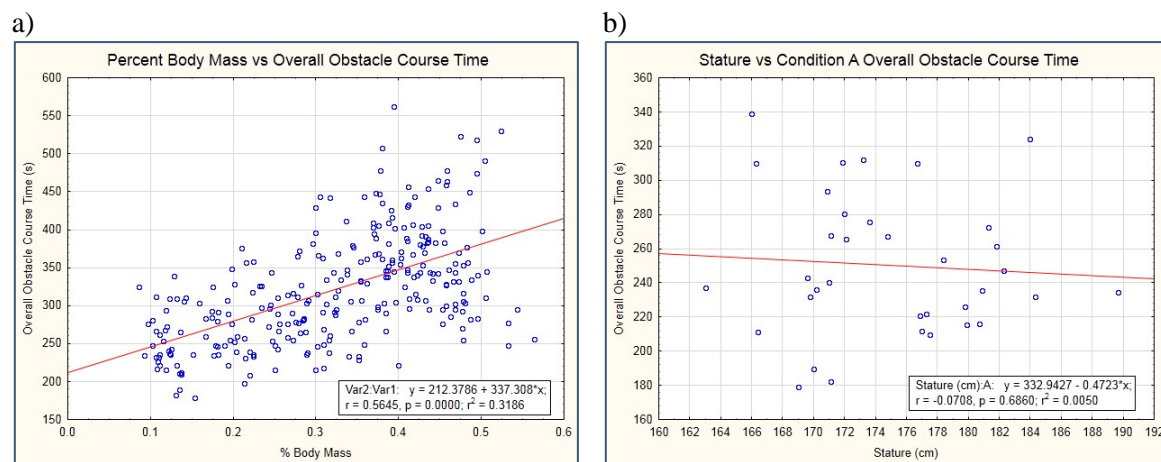


Figure 4.2 a) Correlation of percentage Body mass and b) stature to overall course time

A similar comparison of participant stature to total course time did not yield a significant correlation. Correlation analyses were undertaken for three load order conditions (i.e. A, E, and H) and no significant correlations were found [9]. Figure 4.2 b) depicts the correlation for condition A. It seems that the LEAP course design did not significantly favor or disfavor soldiers of different statures.

Another trial conducted in Australia 2014 tested the influence of different body armor configurations on mobility. During this trial USMC prototype body armor was compared with Australian body armor. This was possible as both countries use the identical LEAP system.

## 4.2 Gruntworks Squad Integration facilities

At this place we would like to mention that the MC-LEAP is a capability belonging to Gruntworks. The Gruntworks Squad Integration Facility located at The Basic School on Camp Barrett is founded by MERS. The mission of MERS is among others to provide the ability to conduct systems engineering, human factors, integration assessments, and spiral development in a reduced time cycle by operating the Gruntworks Squad Integration Facility as a Marine Corps Systems Command provided resource.

Gruntworks consists of a large building with a high bay area (15,000 square feet (ca. 1400 m<sup>2</sup>), storage space and lab areas. In addition there is a large field next to the building and access to training areas. Gruntworks is Navy Marine Corps Intranet capable and has Nett Warrior Systems (PRC-117G/PRC-152) onsite. All this and especially the location at a Marine Corps Base, together with the described facilities, make it easy to conduct MC-LEAP trials whenever needed with a sufficient number of participants.

Gruntworks has a number of capabilities besides the MC-LEAP. These are not essential in the MC-LEAP context. Anyhow, they ensure that Gruntworks operates as an independent and powerful facility for soldier system integration as well as the integration of the soldier in mobility platforms. The Gruntworks capabilities are:

- *Human Factors Lab*
- *3D Printer capable of multiple materials*
- *Sewing machines for textile prototyping (limited currently)*
- *New computers with Engineering Software installed (SolidWorks)*
- *Squad Equipment Inventory*
- *Marine Corps Load Effects Assessment Program (MC-LEAP)*
- *High bay for vehicle Human Factors analysis and equipment load configurations*
- *3D Full Body Scanner and Head Scanner for equipped and semi-nude human anthropometry scanning*
- *Biodex Dynamometer for Strength and Joint Torques*
- *Physiological Status Monitoring (heart rate, core and skin temp, respiration rate)*
- *GruntSim Biomechanics Software*
- *Various human factors tools and collaborative work environment*
- *Operational Environment Simulator (Pacific, Africa, Middle East)*
- *Noise dosimeters and in the boot load sensors*
- *Advanced Physiological Status Monitors*
- *Reconfigurable Vehicle Simulator for conducting integration of Marines and Equipment in various mobility platforms*
- *Design completed. Funding shortfall.*
- *Investment in additional anthropometry and human factors data collection equipment*
- *Prototype squad equipment added to inventory*
- *Knowledge Management Systems*
- *Improved automated survey tools*
- *Additional equipment for Human performance and mobility testing*

