ARMY SCIENCE BOARD

FY2001 SUMMER STUDY

FINAL REPORT

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

"THE OBJECTIVE FORCE SOLDIER / SOLDIER TEAM"

VOLUME II
THE SCIENCE AND TECHNOLOGY CHALLENGES

November 2001

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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.

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CONFLICT OF INTEREST

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

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Fightability - Mr. Srinivasan Rajagopal;
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Bold denotes Panel Reports included in this Volume. For a listing of all participants see Appendix B

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(ES)

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The Objective Force 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

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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

Volume II - The Science and Technology Challenges

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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, communications, computers, intelligence, surveillance and reconnaissance), lethality, survivability and sustainment. Due to the logical assignment of mobility and sustainability to the weight and power panels, respectively, our panel focused its attention on C4ISR, Lethality and Survivability.

The panel recognized the excellent work that was on-going in the Army to support the soldier and has attempted to investigate the technology areas that could make significant additions to the soldier fightability in the objective force timeframe. Often there were excellent programs which the Army has initiated but not programmed with sufficient resources to reach the TRL levels necessary to allow a decision to place in the objective force inventory.

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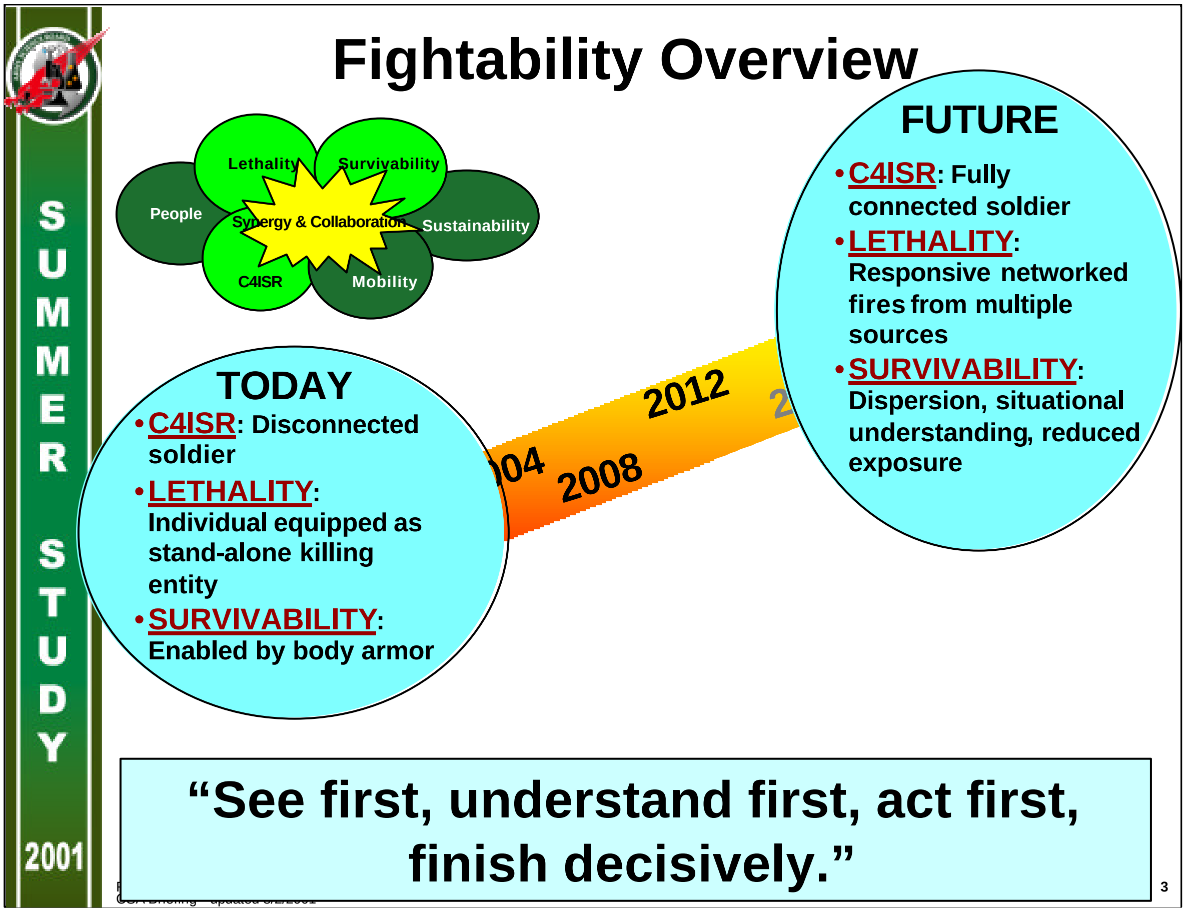
Fightability Panel Members

- Herb Dobbs
- Robert Dodd
- John Holzrichter
- Suzanne Jenniches
- Kalle Kontson
- Prasanna Mulgaonkar
- Raj Rajagopal
- John Reese
- James Whang
- Dan Beekman, ARL (Govt. advisor)
- John Hopkins, ARL (Govt. advisor)
- Dennis Gibson (Staff Assistant)
- CDT William Sweet

Panel Members: The panel was made up of ASB members and consultants knowledgeable in the above areas, augmented by government advisors, staff assistant, and ROTC cadet.

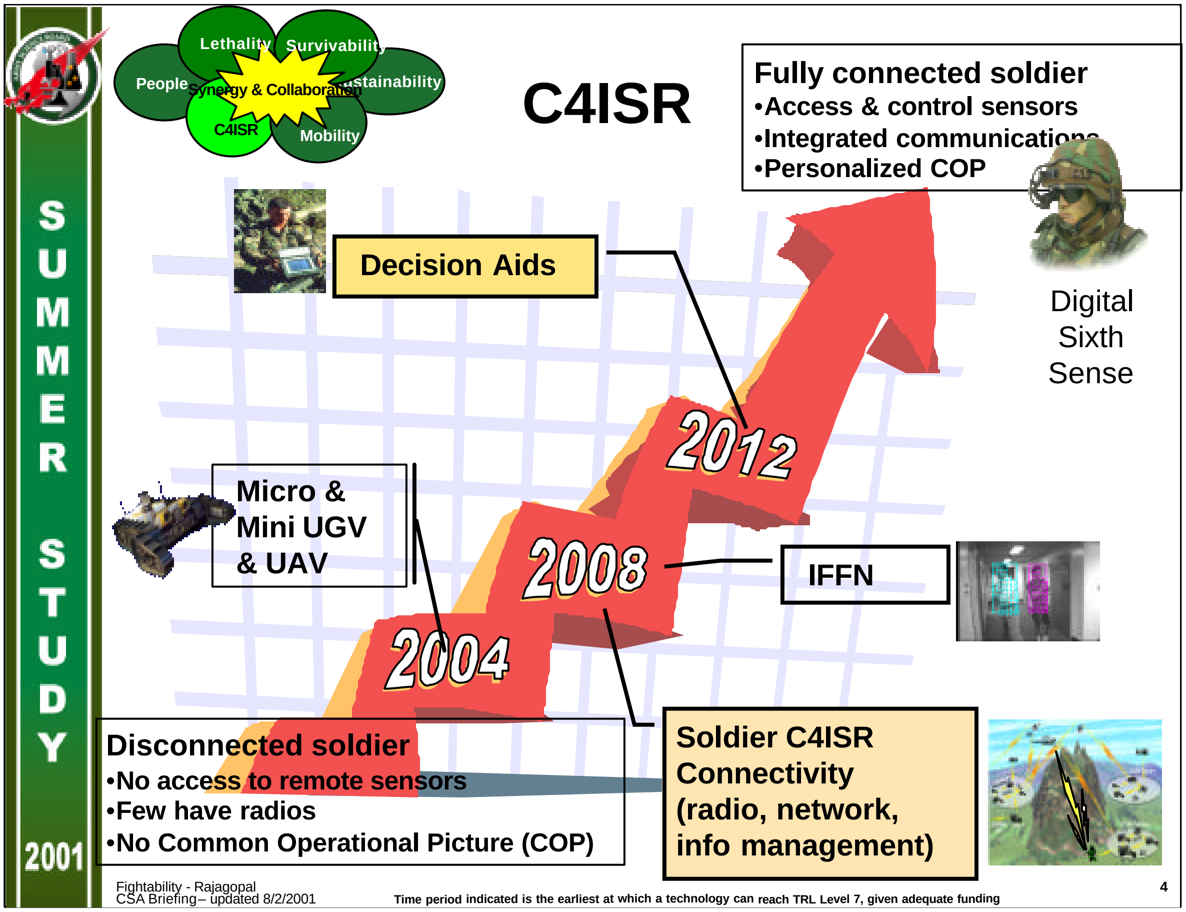
The panel study kicked off in October 2000 and concluded in July 2001 with a final report writing session in Irvine, CA. The panel participated in several meetings as a panel and as part of the overall Summer Study. Meetings included trips to TRADOC at Fort Monroe, Soldier Systems at Natick, 18th Airborne and ARSOC at Fort Bragg and several meetings in Washington DC. The panel interacted with ARL, ARI, DARPA, CECOM, TARDEC, Natick, FBI, USMC, PEO soldier systems and others. The meetings generated significant individual panel member interaction with these organizations and research into the key areas of interest.

