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The Future Soldier's Load and the Mobility of the Nation

A Soldier Domain for Full Spectrum Warfare:

Information and Load Sharing within the Tactical Fractal
Exoskeletal Strength Amplification for Body Armor and Ordnance
UGV Support for Fractal Sustentation
Aerial Overwatch of Fractal for Anticipatory Awareness

In Afghanistan a lieutenant led his patrol in hot pursuit of a Taliban band mounted on stolen pickup trucks. His six-ton up-armored vehicles bucked and swerved through the cross-country chase. The more agile pickups easily pulled away, and enabled the insurgents to escape on foot up the slope of a mountain. When the officer dismounted his troops and sent them after their quarry, they fell even further behind, for each man had to clamber upward encumbered with 60 pounds of body armor, and well as weapon, ammunition, communications and survival pack. The officer aborted the mission…*McClatchy Newspapers, 1-11-09*

Month by month, year-by-year, units equipped to combat insurgents amid Iraq's towns and paved roads became ever more heavily armored against deadly IED and furtive snipers. But Afghanistan is not Iraq, and the Taliban, when they choose to engage, fight as companies and even battalions, and exploit in their tactics greater agility over primitive roads and rugged terrain. The protection that we have provided our infantry and Marines impairs their ability to close with Taliban adversaries. Moreover, force protection for logistical and other support elements have been similarly onerous. "Full spectrum" capabilities elude us in Afghanistan, and the future bodes ill for the foot soldier— despite DoD's incessant rhetorical emphasis on meeting the challenges of persistent conflict, and the primacy in recent spending accorded to force protection.

Ours is an ancient quandary. The Romans learned to march their legionnaires with a total load of less than 60 pounds, and to fight with 33 pounds per man, but each section of 8 men (*contubernium*, the mess group) shared a mule to carry their leather tent, a grindstone, extra weapons, cooking utensils, and clothing. Each company (*centuria*) usually had two-wheeled mule-drawn carts to haul wine,[1] heavy weapons, and tools for fortification and siege. That set a pattern that lasted for more than a millennium:

"**They carry weapons to the ships, and thus pull carts with wine and arms…" *Bayeaux Tapestry (ca. 1066)***

[1] Transporting wine was preferred to the uncertainties of drinking local water or other beverages, and troops on the march drank a mixture of vinegar and water.

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S.L.A. Marshall, in his classic The Soldier's Load and the Mobility of the Nation (1950), held that the combat load of a soldier should vary with body weight: foot soldiers should train with gear no more that one-third of their body weight, and that load should be reduced by 20% in combat. If the average infantryman weighs 180 pounds, his fighting load should be no more than 48 pounds. Field Manual 21-18 (1990) postulated a combat load of 40 pounds, and cited experimental data to show that for every ten pounds in excess of 40, distance traveled in a 6 hour approach march would be reduced by 2 kilometers, and time over an obstacle course would be slowed by 15%. Yet infantrymen in DESERT STORM, OIF, and OEF marched with loads two or three times as heavy. A battalion commander recently returned from Iraq has written "I weigh about 185 pounds in my shorts, but tip the scales at about 265 pounds in full kit.... I have no doubt that some of my soldiers carry fighting loads close to 100 pounds at times." N.B. his unit was 4 Battalion, 9th Infantry (Manchus), a Stryker mechanized unit.

Note also that SLAM's data, the experiments cited in the FM, and the Army's older quantifications from the Combat Development Experimentation Center, reflect preoccupation with equipping one dismounted soldier for symmetric combat. Although more recent technology programs have included provisions for aiding teamwork, their icons have invited the same misapprehension.

Land Warrior

Ground Soldier System

Future Soldier 2030

Infantrymen do not fight as individuals, but as members of a team. The Army's ethic, its core values, stress interdependence: loyalty, duty, respect, selfless service, honor, integrity, personal courage…"put the mission first, refuse to accept defeat, never quit and never leave behind a fellow American."

