ARMY SCIENCE BOARD

FY2001 SUMMER STUDY

FINAL REPORT

DEPARTMENT OF THE ARMY
ASSISTANT SECRETARY OF THE ARMY
(ACQUISITION, LOGISTICS AND TECHNOLOGY)
WASHINGTON, D.C. 20310-0103

"THE OBJECTIVE FORCE SOLDIER / SOLDIER TEAM"

VOLUME I
EXECUTIVE SUMMARY

November 2001

Distribution Statement:
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CONFLICT OF INTEREST

Conflicts of interest did not become apparent as a result of the Panel's recommendations.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Hwy, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington D.C. 20503.

1. AGENCY USE ONLY (Leave Blank)

2. REPORT DATE
November 2001

3. REPORT TYPE AND DATES COVERED
Army Science Board – FY2001 Summer Study

4. TITLE AND SUBTITLE
The Objective Force Soldier / Soldier Team - **Volume I - Executive Summary**

5. FUNDING NUMBERS
N/A

6. AUTHOR(S)

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8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

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10. SPONSORING/MONITORING AGENCY REPORT NUMBER
N/A

11. SUPPLEMENTARY NOTES
N/A

12A. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release; distribution is unlimited

12b. DISTRIBUTION CODE
A

13. ABSTRACT (Maximum 200 words)

The Army Science Board was tasked to:
(1) Characterize the level and nature of lethality, survivability, logistical and information systems for command, control, communications and computer improvements that must be achieved to yield a more effective Objective Force Soldier across the operational spectrum. Evaluate connectivity/interface between Future Combat System variants and the Objective Force Soldier. (2) Map the technology from present to future that would obtain the improvements as described above. (3) Include in the technology roadmap an assessment of current and projected Research Development and Acquisition efforts. Highlight those areas where modest investments now may yield significant capabilities in soldier effectiveness, weight reduction, power efficiency and affordability of soldier systems. (4) Recommend alternative science and technology strategies that can provide the level of improvements outlined above. Stratify the level of cost, technical and schedule risk associated with each alternative. Address emerging technologies from academia, industry and other government agencies.

The ASB responded by identifying specific goals, highlighting the uncertainty in connectivity, identifying top effectiveness gains and preparing S&T investment/activity roadmaps.

Each ASB subpanel provided specific recommendations corresponding to subpanel topics: Future Threats, Conceptual Framework, Analysis, FightabilityTechnologies, Weight Considerations, Power System Technologies, Manpower and Personnel, S&T Investment Strategy, Affordability and Cost Control, Senior Officer Observations.

14. SUBJECT TERMS
The Objective Force Soldier, Dismounted Soldier, Fightability, Objective Force Fightability, Soldier System Weight, Power, Battlefield Power, Soldier System Power, Science and Technology, Soldier Systems Science and Technology, Soldier Systems Investment Strategy, Affordability, Soldier Systems Affordability, Cost Control, Soldier Systems Cost Control, Threats, Future Threats, Soldier Systems Conceptual Framework, Manpower & Personnel, Objective Force Manpower & Personnel, Senior Officer Observations

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THE PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	None

In memory of LTG Timothy J. Maude,
Deputy Chief of Staff for Personnel,
who lost his life in the terrorist attack
on the Pentagon, 11 September 2001.

The Objective Force Soldier / Soldier Team

Executive Summary

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Army Science Board
2001 Summer Study

Objective Force
Soldier / Marine Team

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SUMMER STUDY 2001

The National Requirement

- **The Nation must have a rapidly deployable ground component to both rapidly and potently stop aggression, killing, dying …***
- **The FCS Program will produce the appropriate family of medium weight vehicles**
- **But the Study Members believe:**
  - **The Dismounted Soldier/Marine Team will hold the key to implementing national objectives**
  - **Our current force will be unable to undertake such tasks in the future without a high likelihood of significant casualties and collateral damage**

Therefore:
Our Nation must, on a priority basis, undertake a comprehensive program to significantly improve dismounted Soldier/Marine Team capabilities

***Paraphrased from: Transformation Study. Gen Jim McCarthy, USAF (Retired)**

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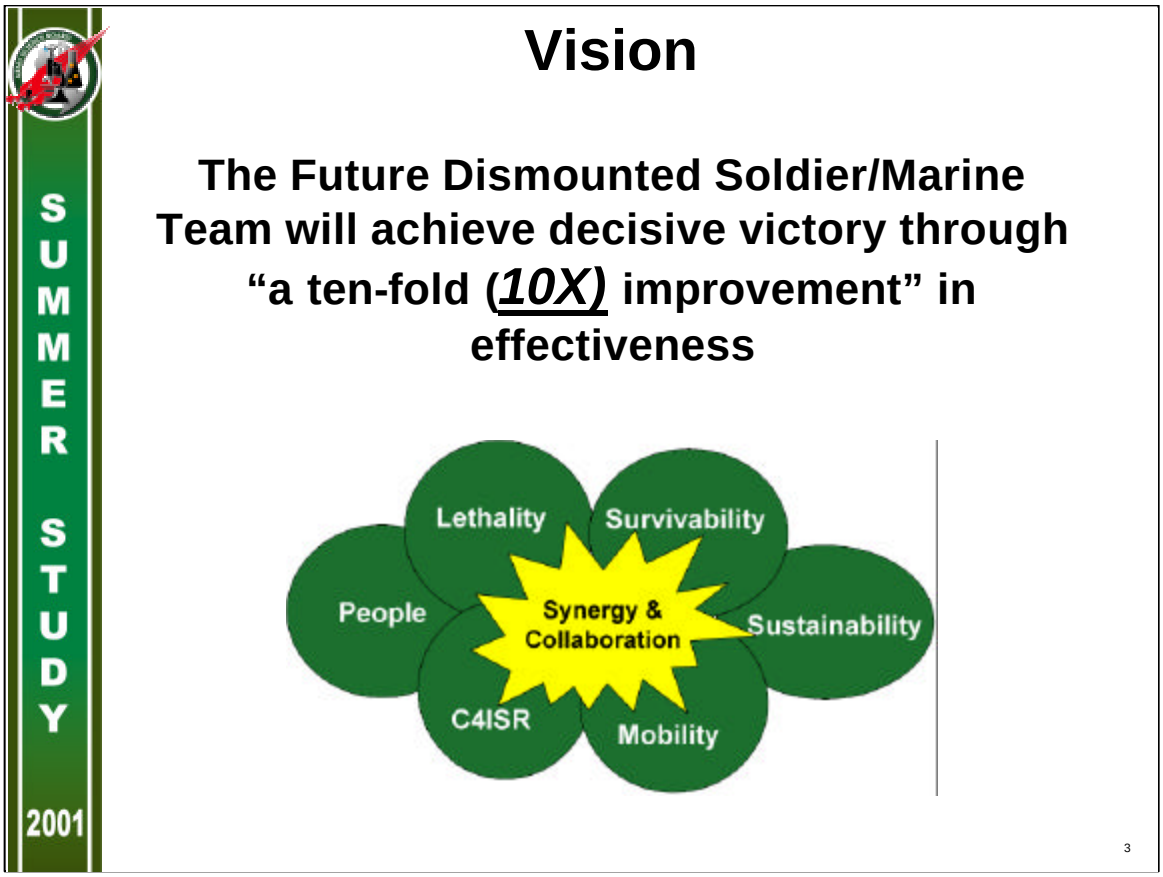
As the study progressed, the team members came to realize that our nation was entering into an era wherein employment of dismounted soldiers would hold the key to achieving our national objectives during a period of crisis. However, as we reflected on recent events, we knew there would be a strong reluctance to employ our soldiers due to concerns about the prospect of considerable casualties. As a result, our national arsenal was effectively devoid of a very important element for the future crisis management – specifically, a soldier that could enter a most challenging environment, close with and destroy the enemy and, importantly, survive.

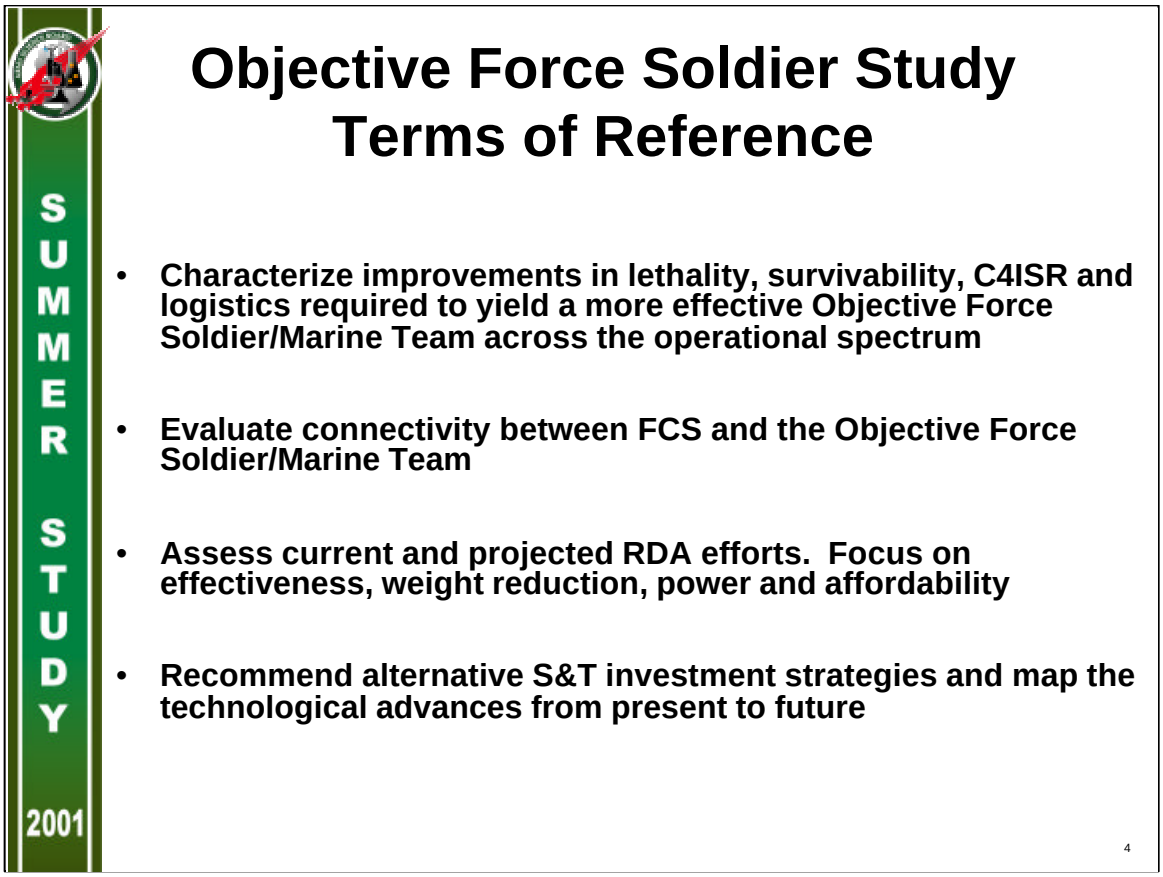
We also came to the realization that it was possible to accomplish the very challenging missions that may arise in whatever difficult environment provided that the Soldier/ Marine Team was equipped with technologies that are emerging, invoked the qualities of first in engagements and was trained in the use of the technology.

Therefore, our heartfelt recommendation that our Nation should undertake on a priority basis a comprehensive program to improve the Soldier/ Marine Team capabilities. This report is dedicated toward pointing the way for such a program.



The vision the study team set was to increase the capabilities of our Dismounted Soldier/ Marine team by a factor of 10! This would, of course, necessitate a dramatic change in the way the soldier would fight and the way he is equipped.

Our analysis suggests this stretch goal can be achieved. But it can only be achieved through synergy and collaboration and with qualitative advances in lethality, survivability, CV4ISR, mobility, sustainability and people.



The Study Terms of Reference have been summarized and are shown above. The full text is included in Appendix A.

Objective Force Soldier Study Team

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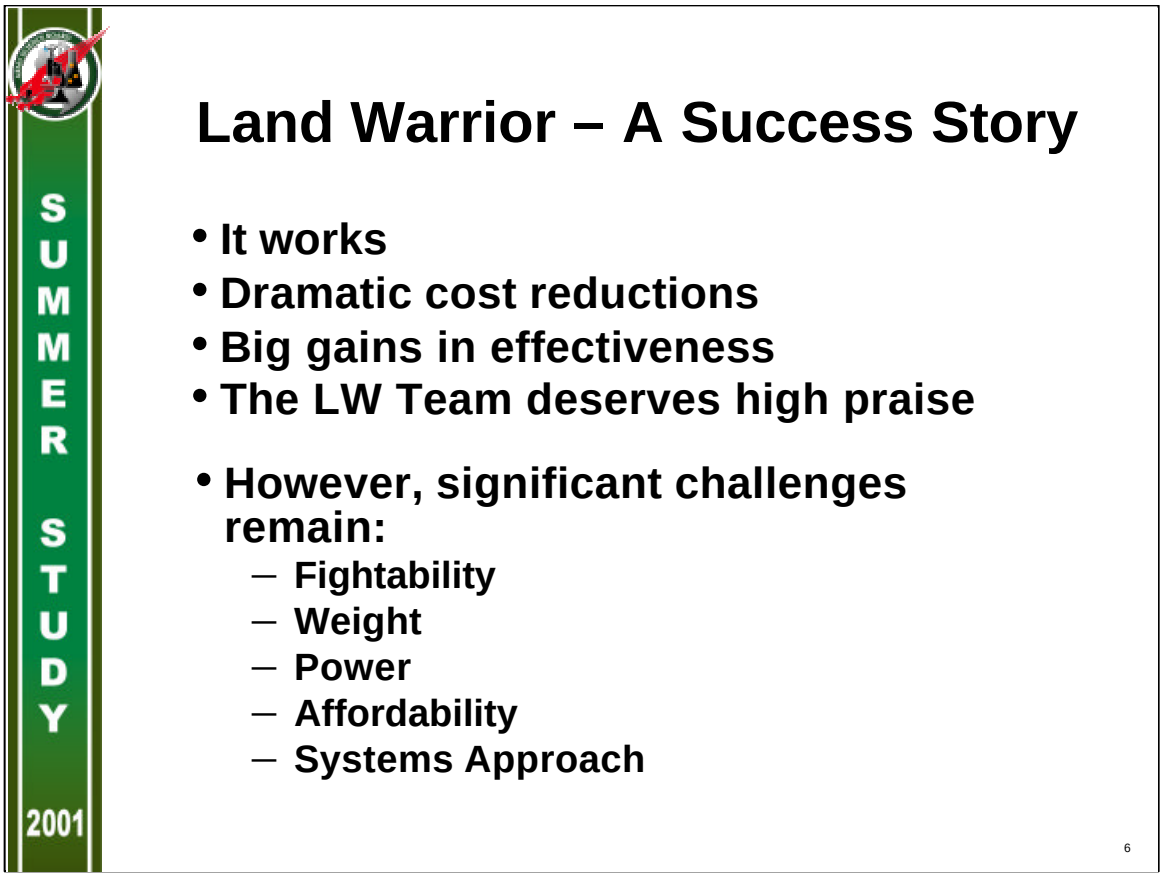
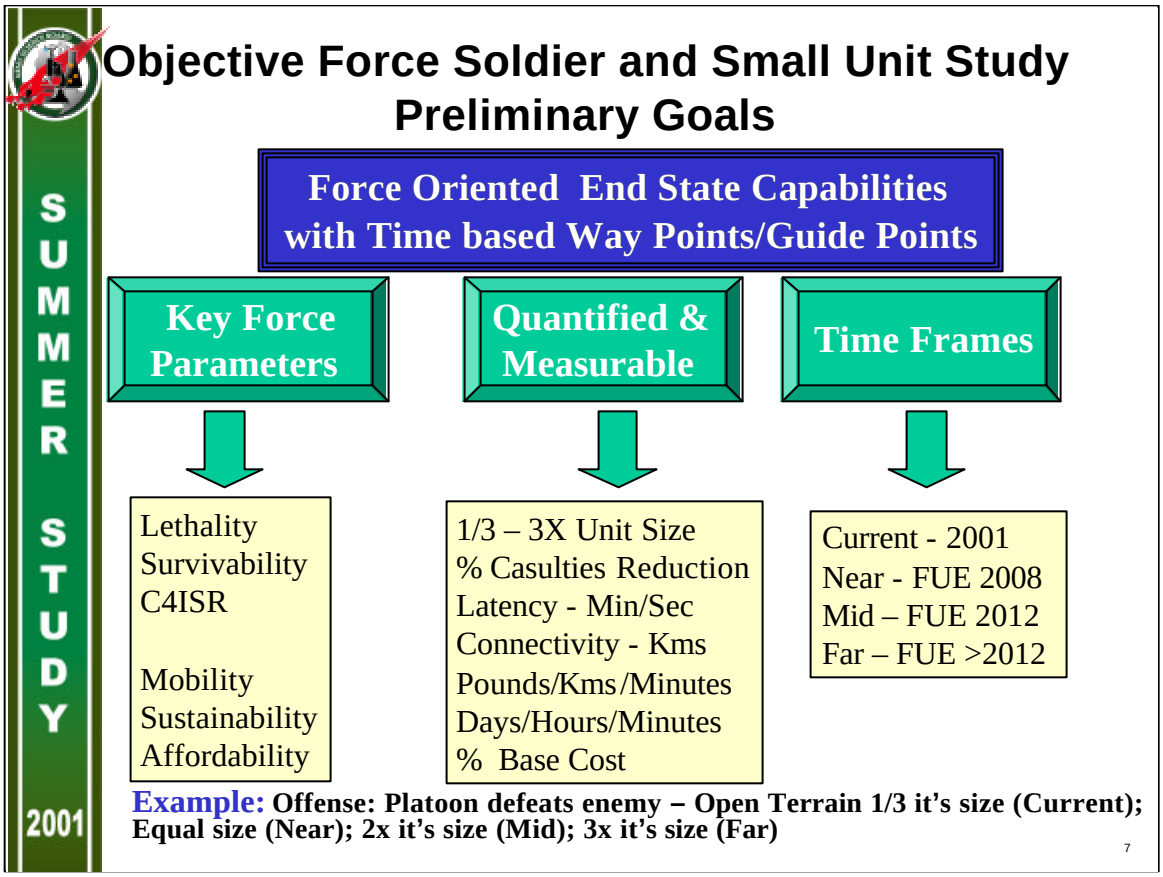
The team included members and consultants from the private sector and academia, as well as retired general officers. More information on Panel membership, roles in this study and participant organization or occupation is available in Appendix B – Participants List.



The first major finding was that the Land Warrior program is a success story. Congratulations are due to Dr Brandlier of Natick Laboratory and COL Jette, the program manager.

This finding is supported by the following observations. The program costs have been significantly reduced which will save the Army millions of dollars. Further, in field trials at the Joint Readiness Training Center, the Land Warrior system enabled soldiers to dramatically change the course of selected battles. An example being a confrontation with snipers wherein soldiers equipped with Land Warrior were able to knock out the snipers with very few losses as compared with prior exercises in which the forces had high losses.

Significant challenges remain, however. These challenges can be categorized into: fightability, weight, power, and affordability. Each of these categories will be addressed in detail in the study.