The panel accomplished an intense review of ideas and issues by electronic media during the period between meetings and then arrived at Irvine and developed this consensus report. Many areas of interest resulted in in depth individual reports on the key subjects and these are available as backup to this report.



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. The Fightability panel has identified a range of technologies and a path to achieve this Fightability objective. The panel recognized the critical aspect of synergy across functional areas which bring the major benefit. These areas include Mobility, Sustainability, Lethality, Survivability, C4ISR. The panel covers Lethality, Survivability, C4ISR and the weight panel covered Mobility, Sustainability.

"**See first, understand first, act first, finish decisively**" is enabled by providing the OF Soldier an assured wideband connectivity both intra-squad, inter-squad and up Echelon. This enables the delivery of the best possible situation awareness and access to Net Fires and never-too-late logistics. The provision of increased sensor and weapon capability enabled by robotics (UAVs. UGVs) and the opportunity to support the soldier with robust supporting fires from squad organic, FCS organic and Joint reach-back fires makes the OF soldier 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 come with the weapon; thermal sights, and vision augmentation. Yet, the battlefield is rapidly becoming rich with sensor opportunities that offer a revolutionary opportunity for implementing situational awareness. The key missing ingredient for evolving from the disconnected soldier is the connectivity to C2 and sensor access/control; i.e., the soldier has no radio and surrounding network infrastructure capable of implementing the capacity and versatility to allow each soldier a common operational picture.

Key Technologies: Advanced sensor capabilities such as the ability to "see" through walls, or fire sensor-enabled bullets from the OICW are going to be available to the soldier in the near term. 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 is capable of forming networked connectivity when available, or operating 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. 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 be fully connected so that he has 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. It will leave the enemy to do the wondering and guessing.

Micro and Mini UGVs and UAVs

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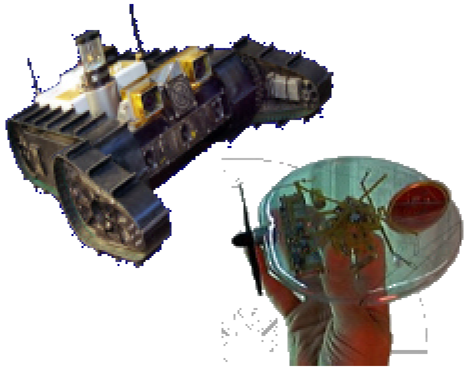

Operational Need:

- Ability to rapidly insert sensors, communication relays, electronic warfare (EW) nodes

Operational Impact:

- Ability to "See First"
- Lethality and survivability in urban environments
- Robust communications and situational awareness

Technology Approach:

- Multifunction payloads : EW, sensors, comm relay/router
- Tactical airborne and ground robots support soldier team
- Supplement with weapons-delivered sensors/electronics

Technology Assessment for TRL 7

Solution	Near	Mid	Far
★ Miniature Payloads		G	G
★ Tactical UGVs		G	G
★ Small Air Vehicles			G
Weapon-Delivered			G
To Achieve Capability			G

Fightability - Rajagopal
CSA Briefing– updated 8/2/2001

★ - Critical G Adequately funded; Opportunity with D funding; R -Cannot be done 6

QUAD CHART FORMAT

This is the first of several such charts and they provide details on specific enablers of the 10X soldier in the areas of C4ISR, Lethality and Survivability.

The charts include a graphic example of an enabling technology, statement of operational need and impact, the approach to closing the technology gap, and a stop-light chart indicating likelihood of maturing the technology (to TRL Level 7, ready for SDD) in the near-term (2004), mid-term (2008) and far-term (after 2008). Fielding dates would be 4 years thereafter, i.e., in 2008, 2012, and post-2012.

Red means it won't mature in the indicated timeframe even with additional money, green means that the program and money are there to achieve maturity in the timeframe, and cross-hatching indicated that the technology can be matured in the timeframe but only if additional money is made available.

The additional money required was forwarded to the S&T Investment Panel and is rolled up as part of their presentation.

MAJOR THEMES

We lead with UAV/UGV not because they are No. 1 in priority but because they are first in the operational sequence of "See first, engage first, etc."

> The need to populate the battlefield with electronic eyes and ears has been established for some time. The ability of the soldier team to deploy dedicated sensors is made

possible by the advent of small, affordable assets that are under the direct control of the soldier team. The technology developments in micro unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs) can be combined with the miniaturization trend for electronics that implement sensors, communications relays, and electronics warfare packages. Each UAV/UGV platform can carry multifunction payloads that will enable the sixth sense of the soldier by extending the reach of his eyes, ears, voice, and weapons.

Included in this context are sensors delivered as weapon payloads, e.g., tube-launched UAVs and gun-fired unattended ground sensors.

TECHNOLOGY SUPPORTING DATA

· Integrated Multifunction Payloads – modular, plug-and-play sensors, comms, and electronic warfare subsystems that can be custom-configured for each mission. Major emphasis on reduced size, weight, and power to accommodate limited payload capacities of micro UGVs and especially micro UAVs. Design considerations should include the form factor and shock tolerance necessary for compatibility with weapons delivery subsystems.

· UGVs / UAVs – Micro and mini ground and air vehicles which can be inserted with the soldier team and transported until needed for payload emplacement. Emphasis on payload capacity and power efficiency for maximum mission duration.

· Weapons Delivery – subsystem for employing multifunction payloads by firing a projectile from a standard weapon. The subsystem should be scaleable for compatibility with a mortar, rocket-propelled grenade launcher, or OICW.

OVERALL, THIS AREA REQUIRES ADDITIONAL S&T FUNDING TO MATURE IN THE NEAR TO MID TERM.

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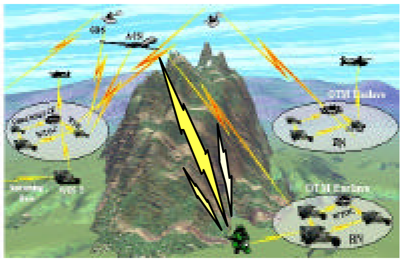
Soldier C4ISR Connectivity

The Far Term Vision



Integrated functions of comms, relay/ router, sensing, IFFN, EW, info mgmt

Operational Need:

- Broadband connectivity - with squad, weapons, sensors, upper echelons
- Anti-jam, low probability of intercept, adaptive and multifunctional

Operational Impact:

- Critical to soldier knowledge superiority and unit effectiveness
- Robust, adaptive, C2 and situational awareness

Technology Approach:

- Develop advanced soldier radio: multi-mode, multi-band, adaptive, military & commercial waveforms
- Develop a Joint wideband network waveform for versatile, packet-switched communications
- Build mobile infrastructure: any platform adaptively interconnects--soldiers, sensors, EW, FCS, reachback

More Details

Technology Assessment for TRL 7

Solution	Near	Mid	Far
★ Adv. Soldier Radio	R		
★ Wideband Waveform	R		G
UAVs/UGVs - Routers	R		G
Ad Hoc Networks		G	G
★ Mobile Routers		G	G
Adaptive Antennas	R		
Info Dissemination	R		
To Achieve Capability	R		

★ - Critical   G Adequately funded;   Opportunity with D funding;   R -Cannot be done

Fightability - Rajagopal
CSA Briefing– updated 8/2/2001   8

MAJOR THEMES

Land Warrior demonstrated the benefits of intra-squad broadband communications (2 Mb/s wireless LAN) coupled with a Common Operating Picture information source

Moving forward to the Objective Force environment, the increasing number of sensors and the need for the squad to have access to information from space, air and terrestrial (multi-mode, multiple path communication) makes broadband communications an imperative. The ultimate, far-term vision is to have each and every platform in the tactical force, including the individual soldier, perform multiple functions with an integrated wireless information system device. Every device is capable of performing as a communications device, a relay, a router, a sensor, an EW system, and an information management system. Every soldier is a platform hosting such a device in the form of a personal electronics suite. Thus, every soldier is not only a consumer of networked information, but a source and sensor, as well.