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SLAM Marshall believed that what distinguished great infantry units from run-of-the-mill outfits was not the number of campaign streamers on their flag, nor the presence in their ranks of survivors of battles past, but a deep sense of responsibility for, and obligation to their comrades. He thought that the American soldier's innate initiative and ingenuity provided him a natural advantage over foreign soldiers. His study of infantry combat in World War II, set forth in his seminal book Men Against Fire (1947), led him to the conclusion that no matter how bright or creative the individual soldier, his unit had to teach him "to act and speak at all times as a member of a team. The emphasis should be kept eternally on the main point: his first duty is to join his force to others! There is no battle strength within a company or regiment except as derives from this basic element within the smallest component..."

Decades ago, the Army Combat Developments Experimentation Command conducted trials of infantry units sized from 7 to 15 soldiers, and found little difference among these in capability to accomplish mission. But they did establish that as size decreased, fire efficiency (hits or near misses per round fired) increased, and maneuver became more successful. Booze|Allen Applied Research, Inc. conducted studies of combat in Viet Nam in 1966-1967, and concluded that the optimum span of control for a small unit leader is three to seven soldiers, and that automatic weapons were critical to success; they also documented a tendency for individual soldiers to form pairs, and to fight, regardless of training, in teams of four. They concluded that such small teams —termed here the tactical fractal— were as effective as large groups. Enhancing the capability of that “tactical fractal” is the proper objective for Army Science and Technology, the future of the Soldier Domain.

Fractals fighting in close combat on foot have suffered most of the casualties in recent wars: although dismounted infantryman have never constituted a population more than 4 percent of U.S. military services, they have suffered 80% of battle deaths. But in Iraq and Afghanistan we have encountered enemies whose close-combat tactics have shifted the casualty burden to include logistical and other support forces as well as infantrymen. Our force-protection countermeasures to date have largely relied upon increased armor, and we have thereby rendered our forces less mobile, less sustainable, and because they are slower and more numerous, more vulnerable. For full spectrum warfare the Future Soldier Domain deserves better concepts, and advanced technologies.

In the past, platform-centric approaches to equipment for the individual combatant have foundered on the rocks of size, weight, and power (SWAP). In the 1990s a frustrated Army turned to the National Research Council for advice. The NRC recommended (1992) that the Army move away from a singular equipment architecture toward “integrated support,” aim at reducing energy demand to achieve energy sufficiency (1997), and consider human factors that affect situation awareness (1997). That advice remains pertinent.

The Army’s Land Warrior program, initiated in the last decade, aimed high: a DA booklet entitled “Weapon Systems, United States Army 1998” proclaimed that “The Land Warrior (LW) System will provide significant improvement …The systems approach will optimize and integrate capabilities without adding to the soldier’s combat load…” Of course, that did not happen. Weight goals were never achieved, costs rose, and problems related to batteries were showstoppers. Over time these deficiencies have been ameliorated, and in April 2007, 4th Battalion, 9th Infantry (Manchus), a Stryker-equipped mechanized infantry unit, was allowed to take into Iraq a Stryker-interoperable version of LW. There they demonstrated that LW added significantly to combat capabilities. The Manchu commander, LtCol (P) Bill Prior, reported that:

> **The infantry battalion that I command has used LW fighting in Iraq for the last ten months on every mission, every time that we go outside the wire. The accurate, timely information that we receive from LW enables my leaders and me to make better battlefield decisions, and to act faster than our adversaries – the essence of information superiority…LW equipped Soldiers know where they are and where their team mates are in the dark the first time that they set foot on the terrain… Manchu leaders look in their helmet-mounted display and see themselves and their men relative to the terrain and graphics without radio chatter and without hesitation. When posted by any user, LW leaders see enemy and environmental icons such as obstacles, suspected enemy positions or IEDs. Furthermore, that information is automatically shared between the LWs and the Strykers so that each knows where the other is and what the other knows. LW is a leap ahead in solving the age-old problem of "touch" between men and small units in the close fight. You are not alone even if you do not have voice or visual contact with other LWs. Complementary to the shared situational awareness is our capability to configure and LW's capacity to carry large geo-referenced maps and imagery files…In the vicinity of the objective, we want 1 meter imagery for maximum clarity and detail. Since the LW view is infinitely scalable, the LW leader can zoom out to see where the adjacent platoon is then zoom in when on the target to easily distinguish first and second squad's positions in the cordon while third squad takes down the target house and weapons cover routes to the flank.... Any addition to the infantry Soldier's load comes at a price, and the price for LW is steep. At about 12 pounds in its current configuration, the first and foremost improvement to LW must be to decrease its weight. Infantrymen in Iraq carry all of the things that infantrymen have carried for many years including ammunition, water, helmets, etc… Relatively new to U.S. forces, modern body armor has dramatically increased Soldier load and LW ups the ante further…Like body armor, LW provides such an advantage that it is worth it. Also like body armor, we must find ways to decrease its weight so that Soldiers are physically able to exploit the advantage that it provides during sustained combat operations… The next upgrade should be in battery size and life. Full sized LW batteries are heavy and bulky – about the size and weight of two full 30 round magazines of 5.56 mm ammunition. Soldiers must carry at least one and often carry a spare on them. The batteries normally last about 6 to 8 hours during continuous operations…As a Stryker force, recharge and storage capability on our vehicles mitigates this problem. But we need smaller, longer lasting power supplies (batteries or otherwise) and this need will become more acute if units without ready access to chargers intend to use LW regularly.**