We considered intermediate goals to determine attainment of a '10X' soldier. With no pre-established set of measures for a soldier system, a preliminary was prepared to spur discussion.

To assist in interpreting this chart, consider that several time frames were selected for this study: Near term was selected to be consistent with the initial fielding of the FCS force. This would require a Technical Readiness Level (TRL) of 7, or readiness for engineering development by 2004, which would in turn permit a First Unit Equipped (FUE) in 2008. Similar TRL's and FUE's were specified for the mid and far terms.

Lethality: An example of how one might interpret these measures would be to consider the 1/3 – 3x line relating to 'Offense: Platoon defeats enemy: Open terrain, dug in'. Typical planning factors today require a 3 to 1 advantage over the threat to accomplish the mission. For today's force, that is shown as defeating a threat of 1/3 its size. In the near term, the goal would be to defeat a threat of equal size and, in the future, defeat one 3 times its size. This would be roughly a ten fold increase in capability. In other tactical situations comparable gains were specified.

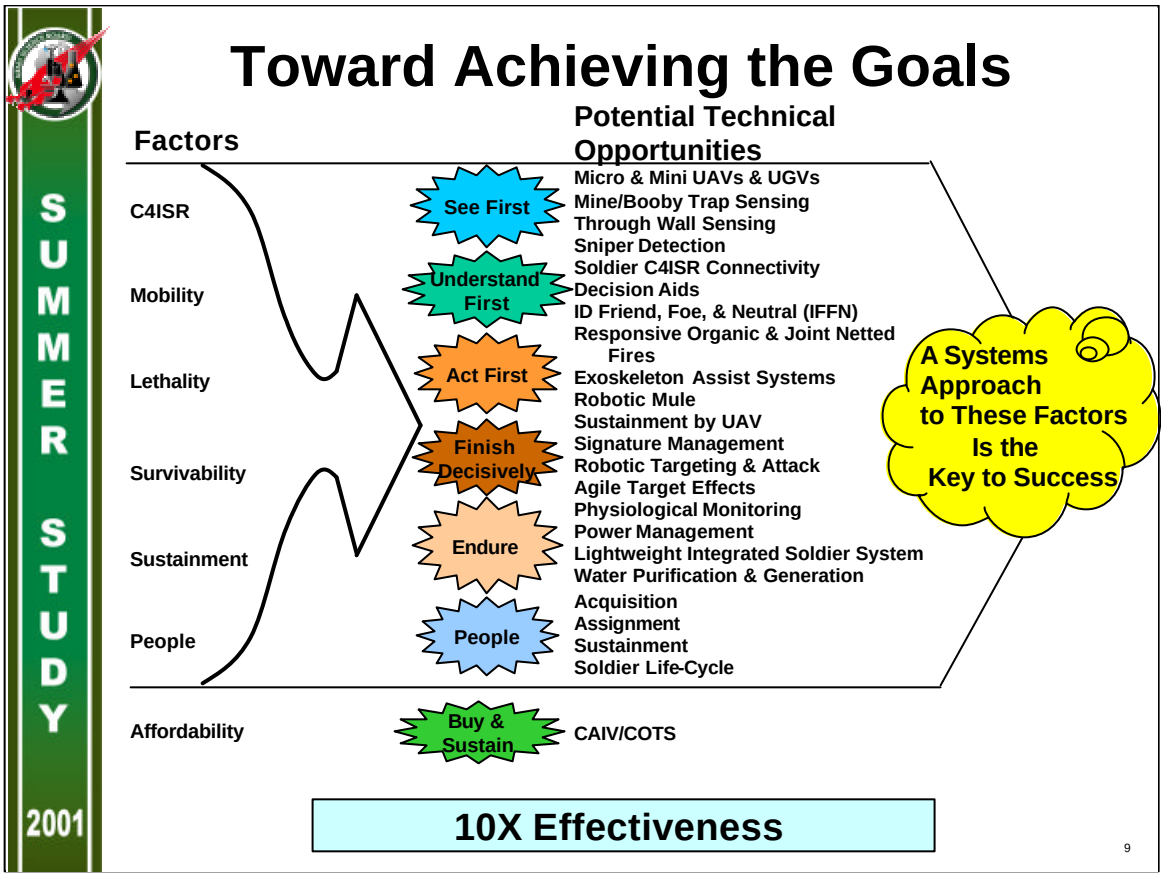
Survivability: Reduced casualties with, in the far term, an overall reduction of 50% in blue casualties being desired.

C4ISR: In considering situational understanding in our deliberations, it was deemed to include both a degree of completeness in terms of knowledge of red and blue forces as well as a time latency. Assured connectivity is integral to achieving the 10X soldier. This is particularly challenging in areas of broken terrain, mountains and urban canyons. As the Future Combat Systems dominate greater areas, the assured connectivity distances need to increase accordingly.

Mobility: A soldier's mobility is closely linked to the weight that he carries. Although different units carry somewhat different items, a 92 pound load fighting load is representative. A load this heavy severely restricts soldier mobility. A major reduction is necessary and, therefore, a future goal of 30 pounds was selected.

Sustainability/ Resupply: There is high correlation between one's confidence in timely receipt of supplies and the amount one carries. If a resupply system were 'never too late', then one could confidently carry less water, etc. A future goal of resupply within 6 minutes was specified.

Affordability: All is for naught if the technical solutions cannot be afforded. The baseline for comparison of current soldier system is specified as Land Warrior and OICW. For the future, a goal of 50% reduction in costs was suggested.



The various factors of C4ISR, mobility, etc., were mapped across the ‘qualities of first’. The technologies which our assessment process identified as high potential are shown. These technologies will be described in detail in later sections of this report. Technical readiness levels and adequacy of funding will also be addressed.

A very significant important message throughout this report is that a systems approach is mandatory. The solution to a 10X soldier will not become a reality unless a systems approach is taken.

Analysis Panel Mission

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Hue 1968

Grozny 2000

- **Recommend initiatives to enhance assessment tools and capabilities**
- **Explore mission effectiveness to identify needed operational enhancements**

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The Analysis Panel performed two related jobs for the study team. First, they assessed the capabilities of existing analysis tools to support the assessment of dismounted operations in complex terrain. Based on that assessment they recommended initiatives to enhance these tools. Second, taking advantage of appropriate tools, they performed analyses to highlight those operational capabilities that were needed to significantly enhance mission effectiveness. These latter results were provided to the other Study Panels to focus their efforts to identify relevant technological and system initiatives to achieve those operational capabilities.

Challenges in "Analyzing" Dismounted Operations

- Key constructive and virtual model research is missing or inadequately resourced
- Core physical and behavioral models are inadequate
- Unit effectiveness models have key limitations, particularly in urban scenarios
- Little agreement on representative scenarios
- Current models are resource intensive and inflexible
- Data are difficult to acquire

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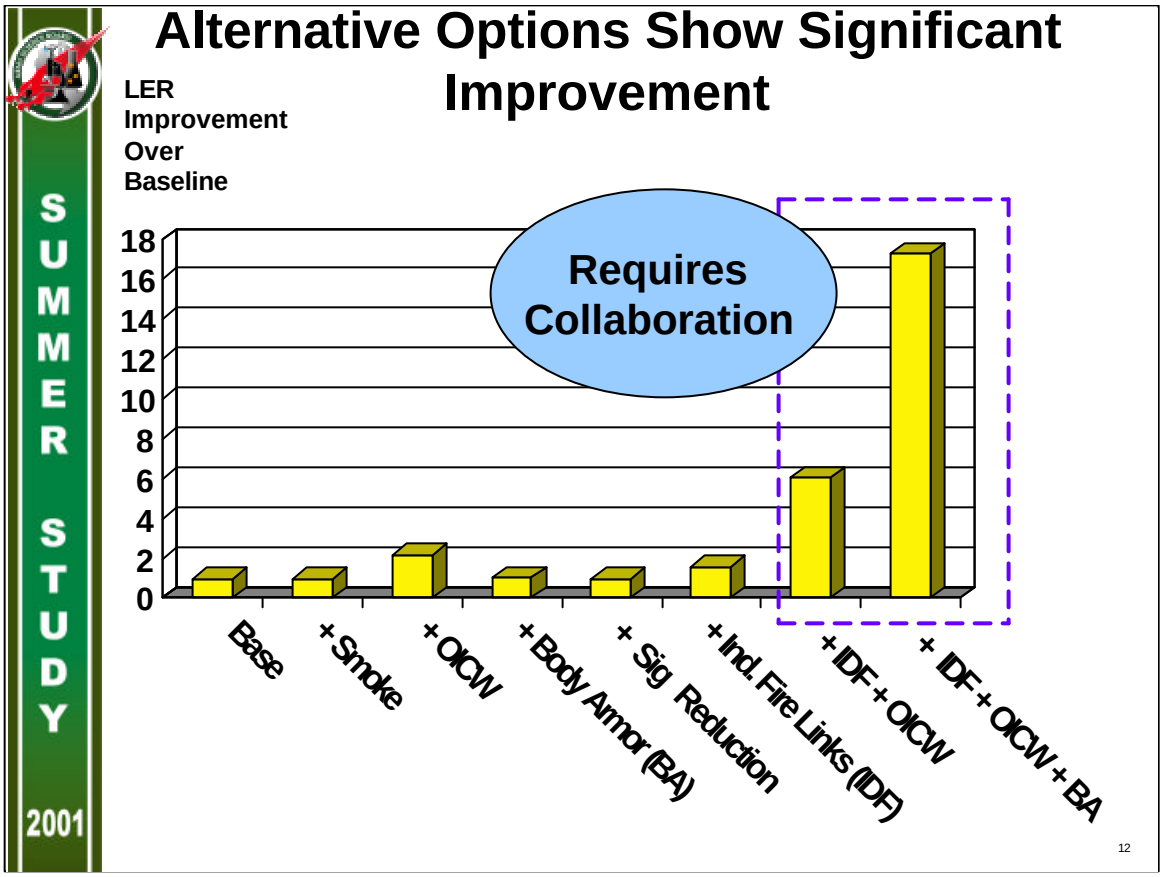
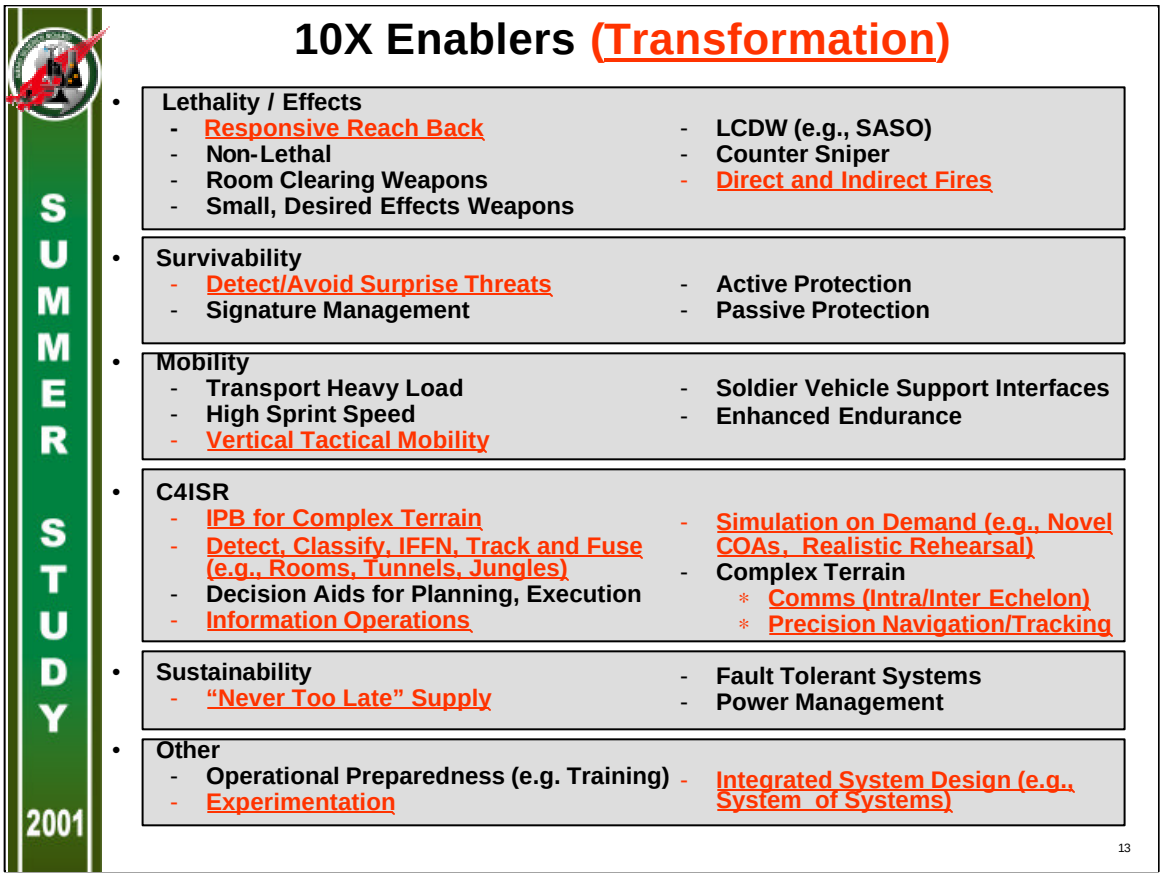
Based on our review of existing and planned tools to evaluate dismounted operations in complex terrain we concluded that the community has a number of important limitations. We have identified six specific challenges that warrant immediate attention. First, we have concluded that key constructive and virtual model research is missing or inadequately resourced. This is broadly consistent with the preliminary findings of the recently formed MOUT Functional Area Concept Team (FACT). Our only sense of disagreement with that group is that we believe that they are overly optimistic in their assessment of the state of the research base. Second, we rate core physical and behavioral models for complex terrain as inadequate. For example, as pointed out by Mike Bauman, Director, TRAC, we lack an understanding of the process by which an individual performs the search process, either unaided or with a sensor, in an urban environment. Third, we have key limitations in unit effectiveness models particularly to address complex and urban scenarios. In the analyses that we performed to support the Summer Study, the inability to represent innovative TTPs easily, as well as the lack of credibility in existing unit effectiveness models, became quite apparent. Fourth, we have little agreement across the community about what these representative scenarios should be. During the Cold War, we had the comfort of dealing with the Fulda Gap and SCORES 6A. We have yet to replace these scenarios with a set of conditions that people understand and believe to be representative of future conflict. Fifth, we have found current models to be highly resource intensive and relatively inflexible. This means that it takes extensive time and resources to do focused analysis in this arena. As a consequence, current analyses are often limited to a very restricted set of conditions. Finally, the data that are available is very difficult for analysts to acquire and assimilate into existing models. As an example, simulations of MOUT generally require very high resolution terrain data (e.g., 1 meter resolution or DTED level 5). Currently, the regions of the world where DTED level 5 data are available is extremely limited and extremely time consuming to acquire and adapt to the needs of the models. It is even more challenging if subterranean features (e.g., sewer systems) are needed for the models. In addition, valuable data that have been acquired at the Combat Training Centers have not been made available for research.



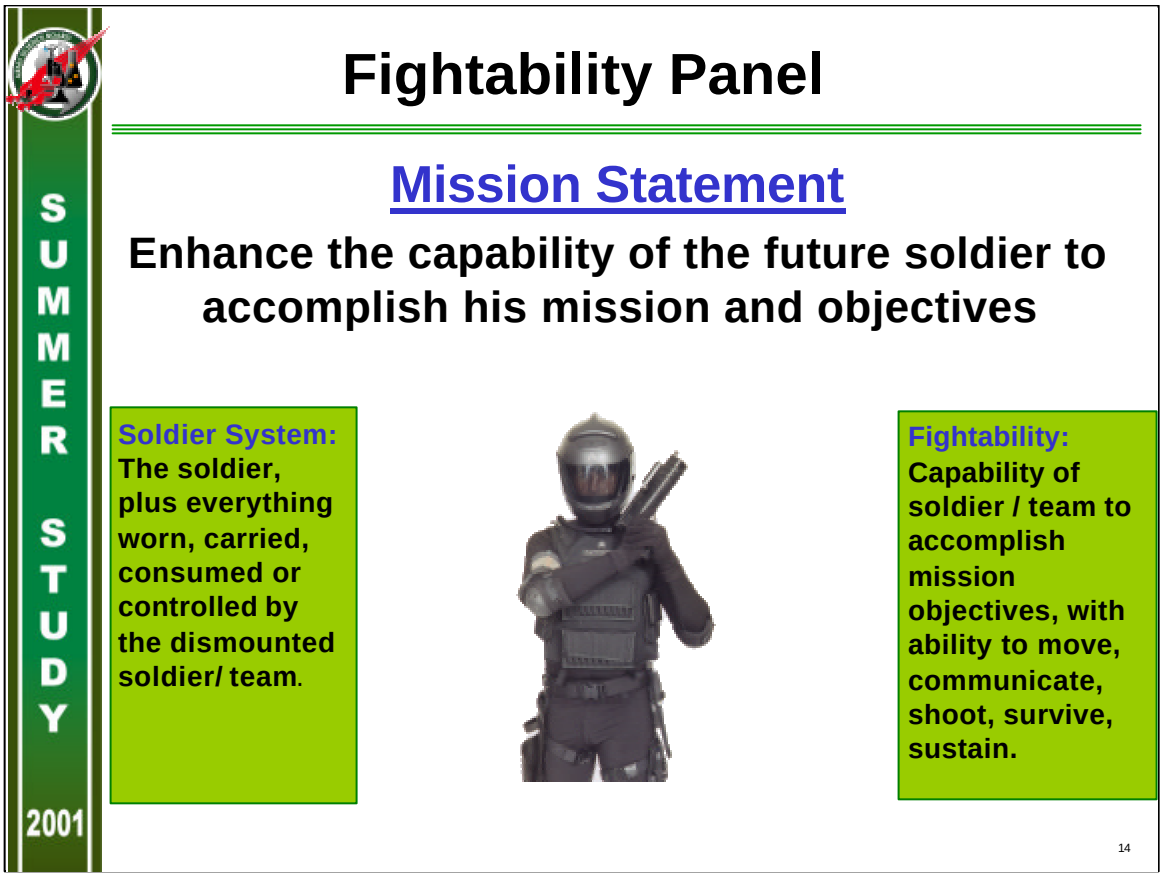
Five different analytic studies were undertaken in this effort. Most of the focus was on urban operations but one looks at complex terrain where the dismounted soldiers must attack across 300 meters against dug in red soldiers hidden in a woodline. The scenario evolved from RAND research in Kosovo. This slide depicts the results. Options are added one at a time as indicated.

We then moved to the next phase of the analysis and considered adding combinations of these options into the base case. The first variant added indirect fire with the OICW. That served largely to nullify the effect of Red's machine guns (which were the major killer of Blue Forces, even when they were equipped with body armor). Subsequently, when we added the body armor to the mix we got a substantial improvement in effectiveness (i.e., a 17 fold improvement in LER over the base case). At this stage, with the elimination of Red's machine guns, Blue's body armor provides extremely effective protection against Red's small arms, substantially reducing Blue's losses. Although it is not explicit in the model, you need the ability to communicate and collaborate amongst the Blue forces in order to conduct this type of activity.