## **5 Do we need and can we realize a Norwegian LEAP?**

MC-LEAP has been shown to be a useful research tool to assess the influence of different soldier system component configurations on a soldier's mobility. At the same time, depending on the intended use and availability, this standardized test method requires considerable resources. Today Norway is not capable of treating the soldier equipment as a system as there are no tools available to evaluate the performance of soldier systems in a standardized way. As a consequence it is very difficult to understand the importance of one component in comparison to another when integrated in the soldier system. Such an understanding would not only give a better understanding of existing configurations, but also be very useful when procurement projects for different components have to be prioritized. Therefore we suggest considering the purchase of a LEAP system as a powerful tool for soldier system handling in Norway. However, if LEAP

seems to be a useful and feasible tool for Norwegian purposes, there are a number of questions which need to be discussed and answered to secure a proper launch. These questions are asked in Section 5.2.

## **5.1 Purchasing LEAP**

MC-LEAP can be purchased from HumanSystems® Incorporated in Ontario, Canada. They provided us with a Rough Order of Magnitude (ROM) price of \$320,000 CAD (not including freight/delivery fees) in October 2014. This price includes all labour and materials, and is subject to adjustment or change depending on specific client requirements and/or vendor conditions. They can provide a full and formal quote within 2-3 weeks, as they must contact all of their vendors and obtain up-to-date quotes from them in order to build our quote.

The LEAP would be ready for delivery approximately 12-14 weeks after contract award.

## **5.2 Questions to be answered**

In the previous chapters we described both the value of the LEAP and the resources needed to conduct trials and data analysis. Furthermore this advanced standardized mobility metric requires storage and maintenance. To conclude whether or not Norway should own such a system we therefore need to answer some questions. These questions are listed below. The text followed each question describes some arguments which can be taken into account. We want to underline that we do not provide answers to the questions.

### **What is the intended use of LEAP for the Norwegian military?**

LEAP can provide answers to a variety of questions concerning the mobility of soldiers using different equipment configurations. The answers should be of interest for all military branches. LEAP can also be an important tool in procurement processes with regard to the soldier system integration.

### **Who will request LEAP trial results?**

The results can both be used in research programs and in the procurement process. In purchasing processes the user can get objective answers about how the equipment influences the soldiers' mobility. Another important aspect is the possibility to compare the same equipment component from different companies in connection with existing gear with regard to the soldiers' mobility. This is possibly most important for the logistic organization.

### **Where should LEAP be used?**

The LEAP is a mobile system and can be moved around. However, some decisions about at what location it will be most useful should be made. When conducting trials a sufficient number of participants (trained soldiers) is essential.

### **Who should own it?**

LEAP is more a research tool requiring specialists. Conducting a trial and the data analysis requires engineers, physiologists and other scientific staff. The results provided by LEAP are of much interest for all Norwegian Armed Forces. This raises the question who should own and who should finance this standardized testing tool?

### **How should we use it?**

LEAP and LEAP trials will only be a part of all testing necessary in the procurement process. To make sure that it actually will be used it must be discussed if 1-2 defined by dates LEAP trial periods per year are sufficient or if the trials should be conducted when needed (e.g. the LEAP is held operative the whole year round).

In addition LEAP can be used to answer scientific questions connected to soldier system configurations.

### **Which questions do we need to be answered the next 10-20 years?**

In the beginning LEAP will be an important tool to describe soldier systems that are in operative use. In the future it will be a valuable tool for some equipment purchases. However, we have to identify the components planned to be purchased the next 10-15 years for which LEAP will be a suitable tool for evaluation. Within the soldier system integration MC-LEAP can provide informed arguments for one configuration against another.

