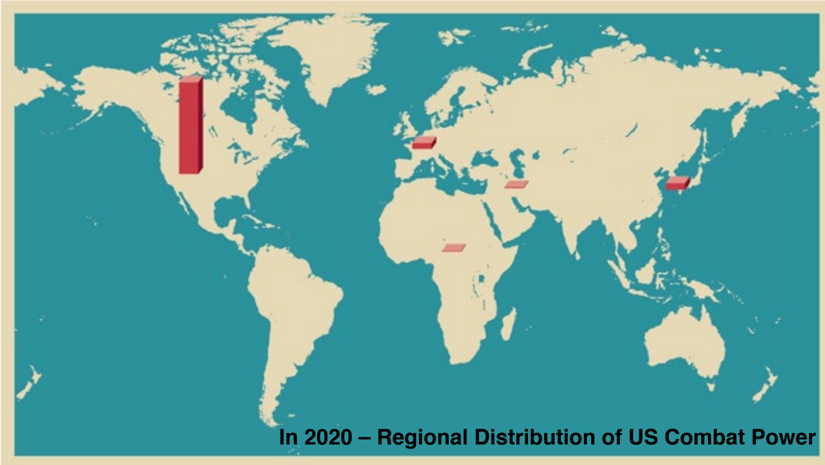
Squad Mission Equipment Transport (SMET)

Lessons Learned for Industry

Annotated Version of Briefing
at NDIA Ground Robotics Capability Conference
March 2, 2016

This briefing is based on seven soldier evaluations that HDT has participated in since 2012. There is particular focus on the recent NIE 16.1, which was a two-month long exercise with an infantry company and combat engineer squad. The exercise used nearly a dozen different SMET surrogate vehicles that were provided by several different vendors.

The opinions expressed in this document represent the personal views of the presenter, Kent Massey, based on his five years of work at HDT Expeditionary Systems as the program manager for their SMET vehicle.



Why SMET? Looking Ahead

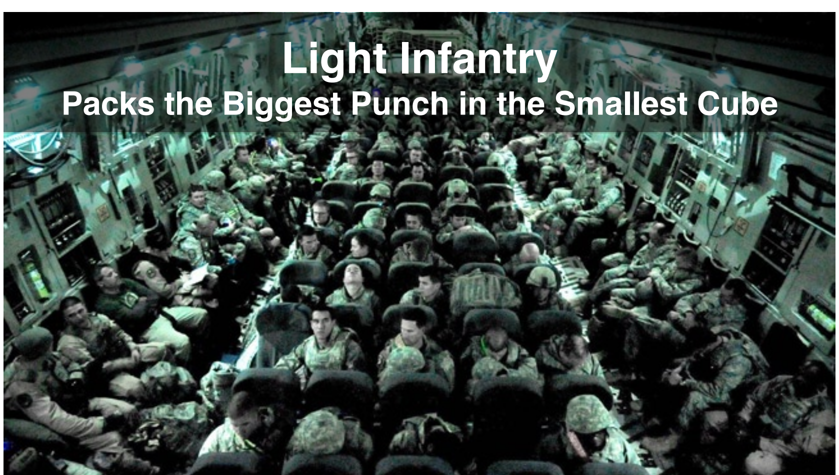
In five years, the vast majority of US military combat power will be based in the United States.

Crisis Erupts

There will be an ongoing need for the US military to conduct expeditionary operations with little or no warning.

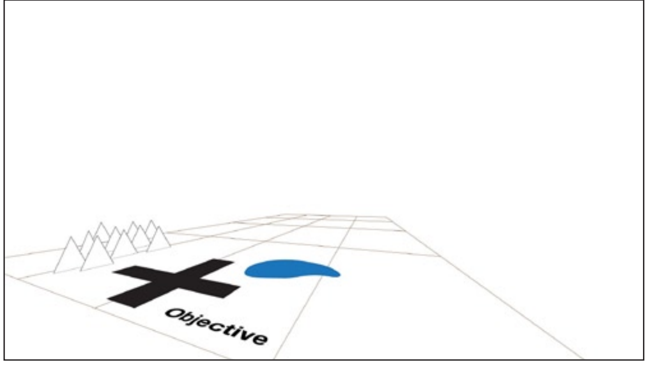
Fastest Response

Getting US forces into the affected area will require getting on an airplane.



Highest Density of Combat Power

Mechanized and heavy forces are slow to deploy. When immediate action is required, dismounted infantry puts the greatest amount of combat power in the smallest possible cube.