This requires:

- a multi-mode, multi-band advanced "radio" for the soldier which is integrated into the personal electronics suite
- a communications infrastructure embedded in the mobile tactical force to support the required Ad Hoc connectivity, and integrated sensor and communications architecture.

TECHNOLOGY SUPPORTING DATA

Advanced Radio - Current Army programs underway that will partially address these needs are JTRS, SUO SAS, Terrestrial PCS, Universal Handset, and MOSAIC. Commercial technology air interfaces and protocols, such as CDMA, Bluetooth, and Personnel Data Assistants (PDAs) will provide technology infusion which must be integrated with military waveforms.

Wideband Network Waveform Design - The current OSD mandate directs that all future radios be JTRS compliant. In order to meet the Objective Force needs, the JTRS must be tasked to develop a Wideband Network Waveform that will go down to the individual soldier. Development of this waveform is essential to implementing an broadband, adaptive, flexible, packet communications technology in a tactical setting.

UAV Comm Relays & Routers - The ability to maintain connectivity to the soldier in all terrains, under various operating conditions will require line-of-sight. UAVs serving as relays, routers and network access points (cell sites in the sky). This requirement can be met by development of communications payloads for currently programmed UAVs (e.g., Shadow 200, TUAV), or by implementing micro-UAVs. As packaging of these capabilities becomes smaller, communications payloads can be added to multi-function UAVs.

UGV/Mules Comm Relays & Routers -The multiple path, multiple mode operation that is needed to maintain connectivity under all possible conditions will require ground-based vehicles serving as relays, routers and network access points. The soldier "mule" should serve as a key player in supporting these functions. In addition, to cover the need for redundancy and adaptive network topology, most other robotic, as well as manned ground vehicles that are part of the FCS should be equipped with the ability to serve as a relay, router or network access point.

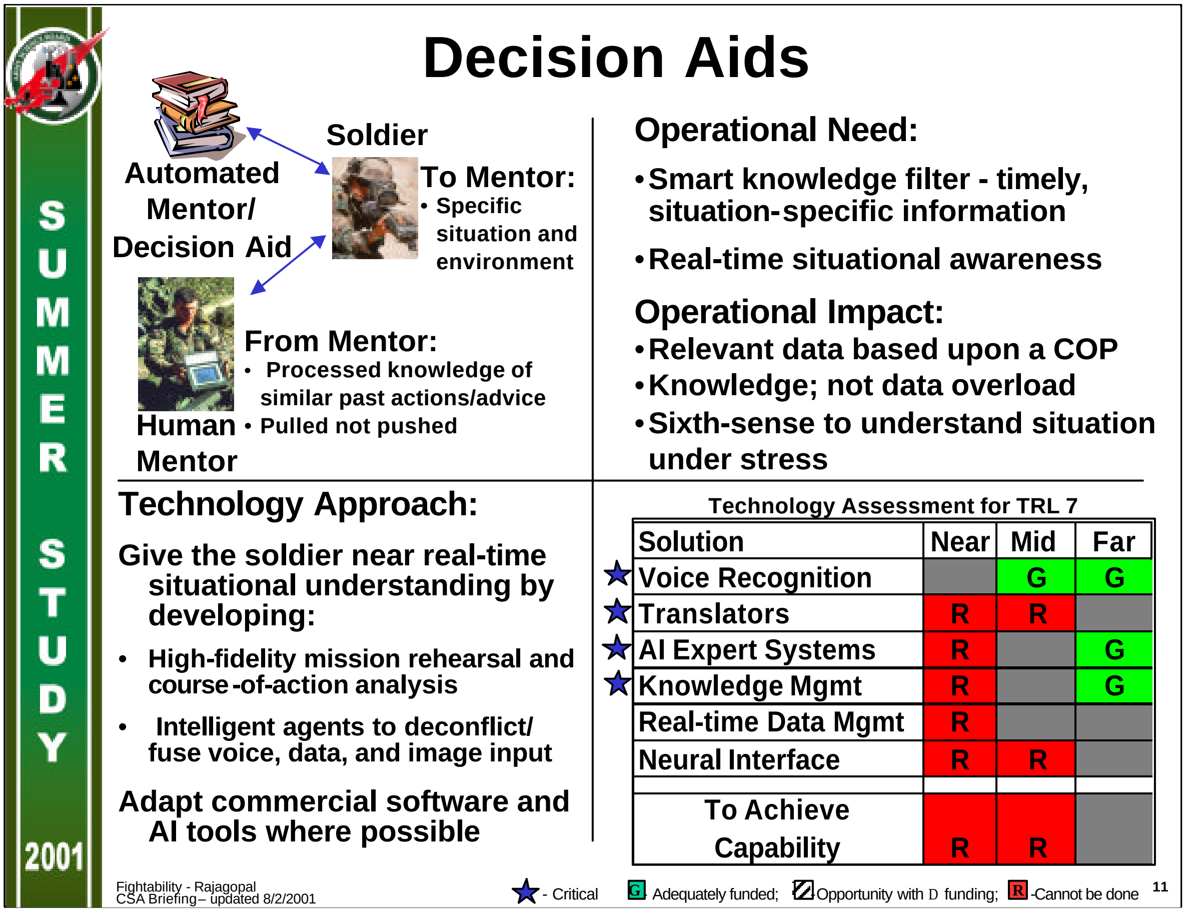
AdHoc Networks - Current developments in ad hoc wireless networks (e.g., MOSAIC and SUO SAS programs) would allow a soldier subscriber to enter an area and have the link establishment and connectivity be handled automatically, with no network management actions required by the soldier. Continuing these developments to drive wireless ad hoc network capability to the individual soldier level is an essential element of the C4ISR connectivity.

Mobile Routers - Implementation of these ad hoc, mobile networks requires the ability to implement mobile access points into which the soldier radio can connect. Current technology used in commercial cellular systems accomplishes the routing of communications through fixed towers scattered across the country. The Army challenge is to make those routers mobile. The Multifunction, On-the Move, Secure, Adaptive, Integrated Communications (MOSAIC) system ATD being developed at CECOM RDEC is beginning to address this technology.

Adaptive Mobile Antennas - Adaptive antenna requirements are driven by a need for maintaining connectivity, and operating under hostile electromagnetic environments filled with jamming, interference and hostile intercept. The adaptive "smart" antenna technology is a key element of the ability to successfully develop adaptive, multi-mode, multi-band radios for the soldier, as well as the supporting infrastructure. These Adaptive Antennas will be conformal, lightweight MEMS transmit and receive devices.

Sensing to Knowledge Management (Information Dissemination) - A logical extension of the output of sensing and C3I inputs requires a management system to organize and move the information through the systems while preventing overload. This process will take the ‘one size fits all’ Common Operating Picture and provide a mechanism to customize the views and information to the needs of the individual user. It also determines the information refresh levels required for various types of data so that updates are pulled into the COP. Providing the bandwidth and routers is not enough, the Army must manage the content that flows through the ‘pipes’. Soldier decision aids and IFFN are integral to the overall solution.

THIS IS A CRUCIAL AREA, AND REQUIRES MORE FUNDING TO ACHIEVE MATURITY IN THE MID TERM.



MAJOR THEMES

Currently the soldier receives very little external data which leaves him isolated from a RSTA point of view. However once the communication devices and gateway bandwidth capabilities are available, the soldier will be swamped by an avalanche of disparate data. Soldier Decision Aids will sort the "relevant" data for the soldier in the mid-term and give him "sixth sense" in the far term.

The first problem, after data collection from the various sources, is the fusion of the data from voice, image, sensors, data, etc; all of which must be time-tagged and 'deconflicted' to remove redundant and old data. This will then be formatted into a Common Operating Picture which can be displayed in various manners that meet the individual's needs.

The objective is to make information available with knowledge-based alternatives for the soldier to evaluate and chose from. The soldier and his interpretative skills and experience are still an important component in the decision making.