These analyses suggest that there is a substantial potential for synergy among materiel and tactical options if they are implemented in a synchronized fashion.



Based upon our data mining and assessment activities, we have identified key capabilities that are needed to perform effective dismounted operations in complex terrain. We have organized these potential capabilities into six categories: lethality, survivability, mobility, C4ISR, sustainability, and other (e.g., training, experimentation, systems perspective). All of these capabilities are potential areas for improvement. However, there are two key points to emphasize. First, the panel reviewed these capabilities and highlighted those that could truly transform the nature of dismounted operations in complex terrain. Those transformative capabilities are highlighted on the slide. Second, it is interesting to note that the bulk of these transformative capabilities are clustered in the area of C4ISR. Thus, the primary challenge to the S&T community is to develop the technologies that are needed to make these C4ISR capabilities a reality.



Mission:

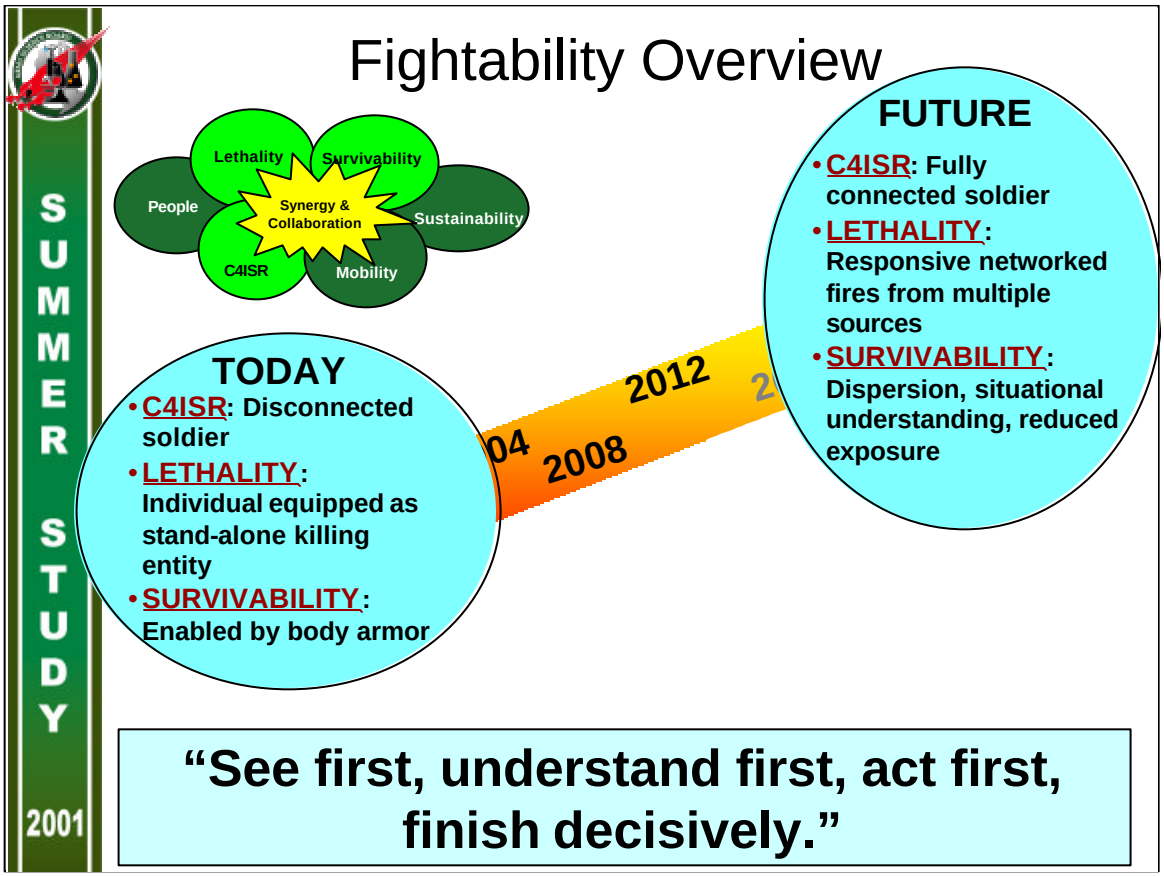
The Fightability panel was chartered to look at technologies that enhance the fighting capability of the future soldier.

Definition of Soldier System:

We adopted the Army definition of soldier system as inclusive of the dismounted soldier/team and anything worn, carried, consumed or controlled by the soldier/team.

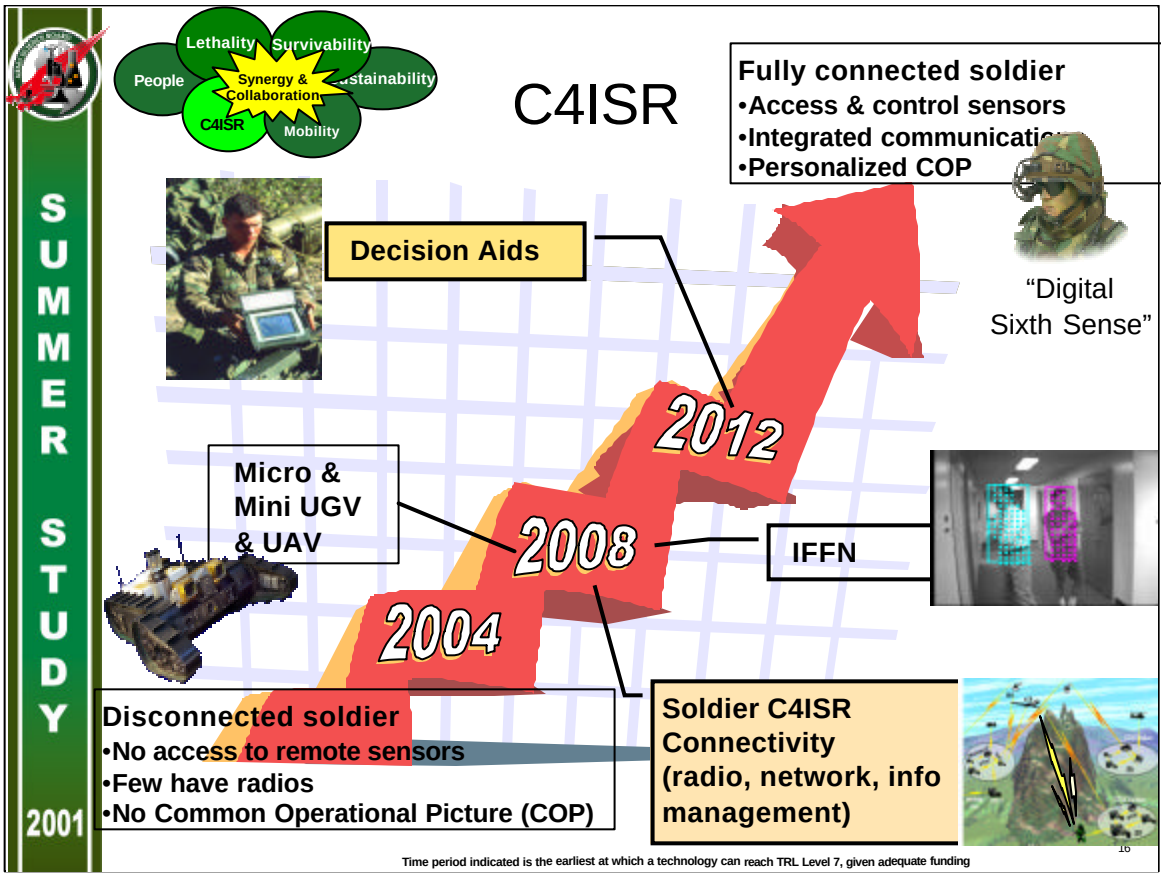
Definition of Fightability:

Fightability encompasses mobility, C4ISR (command, control, communicate, computers, intelligence, surveillance and reconnaissance), lethality, survivability and sustainment. Due to the assignment of mobility and sustainability to the weight and power panels, respectively, our panel focused its attention on C4ISR, Lethality and Survivability.



Fightability of the objective force warrior can move from the current level of capability to a 10X objective warrior capability by correctly inserting technology into the Soldier System – both organic capabilities and reach-back capabilities to augment the soldier team. The Fightability panel has identified a range of technologies and a path to achieve this Fightability objective. An integrated, synergistic approach across the areas of Mobility, Sustainability, Lethality, Survivability, and C4ISR is essential to achieve optimum capability. As noted earlier, this panel addressed Lethality, Survivability, and C4ISR; the weight panel covered Mobility and the power panel covered Sustainability.

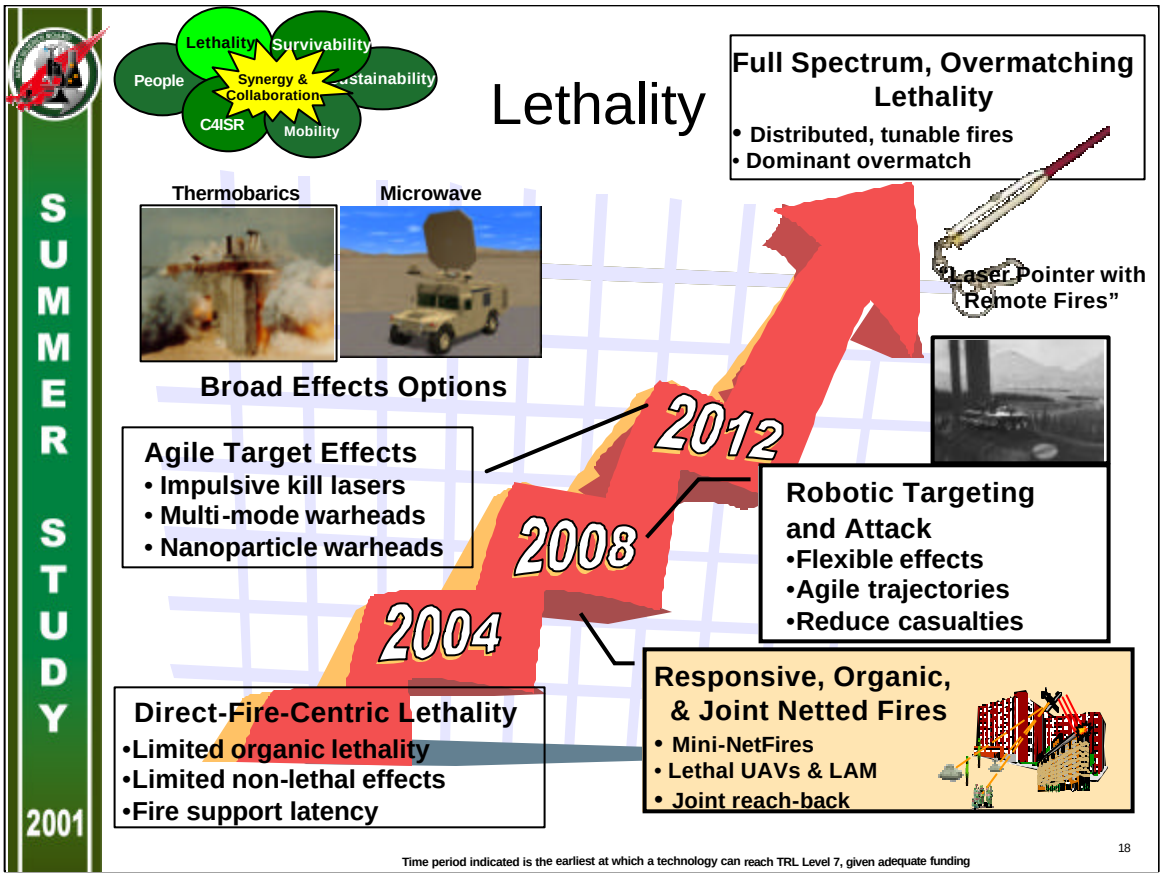
The operational goal to "See first, understand first, act first, finish decisively" is enabled by providing the OF Warrior assured wideband connectivity at all levels -- intra-squad, inter-squad and up-echelon. This enables the delivery of the best possible situation awareness, and access to reach-back fires and never-too-late logistics. The provision of (a) increased sensor and weapon capability enabled by robotics (UAVs and UGVs) and (b) robust supporting fires with tunable lethality from squad organic, FCS organic and Joint reach-back fires makes the OF Warrior many times more lethal than the current soldier. And survivability is enhanced, not merely by more or better body armor, but through new tactics, techniques and procedures enabled by the application of technology – allowing greater dispersion and less exposure to enemy fires.



Current Situation: The soldier of 2001 has access only to the sensors that he is equipped with, typically weapon thermal sights and vision augmentation. Yet, already the battlefield is becoming rich with sensors that are not readily accessed by the soldier. The key missing ingredient for evolving from the disconnected soldier to the future connected soldier is connectivity to C2 and sensor access/control; requiring the radio and surrounding network infrastructure to give each soldier a common relevant operational picture, tailored to the specific needs of the individual, team and tactical situation.

Key Technologies: Advanced sensor capabilities such as the ability to "see" through walls, or sensor-equipped bullets from the OICW are capable of being matured in the mid term (2008). To tie this information together and share a common operational picture, the soldier must be equipped with an advanced multi-mode, multi-band radio that establishes networked connectivity when available, and operates in a peer-to-peer mode when that suits the situation. To enable the soldier radio to fully leverage its capacity, the components of the FCS, UAVs, UGVs, sensor platforms, and eventually EW platforms must be tied together and made accessible to the soldier radio. The surrounding infrastructure to support "fully networked connectivity" will be supplied by deploying mobile access points, relays and routers on every possible platform. In addition, information management technologies must be embedded in the C4ISR system of systems to manage the knowledge-bearing traffic. IFFN (identification, friend, foe or neutral) capability will also be embedded as an integral part of the soldier's electronic suite. Most of these technologies could be available in the 2008 with some additional investment in an integrated C4ISR system for the soldier. In the longer term, the C4ISR suite will integrate automated decision aids that supply smart knowledge filters to help the soldier think through the situation, and provide a basis for decisive actions by the soldier that are based on collective knowledge that stems from well beyond the soldier alone.

The Future: The distillation of data and information into “smart cues” for the soldier -- thru the combination of sensors, network, intelligent information management, and cognitive decision aids -- brings an order of magnitude increase in his survivability on the battlefield. When the soldier C4ISR is fully matured, the soldier will have a sixth sense at his disposal. The soldier can walk into a situation and the radio system automatically establishes connectivity through the most appropriate means - through commercial cellular towers, through the closest UGV mule, or through a satellite - all using the same integrated wearable electronic suite. The surrounding sensors each supply information that can be added to the personalized COP available on the soldier’s wearable system computer. The location and disposition of the team, the FCS, and the enemy is presented as part of the COP. Verbally or through motions, the soldier commands and controls the information, actions, and battle decisions under his control. With this sixth sense enabled, the soldier can exercise situation-dependent control of assets ranging from EW or electronic deception, to lethal weapons engagement, with a minimal amount of wondering and guessing.



Current Situation: Dismounted soldiers today, individually or in small units, have direct control only over the weapons they carry-- rifles, grenade launchers, machine guns, small mortars, etc. This adds up to relatively short range, mostly direct fire lethality, 100% organic to the soldier and squad. Responses to calls for support from artillery or aircraft typically have a high latency, and the requested heavy ordnance can often arrive too late to hit the target it was intended for. Non-lethal weaponry choices, such as often needed for use in Operations Other Than War (OOTW), are limited and less than adequate in many situations.

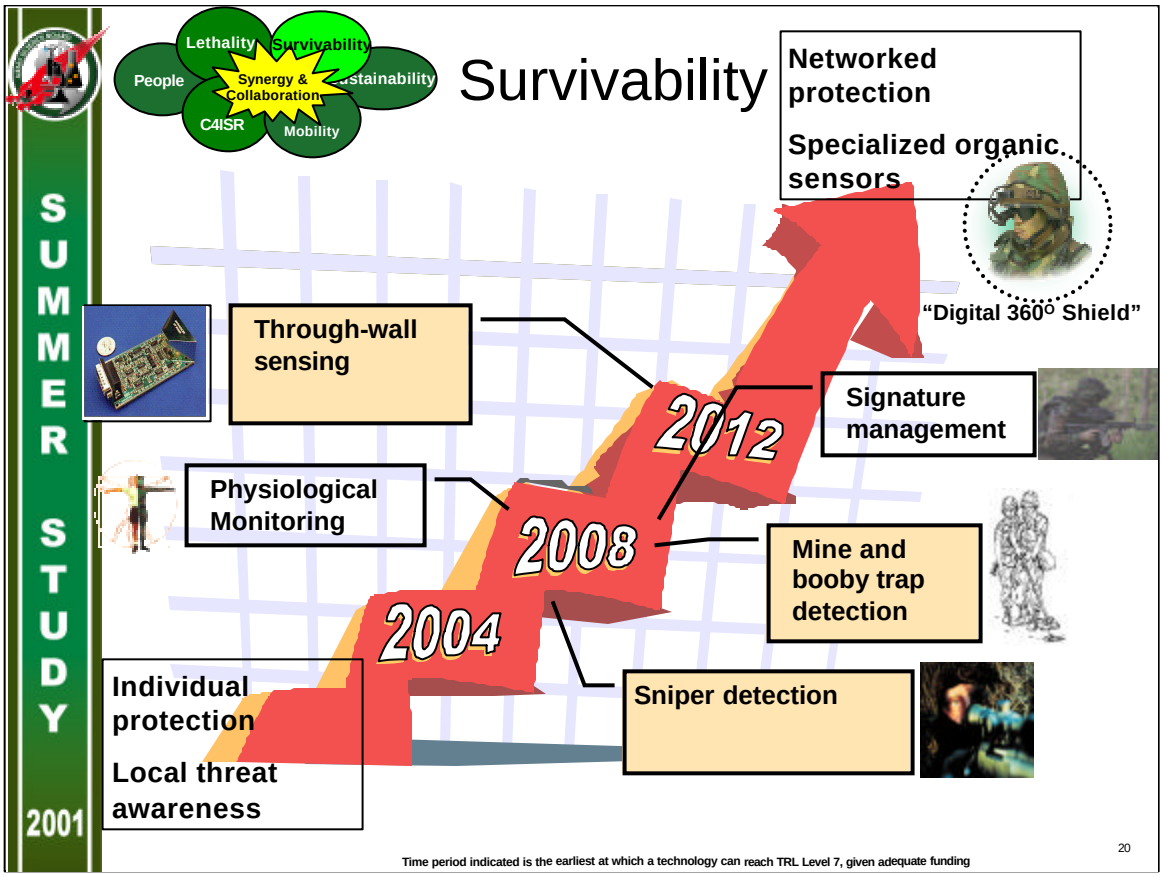
Key Technologies: Many improvements still can be made to conventional infantry weapons. However, for major gains in small unit lethality three areas must be pursued:

1. The most quickly realizable gains can be achieved with responsive, organic, & joint netted fires. Major improvements in soldier connectivity are essential to obtaining this capability (see C4ISR recommendations). The latency built into the current fire support system must be squeezed out, and will be with high-speed wireless connectivity. Protocols and munitions should be developed for reach-back to a range of complementary lethality effects from nonlethal munitions to tunable directed energy weapons. Part of these, and essential to their high effectiveness, are lethal UAVs & Loitering Attack Munitions designed for support of small units and dismounted infantry.