### **How and who should introduce LEAP in the Norwegian Armed Forces?**

LEAP will only be useful if there is a customer demand for trials to answer specific questions. The customer can be the e.g. the Logistic Organization, Armed Forces or the Ministry of Defence. Whether or not a LEAP system will be used depends fully on the acceptance and understanding of its impact in the Armed Forces or at least the Army who has the main responsibility for the soldier system integration.

## **5.3 How can we realize a Norwegian use of LEAP?**

As specified earlier in this report LEAP requires educated personnel, storage and maintenance. Storage for the LEAP system only requires the storage of two twenty-foot containers. LEAP can be used both indoors and outdoors. MERS only uses it outdoors on grass areas to ensure as similar as possible conditions during different trials. Canada conducts indoors trials during winter.

Both the US and Canada have permanent staff committed to the LEAP system. The staff has to have a good understanding what the LEAP system can be used for, what kind of results one can

get. Furthermore, they have to ensure that the LEAP system is operable. This includes both keeping the obstacles in good conditions and the electronically instrumentation functional.

### **Norwegian LEAP**

In case Norway decides to purchase LEAP for domestic use the following aspects need to be settled / resolved:

- who will finance the purchase?
- who will own the system?
- who will be the staff, how should the staff be assembled?
- where will the system and the staff be located?
- when do we conduct the first trial and what will be the purpose with the first trial?
- who will be responsible for analyzing the trial data?

### **Scandinavian LEAP cooperation**

In case Norway don't want or doesn't have the resources to buy and maintain a separate LEAP system, a Scandinavian cooperation might be a way to go. MC-LEAP trials are extensive and conducting LEAP trials together can ease the burden for each country. In addition the necessity of trials might not exceed one trial per year, or every second year for each nation. However, such cooperation must be based on either one country committing all permanent staff to the system or different countries sharing the responsibility to commit the necessary permanent staff together.

### **European LEAP cooperation**

The same arguments as for a Scandinavian LEAP cooperation can be used for a European cooperation. Both alternatives imply a dialogue with the involved countries. For a European cooperation it also has to be decided with which of the countries that are interested in a LEAP cooperation Norway wants or should cooperate.

### **Hiring MC-LEAP**

As the MC-LEAP is a mobile system it would be possible to hire the system from another country along with experienced staff to conduct trials. This possibility wasn't raised with Gruntworks or Canada, yet.

## 6 A possible way to go

It is not straight forward to answer the questions raised in Chapter 5.2. The answers themselves could lead to a decision on how Norway might be able to realize to use of a LEAP system.

To achieve a better insight in the “real world” of LEAP trials, it would be preferable to gain more experience by conducting a first “small scale” LEAP trial. How could that be done?

Sweden is planning to conduct such a “small scale” LEAP trial, for the duration of one week, during spring or early summer 2016. For this trial they want to use an existing LEAP system along with the associated experienced staff. The first choice would be the US MC-LEAP owned by Gruntworks. Another possibility could be the Canadian LEAP. As this demands traveling to the respective location Sweden intend to conduct a trial with 10 Swedish soldiers as volunteers. We were informed about these plans at a “LEAP” meeting with FOI, FMV, MSS and FFI attending in Stockholm in the beginning of September. During this meeting we were invited to coin this activity.

### 6.1 A “small scale” trial in collaboration with Sweden

The idea of conduction a trial at an existing facility as a step towards a decision on how Norway could realize its own LEAP is very appealing and is undoubtedly a very valuable option. Such participation will lead to an extended understanding of the benefits of LEAP and the resources necessary based on own experiences. In addition will the participation of Norwegian soldiers with their own equipment give us some indications about the range of information a LEAP trail can provide to characterize our current soldier systems. Norway should consider joining Sweden and participating with 10 Norwegian soldiers. Norway could of course conduct such a trial on its own, but there are some additional benefits for all involved parties in conducting the “small scale” trial together with Sweden. This will be described in the next section.

### 6.2 Benefits of the collaboration with Sweden

Conducting a “small scale” trial together with another nation will result in a number of benefits. The most obvious is the benefit for the host facility. The host staff will be able to introduce the LEAP system to two other NATO nations at the same time. But also the advantages for Norway can be large. Some of these benefits are:

- To conduct the trial together with Sweden, another ”new-beginner”, can induce valuable discussions, more important questions raised and an extended profit for both nations. This is true for the planning phase, the conduction and the data analysis phase.
- The trial can be conducted with more soldiers.
- Conducting a trial with more nations involved can have a positive effect on the motivation and the effectivity of the staff and volunteers involved.