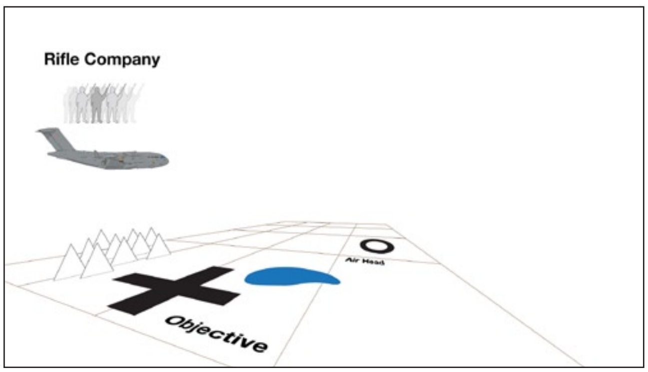


Thousands of Miles Away

The objective may be thousands of miles from the nearest US military base or logistics facility.

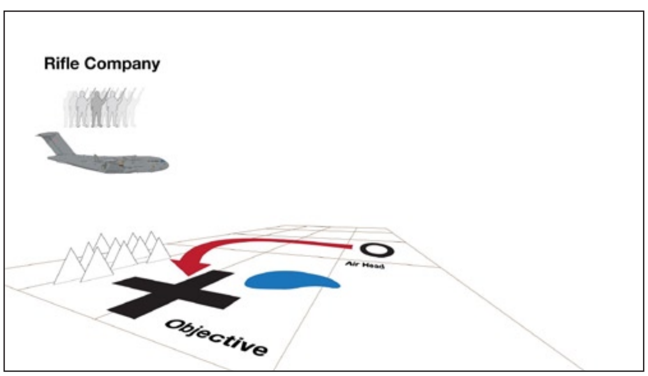
Landing Area Displaced from Objective

Landing directly on the objective is generally too dangerous, so a landing area is selected that is offset from the objective.



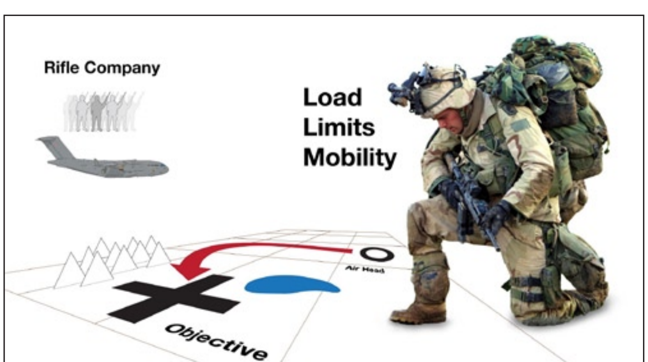
Rifle Company Fits in One C-17

A dismounted rifle company with supplies for 72 hours of operations can easily fit in a single C-17, with a little bit of room left over.



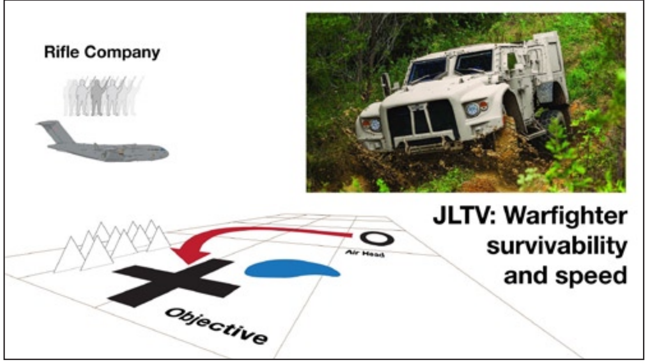
Approach March

Once on the ground, the dismounted infantry must rapidly move to the objective. Light infantry should be able to march 20 miles in five hours.



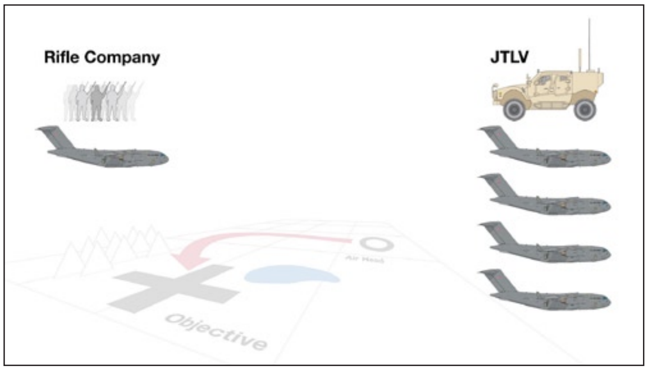
Heavy Loads Slow Infantry and Exhaust Them

With Approach March loads exceeding 100 pounds, dismounted infantry move slowly and are exhausted when they arrive.