2. Technology will permit robotic weapons to be used in support of the objective force warrior. UAVs and UGVs will be common on future battlefields. Some of the smaller machines will be loitering munitions to be expended in a soldier-directed attack on an appropriate target. Some of the larger robots will be specialized as RSTA or fighting robots. These will enormously increase unit effectiveness and greatly reduce casualties.

3. Agile Target Effects System (ATES), a conceptual ensemble of devices employing various, unconventional directed energy effects, promises to give the dismounted soldier a robust, multi-mode weapon system providing controllable effects on targets at tactical ranges. These will be tunable against a variety of materiel and personnel targets and include (1) pulsed impulse lasers, (2) multi-mode warheads, (3) nanoparticle warheads, and (4) nonlethal acoustic devices. The main challenge for each of these is miniaturization of the technologies for dismounted soldier use.

The Future: Developments in lethality such as tunable fires, robotic RSTA and weapons, and agile target effects, in conjunction with low-latency reach-back, will will provide dominant overmatch.



Today's dismounted soldier is predominantly dependent on his own natural senses (eyes, ears, and smell) to avoid threats and survive. Equipment such as thermal weapon sights, night vision goggles, etc. enhance these natural senses but still provide only localized information. Ballistic protection (against bullets or fragment) options are few, bulky, and heavy. Therefore, it is often not used or is left behind when speed and agility are necessary.

Technology enablers:

Distributed, network connected sensors such as specialized tools for sniper detection, through-wall sensors, and advanced IFF techniques to detect the presence of threats in a crowd can significantly extend and enhance the future soldier's ability to understand and react to what is happening in the environment. In fact, sensing technology will have positive impacts not just on survivability, but also improve mobility and lethality (for example, coupling sniper detection to a (semi)automated counter-sniper weapon.

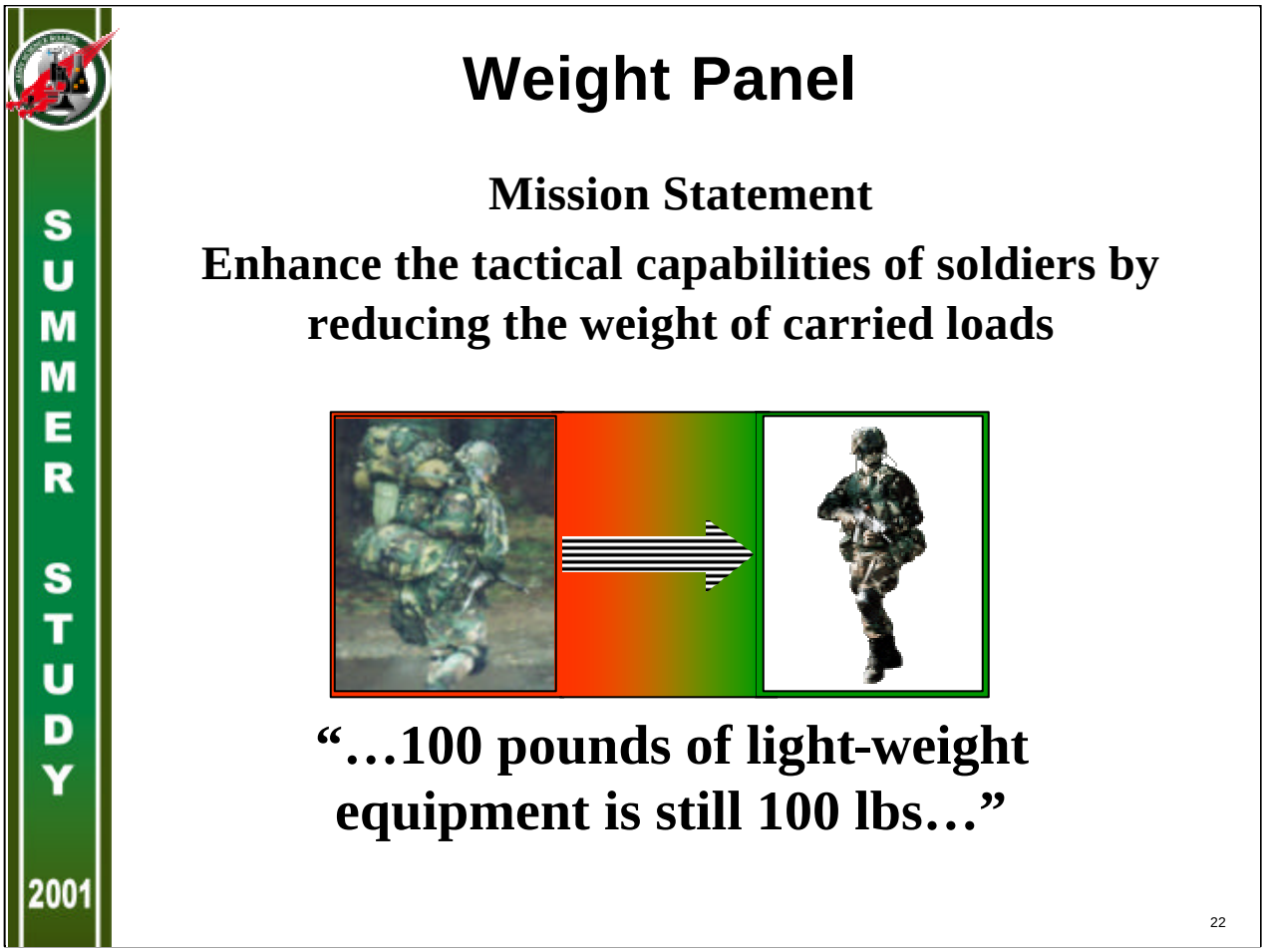
The next generation of physiological monitors will accurately analyze the soldier's vital signs and fluids, and identify the exact physiological state of the individual soldier in real time. If genetically engineered weapons (the next generation of chemical or biological warfare) proliferate in the future – a distinct possibility given the advancing research capability of many nations in this area -- having the ability detect and respond to such threats will be critical.

Finally, in the far term, we find that active multispectral signature management (whether it be stealth, or decoy applications), could be integrated into the soldier ensemble, providing the same benefits to the individual soldier that stealth technology provides larger platforms.

The future:

Appropriately integrated (through a responsive, dynamic, adaptive C4ISR network), this suite of survivability technologies will allow soldiers to leverage the full network of battlefield sensors, reaching what we describe as a full 360 degree digital shield around themselves.

A note on body armor enhancements: The absence of advanced body armor on the Summer Study's Top 20 list, despite noteworthy improvements in that area, is because these improvements don't solve or significantly ease the huge weight problem that burdens today's soldier. If one stays with armor as an enabler (as opposed to netted capabilities and new TTPs), the long-term solution could lie in nanomaterials. The panel is skeptical about jumping on this bandwagon for three reasons: 1) Correlation of high-speed ballistic penetration phenomena with quasi-static material tests has historically been poor; 2) Shock trauma is as important a damage mechanism as penetration, and stopping a bullet (especially with very thin armor) can still result in dismemberment or death; and 3) scaling up to useful quantities of material (beyond a few grams) will be a non-trivial pursuit. The panel encourages continued investigations and scale-up work on nanomaterials armor, at the 6.1 and early 6.2 level.



Introduction

The dilemma for the dismounted soldier is and always has been carried weight. Success on the battlefield requires our warriors to carry and have timely access to an array of items. These items ensure his lethality, survivability, and sustainability. The real issue becomes – "What Must Be Carried and How Much Should It Weigh" versus "What Can Be Readily Accessed and Therefore Not Carried?" Too much carried weight compromises the success of our warriors by decreasing mobility and increasing fatigue/injury. Unfortunately, in recent times the solution for this age-old dilemma has primarily centered on "lightweight equipment", most of which is carried into battle by the individual soldier. The end result is a warrior who is overloaded with "lightweight equipment". This trend of carrying everything that you could possibly need to the fight is exacerbated in part by distrust in the logistic system to be responsive.

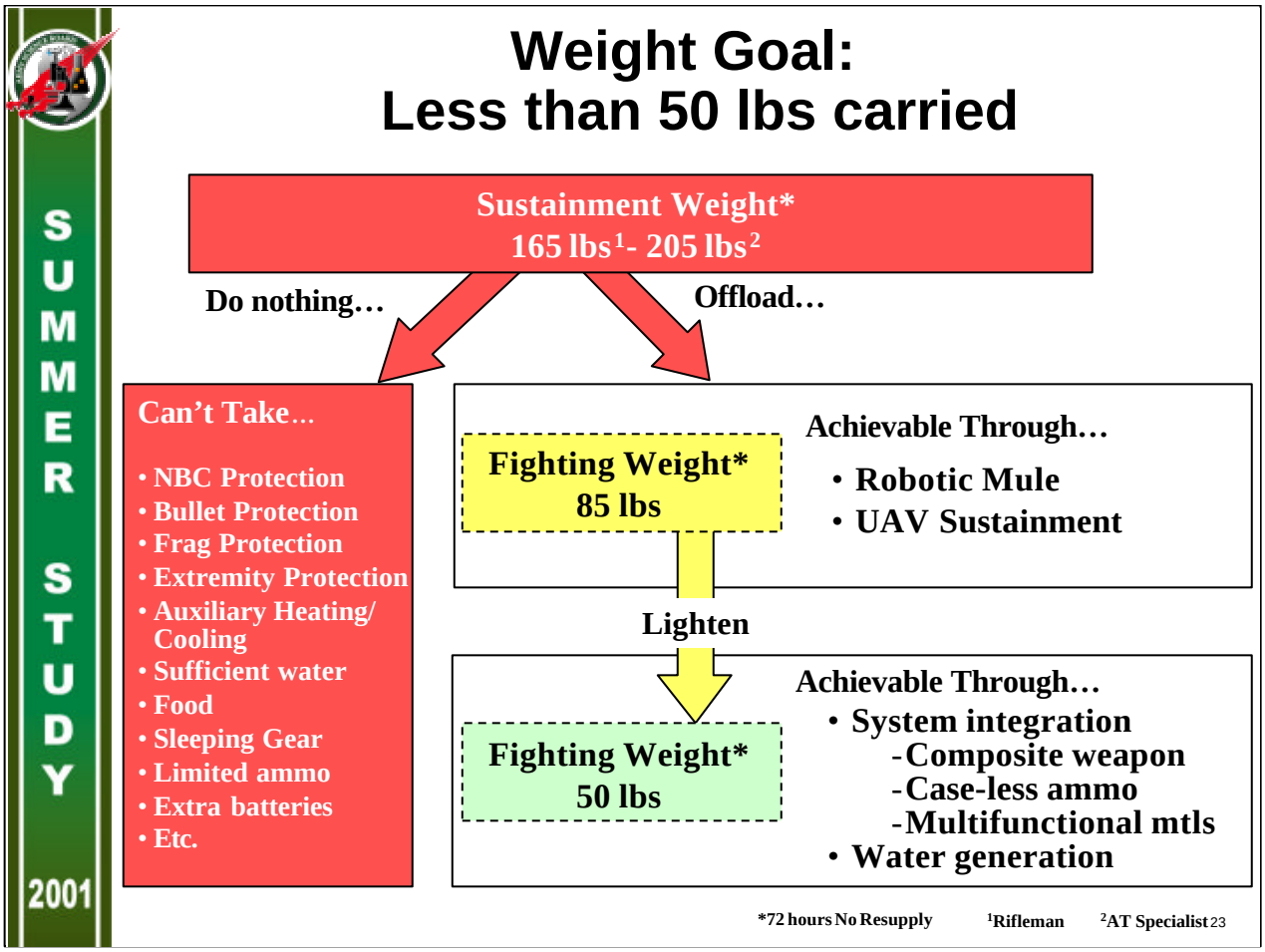
Our objective in studying soldier carried weight was three fold:

Present the effects of carried weight on soldier's performance

Propose a goal for carried weight

Provide some technological solutions to achieve this goal.

In this executive summary we will briefly discuss the latter two.

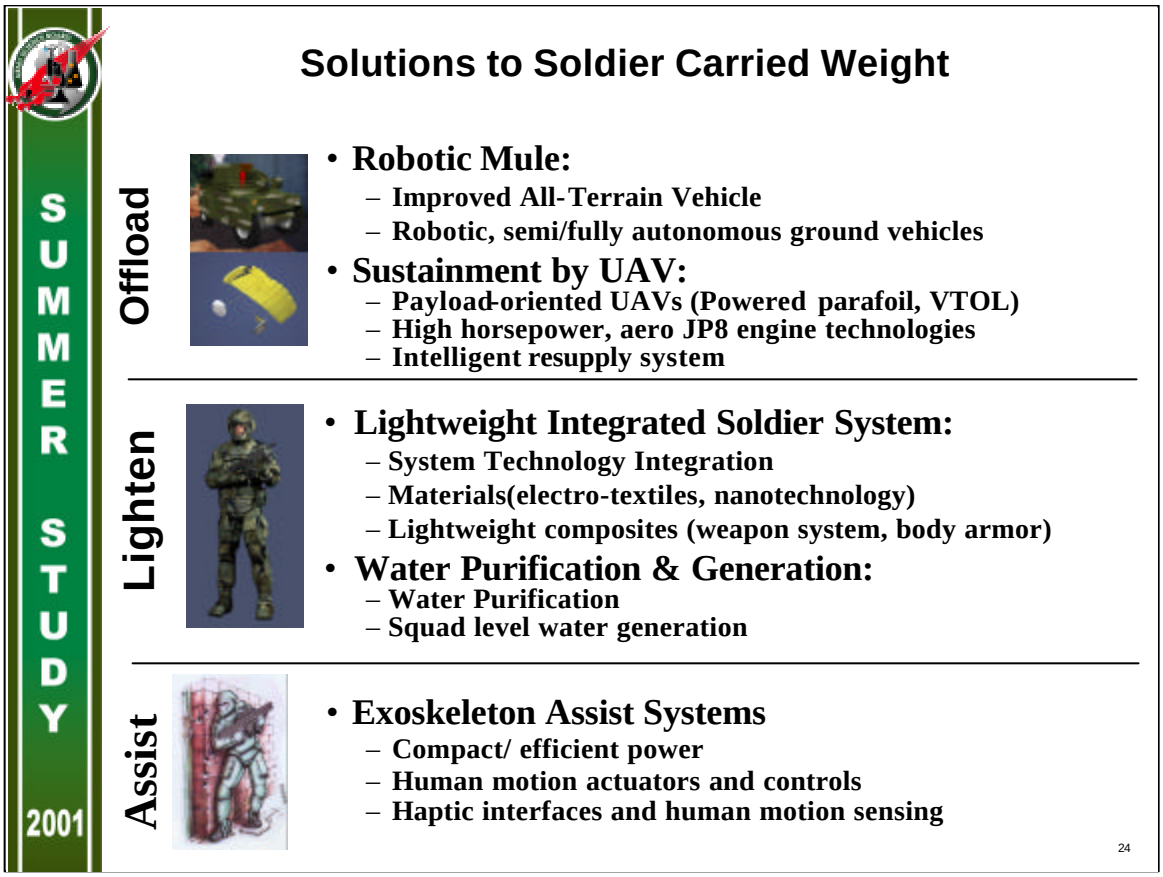


Weight Goal

The weight panel adopted the mantra that a 50 pound load is the maximum that should be carried by a soldier for any length of time. This weight goal was based on senior military judgement and the soldier's physiology.

As the chart indicates, individual soldier loads range from 165 pounds for the lightest position (rifleman) to the 205 pounds for the heaviest position (anti-tank specialist). The "do nothing" option on the left of the chart is how soldiers currently handle weight load reduction. While it is a commander's prerogative (and always will be) to dictate load configuration for his soldier's, the mobility and physiological limitations faced in typical operations requires many items to be left behind. Many of these items are critical to a 72-hour mission without resupply.

However, by offloading selected items onto a Robotic Mule or provide them by unmanned aerial vehicles, an 85 pound fighting load can be achieved. Then by using a combination of novel lightweight material technologies and effective systems integration, this can be reduced to 50 pounds including full NBC and ballistic protection.



Solutions to Soldier Carried Weight

Several potential solutions to the weight problem are Offload, i.e. get rid of the carried weight via some means of auxiliary carrying systems or never late supply/resupply; Lighten those things that must remain a part of the fighting load and therefore cannot be offloaded; and third Assist which essentially negates the weight burden of the dismounted soldier fighting load. The Assist option offers the potential for enhancements that neither of the other options will allow. Through exoskeleton assist systems, we can further enhance a soldier's survivability and lethality by allowing use of heavier armor, armor for the extremities, and carrying a heavier, more lethal weapon.

Offload has two primary complementary candidates. Robotic Mule: The first offload opportunity uses the technologies found in an intelligent ground vehicles or robotic mules. Using this approach, there is the potential to lighten the individual soldier load by a minimum of 80 pounds and the squad by 720 pounds. Such a vehicle could also carry additional items needed for combat in urban environments such as ladders, special munitions etc. Also, it holds the potential to help with water generation and could serve as a platform for battery recharging and a communications relay.

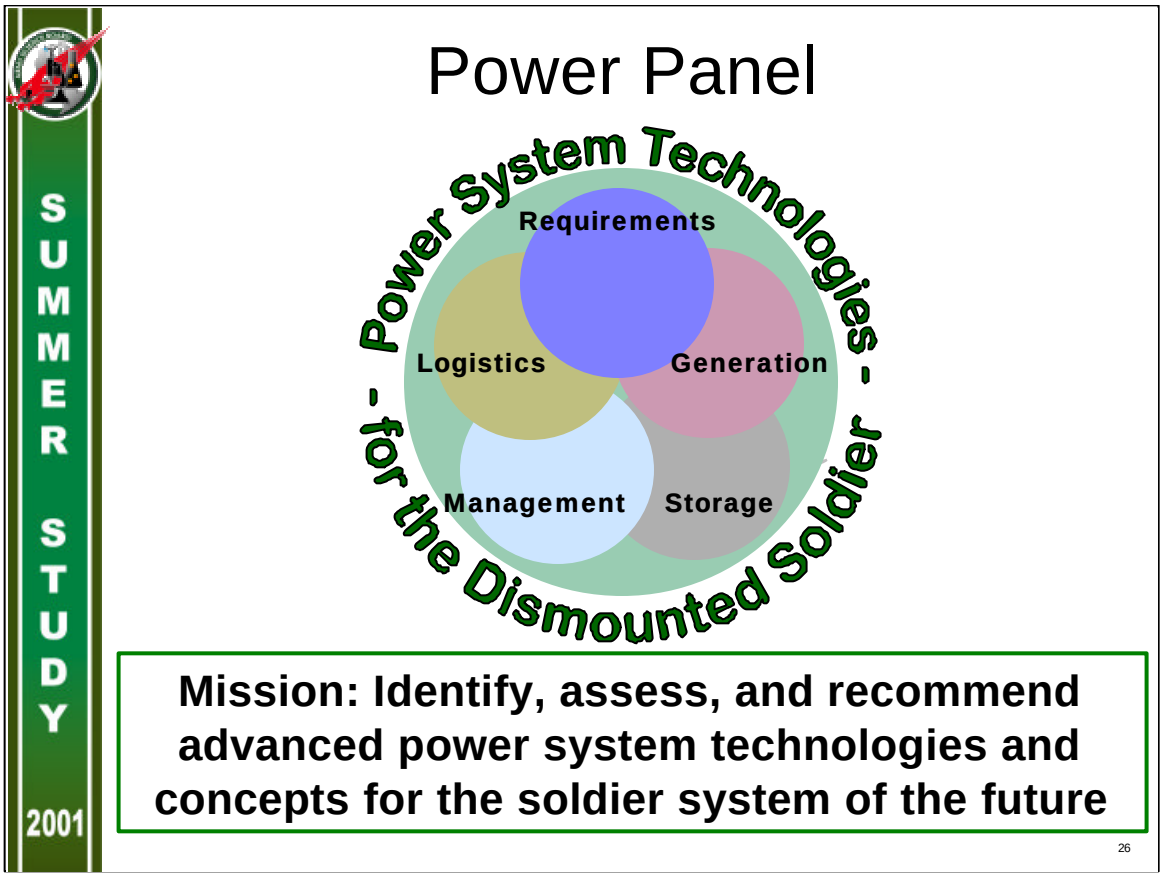
The technology approach could start in the near term with improvements to manned all terrain vehicles. Increases in semi-autonomous mobility could be achieved by accelerating technologies being developed by the Defense Advanced Research Project Agency for the Future Combat System. In the far term, we would look to a fully autonomous vehicle capable of traversing many types of terrain.