TECHNOLOGY SUPPORTING DATA

Voice recognition - This technology is available today in factories and hands-free cell phones in automobiles. However, this is a fairly benign environment with relatively quiet background levels. This commercial technology needs to be hardened for the battlefield environment with voice stress levels. Once tested in a military environment, it can be an effective hands-free data input mechanism.

Translators - A generic term for the function that needs to translate various forms of data (voice, image, IP, sensors, etc) into a single format that will allow disparate data to be merged into a common picture. This will not happen with bottoms-up stovepiped C4ISR developments. An integrating architecture which is engineered top down with necessary protocols and standards is necessary to allow this data fusion. Also, with the various latency periods for data collection and dissemination required, a standard for time-tagging is needed to avoid generating redundant or false 'targets'.

AI expert systems - These artificial intelligence systems will build a knowledge-based system to minimize the 'analyst in the loop' effort that slows down the information dissemination. Using academic and commercial tools such as neural networks which learn, this process can greatly reduce the latency period for analysis over time.

Knowledge management - A logical extension of the output of translators and AI expert systems. This process will take the 'one size fits all' Common Operating Picture and provide a mechanism to customize the views and information to the needs of the individual user, and more importantly, present that information in a perspective that is relevant to the soldier's situation. It also determines the information refresh levels required for various types of data so that updates are pulled into the COP.

Real time data management - The capability is long term and requires the maturation of translators, expert systems, and knowledge management to such a level of fidelity that there is no 'man in the loop' to slow down the process.

Neural interface - Very long term where a direct interface into the human replaces heads up displays and voice communication devices. When fully mature, it increases speed and cognitive recognition; but it is very conceptual during this time period. Maturity of this technology is not expected until the far term.

OVERALL, THIS AREA REQUIRES TIME TO MATURE TO THE FULL LEVEL OF CAPABILITY NEEDED. BUT EVEN GETTING THERE IN THE LONG TERM WILL REQUIRE ADDITIONAL S&T DOLLARS.

SUMMER STUDY 2001

Identification of Friends, Foes & Neutrals

People tracking

Operational Need:

- Rapid, accurate IFFN in complex settings; urban areas, crowds, hostage situations

Operational Impact:

- Survivability - reduced casualties
- Ability to work in MOUT

Technology Approach:

- Adapt commercial recognition technologies
- Implement stealthy identification of friendly soldiers and equipment
- Develop classifiers for identifying foes and discriminating from neutrals in near real-time
- Implement first in controlled situation; more difficult in open arena

Technology Assessment for TRL 7

Solution	Near	Mid	Far
RF Tags		G	G
★ Embedded IFF Comms		G	G
IFF Dust	R		G
Face Recognition	R		G
Genetic ID	R		
★ DB & Processing		G	G
To Achieve Capability		G	G

Fightability - Rajagopal
CSA Briefing– updated 8/2/2001

★ - Critical; G Adequately funded; D Opportunity with D funding; R -Cannot be done

13

MAJOR THEMES

In today's conflicts and peace-keeping missions, the separation of foe versus neutrals is both essential to mission success and increasingly difficult to do. Given the proliferation of electronic devices such as cell phones and Personal Digital Assistants (PDAs) among the indigenous population, traditional means of detecting electronic communications can be misleading.

The initial approach will be to supply the friendlies (our troops) with distinguishing devices, but this does not facilitate the separation of foes from neutrals and ID the threat when dispersed in a crowd. Controlled environments will be addressed early on with the technology. Open areas and urban environments are still very difficult given the lack of specific characteristic data on foes and neutrals.

Supplemental detection technologies can assist with multi-classification correlation to improve the probability of IFFN.

TECHNOLOGY SUPPORTING DATA

RF Tags- Useful in identifying friendlies, but not applicable to the foe/neutral problem. Cost, battery life, transmission distances, and ability to disable when lost are issues that need to be solved before they will be entirely feasible.

Embedded IFF Comms - Every friendly comms device will contain the equivalent of commercial e911 which identifies the geographic location and the identification of the user of the device. Once this is mandated globally, it will help to build the IFF Common Operating Picture for friendly versus foe/neutral.

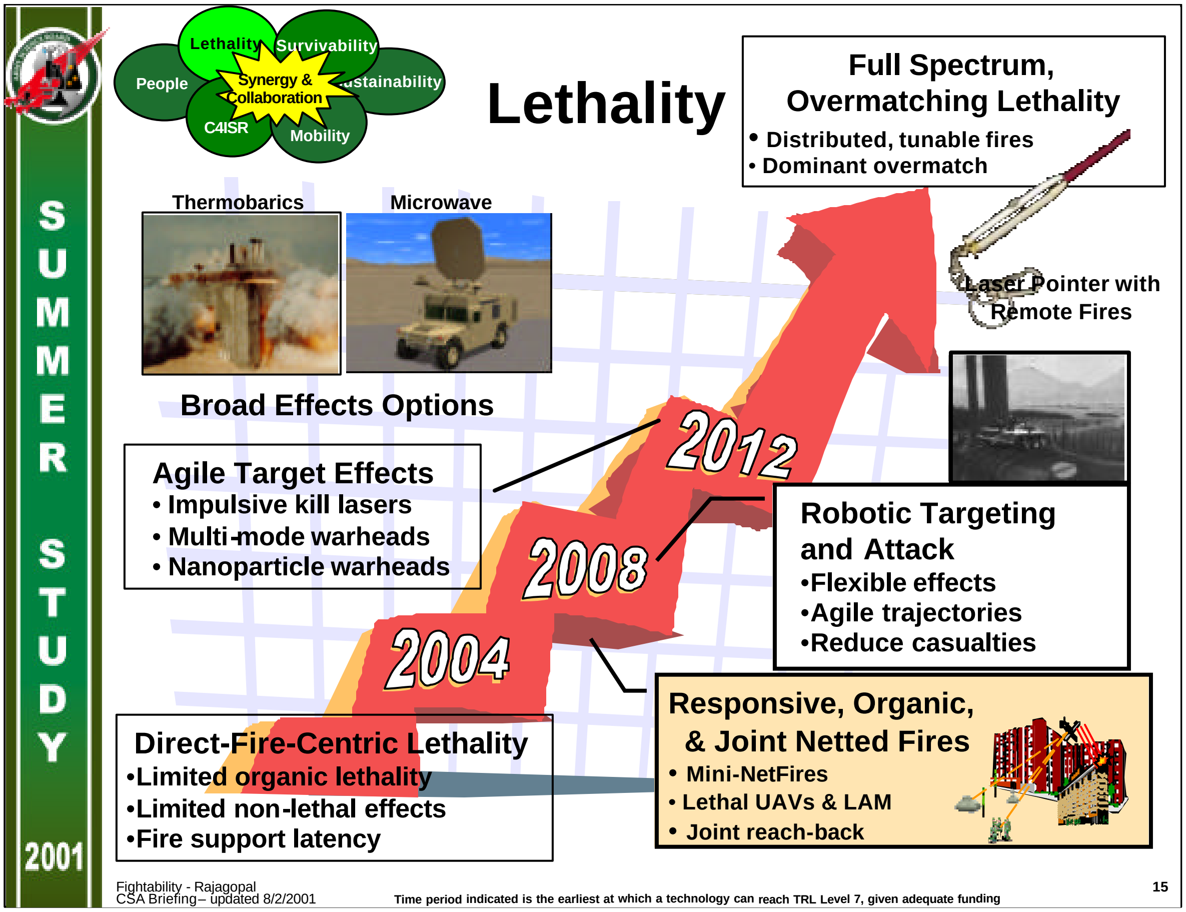
IFF Dust - The Soviets used a version of this technique to identify citizens who touch doorknobs, walked through certain corridors, etc. The same concept and a remote detection device could begin to separate foes from neutrals.

Face recognition - Effective in controlled situations or when the specific facial characteristics are well documented in a database and trained with an optical recognition device. The challenge here is to build the specific database or to develop recognition algorithms that will separate friendly, foe and neutrals.

Genetic ID - Taking advantage of the uniqueness of DNA codes/makeup of each person, one can construct gene or DNA embedded chips which would, in the far term, be used as a pass word or a private key for IFF purpose.

Database & real time processing - in all remote detection techniques, the accuracy of the database for correlation and the real time processing so that the information is useful to the soldier in a stress situation, are significant challenges. Access to data to build the database on the specific indigenous population is a logistics and political challenge. The size of the database and the sorting algorithms are a impediments to real time processing.

