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SMSS™: An Unmanned Ground Vehicle Approach to Lightening the Load for Squad Mission Support

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ABSTRACT

In response to critical need to lighten the infantryman's load, SMSS was developed in collaboration with the US Army's Maneuver Center of Excellence (MCoE). SMSS is an Unmanned Ground Vehicle (UGV), the size of a compact car, designed to transport cargo for dismounted operations. SMSS lightens the load, carrying extended mission equipment, food, weapons, water, and ammunition. SMSS was designed with the right combination of size, weight carrying, volumetric efficiency, transportability, and modularity to optimize the cargo carrying and transportability of the system. This paper defines the scope of the problem of combat overloading and reviews the SMSS approach as one solution.

THE PROBLEM

Overloading the infantryman is not a new development. In 1870, scientists at The Institute William Fredrick in Germany initiated investigations to measure the physiological cost to soldiers carrying various loads under various temperatures. They found that a load of 48 pounds could be carried by a well-conditioned soldier in cool weather with little difficulty. However, in warm weather the same load produced impairment in physical strength, and the soldiers did not return to a normal state until sometime during the following day. Other experiments with the effects produced by increasingly heavier loads demonstrated that soldiers continued to show physical distress regardless of the degree of physical conditioning and concluded that it is impossible to condition the average soldier to march with a load once it reaches 69 pounds, no matter how much training he is given. More modern studies conducted by the US Marine Corp, the US Army Joint Readiness Training Center, and the Naval Research Advisory Committee have reached similar conclusions. Documented US Government criteria [1] for combat loads generally agree that an assault load should not exceed 48 pounds (30% of typical soldier body weight) and an approach march load should not exceed 72 pounds (45% of typical soldier body weight). As a Soldier's load (and resulting fatigue) increases, his combat effectiveness decreases. While individual results vary, a Soldier's endurance has limits which cannot be exceeded, regardless of the level of physical conditioning. Despite this fact, technology has done little to lighten the load of the Soldier, and the trend toward excessive combat loading continues, as shown in Figure 1 [2].

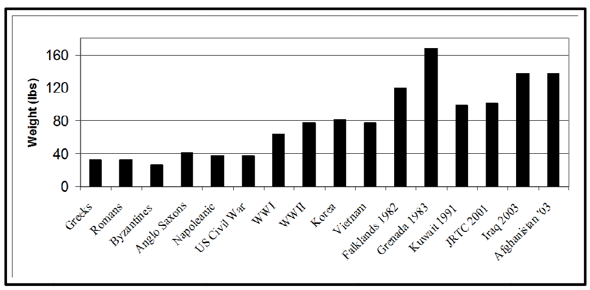

Figure 1: Estimated march load weights carried by various infantry units throughout history.

Today's Infantry Brigade Combat Teams (IBCT) require advanced operational capability, tailored to their specific needs. Even though the mix of sustainment vs. lethality loads are adjusted at the small unit level using Mission, Enemy, Terrain, Troops available, and Time (METT-T) considerations, the Soldier's lethality is limited by what he can carry into the fight. Recent technological advances in body armor, sensors, weapons and weapon sights, night vision equipment, and command and control systems provide no benefit if they don't make it into the fight. These systems include anti-tank, mortars, and other heavy weapons, small unmanned systems, and communications systems critical to maintaining situational awareness without exposing Soldiers, which leads to success on an asymmetric battlefield. Many of these modern improvements are powered by batteries, which generate their own weight and logistics burden. Modern asymmetrical warfare, police and humanitarian actions, conducted by light forces in remote locations and difficult terrains, burdens small units to be more self-sufficient for longer periods of time and carry more supplies with them. A lack of readily available local water combined with operations at high altitude and high temperature extremes exacerbates this situation. Cargo needs include items such as food, water, medical supplies, overhead cover, sandbags, small arms ammo, and virtually every class of supply.