Sustainment by UAV: Another opportunity for offloading and complementary to the robotic mule is supply/re-supply via Unmanned Aerial Vehicles (UAVs). To offload the Soldier's sustainment and approach loads, a "Never Late" delivery mechanism must be provided which anticipates requirements and delivers required supplies (food, water, ammunition, protective gear, batteries, medical and replacement items) when needed. A squad leader-controlled UAV with significant payload capacity and loiter time could provide the squad with a direct delivery platform for resupply, as well as satisfying other critical functions such as being the squad's remote sensor platform. With the further advancement of technologies being explored by the Army and SOCOM for heavy payload UAVs these capabilities could exist in the mid term.

Lighten. Lightweight Integrated Soldier System: By definition, the Soldier System includes everything worn, carried, or consumed by the soldier. The Soldier System also includes those items of soldier-carried equipment required to accomplish unit missions. For that portion of the Soldier System that is not appropriate for offloading onto a mule or delivered by a UAV, the solution of lightening the system and its components must be employed. The Lightweight Integrated Soldier System provides the opportunity to lighten the soldier's load through advancements in technologies associated with multifunctional and lightweight composite materials. In addition, reductions can be achieved through the "smart' integration of these technologies into an efficient system. Our findings revealed that with increased investments the fighting load can be reduced by approximately 30 pounds in the mid-term.

Water Purification & Generation: Water is one of the heaviest and most critically required commodities to keep the worlds most potent weapon, our soldiers, functioning. The most promising technologies in the near term involve increasing the amount of water available from internal combustion engines and improving filtration technologies. In the midterm water generation or extraction from the atmosphere may provide a partial or total solution depending on the humidity and the availability a mule to carry the weight and provide power.

Assist. Exoskeleton Assist Systems: The Exoskeleton System is a promising emerging technology that will increase speed and strength of the objective force soldier and allow increased endurance under heavier loads. The program goals are to develop devices and machines that will increase the speed, strength and endurance of the objective force soldier engaged in combat. The Exoskeleton System will lead to self-powered, controlled and wearable devices based on new actuation, power and haptic technology. The technology challenges in building such machines are formidable. The first challenge includes the need to find smaller and efficient power sources that can convert to mobility movement. Power sources are being developed from fuel cells and micro turbines. The complexity of fuel cells may not provide enough power. Conventional batteries may not be the answer, hence the need for micro-turbines.



The power panel took on the task of identifying, assessing and recommending advanced power system technologies and concepts for the soldier system of the future. Selected taskings from the TOR are listed below and are addressed in this effort.

Map the technology from the present to the future that would obtain the improvements described.

Include in the technology roadmap an assessment of the current and projected Research Development and Acquisition efforts.

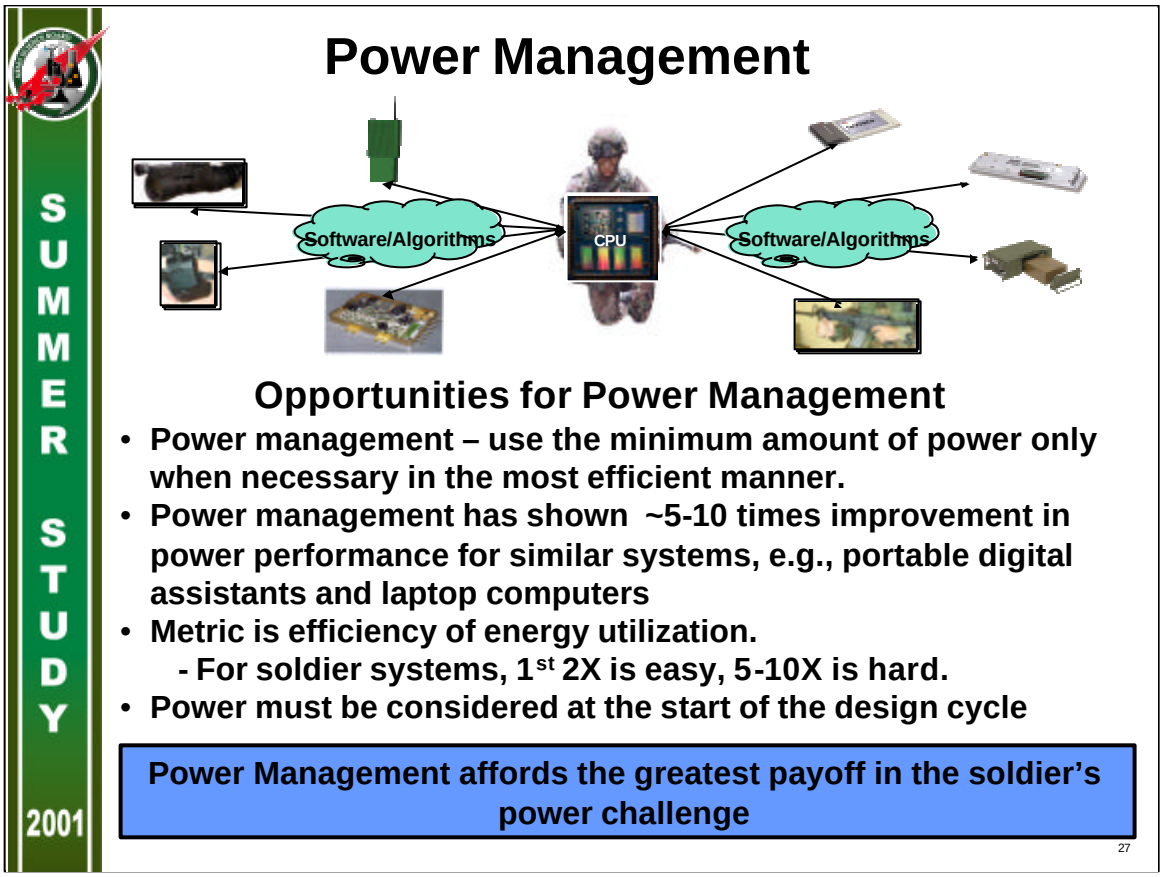
Highlight those areas where modest investments now may yield significant capabilities in soldier effectiveness, weight reduction, power efficiency and affordability of soldier systems.

Recommend alternative science and technology strategies that can provide the level of improvements outlined above.

Stratify the level of cost, technical and schedule risk associated with each alternative.

Address emerging technologies from academia, industry and other government agencies.

The figure depicts the logo developed by the panel. It depicts the fundamental physics definitions of power and energy. It also illustrates the decomposition of the problem that the power panel used. This represents a continuum of the interrelated decomposition elements of requirements, logistics, generation, management and storage. The mission was pursued in the context of each of these elements.

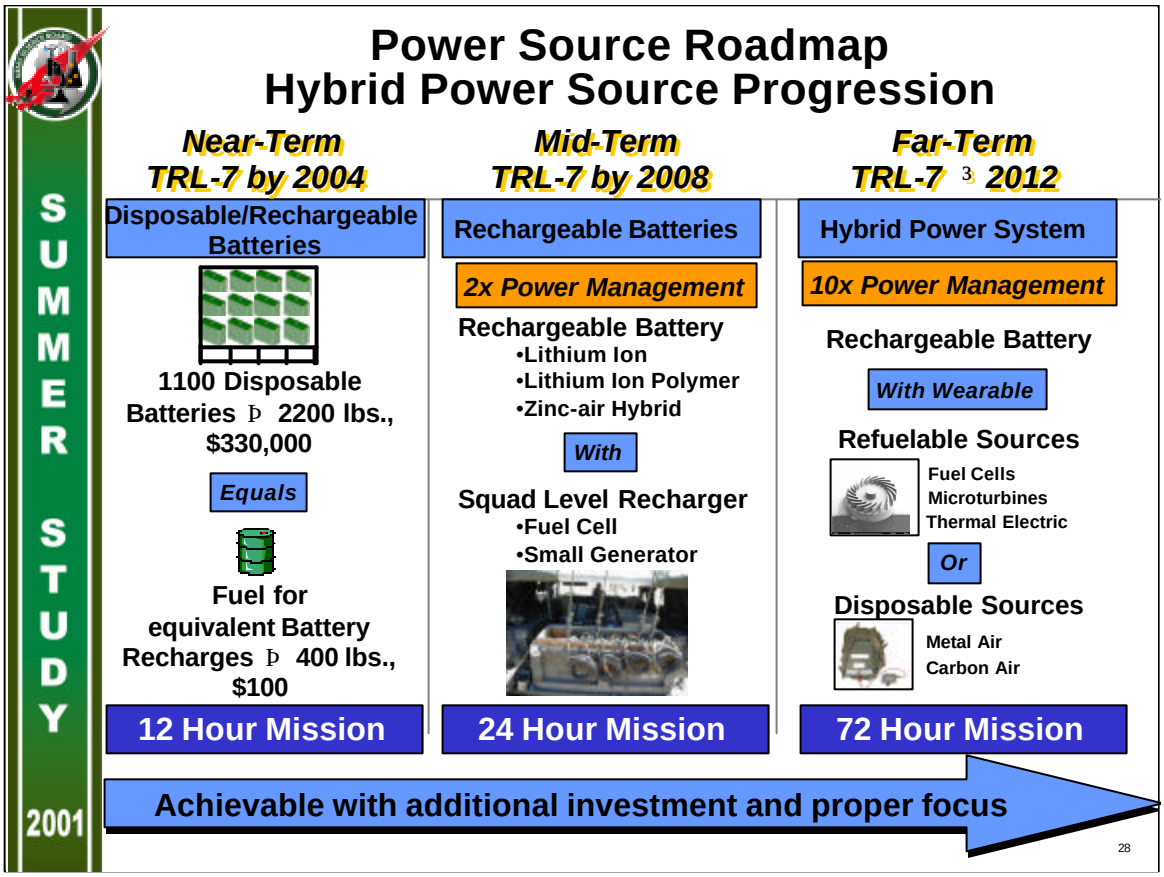


Power management affords the greatest payoff in the soldier's power challenge. That is, the ability to efficiently manage energy utilization is achieved by incorporating adaptable hardware and "smart" software in a fully integrated soldier system architecture.

The objective of power management is to use the minimum amount of power only when necessary in the most efficient manner. This objective will require closely coordinated control of all hardware and software subsystems.

The Land Warrior and the Objective Force Warrior will demand increases in power draws and energy utilization without increasing the soldier system weight. Power management is a critical enabling technology to achieve a 2x increase in mission duration by 2004, and 5-10x by 2008 without imposing additional weight on the soldier. This has been achieved in similar commercial systems, e.g., PDA's and laptop computers.

The metric of power management is efficiency of energy utilization. For soldier systems, 1st 2x is easy, 5-10x is hard. The 2x can be achieved by careful implementation of software to manage existing subsystem (e.g., power on/off devices), as well as through the development by TRADOC of Tactics, Techniques, and Procedures (TPP), which we expect will consider energy conservation and signature management. The 5-10 x improvement will come by considering power, including its management, at the start of the design cycle.



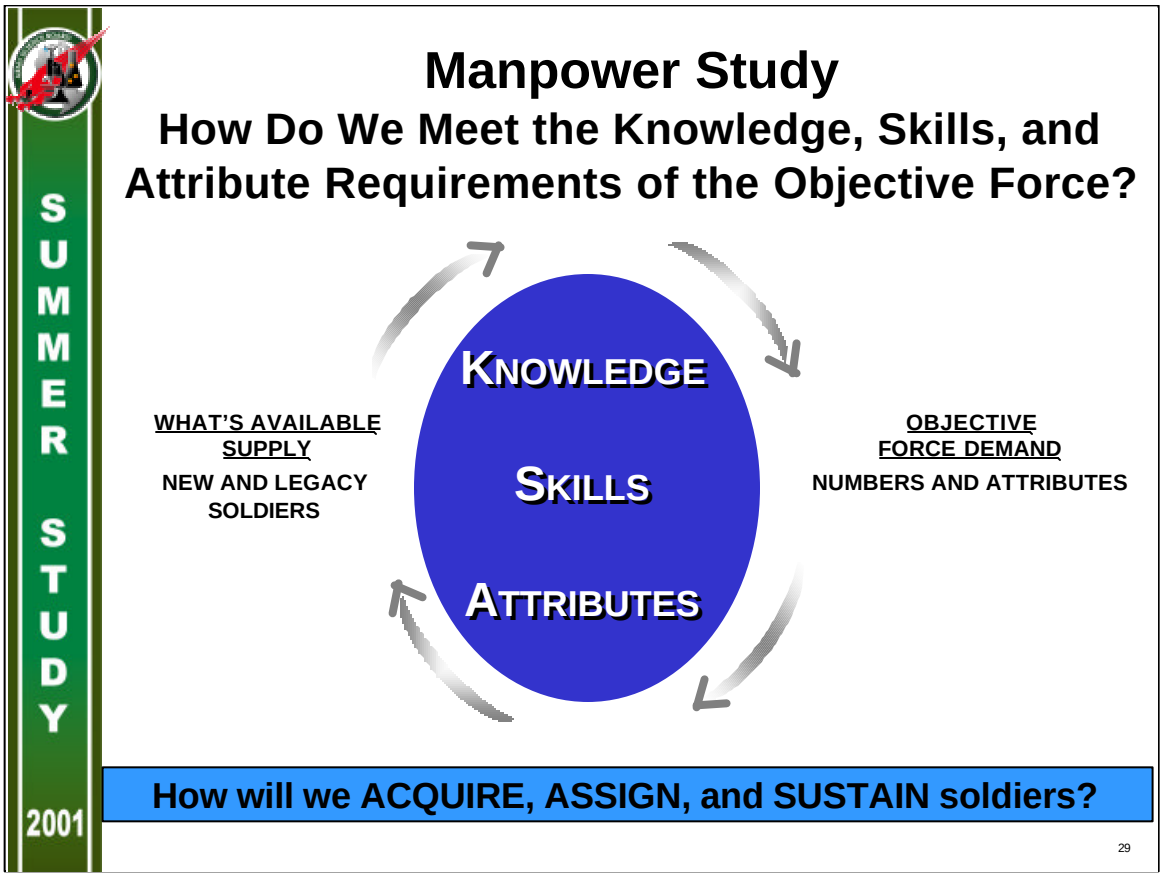
The panel identified three strategies for the power source roadmap recognizing that mission duration progresses from 12 hours in the near-term to 72 hours ultimately. For the near term, we recommend a focus on the use of rechargeable batteries with disposable batteries employed in the situations mission requirements that cannot be met by rechargeable batteries. This exchanges 400 pounds of fuel for every 2000 pounds of disposable batteries, and simplifies logistical support.

For the mid-term, the panel recommends high performance rechargeable batteries and squad level recharging. Zinc-air battery prototypes have been sent to the TRADOC Dismounted Battle Laboratory for evaluations. If these continue to prove successful then a wearable hybrid based on rechargeable and zinc-air batteries will meet the mid-term requirements.

The objective power system would be a hybrid system consisting of a wearable package of an advanced rechargeable battery with either a refuelable source or a disposable source. At this time, the most promising refuelable source is considered to be the fuel cell. Micro-turbines may evolve sufficiently to support the objective soldier system but are considered more of a “long shot”. Wearable thermal electric sources are considered a distant third option.

A hybrid system is necessary because high-energy density power technologies have limitations (e.g., the need to “breathe” and signature generation) in military applications. Hybridization with a rechargeable battery can overcome these limitations.

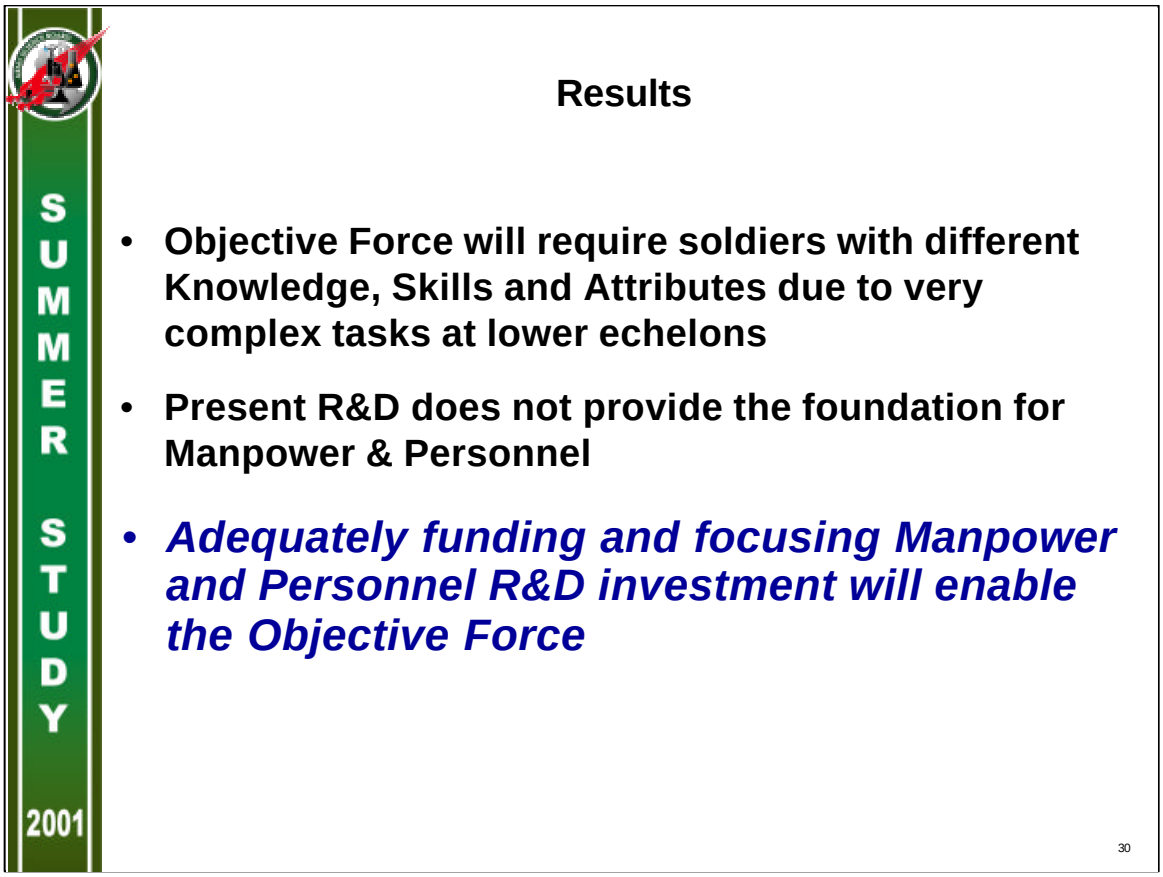
Disposable sources may be the most viable choice for wearable high energy density recharging source. These include the metal air and carbon air batteries. The disadvantage of disposable battery rechargers is in the logistics system.