There were two fractals within each 4/9 Inf squad: the Stryker team —soldiers manning the vehicle and its on-board systems during combat— and the dismounted team. Both fractals regarded their Stryker vehicle as "the mother ship," a vital link to higher and adjacent units for situational awareness, a source for material replenishment (including and especially recharged dry cells), and a superior base of fire for supporting maneuver. LW integrated the fractals, and enabled close collaboration. Nothing is more important within the tactical fractal than awareness of each other, plus a common appreciation for their mission and the situation facing them as they act to accomplish it. During the 1950s General William E. DePuy wrote an article on the infantry rifle squad entitled "Eleven Men, One Mind" to emphasize the cognitive component of combat effectiveness, more important in his view than the numbers of men within the unit, the weapons they carried, or their other impedimenta.

A decision has recently been taken to deploy in 2009 an LW-equipped Stryker Brigade Combat Team (5th BCT, 2d Infantry Division); this BCT should provide more extensive data on capabilities enabled by LW technology. But as importantly, that decision also provided for equipping with LW units within Army Special Forces and an infantry battalion of the 82d Airborne Division at Fort Bragg. Mechanized infantry units like the Manchus equipped with LW enjoy capabilities that may be unavailable to SF or parachute infantry fractals not supported by a combat vehicle. Hence, the coming deployments of LW will (hopefully) produce quantified data on the effectiveness of LW in formations other than Stryker mechanized infantry.

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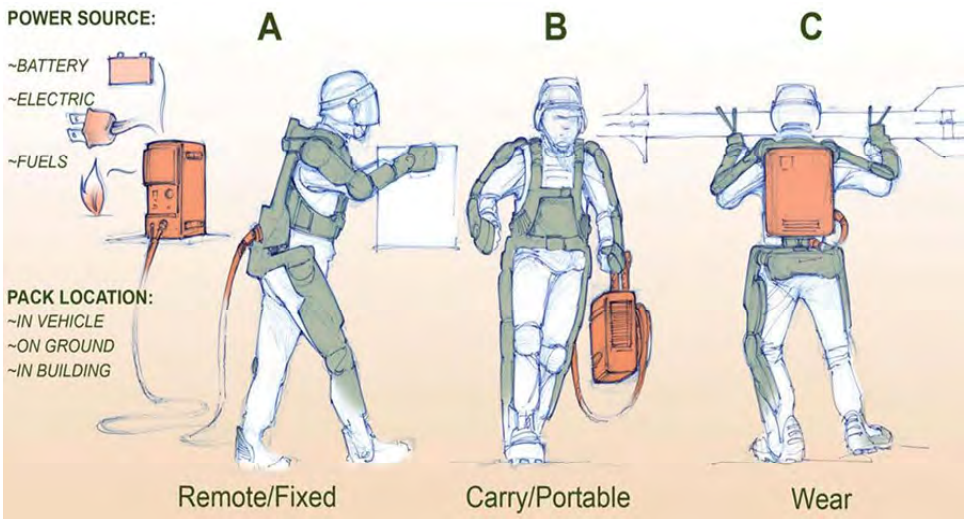
Experience with LW thus far makes it clear that the Future Soldier Domain should be understood as network-centric, embodying a wireless instantiation of mutual reliance within the fractal upon each other's perception of the situation, and each other's physical readiness. LW indicates that optimism is warranted for future network technology's supporting the Soldier Domain. However, as the Manchu commander has pointed out, LW or its successor GSS may not avoid the SWAP shoals. Weight on each soldier is almost certain to increase. Trends in lethality imply that, even given emergence of materials based on nanotechnology, personal armor will be heavier to cope with more massive projectiles of higher kinetic energy. Moreover, man-carried weaponry is likely to be both heavier and more energetic: e.g. e.g., a soldier cannon is possible, and should a future foe field modern main battle tanks, our man-carried, 50-pound, the Javelin shoulder-fired anti-tank weapon may have to be enlarged.