THE CRITICAL TECHNOLOGIES FOR THIS ENABLER ARE EXPECTED TO MATURE IN THE MID TERM WITH THE LEVEL OF FUNDING NOW IN PLACE; ADDITIONAL FUNDS ARE RECOMMENDED IF THE INTENT IS TO ACCELERATE THE RATE OF MATURATION.



Current Situation: Dismounted soldiers today, individually or in small units, have direct control only over the weapons they carry-- rifles, grenade launchers, machine guns, and small mortars. This adds up to relatively short range, direct fire lethality, 100% organic to the soldier and squad. Responses to calls for support from artillery, helicopters, or aircraft typically have a high latency, and the requested heavy ordnance often arrives 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 U.S. Army forces now face..

Key Technologies: Many improvements still can be made to conventional infantry weapons. Some of these promise significant increases in lethality, and these should be pursued. However, for major gains in small unit force lethality three area of work appear to be key.

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. Procedural changes also are essential. C4ISR designed for major war does not work well in the environments U.S. forces now must fight in. With light but lethal, relatively small forces engaged in any given fight they can and must be given immediate access to heavy ordinance. The latency built into the current fire support system must be squeezed out of the system to permit this. This extends even to joint reach-back for air or naval gun fire support.

In addition, protocols and munitions should be developed to enable effective local mini-net fires systems to be set up among small units engaged in an operation. Part of these, and essential to their high effectiveness, are lethal UAVs & LAM designed for support of small units and dismounted infantry.

UAVs and UGVs will be common on future battlefields. These will range from micro devices through mini robots of a few pounds, to the general purpose RoboMules that may appear is sizes from 1,000 to 20,000 lbs., do almost any job soldiers can devise for them, and largely take care of their own needs. 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. RSTA robots will appear in all sizes, and will give the small unit its own organic capability in that area. This will enormously increase unit effectiveness and greatly reduce casualties.

In the mid to far term work on the 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 systems providing controllable effects on targets at tactical ranges. These will be tunable against a variety of materiel and personnel targets. This supports the need of both dismounted infantry and the FCS for mission flexibility in situations where both lethal and non-lethal capabilities are needed.

Among the technologies included in the ATES development work are: (1) pulsed impulse lasers tunable for lethal or non-lethal effects, (2) multi-mode warheads, (3) nanoparticle work that is expected to provide both anti-personnel and anti-materiel warheads, and (4) devices providing unbearable audio and optical effects to force people out of a selected area.

The Future: These developments and others in the lethality area, if pursued, will give the Objective Force Soldier full spectrum, overmatching lethality against any threat U.S. forces may face. Distributed, tunable fires, robotic RSTA and weapons, and agile target effects will provide dominant overmatch.

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Responsive, Organic and Joint Netted Fires

Mini-NETFIRES

Peace Keeping
Low Collateral Damage
Precision Strike

MOUT/ COMPLEX TERRAIN CAPABLE

Operational Need:

- Distributed Fires w/ real-time BDA
- Netted lethality – organic and joint netted fires

Operational Impact:

- LOS and BLOS engagements
- Multi-mode effects
- Low latency
- Low soldier load and logistics burden
- Stand-off overmatch

Technology Approach:

- Demonstrate small unit distributed fires network featuring collaborative engagements and BDA – mid-term
- Provide reach back to organic and Joint Fires (lethal UAVs/UGVs/unattended/ loitering munitions, small mortars)
- Leverage miniature precision munitions for dismounted mini-NetFires application – long-term
- Demonstrate in field environment

► For details, see lethality report

Technology Assessment for TRL 7

Solution	Near	Mid	Far
Distributed Fires	R		G
★ Lethal UGVs/UAVs	R		
★ Minature PGMs	R		
★ Mini-Net Fires	R		
Joint Reachback	R	R	
To Achieve Capability	R		

Fightability - Rajagopal
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★ - Critical G Adequately funded; Opportunity with D funding; R -Cannot be done 17

Netting of organic fires and responsive reachback to higher-echelon fire support are critical to soldier lethality. Organic within the squad and organic to the FCS maneuver battalion, the ability to separate and network sensors and shooters is an essential part of getting to the 10X future soldier. And when operating as part of a mounted/dismounted team, the ability to reach for responsive fires is important both in order to deliver overwhelming lethality on target (to a far greater extent than a small dismounted squad can deliver) and to maintain concealment of the squad when outnumbered or for other tactical reasons.

Global trends toward urbanization will likely have a significant impact on the nature of future land combat operations and warfare in general. Objective Force soldiers and marines operating dismounted in Urban or complex terrain will still need to expand their areas of action while maintaining overmatch and tactical initiative. The ability to find and simultaneously engage threat forces and systems at beyond line of sight (BLOS) ranges will be essential to assure dominance and force survivability. Responsive reach back to organic, support unit and joint fires must provide a broad array of lethality options. Mutually supporting, distributed fires including the FCS NetFires Precision Attack missile and the Loitering Attack munitions, provide inherent flexibility and efficiency at the small unit level.

Lethal UAVs, UGVs and loitering attack munitions (LAM) will also provide a capability for low latency target attack with minimum exposure of the realtively lightly protected dismounted warrior. Small precision missiles and munitions will enable the development of a mini-NetFires capability organic to small units with potential for a broad range of effects. Most lethality options will require man rating with validated need for high reliability to assure safety of employment. The integration of small units to joint reach back fires will often be constrained by C2/connectivity challenges and joint decision time lines until a "joint tactical infosphere" is fielded.

OVERALL, THIS AREA REQUIRES MORE FUNDING THAN AVAILABLE IN THE POM TO ACHIEVE MATURITY (TRL 7) IN THE MID OR EVEN FAR TERM. ALSO, THE PREREQUISITE OF SOLDIER C4ISR CONNECTIVITY MUST BE BUILT IN PARALLEL.

Agile Target Effects

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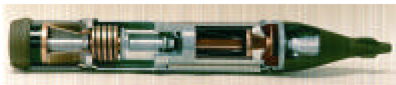
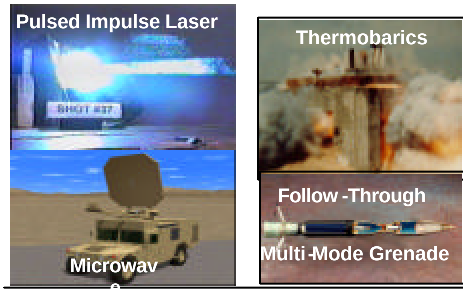


155mm High Power Microwave Projectile (model)



Operational Need:

Multi-mode weapon systems for mission flexibility, providing controllable effects on targets at tactical ranges

Operational Impact:

- Inherent flexibility to match varied mission requirements
- Substantially reduced logistics burden

Technology Approach:

Develop a robust suite of weapons in support of dismounted infantry

- Capable of agile target effects to support varied mission needs
- Tunable against a variety of materiel and personnel targets
- Downscaled for infantry use

Technology Assessment for TRL 7

Solution	Near	Mid	Far
Solid State Pulsed Laser	R		
Thermobaric Warhead			G
Nanoparticle Warhead	R		G
★ Multi-Mode Mini Warhead			
★ Microwave (Antipersonnel)	R		G
To Achieve Capability	R		

Fightability - Rajagopal
CSA Briefing– updated 8/2/2001

★ - Critical; G Adequately funded; Opportunity with D funding; R -Cannot be done 19

Agile Target Effects: This deals with the actual effects of the fires discussed in the prior chart, i.e., the mechanisms by which the lethal/nonlethal effects are produced.

Agile Target Effects System (ATES) is a conceptual ensemble of devices employing various tunable or multi-mode weapons, including unconventional directed energy effects, that will defeat and/or disable the myriad of battlespace threats – both personnel and materiel.

The ultimate program goal is 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. This supports the need of both dismounted infantry and the FCS for mission flexibility.

The threats to be countered range from heavy conventional systems to fixed and rotary wing aircraft, to UAV/UGVs, as well as the agility of the unconventional effects to confer substantial advantages in situations requiring less-than-lethal effects and in MOUT. The complementary nature of the ATES technologies makes them difficult, if not impossible, for an enemy to counter without severely impeding their ability to fight.