- Data analysis depends on what is considered to be the main purpose of the test. Therefore each nation will carry out its own data analysis. Comparing the final results can yield a broader understanding of the power of LEAP trials.
- Expenses on hiring a LEAP system with staff can be shared.
- Norway and Sweden gain a common LEAP experience.
- Norway and Sweden will obtain an important basis for evaluating the advantages and possibilities of a LEAP-cooperation.

## 7 Conclusion and Recommendation

MC-LEAP has proved to be a powerful tool on the way to a holistic treatment of the soldier system. In this report we have provided information on the lay-out and the objectives of MC-LEAP, resources required to own a LEAP system and to conduct LEAP trials, as well as what kind of results a LEAP trial can provide.

If Norway wants to enforce the treatment of soldier equipment as a system we need to establish tools to make this possible. In an earlier report we have described a possible data tool that will support assessment of soldier systems [10]. With this report we want to support the decision if a LEAP system could be the right first step for Norway to establish a tool for test and evaluation of soldier equipment integrated in a soldier systems. This is done by raising the most important questions which need to be answered to be able to effectuate a qualified decision.

We recommend conducting a “small scale” LEAP trial together with Sweden at an established LEAP facility. The experience gained from such a trial can serve as a solid basis for the responsible personnel in the Norwegian Armed Forces to be able to answer the questions raised in Section 5.2 and to allow for a decision on a possible realization of a Norwegian MC-LEAP. Based on those final answers the way ahead can be determined.

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## Abbreviations

FOI	Totalförsvarets forskningsinstitut
FMV	Försvarets materialverk
LED	Light emitting diode
MC-LEAP	Marine Corps Load Effects Assessment Program
MERS	Marine Expeditionary Rifle Squad
MSS	Markstridsskolan
NATO	North Atlantic Treaty Organization
NEC	Network Enabling Capabilities
PUG	Protective Undergarment
POG	Protective Overgarment
USMC	US Marine Corps

## Appendix A

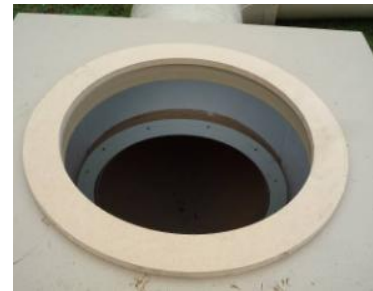
### MC-LEAP COURSE

#### **Station 1: Tunnel and Hatch**

The Marine approaches the stair portion of the tunnel and hatch obstacle (Figure A.1) and climbs up the stairs one step at a time.



Figure A.1 Tunnel and Hatch



Hatch Opening.



Figure A.2 Tunnel Opening.

The Marine then lowers himself (feet first) into the AAV sized hatch opening (Figure 5). Next, the Marine crouches and enters the opening of the tunnel (Figure A.2). The Marine will continue traversing through the tunnel until he emerges out the other end. Upon completing the length of the tunnel, the Marine quickly returns to a standing position and runs across the RFID timing mat.

### **Station 2: Sprint**



*The Sprint station starts once the Marine crosses the timing mat (Figure A.3). The Marine sprints as fast as possible for 20 yards. The sprint ends when the next timing mat is crossed.*

*Figure A.3 Sprint Lane.*

### **Station 3: Stairs and Ladders**



*Figure A.4 Stairs and Ladders*

*The Marine will run to the stair and ladder obstacle (Figure A.4) and progress through this obstacle in the following order:*

- 1) climb up the angled ladder; then down the straight ladder.*
- 2) climb up straight ladder; then down angled ladder.*
- 3) run to the base of the high rise stairs.*
- 4) climb up the high rise stairs; down the low rise stairs.*
- 5) climb up low rise stairs; down high rise stairs.*

*The Marine finishes this obstacle by crossing over the timing mat at the end of the long run/low rise stairs.*

**Station 4: Agility Run**

The Marine runs towards the first flag (Figure A.5). The Marine makes a tight cut around the outside of the flag and heads back in the opposite direction towards the second flag, jumping over hurdle obstacles along the way and continues this sequence for