There is, however, technological opportunity to increase the load-bearing capability of each member of the fractal: DARPA has developed a prototype of a wearable robot, a powered exoskeleton (XOS) that provides the human inside a significant strength/endurance multiplier. Responsibility for further development of XOS now rests with the Natick Soldier Research and Development Center, where it is being adapted for Army purposes. In the near term, XOS could operate effectively so long as it were coupled to an external power source. N.B. an XOS operating on vehicle power enables a soldier to wear very heavy armor and/or perform strength-demanding tasks such as replacing a wheel or track, or uploading large-caliber ammunition, implying less armor on non-combat vehicles, and fewer support personnel at risk. In the longer term, it appears possible to integrate into XOS a power source providing for autonomous operations, including dismounted infantry operations.



Recent tests indicated that it might be possible to develop a small, light power source that will enable sustained, autonomous operation by XOS. This past year the Army Research Laboratory conducted a prize competition for a wearable power pack, in which the Lockheed Martin entry was a solid oxide fuel cell/lithium ion battery, power electronics hybrid, fueled by propane, and weighing 2.4 kg. That engine (right) demonstrated 790 watt-hours per kg running over 95 hours. At the same time, Raytheon-SARCOS, the firm that fashioned the exoskeleton, has been developing advanced valves for the hydraulics that constitute the robot's "muscles," and believes that

improvements in power management thereby achieved are more promising than scaling up engine power/weight.

But even wearing XOS, members of a tactical fractal in the future are likely to have available more weapons, sensors, and other impedimenta for dealing with threats across the spectrum of war than they will have room physically to carry. Moreover, operations in demanding terrain or harsh climate will require each fractal to have access to off-person impedimenta. For example, combat in urban high-rises creates the need for carrying large amounts of hand grenades over stairs; combat in mountains, where re-supply may be arduous, necessitates carrying heavier sustainment loads. Further, the essentiality for network centricity may dictate providing power sources and network relays similar in function to what Stryker provided for the 4/9 Manchus. Accordingly, it would seem sensible that the Future Soldier Domain incorporate into the tactical fractal one or more unmanned ground vehicles (UGV). These vehicles might also perform tasks that for soldiers are arduous or risky: e.g. performing re-supply and medevac in a multi-story building; traversing rubble and shell craters to bring forward under fire ammunition, batteries, food and water; or climbing among boulders on rocky mountain sides. There is a DARPA-funded development that conceivably could perform such missions either slaved to the fractal (e.g. follow in trace), or acting alone, a versatile, snake-like, low-profile UGV, scalable for particular missions, such as shown in the sketch below:

The Center for Army Lessons Learned conducted a survey of the combat load of U.S. dismounted infantry in Afghanistan in the spring of 2003[2] that recommended as follows:

- **Re-think the logistical practices that the Army has been using since WWII and consider novel ways to resupply the dismounted Soldier, to include possible daytime LOGPACs and even multiple LOGPACs each day.**
- **Provide the platoon and squad with small logistical vehicles (SULV's) that can follow closely behind the unit. Place most of the Soldier's Assault Rucksack on these vehicles, together with some of the basic load of ammo, as well as specialty weapons (AT-4s, SMAW-Ds, etc.)**
- **Develop robotic vehicles to replace mnned SULVs.**

A more recent report from the Army Research Laboratory records modest progress thru FY 09, and predicts further load reductions over the POM period:

[2] Task Force Devil Combined Arms Assessment Team. The Modern Warrior's Combat Load. CALL, 2003.