The ATES family includes direct fire, line of sight systems and indirect fire systems to engage an enemy in defilade from buildings or terrain. Some ATES devices act by disabling or upsetting the enemy weapon and C3 electronics, some by physical damage from controlled blast, and some by optically incapacitating the enemy seekers/sensors or personnel. Devices under consideration include vehicle mounted Radio Frequency DEW/High Power Microwave (HPM), artillery delivered or remotely emplaced RF DEW/HPM warheads unconventional laser effects devices, nano-explosives, as well as nanoparticles for aerosol dispersment.

The non-lethal capabilities of ATES devices also can also be employed to great effect. These non-lethal options and non-line of sight potential may allow the ATES to be utilized in counter-terror operations as well as urban combat, MOUT.

ADDITONAL FUNDING BEYOND POM LEVELS IS NEEDED TO BRING THIS CAPABILITY TO BEAR IN THE MID OR EVEN FAR TERM.

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Robotic Target and Attack

Operational Need:

The Objective Force needs a means of attacking enemy forces without exposing soldiers to hostile fire

Operational Impact:

- **Reduce casualties**
- **Increase OPTEMPO**
- **Expand freedom of operations**

Technology Approach:

- **Integrate lethality options into existing unmanned system (UMS) efforts (e.g. DEMO III)**
- **Intensify UMS lethality efforts (including target acquisition and battle command)**
- **Conduct robust field experiments to gain operational confidence**
- **Leverage sensing and decision aids**
- **Explore miniature UMS with lethality and mobility**

Technology Assessment for TRL 7

	Solutions	Near	Mid	Far
★	GV RSTA Robots			
★	AV RSTA Robots			
★	GV Attack Robots	R		
★	AV Attack Robots	R		
★	Mini & Micro UVs			G
	To Improve the Capability	R		

Fightability - Rajagopal
CSA Briefing– updated 8/2/2001

★ - Critical G Adequately funded; ▨ Opportunity with D funding; R -Cannot be done 21

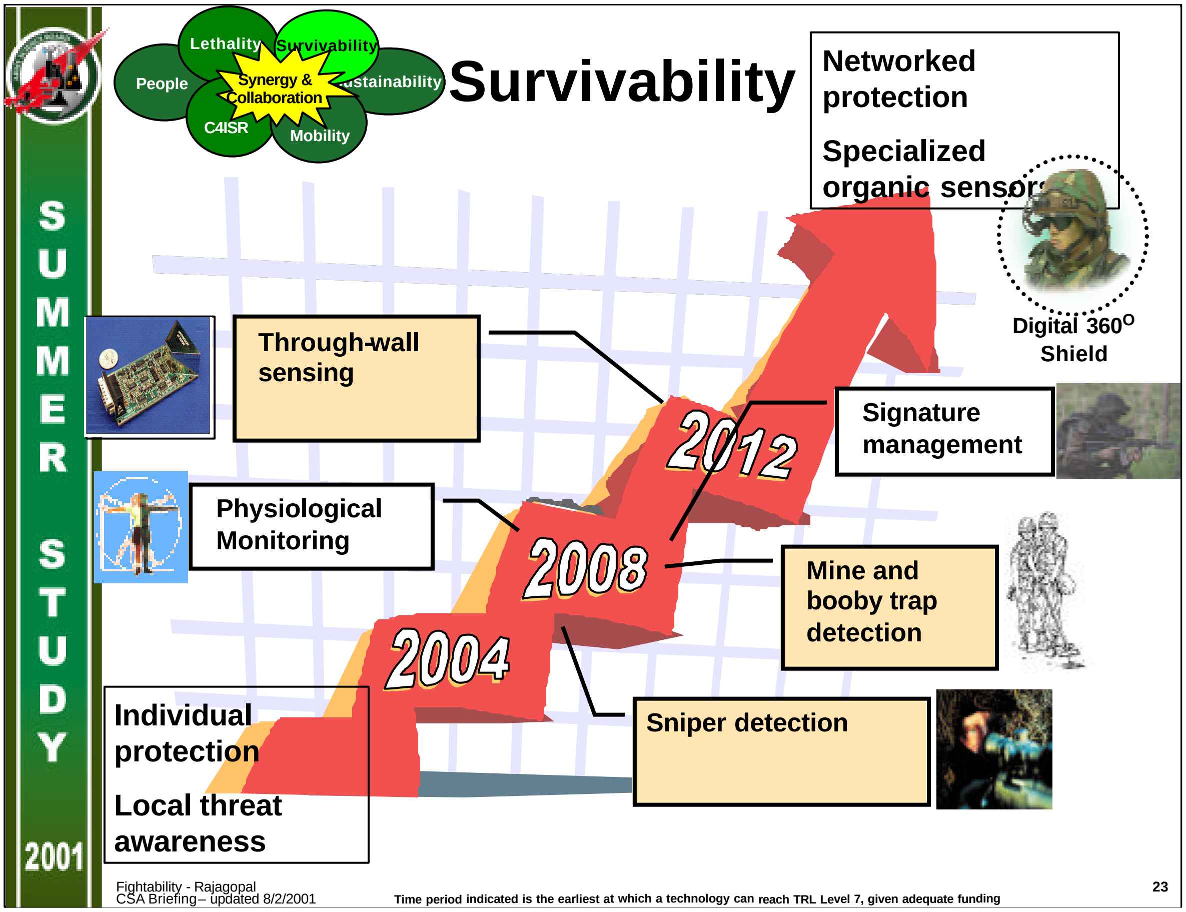
This chart addresses the weapon delivery aspect of the UAV/UGV topic described earlier under C4ISR. Warfighting models – including Rand analysis performed in support of this Summer Study -- show that robotic vehicles, in particular UGVs, are most effective when they are not pure sensors, I.e., when they can deliver a punch as well. Otherwise, an adaptive threat tends to let them go by and attack the manned force that follows.

In terms of doctrine, we expect that any mid term (and perhaps far term) use of attack robots will be human-commanded for the actual fire command. An exception is the weaponized UAV, which can be likened to a cruise missile or LAM.

Objective Force soldiers will face a very broad array of situations that extend beyond the capabilities of existing lethality options. The potential to employ robotic targeting and attack systems will offer new options for expanding battle space and reducing the time soldiers are in harm's way. The capabilities should also reduce decision risks, increase overall small unit OPTEMPO and increase the team's freedom of operations - often enabling simultaneous attack of multiple targets.

There are many initiatives currently ongoing for many types of unmanned systems (UMS) including UAVs, UGVs, unattended/remote munitions and unattended sensors. The integration of advanced target acquisition and weapons capabilities along with appropriate "human in the loop" (HITL) connectivity and decision aids can potentially expand significantly the dismounted team's ability to engage a wider variety of targets with minimum exposure to direct fire threats. The weaponization of smaller unmanned systems, UMS (micro or mini - UGVs or UAV) provides unique capabilities to engage threat forces with beyond line of sight capabilities with minimum burden on the logistics system. As these systems expand in lethal capability additional improvements in small unit battle command of manned-unmanned team options are essential to allow full utility of the team's ability to control greater areas of terrain and conduct simultaneous precision attacks. A key enabler for attack UMS will be a new generation of miniature, smart, precision munitions that are designed to be compatible with remote employment from UMS with HITL decision/supervision. RSTA capable UMS will require additional resources to support integration into the force but significant potential for acceleration, even in the near term time frames. Attack UMS will likely not be an option at a TRL 7 until the mid time frame. Some acceleration of lethal version of mini and micro UMS is possible in the near term. Overall, this is a high payoff opportunity for small dismounted teams with considerable potential for acceleration into several Objective Force soldier efforts.

A POM PLUS-UP IS NEEDED TO MATURE THIS CAPABILITY. AND WHILE THE STOPLIGHT CHART SHOWS THE POTENTIAL FOR MIDTERM MATURATION GIVEN ADEQUATE FUNDING, THAT ASSESSMENT COULD BE OPTIMISTIC.



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 soldiers ability to understand what is happening in the environment. Soldiers who enter rooms in urban environments have casualty rates as high as 85%. The ability to "see" inside a room prior to entry Sensors to detect mines and booby traps that are expected to proliferate in future urban environments (as the primary asymmetric warfare mechanism) will be critical for soldier survival. 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 facility.