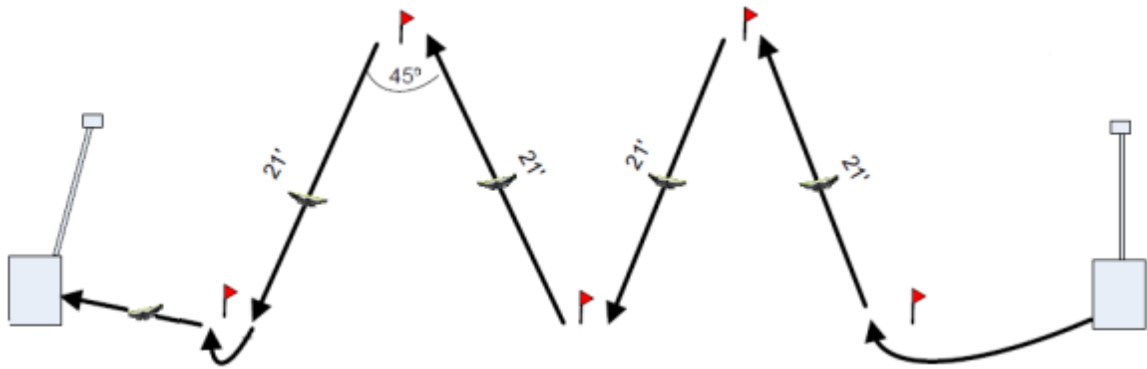


Figure A.5: Agility Run

the set of five (5) flags and five (5) hurdles (Figure A.5). This segment is completed when the Marine crosses over the timing mat after the fifth hurdle.

**Station 5: Casualty Drag**



Using the casualty strap on the MTV, the Marine will drag “Rescue Randy” mannequin (Figure A.6) out to the turn-around point and back to the original position at which the mannequin was located.

Figure A.6 Casualty Drag Path.

### **Station 6: Window Obstacle**

To complete the window obstacles, the Marine must first go through the window opening of Window 1 (Figure A.7, left). The Marine is free to choose whether or not he wants to use toe holds to assist him in climbing up the wall. After landing on the platform, the Marine runs to Window 2 (Figure A.7, right) and climbs through the window opening.

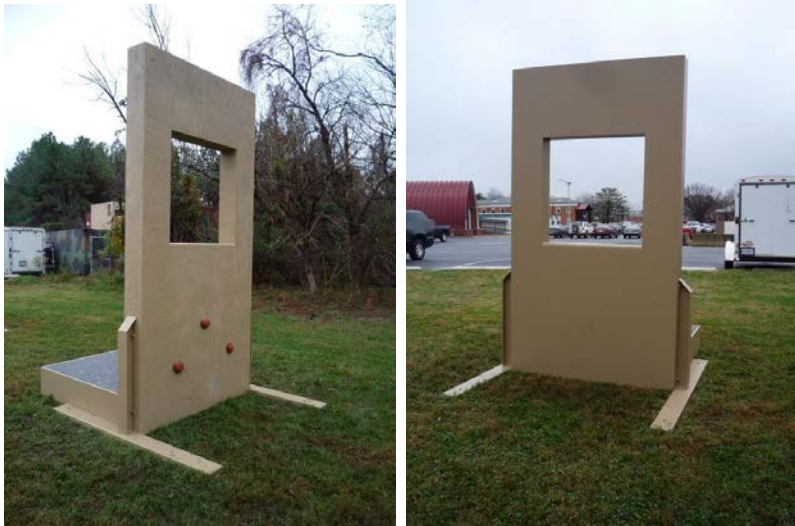


Figure A.7 Window Stations.