The conceptual framework for the study starts on the right with the demand side of the equation. Demand, in terms of numbers, is strength requirement driven. On the other hand, demand is driven not only by the number of jobs but also by the types of jobs. Thus, at the top, "How many are needed with what KSAs?" represents the desired parameters for "Knowing what we would like to have". This serves as the basis for recruitment and incentive activities. Still moving counter-clockwise we reach "What will be available?" This question embraces a KSA's perspective as well as a demographic perspective, i.e., our Objective Soldier Supply. In this supply mix, we must consider legacy soldiers or those which are already on board, as well as those provided by recruitment efforts. The final step is "How to best access or acquire from the supply pool to achieve best job match or assignment?" Also, to identify those factors that will motivate and provide a sense of well being. The ability to achieve the "best job match" will reduce attrition and training costs. It will increase job performance and job satisfaction Combining good job match with well-being factors will also reduce attrition, enhance performance, improve retention and increase morale. Having said this: "Is there adequate Tech Base resources to produce valid tools, techniques and knowledge to answer the questions posed in the schematic?"

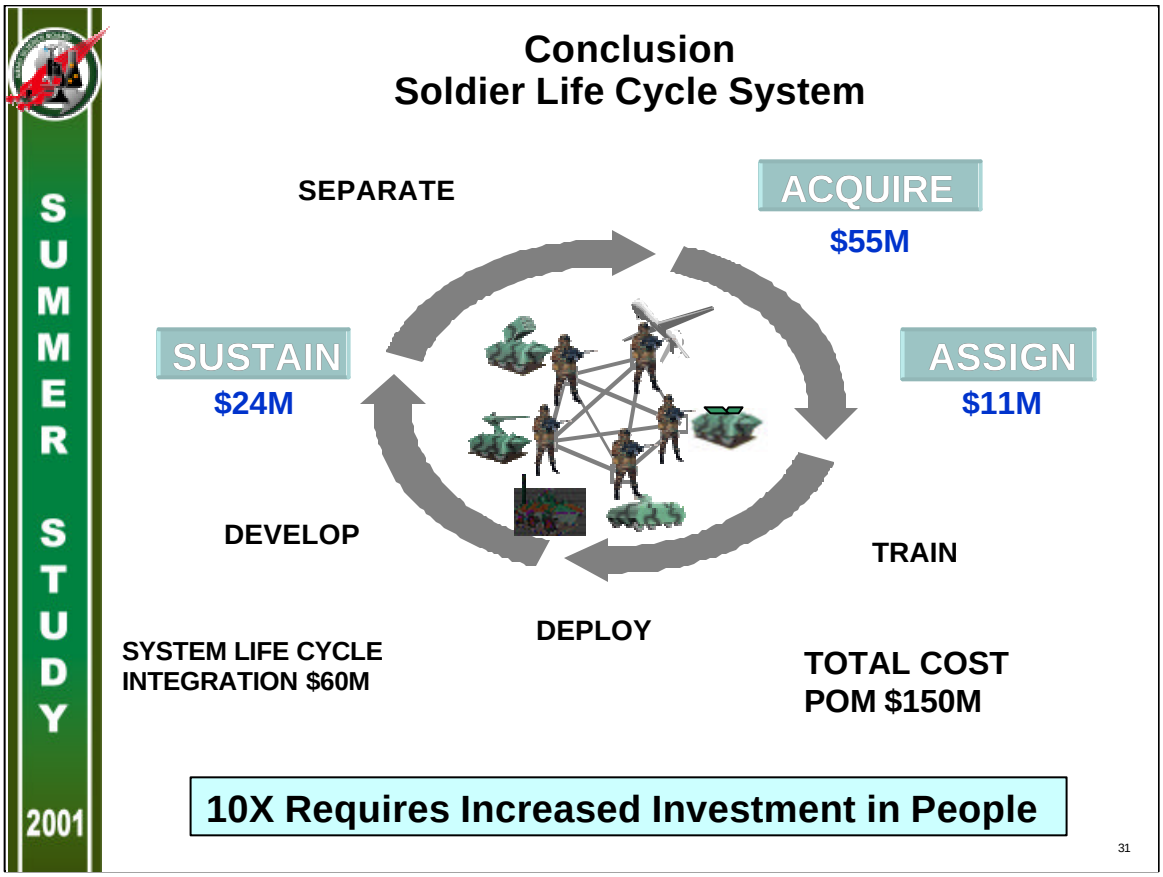
In summary, this is a model for acquiring, assigning and sustaining soldiers for the Objective Force. The model highlights the need to:

- Estimate the number of soldiers and the attributes they must have to meet Objective Force requirements.
- Assess the availability of civilians and the Legacy Force soldiers having these attributes.
- Evaluate Army capability to meet Objective Force requirements with appropriately qualified soldiers.



Given the nature of the FCS, it is expected that different personnel knowledge, skills and attributes (KSAs) will be needed. Given the very low levels of R&D funding in Manpower & Personnel, there is no foundation for such a force. Without an infusion of R&D funds now, the Army will not be ready for the FCS. The funding estimates represent our expert judgment of what the type of research we suggest will cost. They are probably accurate within 10-20%.

This R&D investment will enable accomplishment of FCS, improve readiness and combat effectiveness. We must invest in people.



Regarding the personnel life cycle functions, AR 600-3 (2.16) specifies the three functions our panel was concerned with (www.usapa.army.mil). Consistent with what the AR says, we know that acquire primarily relates to recruiting; assign matches faces to the spaces in the force structure; and sustainment relates to retentions efforts like quality of life and well being. We have adopted the Army ODCSPER's Soldier Life Cycle model for focusing R&D issues (ARI 2001 Work Program). This model, although slightly different in terminology and function, is consistent with the Army Regulation. In our graphic, ACQUIRE is consistent with Acquisition in the regulation, ASSIGN is consistent with Distribution in the regulation, and SUSTAIN is consistent with Sustainment in the regulation. To Improve the Objective Force Acquisition/ Recruitment Process you must (1) Create and validate new selection measure ($50M), (2) Validate skills required by Objective Force, (3) Leader tasks vs. soldier tasks, (4) Test youth population on very complex tasks, (5) Revise and validate ASVAB, (6) Develop performance assessment measures (e.g., SQT/ARTEP), and (7) Determine the cultural characteristics of Latinos that would improve ACQUIRE/ASSIGN process ($5M). Possible action agency for studies is ARI. A POM increase = $55M for ACQUIRE R&D.

To Improve the Assignment Process you must (1) Match Knowledge, Skills and Attributes of available Objective Force soldiers to available Objective Force jobs, (2) Use new assignment process with existing ASVAB ($10M), and (3) Use new assignment process with revised ASVAB, e.g., simulation ($1M). Again a possible action agency is ARI. POM increase = $11M for ASSIGN R&D.

To Improve the Sustainment/Retention Process you must (1) Validate cost-effectiveness for alternative well-being factors ($15M), (2) Determine how educational opportunities provided by the Army impact the skill level, commitment, and attrition of the force, (3) Validate motivation measures for distance learning ($5M), (4) Establish factors needed to trust in robots/ automation ($3M), and (5) Examine how the changing ethnic and gender composition impacts outcomes important to the Army (e.g., cohesion, cultural tolerance, attrition) (1M). Possible action agency ARI. POM increase = $24M for SUSTAIN R&D.

To Improve Total Soldier
Life-Cycle for Objective Force

Develop trade-off models: Selection (recruit smarter people) vs. Training (train to be smarter) vs. Human Factors (design simpler interfaces) vs. Medical (develop a smart pill) ($10M)

Possible action agency ARI

Develop virtual, distributed, man-in-loop simulations for ACQUIRE, ASSIGN, and SUSTAIN functions ($25M)

Possible action agency STRICOM

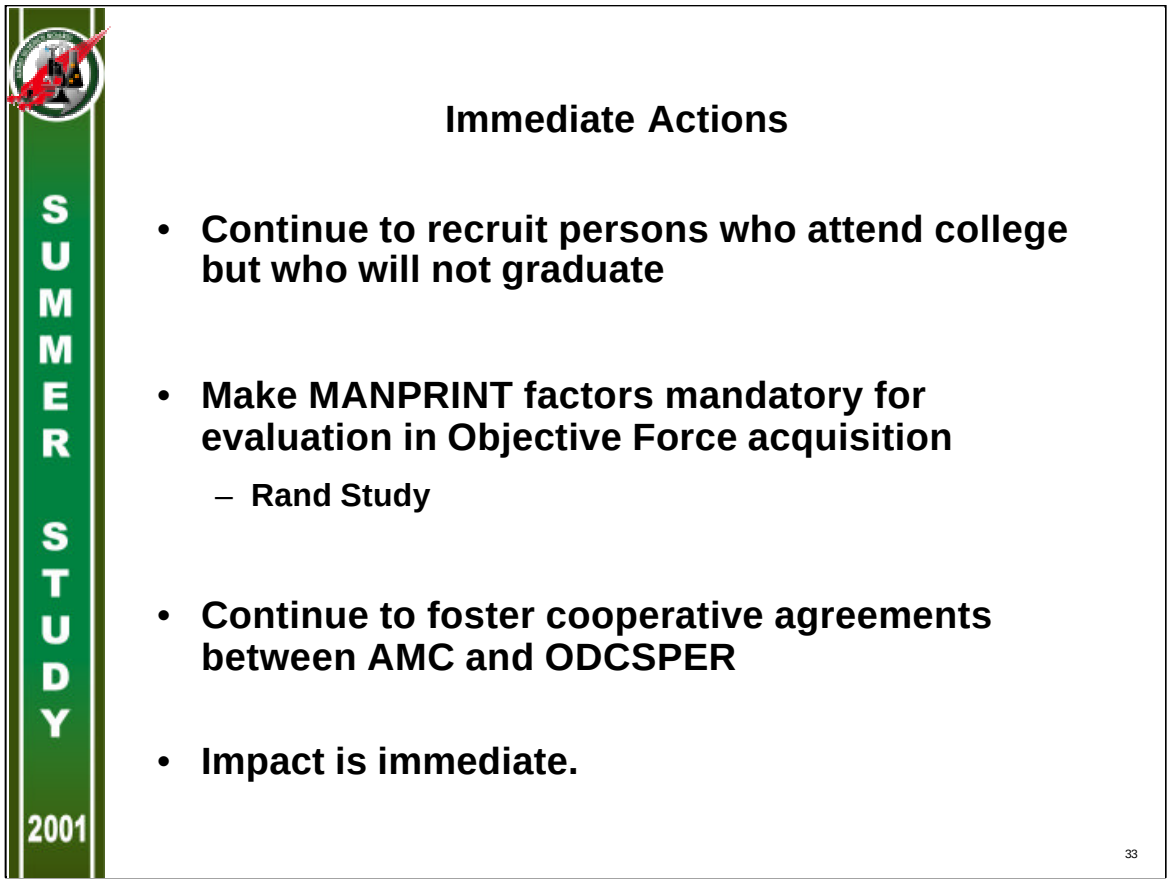
Develop/refine "system of systems" MANPRINT tools ($20M)

Possible action agency Human Research and Engineering Directorate, AMC

Develop manpower and personnel scorecard ($5M)

Possible action agency ARI

POM increase = $60M for TOTAL LIFE CYCLE R&D



1 Personal communication, Martin Orland, email. 3/30/01

2 Currently, MANPRINT is an optional program. It should be made mandatory with resources added to accomplish policy and oversight. RAND briefing 3 April 01.

3 AMC and DCSPER or HR/Personnel Mission Area do not have cooperative agreements to support the personnel info technology R&D, modernization, or recapitalization. This is a void in AMCs Army support structure. The Personnel community (Guard, Reserve, and Active) gets minimal benefit from AMC wide software management efforts. AMC has programs to support the Commander, S2-G2, S3-G3, S4-G4, Fire Support (FA and Air Defense), all maneuver, and most classes of supply (repair parts, ammo, fuel, etc). There is no AMC program to benefit the S1-G1. Given transformation, it is time to fix this condition.

SUMMER STUDY 2001

Grand Operational Challenges to Achieve the Goals

- **See First**
  - Micro & Mini UGVs & UAVs
  - Mine/Booby Trap Sensing
  - Through-Wall Sensing
  - Sniper Detection
- **Understand First**
  - Soldier C4ISR Connectivity
  - Decision Aids
  - Identification Friend/Foe/Neutral (IFFN)
- **Act First**
  - Responsive Organic & Joint Netted Fires
  - Exoskeleton Assist Systems
  - Robotic Mule
  - Sustainment by UAV
- **Finish Decisively**
  - Signature Management
  - Robotic Targeting & Attack
  - Agile Target Effects
  - Physiological Monitoring
- **Endure**
  - Power Management
  - Rechargeable Energy Systems
  - Wearable Fuel Cells
  - Lightweight Integrated Soldier System
  - Water Purification & Generation
- **People**
  - Acquisition
  - Assignment
  - Sustainment
  - Soldier Life-Cycle

System Integration is key to making it work.
Hanging tough on ensemble is essential to synergy gains!

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Grand Challenges are those key activities that have identified that, if undertaken, will have a significant impact upon the soldier effectiveness. In a sense, these are “must-do” activities necessary to achieve the 10X soldier.

Challenges were grouped into “functional” packages or modules. We utilized six functional modules as indicated above using the key technology inputs we have from the Fightability, Power, and Weight Panels.

Under each functional package, those key capabilities/technologies that the Army needs to focus on were identified. Again, these were created in a “bottoms-up” approach.

This chart would be the basis for a single take-away chart for the CSA on what the ASB says the Army should do to cause significant improvements in the soldier system.

Major Enablers

(1 of 2)

SUMMER STUDY 2001

++ Significant Positive Impact
+ Positive Impact
0 Little or No Impact
– Negative Impact
– – Significant Negative Impact

	Major Enablers	See First				Understand First				Act First			
		Micro & Mini UGVs & UAVs	Mine/Booby Trap Sensing	Through -Wall Sensing	Sniper Detection	Soldier C4ISR Connectivity	Decision Aids	Identification Friend/Foe/ Neutral (IFFN)		Responsive Organic & Joint Netted Fires	Exoskeleton Assist Systems	Robotic Mule	Sustainment by UAV
MILITARY UTILITY	Lethality	++	0	+	+		+	++	++		++	++	+	+
	Survivability	++	++	++	++		+	+	++		++	++	+	+
	C4ISR	++	+	+	+		++	++	0		+	0	+	+
	Mobility	0	++	0	+		+	+	+		+	++	++	++
	Sustainability	-	+	0	+		+	+	-		+	-	++	++
TECH ASSMT	Near Term		R	R	R		R	R			R	R		R
	Mid Term							R	G			R	G	
	Far Term	G							G				G	G

G -Adequately funded; Opportunity with Δ funding; R - Cannot be done

35

These next two charts summarize the results of the Military Utility, Technology Maturity, and S&T Cost assessments for the 24 enabling technologies. This chart contains the first three "Quality of First" areas.

The military utility of each Major Enabler was determined by evaluating its utility to support the different "ilities" and is indicated by a 5 point scale that ranges from -- (significant negative impact) through ++ (significant positive impact). This evaluation was conducted by members of the Study Panel which included retired senior General/Flag Officers.

The technology maturity of each Major Enabler to enter System Design and Development (SDD) was evaluated for the near-term (TRL 7 by 2004), mid-term (TRL 7 by 2008), and far-term (TRL 7 after 2008). A green box indicates that the Major Enabler can reach TRL 7 in the specified timeframe with a continuation of the funding allocated in the FY 01 – 05 POM. A red box indicates that the Major Enabler cannot reach TRL 7 in the specified timeframe regardless of the money invested. A cross-hatched box indicates that the Major Enabler can reach TRL 7 in the specified timeframe with additional funding being added to the FY 01 – 05 POM. The cross-hatched areas represent technology opportunities where enhanced capabilities can be provided for the soldier system with additional S&T investments.

A cost assessment was conducted for each technology opportunity (cross-hatched box) to provide a rough estimate of the increase to the FY 02-07 POM (from the FY 01-05 POM) necessary to accelerate the maturity of the Major Enabler to TRL 7 in the specified timeframe.

Major Enablers

(2 of 2)

SUMMER STUDY 2001

++ Significant Positive Impact
+ Positive Impact
0 Little or No Impact
– Negative Impact
–– Significant Negative Impact

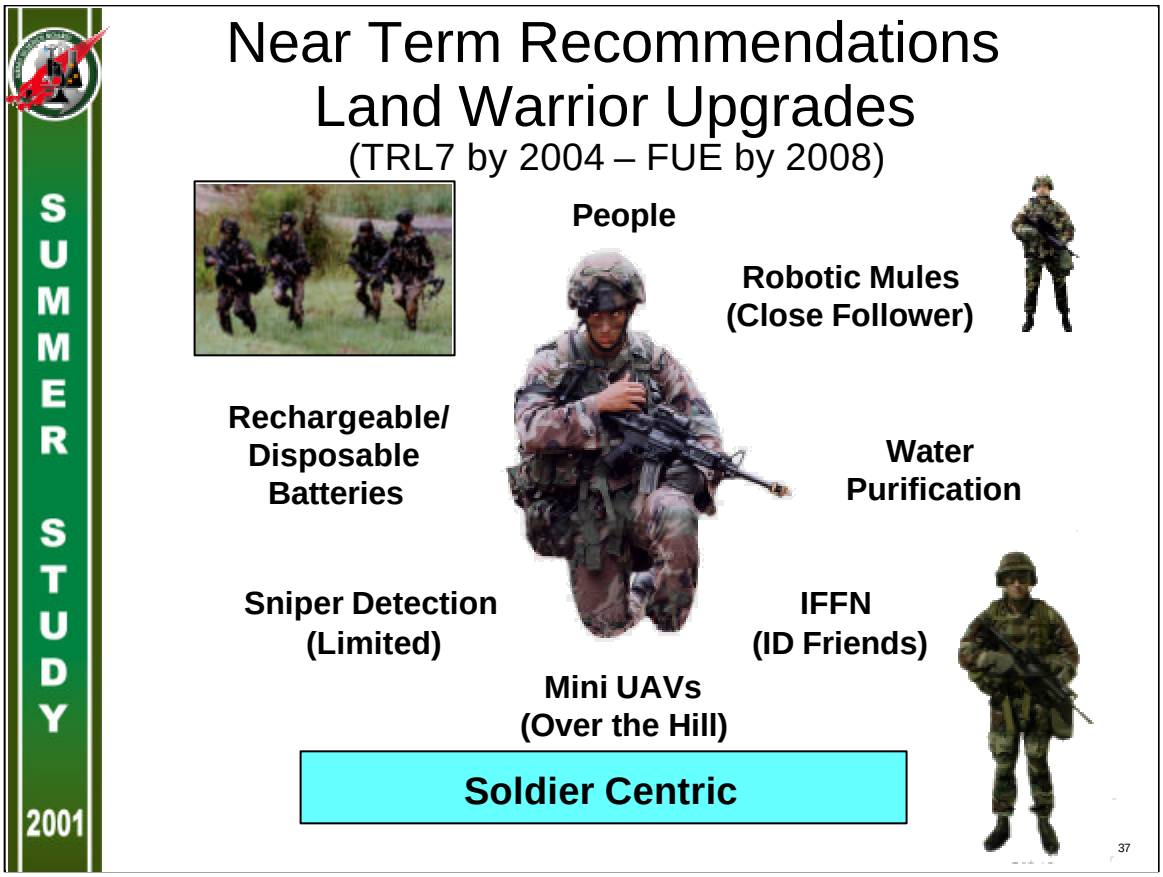
	Major Enablers	Finish Decisively				Endure					People			
		Signature Management	Robotic Targeting & Attack	Agile Target Effects	Physiological Monitoring	Power Management	Rechargeable Energy Systems	Wearable Fuel Cells	Lightweight Integrated Soldier System	Water Purification & Generation	Acquisition	Assignment	Sustainment	System Life - Cycle Integration
MILITARY UTILITY	Lethality	+	++	++	0	+	0	0	+	0	++	+	+	++
	Survivability	++	++	++	++	0	0	-	++	+	++	+	+	++
	C4ISR	0	+	0	+	++	+	++	+	0	++	+	+	++
	Mobility	+	++	+	+	++	++	++	+	+	++	+	+	++
	Sustainability	+	+	++	++	++	++	++	+	++	++	+	+	++
TECH ASSMT	Near Term	R	R	R	R	R		R	R					
	Mid Term													
	Far Term						G		G	G				

G -Adequately funded; Δ - Opportunity with Δ funding; R - Cannot be done

36

This chart summarizes the results of the Military Utility, Technology Maturity, and S&T Cost assessments for the final three "Quality of First" areas.