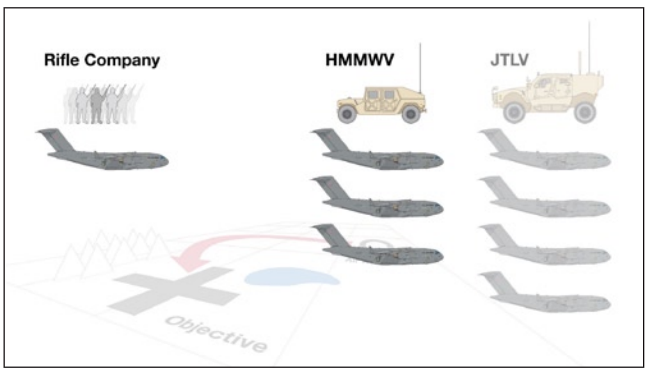
JLTV: Speed and Protection

The new JLTV provides expeditionary forces with high speed over rough terrain and superior survivability.



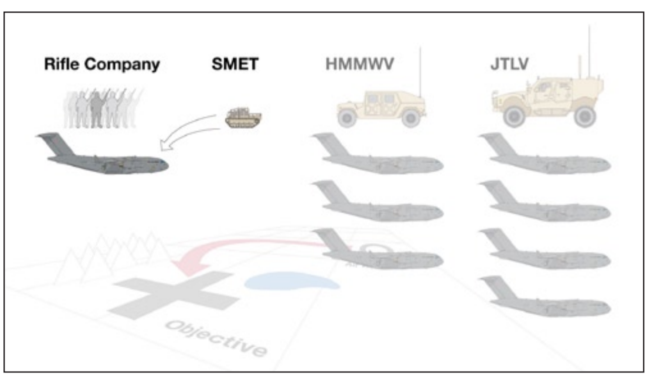
JLTV Quintuples Airlift Needs

Providing enough JLTV transport for a rifle company requires four more C-17 aircraft, increasing the total number of flights needed to deploy a rifle company from one to five.



HMMWV is Only a Little Less Cube

A HMMWV is smaller and lighter than a JLTV, but bringing enough HMMWV transport for a rifle company quadruples the airlift requirement.



SMET Fits on the Same C-17

All the SMET vehicles needed to support a rifle company can fit on the same C-17 as the rifle company. Although an SMET does not offer the speed or protection of a manned vehicle, these unmanned systems can carry the soldiers' load, provide heavy firepower, conduct combat breaching, and clear routes.

Brigade Lift

There are about 20 company-sized combat units in a brigade, but:
Light Infantry Brigade: 141 C-17s
JLTV Infantry Brigade: >200 C-17s
Stryker Brigade: about 250 C-17s
Heavy Brigade: about 500 C-17s

SMET: 80% of the combat power of a brigade in 15% of the flights

Two SMETs
Carry the Load of One Platoon

- Soldier's rucksacks
- Water
- Food
- Extra ammo
- Radio from Stryker
- Battery charger
- Stretchers for CASEVAC

The Impact

The warfighters arrived at the objective fresh and functioning at a much higher level than if they had to carry a heavy load through their entire approach march. Everyone, officers and enlisted, felt that the SMET's load carry was its most important and valuable function. Export power for radios and battery chargers was also seen as very important.

The mortar section strongly endorsed SMET for its ability to carry many more mortar rounds and possibly larger caliber tubes.

SMET Can Carry the Load

Soldier evaluations have shown that SMET can carry heavy loads across a wide variety of rough terrain: forest, arctic, desert, and jungle.

The system shown above is carrying over 2,000 pounds of gear, including a radio and battery charger from a Stryker. The radio connected the squad, platoon, and company radios, as well as provided reach-back to higher command, artillery, and air support. The radio also gave all friendly forces a Blue Force Tracker position for every squad.

Because the SMET could export over 2 kW of continuous power, the radio and battery charger could operate during the entire mission. All of the soldiers appreciated not having to carry spare batteries.

SMET systems with diesel/JP8 power carried much heavier loads, many times further than battery-powered SMET systems. The noise of the diesel/JP8 engine, however, meant that these vehicles had to halt 1 km short of the objective. Soldiers off-loaded their gear and reconfigured the SMET for CASEVAC, prior to the assault.

Greater Lethality

Some SMET vehicles were equipped with M2 heavy machine guns or M134 miniguns, mounted on Remote Weapon Stations (RWS).

The dismounted Stryker infantry at Fort Bliss were not as positive about this capability as the 82nd Airborne scout platoon had been at Fort Benning. The RWS scenarios were more realistic at Fort Bliss, so shortcomings in the operator control interface were more obvious. Much more work is needed on the dismounted operator interface.

Combat Engineers

The SMET systems were used by the combat engineers to assist in a variety of assault breaching techniques. While the overall response was very positive, much more effort needs to be spent developing specific tools, tactics, and procedures to best utilize these new assets. Most of the focus to date has been on infantry.