The negative impact on combat effectiveness of soldier overloading is well understood and well documented. What is less well understood and less documented is the cost of soldier overloading in human misery and dollars. Recent analyses performed by Lockheed Martin have quantified this part of the problem. Data from a representative IBCT combat deployment for 15 months over 2009-2010 in Operation Iraqi Freedom (OIF) [3] was studied. Annualized, the Unit sustained 1,059 annual Disease and Non-Battle Injuries (DNBI). Based on this data, 50% of the annual DNBI in similar combat are expected to be musculoskeletal in nature. On average, across OIF and Operation Enduring Freedom (OEF), 51% of those injuries are expected to be due to overuse [4]. Approximately 92% of those return to duty (RTD) after some level of treatment, and about 10% are medevac'd. Approximately 20% of the RTD cases become chronic injuries that persist into future deployments and/or for the remainder of the soldier's career service [5]. Multiple source orthopedic data indicates individual soldier readiness will suffer gradual degradation with repeated infantry combat tours. Data indicates that the average cost of treatment per soldier, depending on level of care, ranges from $200 to $20,000. If the soldier is medevac'd to Landstuhl, the cost rises to $43,000 per soldier, and if medevac'd to the US it soars to $115,000 per soldier. The data also suggests that follow-up care will double those costs [6]. Add to this the costs of lost combat mission days prior to RTD, medevac casualty lost mission days, expected increased combat injury exposure for remainder of Unit and cost of "preventable" IED or ambush situations resulting from reduced Unit manpower, and the average annual cost to the IBCT, not counting those killed in action, is a staggering $11.7 million [7]. But, the expense does not end there. Of those soldiers medevac'd, 75% cannot RTD, and as mentioned earlier, 20% of the RTD cases will elevate to a chronic condition following deployment. The CONUS care of medevac'd soldiers combined with average disability payments for those who elevate to chronic conditions exceeds an additional $14.8 million per IBCT [8]. It is estimated that 43% of OIF/OEF veterans will ultimately exhibit musculoskeletal issues following active duty, a tenfold increase over prior service averages [9]. The total number of soldiers cycled through operational theaters exceeds 1.7 million, and the number of veterans entering the Veterans Administration medical system will continue to climb as long as combat operations persist. As these soldiers transition back into civilian life after multiple deployments (many current soldiers are on their fourth or more year-long deployment), they will present in greater numbers to musculoskeletal specialists [10]. The total lifetime cost of OIF/OEF veterans will likely be in the $380 billion to $720 billion range (2011 dollars) [9]. Clearly this is an unsustainable and unacceptable situation from both soldier suffering and cost bases.

POTENTIAL SOLUTIONS

There are several approaches to solving the issue of combat overloading. Some have suggested that the answer is as simple as having the soldiers carry less gear. In some cases, this may actually be viable, depending on mission and location. However, this often leads to a propensity for the individual soldier to shed potentially life-saving gear such as body armor plates and additional water in favor of more ammunition and other useful technology items. Reduction of the gear is an option best left to the Unit commander on specific case by case bases, and it cannot be counted on as an effective general solution to the problem.

Another approach is to reduce the weight of the individual items that the soldier carries. There have been notable successes, but as a community, we have fallen far short of making significant improvements. While this approach should be continued, it is by nature evolutionary, distributed across many items, and it will therefore take much time and investment to yield significant aggregate improvement.

Yet another approach is to transport the soldiers and their gear some good portion of the distance using ground vehicles or helicopters. Both have found widespread use in various areas of OIF and OEF, and in some cases this approach has proven viable. However, the widespread use of Improvised Explosive Devices (IED) by the enemy has in most areas all but eliminated transport in unarmored vehicles, especially areas still being patrolled regularly by foot soldiers and where combat operations must be carried out dismounted. The Mine Resistant Ambush Protected (MRAP) vehicles and variants have done an excellent job of reducing soldier injuries and deaths from IEDs, but the MRAP fleet has been spectacularly expensive, and they are of limited utility in areas with harsh and steep terrain, deep loose sand, spring-time mud, and small villages with narrow streets, due to their large size, ponderous weight, and relatively high ground pressure. The typical light infantry unit is not equipped to maintain and repair such vehicles. Helicopters offer an alternative, especially in conflicts such as OIF/OEF where the enemy's air defenses have been almost completely suppressed. Such luxury will not always be the case in other conflicts, however. Helicopter transport is also very expensive and often in short supply. In all of these cases, the infantry soldiers will at some point still be compelled to dismount and fight on foot, and they will still have to carry their gear with them, albeit for somewhat shorter distances.