Additional information relating to the People Major Enablers is available in the Army Science Board Special Study entitled "Manpower and Personnel for Soldier Systems in the Objective Force" dated June 2001 (Ed. Note: awaiting PAO approval for Open Distribution on 8-23-2001).



If the recommendations for S&T funding increases are realized and development is performed with the same innovative approaches as the current Land Warrior program, the fielding of new capabilities which can dramatically improve Land Warriors' battlefield performance can begin as early as 2008, allowing for a more "soldier centric" focus.

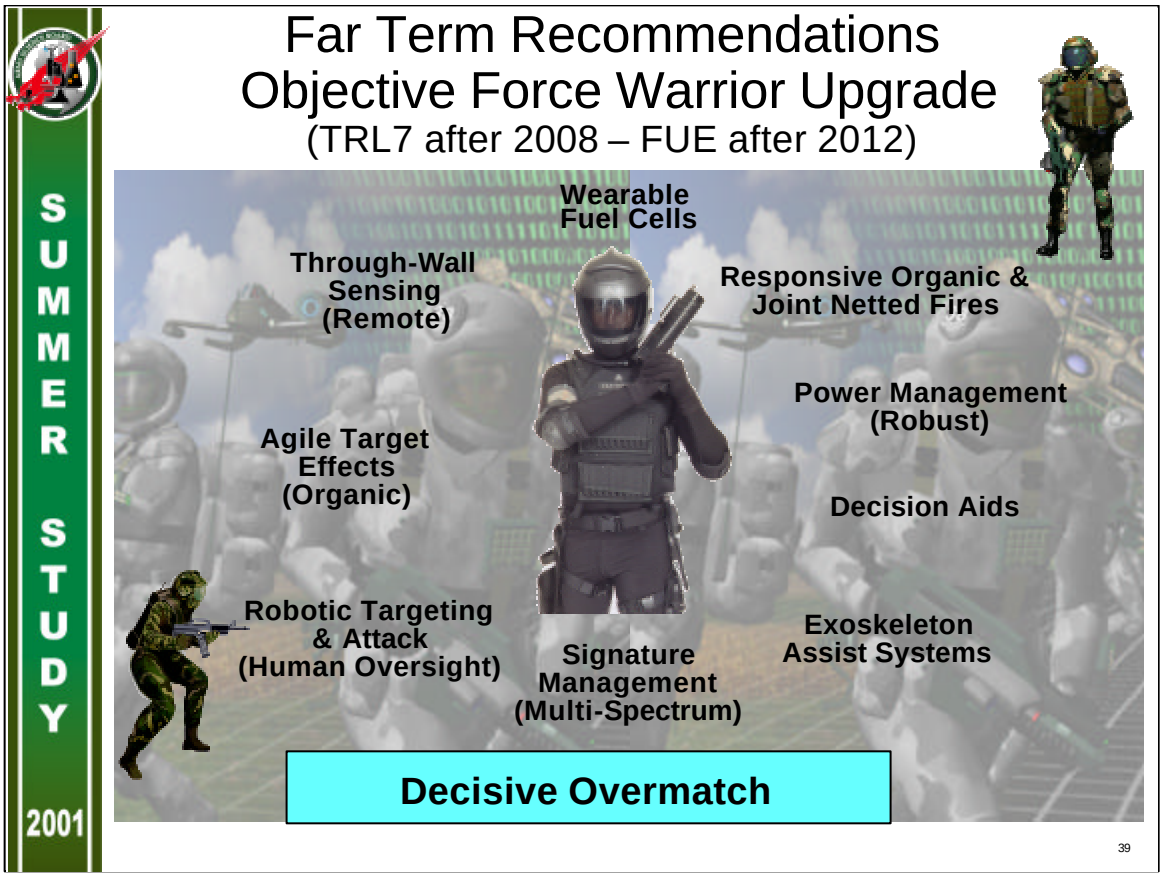
For the first time in the history of land warfare, mini-UAVs could allow soldiers to see what is "over the next hill", in alleys and behind buildings, giving them an unprecedented tactical advantage. They could also have technology that gives them a modest increase in their ability to detect snipers - a capability that will continue to improve over time. Significant improvements in soldier sustainment and support can also be realized. A robotic mule can emerge, which will have limited autonomy but can assume a major role in load-carrying. Water supply can also become less of a logistics issue with new water purification technology emerging. The soldier can have fresh water on demand under most operating conditions. Finally, rechargeable and/or disposable batteries can add to reductions in logistical burdens as well as lower sustainment and training costs.

The mid-term technologies that could be fielded starting in 2012 will truly revolutionize the way dismounted Objective Force Warriors (OFW) fight, and, even more significantly, increase their chances of survival through the collaborative advantages of multiple technologies.

The Objective Force Warriors can be equipped with a light-weight, fully integrated Soldier System that will provide protection from the elements, as well as ballistic and Chemical/Biological agent protection. Commanders and medics can track the OFWs' ongoing physiological status with casualty information accessible remotely. Survival rates can also be significantly enhanced with the maturation of limited-spectrum, signature-management technologies.

The ability to "see first" can be realized by large increases in C4ISR connectivity and additional sensor capabilities on both micro- and mini-UAVs/UGVs. Combat ID can be extended to foes and neutrals. "Acting first" can now be a function of responsive joint netted-fires, agile (lethal and non-lethal) target effects, and robotic targeting and attack. Enhanced mine- and booby-trap sensing can also be added to the list of operational capabilities.

For complex terrain operations, the OFWs can have limited see-through-walls capabilities and much more sophisticated sniper detection capabilities. Sustainment enhancements could include rechargeable energy systems, water generation, and robotic mules that can be semi-autonomous.

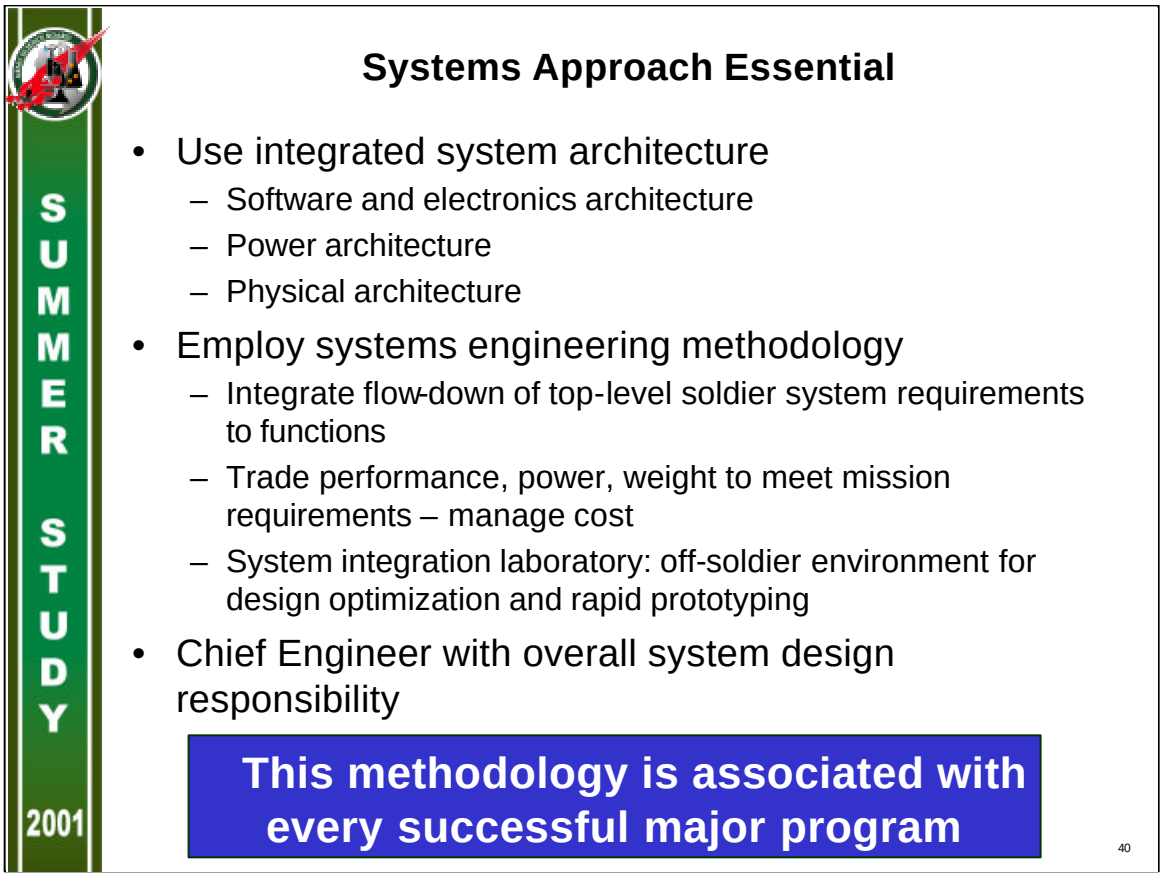


Far-term upgrades to the Objective Force Warrior can be realized after 2012. The recommended investments are expected to yield leap-ahead technologies that can increase the Army's ability to maintain its current overmatch abilities.

Agile target effects organic to small units can be a reality, as can responsive organic and joint netted fires. Robotic targeting and attack can be greatly improved as human oversight is now possible.

The OFWs can have advanced decision aids, as well as the ability to see through walls from remote locations. The multi-spectral signature management capabilities that can be provided in the far term can continue to increase survivability statistics.

Continued sustainment advances can be expected in the far-term. Robust power management, wearable fuel cells, and exoskeleton assist systems are among the possibilities.



Today the phrase "soldier system" is a misnomer -- the soldier's systems are designed and developed as a series of programmatic and technical stovepipes. There is no overall systems architect who resolves the performance, weight, power, and sustainability objectives for the warrior.

The key technology is a top level systems engineering approach to the soldier system. The individual functional requirements must be integrated and an architecture that takes advantage of the synergies to eliminate the redundancy of communications, power, sensors, physical packaging, etc. Once the functional requirements have been rationalized through simulation, modeling and technical trades-offs, the top-down allocation of weight, space, power, and cost can be assigned to the subsystems and components through a series of individual, yet integrated, interface control documents.

A Chief Engineer with overall system design responsibility should be established to effect the requisite systems engineering. The Chief Engineer must be empowered to ensure that the requisite trades are carried out and that the resulting system design is technically feasible, affordable and manufacturable.

PM Land Warrior Funding thru FY 2012

An example of the Soldier System funding challenge

	Program	POM/EPA	Unfunded
RDTE	$0.3B	$0.1B	$0.2B
Procurement	$2.0B	$0.9B	$1.1B
Operations & Maintenance	$1.0B	$0.1B (est.)	$0.9B
Total	$3.3B	$1.1B	$2.2B

Notes: Does not include Objective Individual Combat Weapon (OICW)
EPA = Extended Planning Annex
Source: PM Soldier Estimates

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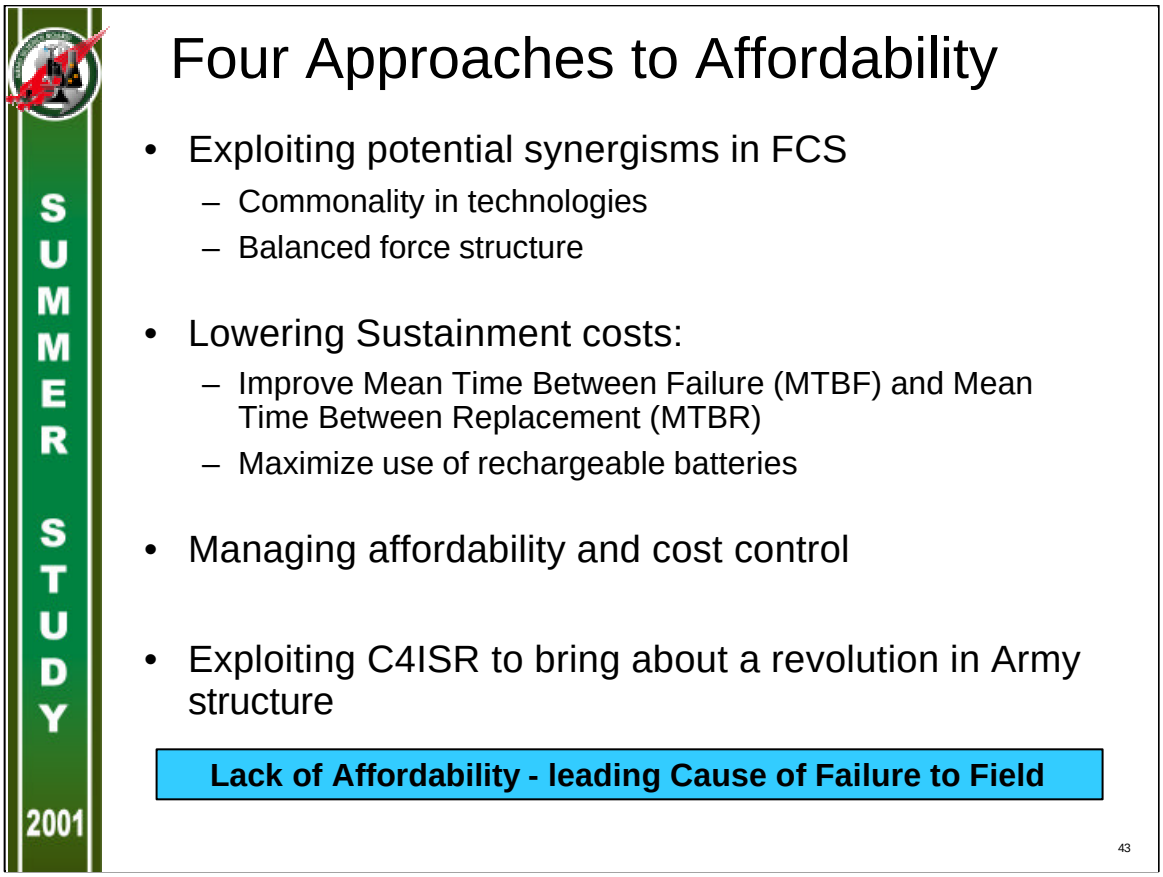
The Soldier System we evaluated is a system of systems evolving through a spiral development strategy. The back bone of the system is the Land Warrior System and is complemented by an emerging Science and Technology (S&T) program which could lead to a revolutionary new, integrated system or a very robust evolutionary spiral development of the Land Warrior system.

The baseline Land Warrior transitions through its lifecycle with significant capabilities and enhancements projected. These will not only improve the total lethality of the soldier and combat team, but also significantly improve soldier survivability. On a parallel course S&T developments will progress and either be inserted as applicable into Land Warrior or held for integration into the penultimate combat soldier system, the Objective Force Warrior. Beyond FY2004, there is little RDTE funding programmed for the Land Warrior system. The little RDT&E funding there is will be in support of pre-planned product improvement and software evolution with minimal assets to enable capitalization of new technologies.

A closer look at the current Army Land Warrior (LW) program through FY 2012 illustrates the funding challenges facing this and most Army programs. During this period, development and fielding is evolutionary and not driven or dependent on new, revolutionary technology. Land Warrior is not a huge program when compared to a major weapons system. Notwithstanding the significant incremental increase in fighting capability and survivability of the soldier, which truly transforms the individual soldier from a grunt with a rifle to an integrated combat system with capabilities on par with weapons systems, the LW system funding is constrained after competing with other major systems. Through 2012 only 33% of the funding anticipated for the program is programmed. This does not include additional costs for the OICW which is the center piece of the lethality component for the total system. Consequently, a combination of reductions in life cycle costs and programmatic tradeoffs will have to be addressed, not unlike most other Army programs.

Indications are that reprioritization of the Army S&T budget will provide a viable objective force soldier system S&T program

There are some funds available in the overall objective force budget, but these will be diluted in providing the technological enhancements necessary for the overall objective force structure, which includes Future Combat Systems and Objective Force Warrior. Without management attention, it is anticipated that competition between programs could preclude timely integration of critical technologies into either Land Warrior or into the fledgling Objective Force Warrior system.



As stated earlier, a System of Systems approach needs to be brought to this effort. This can be done through the establishment of a Super Program Manager for all elements within the Soldier System or by placing all the various elements within a single Program Executive Office for control and integration. Within this responsible entity, there needs to be a Chief Systems Engineer with responsibility for technical integration across the System. Additionally, this provides a single voice to Objective Force and FCS Overarching Integrated Process Teams. The Chief Systems Engineer's responsibilities would include oversight of an aggressive Cost As an Independent Variable (CAIV) Program for both Acquisition and Sustainment that would look across the Soldier System to optimize both funding and requirements. All future requirements and upgrade solutions must then buy their way into the Soldier System. They must assess the performance parameter they are trying to meet with the cost of meeting that requirement. Looking at the cost drivers across the program in both Acquisition and Sustainment we found that many of the significant cost drivers were outside of the PM's control. Yet these same areas are critical cost drivers as well as key portions of the functionality. This fragmentation is further compounded by the inability of the PM to consolidate and standardize key functionality and achieve reductions through integration as well as cost trade-off. CAIV is currently applied to only pieces of the over all Soldier System. This would be unacceptable in the commercial environment. The Chief Systems Engineer would ensure total Soldier System Configuration Management and a single synchronized Science and Technology program that assures the Soldier System is fielding in lock step with the overall needs of the FCS Force.