The small size of an SMET means that it is inherently less capable than a Grizzly, M1 ABV, HMEE, Wolverine, M9 ACE, or any large earthmoving equipment. The very small cube of an SMET, however, means that it may be the only tool available to combat engineers in the early stages of an expeditionary operation.

Construction and Counter-IED

One of the SMET systems had a backhoe/loader kit, but the 12B combat engineers did not have the training and experience to operate the system. In testing at Fort Leonard Wood, 12N combat engineers were able to use this capability. It can be used to dig fighting positions and fill Hesco barriers – much faster than with an entrenching tool.

Operating Environment is Tough

Tele-Operated Vehicles Roll Over

The Field is Harsh

Over the two months of exercises at Fort Bliss, the missions became progressively more realistic and challenging. By the end, half of the surrogate systems were breaking down during each mission.

Many SMET surrogates had great difficulty with overheating. Even the battery-powered systems had problems with electric motors overheating.

Many mechanical components also proved too weak enough for the heavy loads that the soldiers put on the systems.

All of the surrogate systems experienced problems with roll-overs. The narrower SMET vehicles had more trouble with side slopes, but even the widest systems over-turned.

Dynamic stability is a notoriously difficult problem for remotely operated systems. Taking the operator out of the vehicle eliminates any vestibular and proprioceptive sense of the vehicle's stability. This difficult situation is compounded by having young soldiers operating the vehicles, at night, in rough terrain, using night vision goggles.

Ruggedness
Field Operations Are Worse Than Spec

- Soldiers will overload systems
- Design for overload, not required load
- More power and torque
- Rollovers
  - Width and low center of gravity help
  - Width can limit mobility in tight spaces
  - Tele-operation = vehicle rollover
  - Use driver assist behaviors to mitigate
- Modular architecture

The Field is Really, Really Harsh

The evaluations at Fort Bliss were particularly sobering for all of the vendors. It is clear that we could build a vehicle that meets every requirement in a formal specification, but is a complete failure in the field. The warfighters using the system will ask far more from it than any specification can capture. The scale of these small vehicle in the terrain lies outside of standard specifications for manned vehicles. We must design these systems to be very, very tough. In the photo above, a 3/4 inch hardened steel drive shaft snapped in two under load.

Each SMET vehicle must be able to carry a much heavier load than what is required. The power and torque needed to carry these loads across rough terrain is far greater than any traditional sizing of power-train would suggest. One of the battery-powered SMET surrogates had up-sized their electric motors to eight times the torque of our hydrostatic drive. The up-sized electric motors delivered the performance that the soldiers wanted, but under heavy loads in the hot desert environment, these motors overheated very quickly and then had to be shut down for about ten minutes to cool off. More work is needed on power-train.

Making a remotely operated vehicle wider and lower is not enough to prevent roll-overs. All of the systems rolled over. Some of the work in autonomy needs to be adapted to create driver-assist behaviors that detect unsafe situations. The system then needs to slow down and alert the operator to a possible roll-over. We also need to experiment with active suspension for side slope leveling.

HDT's vehicle was designed to be modular, with each module being a four-man carry, so the vehicle could be taken apart in a few minutes and portaged across an obstacle. While this capability was never used, the soldiers were enthusiastic about the combination of our self-diagnostics and modularity. Knowing which module had failed let them replace that module and get the vehicle operational right away. The bad module could be sent back for repair. (An infantry platoon does not have the organic capability to repair these systems.)

Modular Mission Equipment Packages

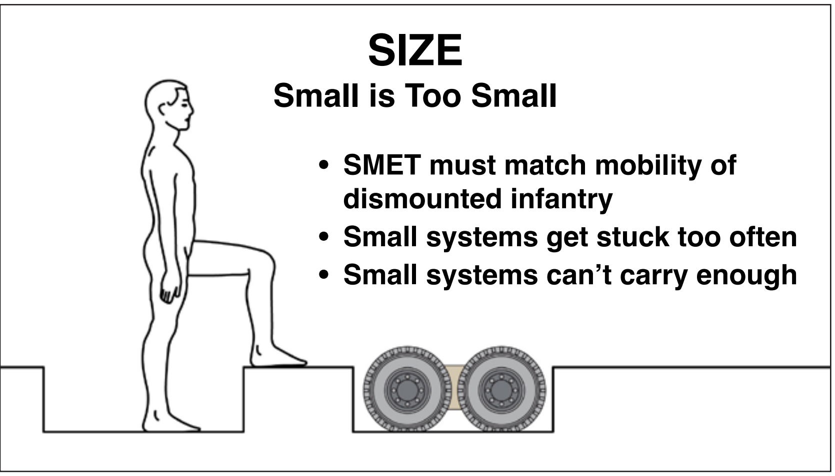
Modularity is Important for Mission Equipment Packages Too

A useful analogy for an SMET could be the Willys Jeep from WWII. The core vehicle is simple, strong, dumb, and cheap, but is also infinitely adaptable. The SMET shown above has an open architecture with non-proprietary interfaces. The vehicle provides mechanical, electrical, hydraulic, and data bus connections for a wide variety of payloads.