With the significant increase in technologies for genetic manipulation and gene analysis, it is feasible to think of the next generation of physiological monitors that can accurately analyze soldier's vital signs and fluids, and identify the exact physiological state of the individual soldier in real time. Industry is investing billions of dollars into gene chips, proteomics, and advanced bio-technology tools that the Army should exploit. 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:

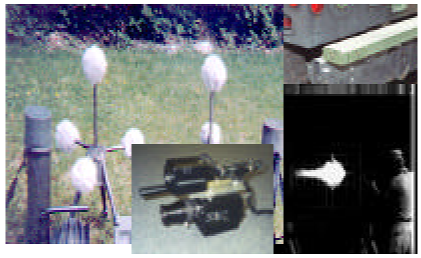
Appropriately integrated (through a responsive, dynamic, adaptive C4ISR network), this suite of survivability technologies will allow soldiers to leverage the *entire* network of battlefield sensors, reaching what we describe as a full 360 degree digital shield around themselves. Any threat that attempts to penetrate that shield will be detected and appropriate tailored responses can be generated, leading to an exponential increase in soldier survivability.

A note on body armor enhancements: The absence of advanced body armor in this and following slides deserves an explanation as to why it did not make the Summer Study's Top 20 list.

The panel recognized the improvements already made to body armor and those being considered for near-term application to Land Warrior, which essentially provide torso protection from more lethal (armor-piercing) threats, and at weights similar to or even lower than today's less capable body armor. These improvements are laudable and should be capitalized upon as quickly as possible.

However, 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. This technology is in its embryonic stages, at least insofar as its application to armor protection. Bold projections are being made by materials scientists…claims that the huge gains in material strength and fracture toughness will result in a corresponding improvement in ballistic performance….leading even to the use of armor for protection of extremities. 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.

Sniper Detection



Multiple acoustic/IR technologies have been demonstrated.

- **Operational Need:**
  - All dismounted missions from assault to SASO are subject to disruption by sniper fire. Rapid and accurate detection of sniper location is critical
- **Operational Impact:**
  - Improved survivability
  - Improved mobility

Technology Approach:

- Create Army ORD for sniper detection (none exists today)
- Leverage existing mature technologies (sensors, fusion)
- Integrate multiple sensor types: acoustic (blast, bullet), IR (muzzle flash, bullet track), glint
- Demonstrate through ATDs/ACTDs and other field experiments

Technology Assessment for TRL 7

Solution	Near	Mid	Far
★ Integration	R		
★ Acoustic			
★ Glint Detector		G	G
IR/Thermal	R	R	
UGS Platform	R		
IR Flash Detector	G	G	G
To Achieve Capability	R		

Fightability - Rajagopal
CSA Briefing – updated 8/2/2001

★ - Critical   G Adequately funded; Opportunity with D funding; R Cannot be done   25

Snipers constitute a traditional yet difficult-to-counter threat with the capability to affect the mobility and survivability of the Objective Force Soldier team.

Counter sniper capability begins with the ability to detect the presence and location of a sniper with sufficient accuracy to return fire. There are three main sensing modalities that have been developed (to various levels of maturity) in the S&T community: acoustic detection, IR muzzle flash detection, and IR detection of the bullet in flight.

Acoustic techniques focus on determining either the supersonic shockwave of a high-speed bullet, or detecting the acoustic signature of the weapon. In either case, an array of accurately positioned microphones are used to triangulate the position of the bullet track or the source based on the time-of-arrival of the acoustic energy at the detectors. Several systems are already available, such as the French PILAR™ system, and the vehicle mounted PDCue™ Counter Sniper System. The National Institute of Justice (NIJ) has funded the development of low cost technology for police monitoring of urban areas such as the Trilion Technology's ShotSpotter™ system which has been tested in Redwood City, CA.

The Counter Sniper ACTD that ended in 1998, tested three technology demonstrators developed under various DARPA programs, including BBN's Bullet Ears, the TAG-IT-CS system, the NRL funded VIPER Infrared system. The conclusions of the ACTD were that the fundamental technical approaches for the acoustic shock wave systems were sound and that sufficient accuracies could be achieved by the technology whenever the bullet track went through the sensor field. The IR technologies for muzzle blast detection were very accurate, but the field-of-view of the IR sensors limited the usefulness. IR tracking of the bullet path was inaccurate (mainly due to device-noise limitations), although that technology has improved over time. Tests by the NIJ in Redwood City also indicated that 80% of the shots fired were identified, and 72% were triangulated to within 25 feet of the target.

Rafael in Israel, and BBN have demonstrated man-portable (helmet mounted) microphone arrays. So far these demonstrations have been limited by the accuracy with which the individuals carrying the microphones could be located, the accuracy of head position and orientation, and the bulk that was added to the helmet.

While the technology is maturing, the Army does not have a formal requirement for sniper detection today. USSOCOM has a draft ORD for sniper detection, and is procuring a few of the PILAR systems though it meets only minimal requirements. USMC is evaluating a sniper detection system built into a vehicle and integrated with an automatic gun mount for automated return fire. DERA and ARL have a cooperative agreement for acoustic perimeter detection systems.

The panel recommends that the Army focus on (a) defining requirements for sniper detection, focusing on both perimeter detection and tactical deployments, (b) develop technology for integrated multi-sensor sniper detection, and (c) initiate a new ACTD to mature the integrated technology to TRL level 7. Integration of the disparate sensing modalities into a fused system will reduce false alarms and improve detection accuracy in much the same manner as it does for ATR (aided target recognition) or any other form of image recognition. With the appropriate funding, this could be achieved in the 2008 timeframe, even though certain capabilities such as acoustic perimeter protection could be at TRL level 7 by 2004. Techniques such as detecting the optical sights of the sniper scopes (glint detection) should be leveraged from appropriate vehicle based programs and integrated into sniper detection to provide the ability to detect a sniper *before* a shot has been fired. Such an integrated system could provide a significant improvement to the survivability of warfighters in future operations.

GIVEN THE ABOVE PLUS-UPS TO THE POM, THE PANEL FEELS THAT A MID-TERM CAPABILITY IS ACHIEVABLE IN SNIPER DETECTION WITH SUFFICIENT RESOLUTION TO USE IN AUTOMATIC (OR AIDED) COUNTERFIRE.

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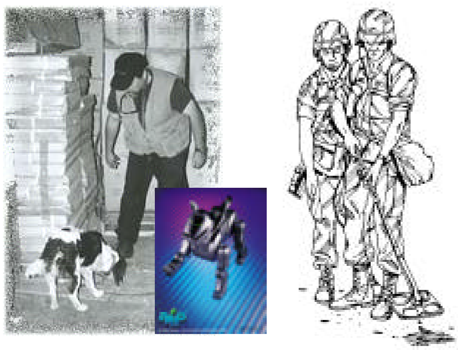
Mine/Booby-Trap Sensing



- **Operational Need:**
  Detect and warn soldier and soldier teams of presence of mines and booby traps
- **Operational Impact:**
  Mobility, survivability and sustainability of soldiers is significantly improved

Technology Approach:

- Ground penetrating radar image processing for buried mines
- ►Chemical sniffing to detect explosives
- UGV/Robotic systems to carry sensors into risk areas
- Specialized electronic support measures (ESM) to detect radio triggers

Technology Assessment for TRL 7

Solution	Near	Mid	Far
★ Ground Pen. Radar	G	G	G
★ Chem Sniffers	R		G
★ Unmanned Grnd Veh			
Image Comparison		G	G
ESM Sensors			G
★ Robotic Dogs	R		
To Achieve Capability	R		

Fightability - Rajagopal
CSA Briefing– updated 8/2/2001

★ - Critical G Adequately funded; Opportunity with D funding; R -Cannot be done 27

Perhaps the simplest yet single largest asymmetric threat to the soldier will be mines and booby traps. The enhanced lethality and armor of the OF soldier will encourage the hostile force to attack this soldier without directly engaging the soldier in one-on-one combat. As we observe Chechnya, it is possible to see the desire of the Chechen soldier to use weapons that allow standoff from the engagement. Many of the mines and booby traps will be remotely triggered or sensor triggered leaving the asymmetric hostile warrior at minimum risk from the OF soldier. It will be essential to counter these weapons.