### **Station 7: Bounding Rushes**

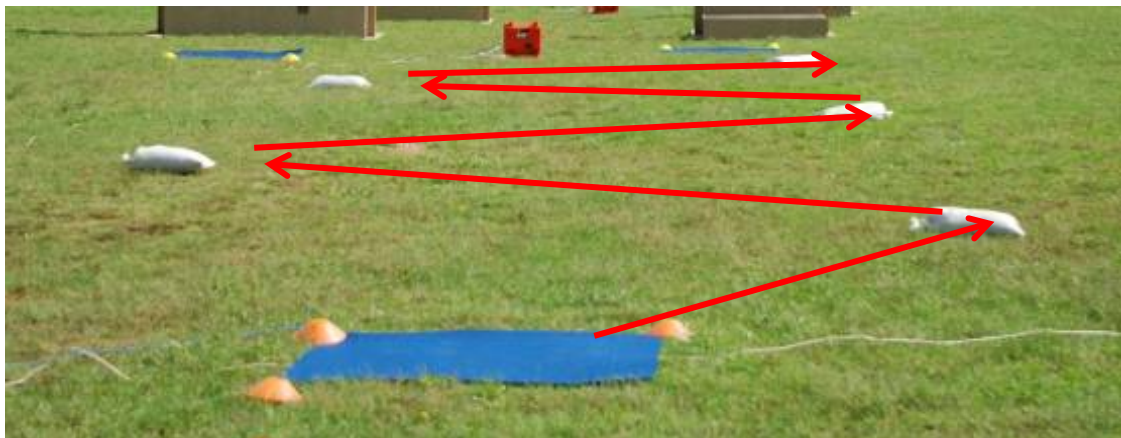


Figure A.8 Bounding Rushes Path.

The Marine runs to the first pile of sandbags (Figure A.8). Upon arriving at the first set of sandbags, the Marine assumes a prone position, acquires a sight picture, then leaps up to a running position. The Marine then sprints to the next (staggered) pile of sandbags and assumes another prone position. This cycle repeats until all piles of sandbags have been reached. This segment (and the timed course) ends when the Marine runs over the final timing mat.



### **Station 8: Balance Beam**



*Figure A.9 Balance Beam.*

*For the balance beam obstacle, the Marine keeps to the outside of the line of cones (Figure A.9) and steps up onto the beam from the left end. Jumping up onto the beam from the side is not permitted. The Marine carefully walks across the balance beam while stepping over padded box-shaped obstacles. Stepping on top of the box obstacles is not permitted. The Marine must exit the balance beam by stepping off the end (not the side) and then keeping to the outside of the line of cones, run towards the next timing mat.*

### **Station 9: Low Crawl**



*Figure A.10 Low Crawl.*

*The Marine begins by crossing the RFID timing mat, and then low crawls underneath the canvas as fast as he can (Figure A.10). At the 10 foot mark there will be a row of sandbags where the Marine will flip over and crawl on his back until reaching the next row of bags (20 foot mark). He will flip over and perform a high crawl for the remainder. He then runs to the timing mat thus completing this section.*

**Station 10: Inner and Outer Courtyard Walls.**

The wall obstacle is comprised of an inner and outer courtyard wall set in a staggered formation. The Marine begins by traversing over the outer courtyard wall (foreground, Figure A.11)

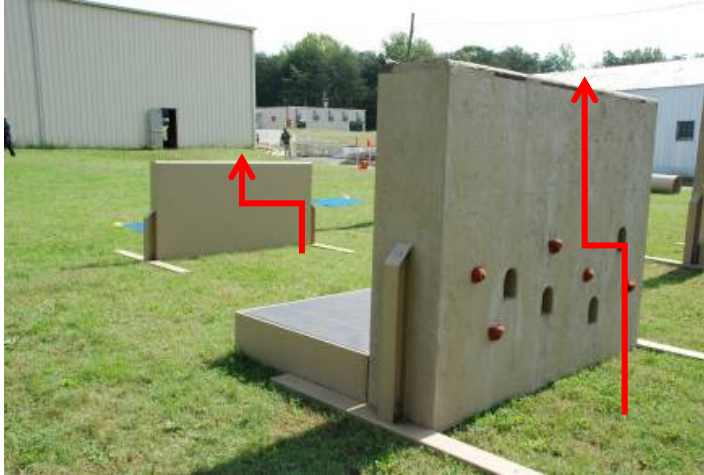


Figure A.11 Outer (foreground) and Inner Courtyard Walls

as quickly as possible. Any manner of traversing is permitted, and the Marine may use the foot holds to assist him if he wishes. After traversing the outer courtyard wall, the Marine sprints to the inner courtyard wall and crosses over it as fast as possible.

**Station 11: Firing Accuracy**

Firing Accuracy will be recorded using the Noptel ST-2000 Expert Marksmanship System.

**Station 12: Vertical Jump**

The Marine will perform a series of three maximal-effort jumps.

**Station 13: Weight Transfer**

The weight transfer station is used to measure the Marine's ability to quickly transfer a weight from one platform to another within each of the test conditions.

**Station 14: Subjective Rating Questionnaire Kiosk**

The questionnaire kiosk consists of a stand-alone computer terminal that runs a program containing a one-page questionnaire.