One advantage is that the core vehicle is automotive and tank technology, which changes very slowly. Rapidly changing technology, such as autonomy, are added as missions kits. Any quickly evolving technology that is built into the vehicle risks being obsolete before the system reaches initial operating capability.

Many capabilities, such as a remote weapons station or some of the combat engineer kits, may not be part of the initial roll-out of the system, but the SMET vehicle must have the power, load carry, and interfaces to support these future payloads.

As shown above, a rifle company equipped with SMET vehicles could have an organic combined arms capability that is revolutionary, including: a “micro tank” with a RWS and a coaxially-mounted Javelin; precision indirect fire from a 120mm mortar with a GPS-guided projectile; and a tethered UAV that could provide ISR and comms-relay for days. A light infantry company commander will have an unprecedented amount of organic combined arms combat power.



Whether it is a 95th percentile male or a 5th percentile female, a person has far more mobility over rough terrain than a small robot.

The Goldilocks Region

Size is a difficult issue. An SMET vehicle that is too small or too big is problematic, but it is not simple to define what those sizes are.

Repeated testing has made it clear that small SMET vehicles cannot negotiate the terrain. These systems also did not carry enough payload to be worth the effort of operating.

At the larger end of the scale, when systems approached the size of manned vehicles, there were also problems. An important advantage for dismounted infantry is being able to go where manned vehicles cannot. When a platoon has something the size of a manned vehicle, that advantage is taken away. At Fort Bliss, larger SMET surrogates became high-centered in rough terrain and had to be towed off. At Fort Benning, the larger systems had difficulty with heavily wooded areas. The Hawaii jungle testing showed that larger systems are blocked by vegetation, while narrower vehicles can get through. All vehicles had problems with stability on side slopes, although the narrower vehicles had a greater difficulty.

A size somewhere in the middle will likely be the best compromise.

This narrow jungle trail in Hawaii is typical. A manned vehicle won't fit.

Another Way to Consider Size

The required payload capability for an SMET is another way to constrain size. While an RWS may not be part of the initial program, it is clear that the SMET should be able to accommodate an RWS at some point in the future. Of all the possible payloads, an RWS is probably the heaviest single load that the vehicle must carry, without off-loading some portion onto a trailer.

MCoE has expressed an interest in the SMET carrying a 20mm or 30mm automatic cannon in an RWS mount. The lightest commercially available RWS with a 20mm or 30mm automatic cannon weighs 935 pounds (EOS R400S-Mk2 with ATK M230 LF and 75 rounds of 30mm). With some frontal armor (resistant to 7.62 mm x 45 mm ball), the total payload weight would be over 1,000 pounds. Managing the center of gravity of this system would be challenging.

If the largest caliber that the RWS fires is a M2 heavy machine gun or a MK 19 automatic 40mm grenade launcher, an M153 CROWS could be used. Kongsberg has developed a "low profile" version of the M153, which the Army is fielding. The low-profile CROWS would greatly improve stability on an SMET. The weight of the CROWS, M2, coaxially-mounted Javelin, ammunition, and some frontal armor is around 800-900 pounds.

The SMET should be able to stably carry a low-profile CROWS on terrain that light infantry can traverse, with a total vehicle payload of around 900 pounds. This size consideration makes the SMET somewhat larger than the current medium-sized surrogate vehicles, but still smaller than a manned vehicle.

Noise
Infantry Hates Noise

Noise
Infantry Hates Noise

- **Diesel/JP8 is necessary for range**
- **Battery very quiet, but vehicle still makes some noise**
- **Wheeled electric was quieter than tracked electric, but soldiers preferred tracked electric because it was better in rough terrain**
- **Heavy muffling of internal combustion engine?**
- **Hybrid diesel/electric?**

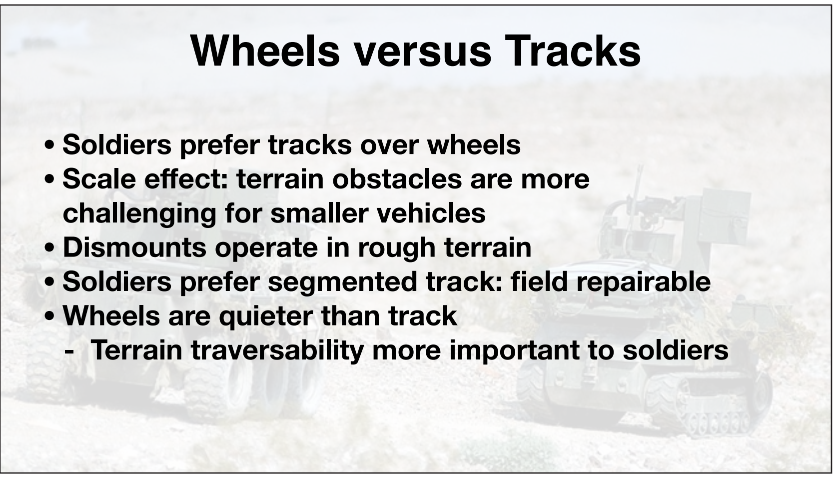
Noise: How Much Noise is Okay?