LBS/SOLDIER	2009		2015	
Armor	39.7	42%	29	42%
Weapon and ammo *	15	16%	10.9	16%
Batteries*	16	17%	3.5	5%
Ruck	8		8	
Night Vision	1.4		1.4	
Comms			2	
Rations**	6		4.8	
Miscellaneous**	9		9	
Total	95	75%	68.6	63%

 # 210 rounds
****For 3-day mission**

In 2001, the individual load was reckoned at 93 lbs; in 2009, 95.1 lbs, with improved protection. The Army S&T program for FY09 allocates $173 M to improve capability ($12 M for mobility, including exoskeleton systems (Raytheon-Sarcos) and lower extremity load carriage (Lockheed-Martin).

The POM FY09-15 reflects S&T expenditures of $1.2B for reduced weight and added capability. The expectation is a 28% reduction in the load overall. Armor (includes helmet) will offer better protection with lower burden, reduced from 33.32 lbs to 29 lbs, but will remain the make-weight. Lighter weapons and ammunition drop from 15 lbs to 10.9 lbs. Batteries will be significantly lighter, being reduced from 16 lbs to 3.5 lbs.

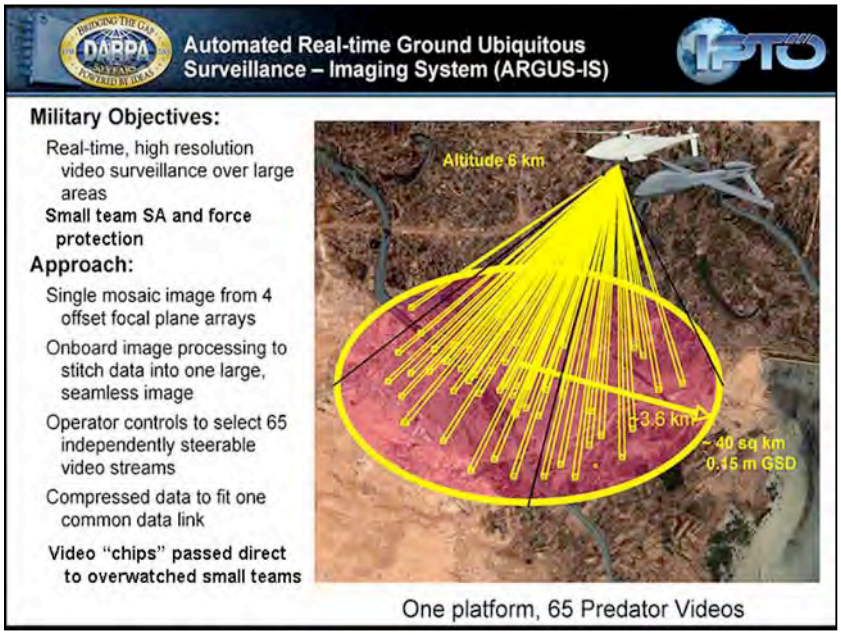
There appears to be no risk-mitigating provisions for a team-load shared with an integrated UGV, or team battle-command/situation-awareness enhanced with an integrated UAS.

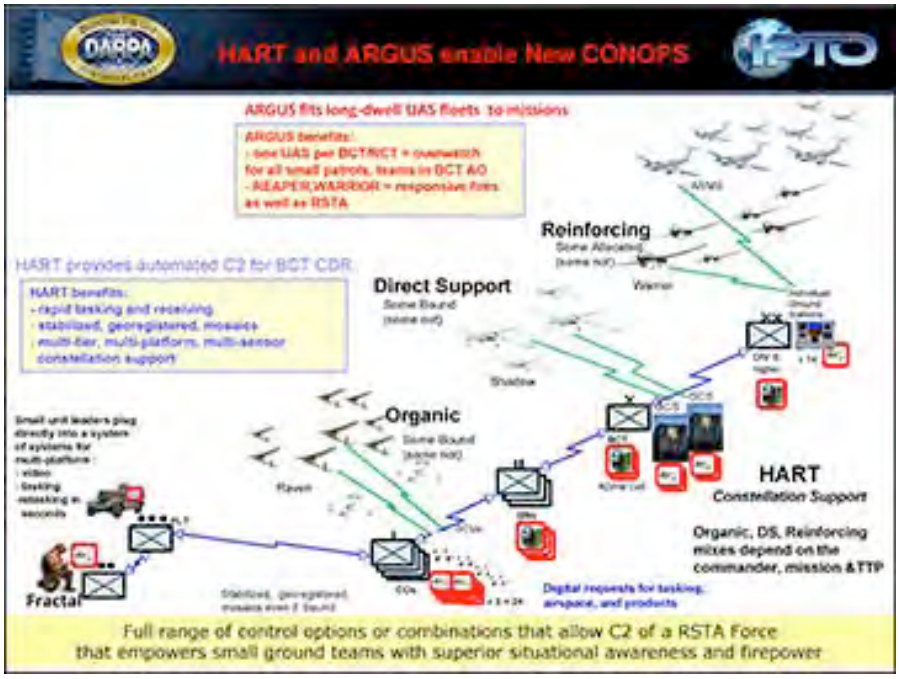
Even more recently, the Army Capabilities Integration Center (TRADOC's ARCIC) conducted a joint study with the Tank-Automotive Research Development and Engineering Center on the feasibility of employing robotics to fill gaps in Army capabilities,[3] among which there is the following:

> ***Soldier Sustainability: Improved Soldier Strength and Endurance and Transport of Equipment and Supplies in Support of Dismounted Maneuver*. Soldiers routinely perform extremely taxing and dangerous tasks in difficult terrain. Performance of these tasks under significant equipment loads can leave Soldiers physically drained and unable to operate at a high degree of effectiveness over long-duration missions. Robotic systems that can offer both the ability to increase the endurance and strength of the Soldier and transfer some equipment load to a robot will combine to increase the Soldier's speed and stamina. They may also provide a means by which to resupply Soldiers or evacuate casualties under fire. Ideally, systems that carry soldiers' equipment should maintain appropriate tactical separation from dismounted Soldiers so as not to compromise their location. These systems must be able to follow the supported Soldiers through the full spectrum of mission sets and terrain. The FCS Mule-T provides one such capability, the need to operate in very difficult and restricted terrain may require a solution that is smaller and potentially more mobile in buildings, small trains, or on very rocky terrain. Robotic systems that provide the Soldier strength and support these kinds of operations must have sufficient un-tethered power, the ability to operate in silence while in the proximity of Soldiers moving to contact, and must be able to autonomously or semi-autonomously navigate for periods of time as designated by the supported Soldier.**

This leads to another recommendation for a robotic addition to the fractal: an unmanned aerial vehicle (UAV) tasked to provide it direct support.. Over half of recent battle deaths within a tactical fractal have been inflicted on soldiers seeking to find the enemy: on patrol among the populace, acting as scouts, or walking point. UAVs offer not only a near-term prospect for less reliance on soldier eyes and ears through sensor-generated, heightened tactical situation awareness, but also a promise of assured graphics-capable, inter-fractal communications, and responsive fire power from above. The UAVs found in today's BCT, however, are unlikely to be useful in any such roles. These smaller, low-endurance platforms, when positioned overhead a fractal, can carry only light payloads —simple relays and inconsequential sensors— are incapable of more than a few hours overwatch, are vulnerable to small arms fire, could flag the position of a fractal for an adversary, and are largely useless at night or in foul weather. The Air Assault Expeditionary Force Experiments conducted by CERDEC and TRADOC have shown that such UAVs flown over a small unit provide more information to the enemy than they collect for the supported unit. Larger platforms (e.g., Predator class), are just as effective in the ISR role, are capable of endurance comparable to the operational tempo of the usual fractal, and operate out of sight or hearing at higher, more secure altitudes. But these larger UAVs are typically reserved for tasking from higher echelons. There are, however, prospects for change in Army UAV capabilities: the Extended Range Multi-Purpose (ERMP) UAS, the SKY WARRIOR, now in production, is a platform of the Predator class, capable of long endurance < 20 hours, an operating ceiling < 20,000 feet, and a robust lift capacity including ordnance. There has been a field demonstration of a Predator equipped with a sensor suite including flash-detection and geo-location, plus a broadband air-ground link. Covert, active illumination means were also available. This objective was force protection against indirect fire, and the utility of high-resolution imagery to ascertain hostile intent, and thus satisfy the rules of engagement for attack. DARPA now has underway programs that essay persistent surveillance by one UAV simultaneously for a significant number of fractals operating within a BCT's AOR, at night as well in daytime, and enabling a BCT to control fleets of small and large UAS to form a RSTA task force. When these programs mature, the Soldier Domain should incorporate them.