Another approach, and the one that will be discussed for the remainder of this paper, is use of the Unmanned Ground Vehicle (UGV) to lighten the load. Critics of the state of the art of UGV technology and supporters of manned ground vehicle solutions will argue that we don't need UGVs because the armed forces already have large fleets of manned vehicles. However, manned ground vehicles don't offer a path for reduced manpower, since at minimum a driver is always required. Likewise, manned vehicles do not offer a path for keeping soldiers from harm's way from vehicle IEDs. Continuing to up-armor and blast harden these vehicles has already been shown to be of limited value for light, dismounted infantry forces, as discussed above. In contrast, adopting UGV technology offers a viable path to turn dedicated drivers into "trigger pullers", for keeping Soldiers removed from vehicle IEDs (and of providing viable platforms for counter IED operations), for providing a means for the dismounted soldier to transport his load closer to his objective with less effort and injury, and for increased mobility and transportability in many more types of terrain. As robotics and autonomy mature, the capabilities will continue to improve, less human involvement will be required, and the human workload and the cost will be reduced.

SMSS DESCRIPTION

Since 2005, Lockheed Martin has been developing the SMSS as a company-funded initiative to lighten the load of the dismounted infantryman in collaboration with the US Army MCoE and the USMC Warfighting Laboratory. The SMSS is a squad-sized, 6-wheeled, 6-wheel-drive UGV platform, about the size of a compact car, capable of carrying up to twelve hundred (1,200) pounds of payload. It is designed primarily to serve as a utility and cargo transport for dismounted small unit operations. SMSS possesses excellent mobility in most terrains, with the ability to go with the dismounted warfighter where he needs to go. SMSS is meant to lighten the load of a 9 to 13 person squad or team by carrying their extended mission equipment, food, weapons, and ammunition on unimproved roads, urban environments, and cross-country terrain. SMSS was specifically designed to have the right combination of size, weight carrying, cargo volumetric efficiency, utility, transportability, and modularity to optimize the efficiency of cargo carrying and transportability of the system to wherever it might be needed. An effective reality-based exercise in system engineering, it is this unique combination of attributes that gives SMSS its utility to the warfighter. Figure 2 depicts the SMSS loaded with an infantry squad's equipment package during load carrying test and evaluations in May 2009.

Figure 2: SMSS with the Load Carried by an Army Infantry Squad.

SMSS specifically addresses the following Critical TRADOC Capability Gaps (TRADOC Capability Needs Analysis 12-17):

- Lightening The Soldier's Load – Preserving Fighting Strength (Gap 147)
- Providing The Ability to Operate For Extended Periods (Gap 208)
- Providing Emergency Medical Evacuation For Dismounted Units (Gap 278)
- Delivering Time-Sensitive Cargo (Gap 365)

With a design Gross Vehicle Weight (GVW) of 5,500 pounds (with 1,200 lbs payload) and sling-load attachment points, the SMSS is intended to be transported via sling-load under a UH-60L, high/hot, or carried internally in CH-47 and CH-53 helicopters. The SMSS has safely operated with Soldiers, in both day and night operations, during evaluations in 2008, 2009, and 2010. SMSS is designed specifically to keep up with dismounted Soldiers at low speeds (four MPH) for extended periods of time without burning up the transmission or other mechanical components. In anticipation of SMSS vehicles being deployed to an Outside the Continental U.S. (OCONUS) theater for further operational testing and assessment in 2011, Lockheed Martin built and is currently testing advanced versions of the SMSS, the Block I variant, which will be provided for OCONUS operational testing by the Army. Incorporating lessons learned from the Army and Lockheed Martin experiments, and discussions with operators and user representatives, has resulted in the Block I systems possessing more robust and relevant capabilities for deployment in an operational environment. The Block I vehicles are equipped with a minimum of one Soldier battery recharge station, but can easily accommodate six. For transportation utility, SMSS also possesses a moveable winch with front and rear hitch receivers for self-recovery, or mounting a hitch ball or pintle hook to tow trailers; lock-out hubs to permit towing on its wheels; a stowable tow bar mounted in either front or rear hitch receivers (interchangeable with winch), and high-intensity lights. SMSS can ford 2 to 3 feet of water, depending on load. To accommodate ease of loading/unloading, SMSS has removable side rails for securing packs and other gear and a fold-down tail gate. Additionally, the Soldier-friendly modular storage racks can be lowered to the side to form a work bench area, or removed and assembled into an expedient assault ladder. SMSS possesses a standard NATO power port and a high-output alternator that can provide up to 4 kW of off-board power for other military equipment and can be used to jump-start other military vehicles if needed. The vehicle's engine has dual fuel capabilities, running on diesel or JP-8. The cargo deck possesses modular/moveable tie-down points for securing all types of cargo as well as litters for emergency casualty evacuation. Figure 3 shows the Block I Variant and Figure 4 shows the potential for use in Casualty Evacuation (CASEVAC) missions.