Soldiers are willing to tolerate some noise, in return for desired capability. For instance, they prefer tracks over wheels because the tracks provide greater terrain traversability, even though the tracks of a battery-powered SMET can be heard out to 100-200 meters.

The current diesel/JP8 SMET surrogates are audible out to 800 meters, which is far too noisy. Heavy muffling could reduce this detection range to several hundred meters, but it is not clear if this would be adequate.

What is clear is that diesel/JP8 is needed for range and load carry. Battery-powered systems were very quiet, but they carried much less payload, for a maximum of about ten miles cross country, compared to around 60 miles for a diesel/JP8 system. A possible compromise would be a hybrid system with a diesel/JP8 engine generating electrical power to drive electric motors. During normal operation, the hybrid would have the same range and noise as a diesel/JP8 system. With a large enough battery, the hybrid could also provide a couple kilometers of 'silent' drive. Unfortunately, such a system would likely increase cost and complexity.

Wheels versus Tracks



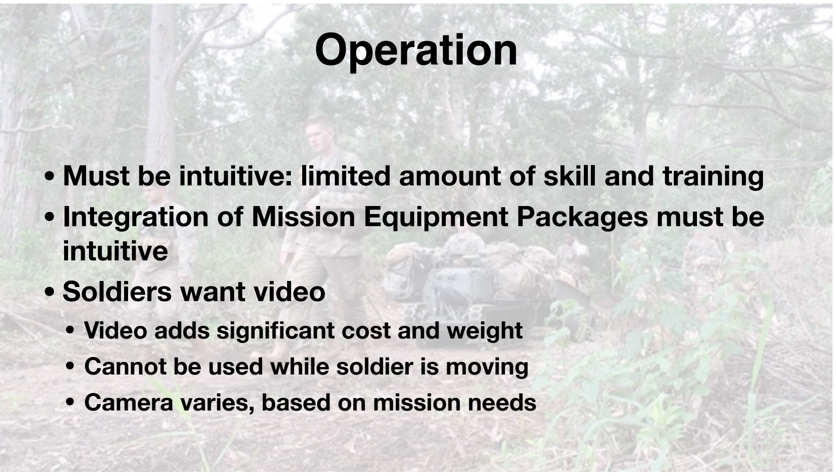
Tracks Win Hands Down

Wheeled Stryker vehicles have proven their worth, but these manned vehicles operate at a completely different scale from an SMET. A Stryker can climb an 18 inch curb. A small wheeled SMET, on the other hand, can have difficulty with a six inch rock.

Dismounted infantry operates in very challenging terrain. Almost unanimously, the soldiers said that tracks were far superior to wheels in this terrain. This view held true for the forests of Fort Benning, the arctic cold of Alaska, the deserts of Fort Bliss, and the jungle in Hawaii.

Soldiers with experience in tracked vehicles were also very strong in their preference for segmented track over continuous band track. Even though segmented track is noisier, it can be repaired in the field. When band track is damaged, the entire track must be replaced.

Operation



"Intuitive"

The soldiers were absolute about the need for SMET operations to be simple and intuitive. The control systems must be easy to learn and require very little attention in use. Any soldier operating an SMET in a rifle platoon will be doing so as secondary task. The soldiers were equally clear, however, that they do not want autonomy in the initial systems. They do not trust autonomy. They want full, hands-on control.

Simplicity must also be the standard for how mission equipment packages are integrated and operated. The soldiers want payloads to mount/dismount quickly and easily.

All of the SMET surrogate vehicles operated through simple wireless hand controllers, without using video. Shown to the left is a typical SMET controller, with an eight ounce hand controller and four pound radio repeater (in the MOLLE pouch). This controller has a one kilometer range and 12 hour battery life.

Adding video greatly increases weight and cost, while also reducing battery life. The Tactical Robot Controller (TRC) weighs about 20 pounds and lasts for a few hours using two BB-2590 batteries. The soldiers want an option for video control that is much lighter (which is a significant technical challenge).