Synergism between Soldier System and the Future Combat System offer extensive potential for sharing technology development costs. Illustrative of this would be experimentation with robotic vehicles which will generate capabilities for extrapolation

directly into the Objective Soldier requirements. Future enhancements and technologies in night vision and situational awareness, while coming from the FCS project, can result in fieldable systems to be inserted into Objective Warrior.

As new C4ISR technologies emerge, they can have a profound impact on not only the overall capability of Land and Objective Warrior, but can have tangential impact on total force structure. For example, enhanced logistics delivery systems will facilitate downsizing of the supply tail in the field, similarly improving Mean Time Between Replacement (MTBR)/Mean Time Between Failure (MTBF) can directly correlate to reducing the size of the organic maintenance support at the tactical level, this will also enable reduction in the amount of spares (ASL / PLL) which much be moved with the tactical force.

The Bottom line is reflected here: Lack of Affordability is the leading Cause of Failure to Field and unfielded systems do not improve combat effectiveness.

Mission Accomplished:
We met the Challenge

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TOR Item	Response
• Characterize improvements required	• Specific goals have been identified
• Evaluate connectivity FCS to Objective Force Soldier	• There is no assured connectivity between FCS and soldier • C4I solutions are critical to the 10X improvement • ATD recommended
• Assess RDA efforts - focus on: –Effectiveness –Weight –Power –Affordability	• Expanded on IRT effort with focus on: – Quantification of effectiveness gains thru multiple analytical approaches – Bottoms up & top down approach to weight – Integrated power management system – Pareto analysis of top cost drivers w/associated recommendations
• Recommend S&T strategies	• Top effectiveness gains have been identified • Recommended roadmaps prepared

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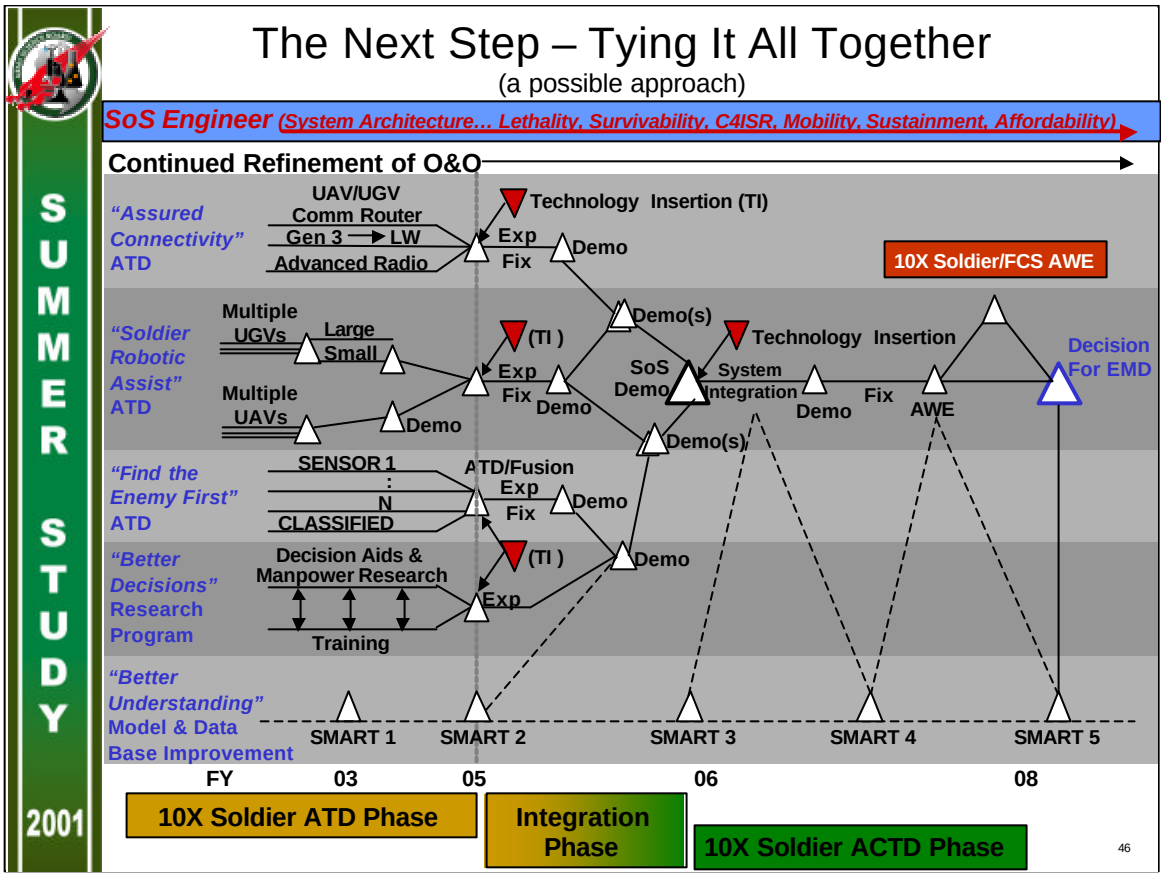
A brief recap of the items in the Terms of Reference is shown in the left column. On the right side is the ASB response.

With respect to the required improvements, recall there were a series of goals that were specified which spanned lethality, survivability, C4ISR, mobility, sustainment and affordability. The goals had specific time frames and improvements by each of the categories just mentioned.

With respect to connectivity of FCS to the Objective Force Soldier, it was determined that connectivity cannot be assured. Further, connectivity is critical to achieving the vision of a 10X soldier. Ways to achieve assured connectivity were outlined in the report. This is considered a critical item for the Army Leadership's attention. An Advanced Technology Demonstration which involved high bandwidth and UAV relay is considered a logical near term step toward achieving assured connectivity.

An assessment of RDA efforts was conducted with focus on the challenges of fightability, weight, power, and affordability. This assessment involved multiple analytical approaches, culminating with a 'ility' factor assessment designed to yield a balanced set of recommended technologies. With respect to fightability, the analytical results to date suggest that an order of magnitude increase in effectiveness is achievable through application of advanced technologies and collaboration with FCS elements. Weight goals are achievable through a combination of off-loading applying a systems approach and application of advanced technology. Similarly, a systems approach is required to achieve desired power goals. In addition, cost drivers were identified and recommendations were given to make achievement of the 10X soldier more affordable.

Finally, a series of technology roadmaps were prepared together with (preliminary) recommended investment increments.



There are multiple ways to structure a comprehensive program to achieve the 10X soldier. Key elements of such a program are shown above.

First, and perhaps most important, an overarching System of System (SoS) chief engineer is considered critical to achieving a system that works and meets the combined challenges of fightability, weight, power, and affordability. Likewise, this engineer needs to work closely with those charged with developing the Ops Concept for the FCS and the Objective Force Soldier to ensure compatibility.

Next, a series of ATD's designed to further the technologies associated with: assured connectivity; use of robotic devices; sensor systems to enable finding the enemy first; making better decisions; and improving modeling and data associated with dismounted combat. Experiments should be conducted in conjunction with each of these ATD's and technology inserted, as appropriate. This phase would be labeled the '10X Soldier ATD Phase'.

A logical next step would be to integrate across the above ATD's. Experimentation would be key, coupled with a 'fix' time period in order to improve on the various designs, insert technology, etc. Also, simulation would play a key role in the process.

After the connectivity and interoperability issues had been solved across the ATD's, then a demonstration of the objective force soldier should be considered. Then, given an enhancement period, perhaps an Advanced Warfighter Experiment which could include elements of the FCS system of systems.

GEN (Ret) Downing's Observations

SUMMER STUDY 2001

- People-- always the key; Army very good at creating high performing units w/ diverse people; equip with the best technology available
  - Consider SOF tools for assessment & selection, training, retaining
  - Technological advances warrant a fresh look at leader/led ratios and span of control
- The dismounted warrior is grossly overloaded—and, the Army appears to accept those loads. Needed:
  - A Logistic system that works and is trusted by leaders and soldiers
  - Command discipline and control
  - Lighter weapons, ammunition, equipment, and body armor
  - Centralized Management of Soldier Systems
- Need to be prepared for urban combat-- cannot pick your battlefield
- Training -- the "glue" that holds the unit together in peace and war
  - Embed technology in all our new systems on fielding
  - No substitute for realistic, hands-on in the environment

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This slide is a synopsis of GEN(R) Downing's Senior Officer Observations. These are self-explanatory.

GEN (Ret) Downing's Observations

SUMMER STUDY 2001

- The dismounted warrior has an enduring role in future military operations
  - D-T-L-O-M-S will mandate changes
  - The Army will take and hold 'dirt'; control people and critical resources
  - Close combat will always be a possibility
  - S&T cannot create a risk free environment
- The ASB technologies are affordable
  - Identify and manage the cost drivers
  - Share FCS technology development
  - Appoint a single manager for Soldier Systems
  - Look for economies in the total Army structure especially HQs and TDA units
  - Continue to work Congressional and industry sponsors

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The three most important messages of the study are indicated above.

The bottom line is that our country has a critical need for a Soldier/ Marine Team that can be deployed in time of crisis and can accomplish the assigned mission with minimal casualties. If a systems approach were taken which was oriented toward qualitative advances in the six synergistic dimensions shown, then the vision of a 10 X soldier can be achieved.

The 'Top' programs which were identified will, collectively, produce the desired gains. The roadmaps which were provided will point a programatic way to implement these technical advances.

Finally, it is our belief that the time is now to implement the recommendations.

APPENDIX A

TERMS OF REFERENCE

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY OF THE ARMY
ACQUISITION LOGISTICS AND TECHNOLOGY
103 ARMY PENTAGON
WASHINGTON DC 20310-0103

REPLY TO
ATTENTION OF

December 28, 2000

Mr. Michael Bayer
Chairman, Army Science Board
2511 Jefferson Davis Highway, Suite 11500
Arlington, Virginia 22202

Dear Mr. Bayer:

I request that the Army Science Board (ASB) conduct a study on "Objective Force Soldier/Soldier Teams" in line with recent ASB studies that support Army transformation toward the Objective Force. The study should address, but is not limited to, the Terms of Reference (TOR) Described below. Appointed ASB members to this study are to consider the TOR as guide lines and may expand the study to issues considered important to the study. Modifications to the TOR must be addressed with the Chairman of the ASB.

Background:

a. Deployment of forces to Southwest Asia, Bosnia, Kosovo and Somalia demonstrated the growing need for a strategically deployable, medium-weight force that is mobile and as survivable and lethal as current Heavy Forces.. Future adversaries are expected to use urban and complex terrain, state-of-the-art commercial technology, human shields and asymmetric means to mitigate U.S. military strengths. The medium weight Objective Force must be capable of deploying and fighting in situations where it is outnumbered and facing a technologically laden threat. Moreover, soldiers will more likely fight dismounted from their platforms in the streets and alleyways of urban complexes. Strict rules of engagement will dictate that targets are clearly identified and that collateral damage is minimized. Soldiers of the Army's Objective Force, enabled by a network-centric suite of manned and unmanned ground and air platforms, robust C4ISR and non-lethal means, must be able to fight, survive and win in those environments.

b. I envisage that this study will provide practical insights into current and future science and technology opportunities that will assist Army Leadership prioritize research, development and acquisition in order to yield dramatic improvements in Objective Force Soldier lethality, survivability, supportability and situational awareness. The study will examine those technologies that will enable the mounted and dismounted Soldier to fight within a network-centric, system-of-systems across the full spectrum of operations. Military operations in urban and complex terrain will be addressed as part of the study

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TOR: The study should be guided by, but not limited to the following TOR.

(1) Characterize the level and nature of lethality, survivability, logistical and information systems for command, control, communications and computer improvements that must be achieved to yield a more effective Objective Force Soldier across the operational spectrum. Evaluate connectivity/interface between Future Combat System variants and the Objective Force Soldier.

(2) Map the technology from present to future that would obtain the improvements as described above.

(3) Include in the technology roadmap an assessment of current and projected Research Development and Acquisition efforts. Highlight those areas where modest investments now may yield significant capabilities in soldier effectiveness, weight reduction, power efficiency and affordability of soldier systems.

(4) Recommend alternative science and technology strategies that can provide the level of improvements outlined above. Stratify the level of cost, technical and schedule risk associated with each alternative. Address emerging technologies from academia, industry and other government agencies.

Study Sponsorship: Co-Sponsors for this study will be Vice Chief of Staff; Army; Assistant Secretary of the Army, Acquisition, Logistics and Technology; Deputy Chief of Staff for Operations and Plans; Deputy Chief of Staff for Programs; Deputy Chief of Staff for Logistics; Deputy Chief of Staff for Intelligence; Director, Information Systems for Command, Control, Communications and Computers; Commander, United States Army Training and Doctrine Command; and United States Army Materiel Command.

Study Duration: The study shall be completed by July 31, 2001.

Sincerely,

Paul J. Hoeper

Paul J. Hoeper
Assistant Secretary of the Army
(Acquisition, Logistics and Technology)

APPENDIX B

PARTICIPANTS LIST

PARTICIPANTS LIST

ARMY SCIENCE BOARD
2001 SUMMER STUDY

THE OBJECTIVE FORCE SOLDIER / SOLDIER TEAM

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LtGen Marty Steele (USMC, Ret.)
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Dr. Anthony Hyder
University of Notre Dame

The Conceptual Framework Panel
LTG Charles Otstott (USA, Ret.)
Global Infotek , Inc.

The Analysis Panel
Mr. Ed Brady
Strategic Perspectives, Inc.

The Fightability Panel
Mr. Srinivasan (Raj) Rajagopal
United Defense L.P.

The Weight Panel

Dr. Mark Hofmann
COLMAR L.L.C.

The Power System Technologies Panel
Mr. Gil Herrera
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The S&T Investment Strategy Panel

Mr. Herb Gallagher
Computer Sciences Corporation

The Affordability and Cost Control Panel
Mr. Carl Fischer
Aerojet / GenCorp

Senior Officer Observations
GEN Wayne Downing (USA, Ret.)
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* The Manpower and Personnel Study was conducted as an independent Special Study and then integrated into this study.

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2001 SPECIAL STUDY

MANPOWER AND PERSONNEL FOR SOLDIER SYSTEMS IN THE OBJECTIVE FORCE

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APPENDIX C

ACRONYMS

AAA	Anti-Aircraft Artillery
ACTD	Advanced Concept Technology Demonstration
AFQT	Armed Forces Qualification Test
AMC	Army Materiel Command
APM	Acquisition Program Manager
ARL	Army Research Laboratory
ASA(ALT)	Assistant Secretary of the Army for Acquisition, Logistics and Technology
ASVAB	Armed Services Vocational Aptitude Battery
ATCOM	Army Aviation and Troop Command
ATD	Advanced Technology Demonstration
BBN	BBN Technologies (sniper detection system; Bolt, Beranek, Newman)
BDA	Battle Damage Assessment
BLOS	Beyond Line of Sight
BN	Battalion
C2	Command and Control
C3D2	Cover, Concealment, Camouflage, Denial and Deception
C4ISR	Command, Control, Communications, Computers, Information, Surveillance and Reconnaissance
CAIV	Cost as an Independent Variable
CENTCOM	Central Command
CIDDS	Combat Identification Dismounted Soldiers
CL-20	An explosive/propellant material
COA	Course of Action
COP	Common Operational Picture
COTS	Commercial-off-the-Shelf
CSA	Chief of Staff, Army
DA	Department of the Army
DARPA	Defense Advanced Research Projects Agency
DISC4	Director of Information Systems for Command, Control, Communications, and Computers
DISIM	Dismounted Infantry Simulator
DTLOMS	Doctrine, Training, Leader Development, Organization, Materiel, and Soldiers
EPA	Extended Planning Annex
ESM	Electronic Support Measures
EW	Electronic Warfare
FCS	Future Combat System
FUE	First Unit Equipped
GFE	Government Furnished Equipment
GPS	Global Positioning System
GSR	Ground Surveillance Radar
HW/SW	Hardware/Software
IBCTs	Interim Brigade Combat Teams

ICBM	InterContinental Ballistic Missile
IDA	Institute for Defense Analyses
IDF	Indirect Fire Links
IFFN	Identification Friend, Foe, Neutral
IPB	Intelligence Preparation of the Battlefield
IR	Infrared
IRT	Independent Review Team
ITEMS	Imaging Technologies and Evolving Management Systems; Interactive Tactical Environment Management System
IW	Information Warfare
JANUS	an interactive, event-driven wargaming simulation
JCATS	Joint Conflict and Tactical Simulation
JFCOM	Joint Forces Command
JP8	Jet Propellant 8
JRTC	Joint Readiness Training Center
JSAF	Joint Semi-Automated Forces
JSOC	Joint Special Operations Command
LAM	Loitering Attack Munition
LAV	Light Armored Vehicle
LCDW	Low Collateral Damage Weapon
LLNL	Lawrence Livermore National Laboratories
LLL TV	Low-light level tv
LOS	Line of Sight
LRF	Laser Range Finder
LRRP	Long-Range Reconnaissance Patrol
LRU	Line Replaceable Unit
LW	Land Warrior
M&S	Modeling and Simulation
MANA	An agent based simulation
MANPRINT	Manpower and Personnel Integration
MEU	Marine Expeditionary Unit
MILES 2000	Multiple Integrated Laser Engagement
MM&T	manufacturing methods and technology
MOUT	Military Operations in Urban Terrain
MTBF	Mean Time Between Failure
MTBR	Mean Time Between Repair
NAEP	National Assessment of Educational Progress
NAVSPECWARCOM	Naval Special Warfare Command
NSC	National Security Council
NVL-11	A computerized fire control night sight for Anti-Tank weapons
NWARS	National Wargaming System
O&O	operational and organizational
ODCSPER	Office of the Deputy Chief of Staff for Personnel
OF	Objective Force
OFW	Objective Force Warrior

OICW	Objective Individual Combat Weapon
ORD	Operational Requirements Document
OTB	Onesaf Testbed Baseline
PGM	Precision Guided Munition
PM	Program Manager
POM	Program Objective Memorandum
PTN	Paint the Night
R&D	Research and Development
RAND	
RDA	Research, Development and Acquisition
RPG	Rocket Propelled Grenade
RPK	squad machine gun
RPO-A	A Thermobaric Munition, Russian
S&T	Science and Technology
SASO	Stability and Support Operations
SBCCOM	US Army Soldier and Biological Chemical Command
SDD	
SMART	Susceptibility Model Assessment and Range Test
SNL	Sandia National Laboratories
SOCOM	Special Operations Command
T&E	Test and Evaluation
TOR	Terms of Reference
TRADOC	Training and Doctrine Command
TRL	Technology Readiness Level
TSM	TRADOC system manager
TTP	Tactics, Techniques and Procedures
TWS	Thermal Weapons Sight
UAV	Unmanned Aerial Vehicle
UGS	unattended ground sensors
UGV	Unmanned Ground Vehicle
USA	United States Army
USASOC	United States Army Special Operations Command
USMA	Unites States Military Academy
USMC	United States Marine Corps
WMD	weapons of mass destruction

APPENDIX D

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