Figure 3: SMSS Block I configuration and features.

Figure 4: Potential for CASEVAC.

OPERATOR CONTROL UNIT

SMSS is remotely commanded by a modular, light weight, wearable Operator Control Unit (OCU). The OCU consists of a hand controller, a tablet-style computer, a data radio, a rechargeable battery, and cables. The components are housed in Modular Lightweight Load-carrying Equipment (MOLLE) pouches that can be attached to the Soldier's Load Bearing Equipment (LBE) vest in a variety of configurations to suit the operator's needs. A spare OCU is stored in the vehicle platform and its battery kept charged when the system is in use. The OCU can be recharged on the vehicle or with a separate stand alone charger. Figure 5 depicts the current OCU configuration.

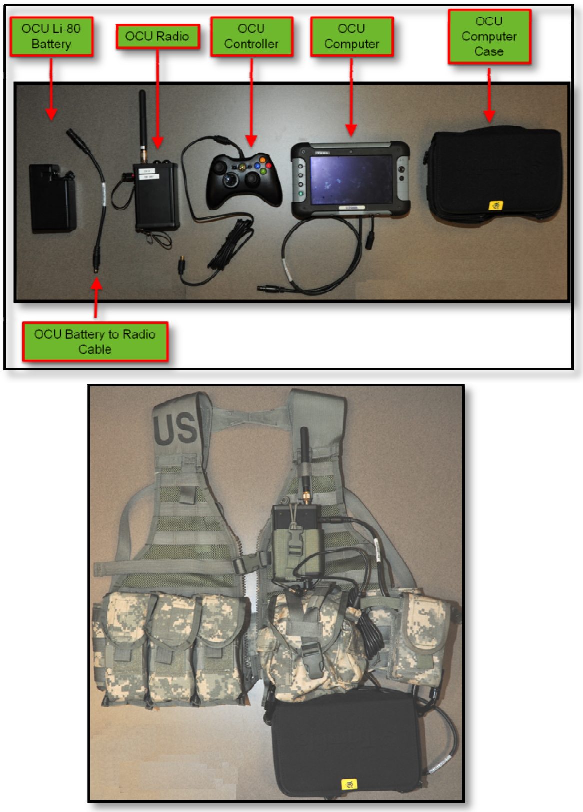

Figure 5: Current Compact SMSS Operator Control Unit Integrated with Soldier's Load Bearing Equipment.

Presently, the total weight of the unit is approximately 6 pounds, including battery, and excluding the LBE vest. Work is on-going to modify the layout and further reduce the size of the current equipment. The Lockheed Martin goal is a total OCU system of less than 6 pounds. Each SMSS employs an Emergency Stop system (E-Stop), also known as a "kill switch" safety capability, completely independent of and separate from the OCU. The E-Stop allows for both immediate shut-down of the system and also simply pausing/resuming a mission.

MODES OF OPERATION

SMSS may be operated in several modes. In autonomous operation, the system can Follow Me (follow a person), Follow Vehicle GPS Breadcrumbs, Follow OCU GPS Breadcrumbs, and in an area that has a well registered and high resolution digital map of the Area of Operations (AO), can do a Come to Me and Go to Point (using pre-defined routes in the data base), as well as Follow Route (points clicked on OCU screen by operator). When operating with well-defined roads, Road/Lane Following is also an option available. Obstacle Detection and Avoidance (OD/OA), Pause and Resume on Command, Controller Hand-Over (permits another operator to take control, when desired) are all features of the system. The system is capable of both Line of Sight and Non-Line of Sight Tele-operation (remote control). To assist the tele-operation, SMSS possesses forward and aft looking infrared and day cameras to enable day and night operations. For maintenance and emergency situations, the vehicle can also be manually driven by an operator riding on board. Several of the operating modes are depicted in Figure 6. New operating modes, Voice Command (for both tele-operation and selected autonomy functions) as well as Assisted Tele-operation (OD/OA running in conjunction with tele-operation), are both under development and test.

Figure 6: SMSS in Various Modes of Operation During 2009 CONUS MUA.