Autonomy

Autonomy

- **Follow-me kit costs more than the robot**
- **Tank and automotive technology changes slowly**
- **Electronics technology changes quickly**
- **Any autonomy built into the base system will be out of date before it reaches Initial Operational Capability**
- **All autonomy should be an add-on kit**
- **Vehicle's onboard processor should be easily upgradable**

Some simple forms of autonomy are appropriate now. For instance, HDT's controller already has a "cruise control" mode that provides automatic speed and heading control.

Active stability control will also involve small amounts of autonomous behavior. The robot will use inclinometers to sense its attitude. If the robot detects that it is at risk of rolling over, it will slow down and warn the operator.

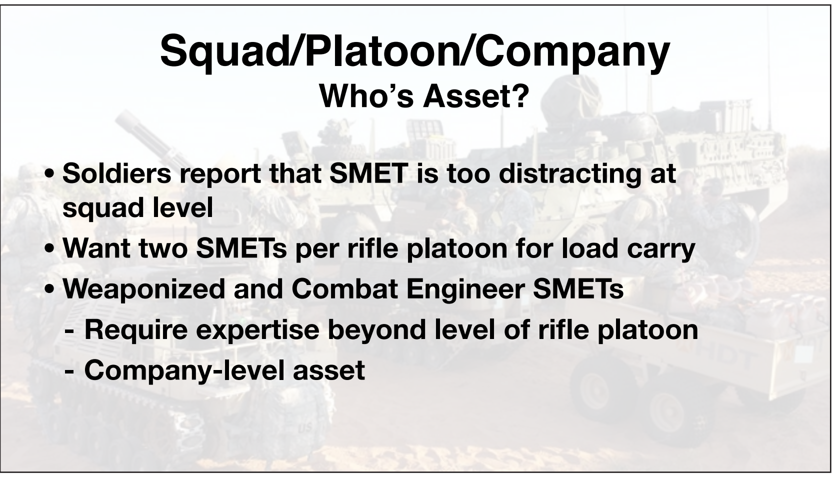
Full Autonomy is not Ready for Deployable Systems

Shown above is a follow-me kit developed by HDT and successfully tested at Fort Benning. The system uses three stereo pairs of thermal imagers, three stereo pairs of high resolution color video cameras, differential GPS, ultra wide band radio triangulation, LIDAR, differential odometry, and an inertial measurement unit with a laser ring gyro. All this hardware is what ATEC agreed would be sufficient to qualify for a Safety Certification.

The system costs more than the vehicle. In five years, the autonomy kit cost will drop by at least a factor of two, and its performance will be much better. The base vehicle, however, will cost about as much to produce and its performance won't change very much. Electronics get better and cheaper at the rate of Moore's Law, while automotive and tank technology moves much more slowly.

Autonomy should always be an add-on kit, so it can be easily update. Any significant level of autonomy that is built into the vehicle will quickly be obsolete. Similarly, the vehicle's onboard computer and radios should all be easily upgradable.

Squad/Platoon/Company
Who's Asset?



Load Carry for Platoon, Special Mission Kits for Company

The soldiers don't want an SMET at the level of a rifle squad because even the electric systems make noise and all SMET systems require too much attention. Nobody in the platoon wants a rifle squad or weapon squad distracted from their primary mission.

The platoon sergeants would like to have two load-carry SMET vehicles at the rear of the platoon to carry all the gear for the platoon.

The soldiers were clear that any SMET with an RWS or a combat engineer mission equipment package would require more training and maintenance than is appropriate in a rifle platoon. The soldiers said these special mission kit systems should be company-level assets that are assigned by the company commander to platoons, as required by the mission.

The soldiers suggested combining the company-level SMET systems with the current mortar section to form a heavy weapons platoon.

Combined Arms

Technology Advancement

Electronics | Miniaturization | Precision Fire

Direct Fire	Indirect Fire	Missiles	Aviation	Combat Engineering
RWS fire on move with accuracy at 2km+ 50cal, 30mm	120mm mortar with GPS-guided round blast effect of 155mm	Stinger, Hellfire, Javelin, Griffin, LMAMS, Spike	UAV/UGV teaming	Breeching, route clearance, bridging, fortifications, vegetation clearance / route construction

A Combined Arms team at the Company level

A single C-17 can deliver anywhere in the world
a combined arms team that can fight and maneuver
without resupply for three days

SMET is not Just a Load-Carry Platform

The advance of technology has made electronics far more capable, miniaturized the size of many systems, and enabled precision fires, which greatly reduces the amount of munitions that need to be carried. A platform the size of SMET can now provide a full combined arms capability.

With an RWS, an SMET can accurately fire at distances beyond two kilometers, while on the move. The SMET can carry and emplace a 120mm mortar, which can fire a GPS-guided round that delivers first round accuracy with the blast effects of a 155mm howitzer.

Using missiles, the SMET can provide both an anti-armor and anti-aircraft capability. UAVs can be flown off the SMET, including tethered quadrotors that can remain airborne indefinitely.