[3] Robotics Strategy White Paper, 19 Mar 1009. L9, pp12-13.





The Army should adopt a procedure now common in the SOF community: mission a Predator-class UAS to provide direct support for each deployed fractal, persistent overwatch for better situational awareness, for assured communications, and for fire support. Adding a vertical dimension to the tactical fractal, amplifying its situational awareness and improving its force protection, could reduce casualties, and could enable a deployed BCT to control more efficiently lands and people, and thereby reduce the requirements for U.S. support units.

Developing capabilities for integrating an UGV into the tactical fractal and its direct support by a multi-purpose, long-dwell, weaponized UAS is a task that TRADOC's Army Capability Integration Center should vigorously pursue, pressing Army S&T to close these gaps.

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Capabilities for the Soldier Domain

<table>
<tr><th colspan="2">Mission</th><th>Δ with LW*</th><th>Δ with LW & XOS#</th><th>Δ with LW, XOS & UGV**</th><th>Δ with LW,XOS. UGV & UAS##</th></tr>
<tr><td>Go</td><td>Operate afoot or mounted</td><td rowspan="3">No change</td><td>Operate unencumbered</td><td>Expanded operational range, duration</td><td rowspan="3">No change</td></tr>
<tr><td>Hide</td><td>Concealment amid clutter</td><td>No change</td><td rowspan="2">No change</td></tr>
<tr><td>Dig</td><td>Assume the best armor: earth</td><td>Dig deeper, faster</td></tr>
<tr><td>Sense</td><td>Interpret with many eyes, ears</td><td>Networked intell</td><td rowspan="2">No change</td><td rowspan="4">Snake-like mobile sensors</td><td>Sense beyond LOS</td></tr>
<tr><td>Seek</td><td>Move to where sensing is best</td><td>No change</td><td>Collect without repositioning</td></tr>
<tr><td>Find</td><td>Ferret out foe</td><td rowspan="2">Networked intell</td><td>Fewer barrier constraints</td><td>Multi-spectral sensing, motion detection</td></tr>
<tr><td>Tell</td><td>RSTA for force</td><td>No Change</td><td></td></tr>
<tr><td>Kill</td><td>Discriminately and surely</td><td>Networked fires</td><td>No change</td><td>No change</td><td>Directly link to overhead weapons</td></tr>
<tr><td>Control</td><td>Land and people</td><td>Baseline TBD</td><td colspan="2">Less personnel or extended area</td><td>Less personnel or further extended area</td></tr>
</table>

- **As used here, any of the several candidate developments aimed at extending the network to encompass members of a tactical fractal.**

 # NSREDEC's Exoskeleton

**** The snake-like, scalable robot being developed by DARPA**

SKY WARRIOR or an equivalent platform

CONCLUSIONS:

1. "Future Soldier 2030" should be presented as design for a technology-leveraged regimen for the tactical fractal, one that can be incorporated into the Soldier Domain to provide, for TRADOC, PEOs, PMs, and Life Cycle Management Centers, a S&T focus for Technology Teams centered upon:

Network **Sensors** **Human Dimension & Training**
Protection **Lethality** **Power & Energy** **Mobility & Logistics**

2. Existing programs, such as Joint Tactical Radio System and Rifleman Radio and Ground Soldier System/Ground Soldier Ensemble, should be pursued. Soldier Domain S&T should formulate and execute programs that are designed to inform the requirements generation and the acquisition programs, and eventually to merge smoothly through planned and funded technology transitions. NSRDEC's XOS should be continued and accelerated as a mitigation of Soldier Domain SWAP risks. NSRDEC should also bring one or more integrated load bearing, task sharing, UGV into Soldier Domain as another capability enhancement and risk mitigation.

3. The Soldier Domain should be network centric for battle collaboration, and should be equipped or supported to operate in three dimensions with XOS, UGV, and UAV. TRADOC's ARCIC should conduct experiments to develop appropriate TTP for UAV DS to fractals.