Follow Me is achieved with no active radio frequency (RF) beacons or tags required. The ability to follow "breadcrumbs" was implemented to improve the system's autonomous capabilities to traverse off-road terrain with no defined path at all, in anticipation of operating in a combat environment. OD/OA and the Follow Me feature are achieved through the use of Light Detection and Range (LIDAR) Sensors, as shown in Figure 7.

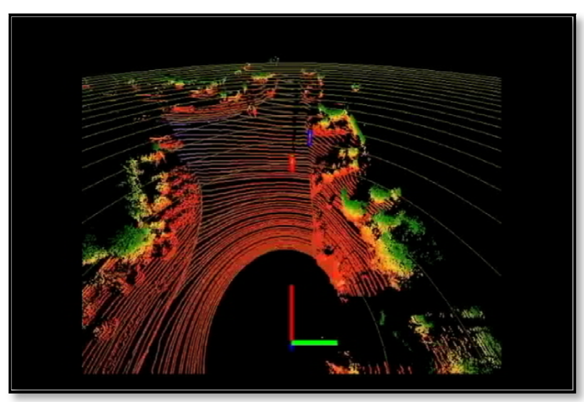

Figure 7: Scanning LIDAR View from Vehicle Shows Person Followed, Terrain, and Obstacles.

Figure 8 shows OD/OA testing conducted at our Robotics Test Center in Dallas. The SMSS is following a person who walked straight between the closely spaced obstacles yet the vehicle successfully drove around the obstacles it could not fit between.

Figure 8: SMSS Following a Person Through Closely Spaced Obstacles. The Person Walked Between Barrels While the SMSS Went Around.

Figure 9 shows testing at our test site in Colorado where the SMSS is successfully following a person up a steep, narrow mountain path.

Figure 9: SMSS Testing Autonomy on Narrow, Steep, Mountain Trail.

PROGRESSIVE UTILITY ASSESSMENTS AND EXPERIMENTATION

SMSS has participated in a number of past assessments and experiments including the Army Expeditionary Warrior Experiment (AEWE) Spiral E in 2008, Lockheed Martin mountain testing in 2009, Army Maneuver Battle Lab (MBL) SMSS Military Utility Assessment (MUA) in 2009, Nett Warrior Limited User Test (LUT) Portable Power Excursion in 2010, and more Lockheed Martin mountain testing in 2010. In the process, SMSS received four Safety Releases for use by and around Soldiers.

In May of 2011, the U.S. Army Rapid Equipping Force (REF), through the Robotics Technology Consortium (RTC), selected the SMSS to deploy to Afghanistan for a first-of-its-kind military assessment. SMSS will deploy as the winner of the Project Workhorse Unmanned Ground Vehicle competition sponsored by the Army. What is believed to be the largest autonomous vehicle ever deployed with infantry, the 11-foot-long SMSS can carry more than half-a-ton of a squad's equipment on rugged terrain, easing the individual soldier's burden. The SMSS is the result of more than a decade of robotic technology development, and the Project Workhorse opportunity offers a chance to demonstrate this capability in theater, where it can have an immediate impact at the squad level. Results will be used to inform the Army's requirements for the US Army's future squad-sized UGV developments for lightening the soldier's load. An in-theater assessment was the next logical step in the process. As part of the three-month Military Utility Assessment (MUA), four vehicles and a Field Service Representative (FSR) will support light infantry in theater as the service evaluates how autonomous vehicles can support or ease the equipment burden of deployed troops. A fifth vehicle, a rolling Hardware In the Loop (HWIL) and an on-call engineering team will remain in the U.S. for analysis and additional support. The Army plans to begin the Afghanistan assessment late in 2011, after a period of safety confirmation testing and training. SMSS will also participate in the 2011 Army's Expeditionary Warrior Experiment Spiral G in November. While SMSS has already demonstrated its ability to reduce soldier loads and provide portable power, the November experiment will evaluate its ability to field a reconnaissance, surveillance and target acquisition (RSTA) mission equipment package. An SMSS equipped with a Lockheed Martin Gyrocam Systems Tactical Surveillance System (TSS) 9M sensor system and 15 foot extendable pneumatic mast is shown in Figure 10. The stabilized sensor system features long range day and night imaging capability as well as a laser designator.

Figure 10: One of many possible Mission Equipment Packages (MEP), RSTA SMSS version for AEWE.

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