There are numerous combat engineering tools that have been successfully demonstrated on an SMET.

The SMET platform gives a platoon or company-sized unit an unprecedented organic combined arms capability. A single C-17 can deliver a dismounted combined arms company anywhere in the world. This combat unit will be able to fight and maneuver for three days, without any need for resupply. This unit will have an significant overmatch against dismounted opponents, and it will be able to hold its own against many heavier units.

Historical Comparison

- 1920s and 1930s development of armored forces
- US, Britain, France
  - No cooperation between branches
  - Little development of tactics or operational art
- Germany lost WWI, motivated to change
  - Integrated effort
  - Two decades of experimentation and development
- May 1940
  - France had more tanks, better tanks
  - Germany conquered France in six weeks

The Tank Was a Disruptive Technology

The tank appeared near the end of the First World War. At that time, tank tracks only lasted twenty miles, before they had to be replaced. Mechanical failures put half of a unit's tanks out of action during each day of operations.

After the war, development of armor followed the same general path in all the armies of the victorious allies. The different branches of each army refused to work together. Each branch wanted to "own" tank development, while they simultaneously saw tanks as a threat to the status of their own branch. On the eve of the Second World War, Major General John K. Herr, the chief of cavalry, did everything possible to impede the mechanization of cavalry, even after the German invasion of Poland conclusively demonstrated the futility of cavalry charges against Panzer tanks.

The Germans, on the other hand, lost the First World War. They were willing to accept change. They adopted a combined arms approach at the very beginning of their interwar efforts. Since the Germans were prevented from having tanks by the Versailles Treaty, they used cars to model tanks in exercises during the 1920's. In the 1930's, they conducted tank development and experimentation in Russia, in cooperation with the Soviet Union. In the twenty years between wars, the Germans iteratively refined their combined arms tactics and operational art for armored mechanized formations.

In May of 1940, the French actually had more tanks, of generally better quality, than the Germans. Similar to Britain and the US, however, the French had not developed a tactical or operational understanding of how to effectively use their tanks. The German Blitzkrieg cut through the French and British forces, destroying their ability to fight. In six weeks, France was forced to surrender.

The combined arms capability of the SMET poses similar developmental challenges to the US Army as did the development of the tank.

We Have Near Peer Competitors

The six ton Russian Uran-9 has a rapid-fire 30mm auto-cannon, four Ataka anti-tank missiles with tandem warheads for defeating reactive armor, and four anti-aircraft missiles, comparable to the US Stinger missile.

Being Offered for Export

Developed by Rostec, the Uran-9 will be available for export in 2016. The vehicle on the left is shown ready to fire missiles, with its RSTA head and missiles raised. The 30 mm 2A72 auto-cannon can be fired in the low-profile configuration on the right.

Russian Platforma-M

Developed by the Progress Scientific Research Technological Institute of Izhevsk, the Platfroma-M carries a 7.62mm machine gun and up to four anti-tank missiles.

Chinese Norinco Assault Breacher

Armed with a 7.62mm machine gun, this Chinese SMET-class combat engineer robot has an APOBS-type line charge and smoke grenade launchers.

Recommendations

- More transparency with CDD
- Release results of testing to date
- Modular architecture
  - Autonomy is follow-on
  - Video is mission-dependent option
- Fund technology development
  - Hybrid powertrain
  - Active stability control
  - Weaponization
- Integrate warfighter communities more tightly
- Develop tactics and operational art

Next Steps

A COTS procurement is being considered for SMET, but industry does not have any insight into the government's desired capabilities, so industry does not know where to invest their IR&D funds. More transparency into the sizes and capabilities of the system in the CDD would allow industry to focus their development efforts and create a more competitive procurement.

Industry has supported many of the Army evaluations using IR&D funds, but the detailed results of those evaluations have not been provided to industry. These results are the best way for industry to identify their systems' weaknesses and target further IR&D funding for improvements.

Modular architecture allows rapidly changing technology to be inserted as mission kits and upgrades, rather than those technologies being built into the base platform. Autonomy and video are two areas where the technology is changing quickly. The base platform does not need either capability in order to fulfill its initial role as a load-carrying vehicle. Requiring video or autonomy in the base platform would substantially increase cost and technical risk.

There are several technology development areas where some government funding would help reduce overall technical risk and encourage more competitors. In particular, hybrid powertrains, active stability control, and weaponization are areas where further work is needed.

Tighter integration between different branches of the military could help avoid the problems that slowed the development of the tank between the First and Second World Wars.

SMET is inherently a combined arms platform. Incremental fielding will allow a small number of brigades to develop a tactical and operational understanding of the system and refine the requirements for the next stage of fielding.

Questions?

Kent Massey
HDT Expeditionary Systems
(610) 453-7893
kent.massey@hdtglobal.com