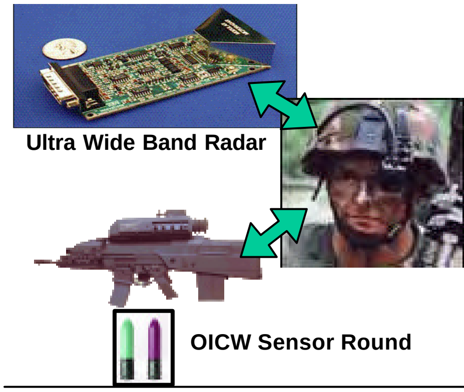
Near term solutions include live, trained dogs, ground penetrating radar (not portable), and soldier-portable metal detectors (slow). Mid-term solutions like UGV mounted probes, explosive/chemical detectors, and ESM sensors to detect and locate RF components of both mines/booby traps and the enemy soldier triggering same can be enhanced and matured long-term into the Robotic Dog – a concept of fusing multiple sensor inputs (IR camera, GPR, chemical scent, and tripwire ESM) on a small moble platform (UGV) to replicate and eventually enhance the sensory and automotive capabilities of a trained canine. used in conjunction with the GPR (ground penetrating radar) and conventional soldier hand held mine detectors.

An important adjunct will be the knowledge management system available to the OF soldier so that near immediate information on hostile force mines, techniques and tactics can be available to support soldier operations. Mines and booby traps will often be the primary cause of OF soldier casualties and must be considered a critical vulnerability well into the OF timeframe.

THIS ESSENTIAL CAPABILITY REQUIRES ADDITIONAL FUNDING FOR MID-TERM MATURATION.

SUMMER STUDY 2001

Through-Wall Sensing



- **Operational Need:** Ability to to sense enemy presence behind walls, tunnels, revetments, barriers.
- **Operational Impact:** Soldier survivability is significantly enhanced as are C4ISR and Lethality

Technology approach:

- Develop sensors which can be emplaced within structure or delivered by UAVs, UGVs or the OICW 20mm round
- Continue R&D on Ultra-Wide Band-radar & acoustic sensors
- Develop air sampling sensors to detect explosives, and humans

Technology Assessment for TRL 7

Solution	Near	Mid	Far
★ Ultra Wide Band Radar	R	R	
★ Emplaced Sensors			
Micro UAV/UGV			G
Acoustic			
Air Quality	R		
★ OICW 'sensor rounds'	R		
To Achieve Capability	R		

★ - Critical G Adequately funded; Opportunity with D funding; R -Cannot be done

Fightability - Rajagopal
CSA Briefing– updated 8/2/2001

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Current Situation:

The current situation for MOUT and close warfare often requires the soldier to enter enclosures, caves, tunnels, behind obstacles where is knowledge of the area is extremely limited. This (based upon MOUT exercises) can result in extremely high causalities.

Key Technologies:

The Objective Force (OF) soldier will be placed in many situation where it is essential to have surveillance of interior facilities and behind obstructions or within caves and tunnels. The results of the futures panel report suggest the soldier will often be in an urban environment where moving from room to room or building to building will be both necessary and dangerous. Technology for sensing the interior or behind the obstruction prior to entry is a critical enabler for the OF soldier's survivability. Many areas of technology combine to show significant promise for the future.

In the near-term the use of emplaced sensors with or behind the walls or obstruction have significant capability. As the soldier clears an area, these devices can be emplaced and the area can be monitored for 'reoccupation" by hostile forces. The use of unmanned vehicles, either small UAVs or small UGVs similarly holds near term promise for providing the platforms to carry surveillance sensors into the area of interest with minimal risk to the soldier. The DOD S&T program is developing the technology to support these concepts both within the Army and at DARPA and other service labs. Other sensors which can be used external to the target enclosure include such technologies as acoustic and air sampling.

The OF soldier will be equipped with an OICW. The technology provides the opportunity to use this weapon to deliver a "sensor round' into an enclosure or behind obstructions to survey the area and report the results to the soldier. This would provide an additional capability to the OICW to increase the soldier's survivability.

Future:

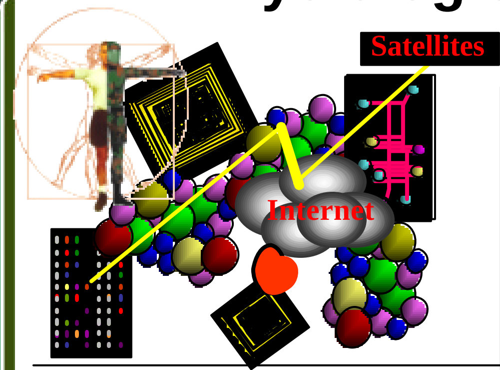
The OF soldier will have the option to accomplish "remote" surveillance of enclosed areas or behind obstacles prior to making a decision to enter these enclosures. This will allow the soldier to make knowledge informed decisions concerning the best way to accomplish his objective.

A FAR-TERM CAPABILITY WITH ADDITIONAL FUNDING REQUIRED.

Note on subterranean detection: *The panel did not examine the twofold problem of a) detecting underground structures and labyrinths, and b) detecting and targeting enemy presence in those locations. The potential for subterranean enemy activity exists in any type of complex terrain, from forested areas (e.g., tunnels in Vietnam) to cities (sewers in any urban area). This is a key need that did not surface until too late in the panel's study. Some of the technologies that enable through-wall sensing may apply here as well, along with additional technologies that must be evaluated and brought forward.*

SUMMER STUDY 2001

Physiological Monitoring



Problem: The combination of genetic technology, bio-MEMS technology, and micro-fluidic technology and the objective 'infosphere' makes it possible to keep tabs on the real-time health of every battlefield asset, in particular the OF Soldier to enhance real-time telemedicine.

Technology Approach:

To effectively fight in future asymmetric warfare (e.g., bio-warfare), the Army should research, develop, and deploy military-specific biotech/ nanotech for physiological monitoring by using gene chips (e.g., fever chips), protein chips, micro-fluidic lab chips, integrated chips, vital sign monitors, etc.

Technology Assessment for TRL 7

Solution	Near	Mid	Far
★ DNA Chips	R		G
★ Protein Chips	R		G
Lab Chips	R	R	
Integrated Chips	R	R	
★ Vital Signs Monitors		G	G
To Achieve Capability	R		G

★ - Critical G Adequately funded; Opportunity with D funding; R -Cannot be done

Fightability - Rajagopal
CSA Briefing– updated 8/2/2001

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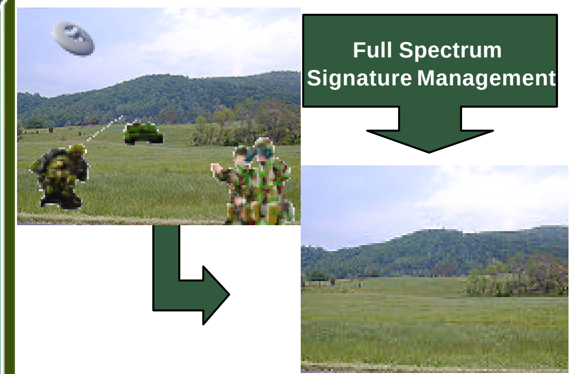
The low-end of physio-monitoring is body temperature and heart rate monitoring, which is available today and can be done automatically once Soldier C4ISR Connectivity is established (see C4ISR area). This chart deals with the high end of physio-monitoring, with the use of genetic science to track and monitor the outbreak of disease in real time, diagnosing fevers, countering bio-weapons, etc.

Judging from the way scientific/engineering advancements are being rapidly made in the fields of biotech and nanotech (including micro-fluidic, bio-MEMS and bio-NEMS technologies), these technologies will certainly have profound effects on the global economy, world's peace, as well as war fighting. Whoever possesses the leading-edge biotech and nanotech (converged with the relevant information technologies) will dominate the global economy and also be a leader in the military field worldwide. Many of said technologies are being developed in the commercial sector. Some will bear fruit soon, others continue to show great promise for the future, yet others may never mature. This and the next slides show families of technologies with promising futures in both near and far terms. The Army should take advantage of R&D efforts in the private sector by actively participating in cost- and risk-sharing (e.g. via venture capital arrangement) to encourage development of specific technologies, which will benefit both the private and the military sectors. The Army should also drastically increase its spending in R&D on specific biotech and nanotech, which will specifically benefit the Army.

It has been said that the latter part of last century belonged to the information technology; and Century 21 will be for biotech and nanotech, including their use for offensive and defensive purposes on the battlefield.

SUMMER STUDY 2001

Signature Management



Operational need:

OF Soldier needs to be able to deny the enemy's sensors reliable detection

Operational Impact:

Significant survivability and mobility advantage for the OF soldier and resultant lethality improvements

Technology approach:

- **Continue development of passive and accelerate active signature management systems for the soldier.**
- **Accelerate development of decoys and deception systems which confuse and degrade hostile sensors – e.g., Wolfpack concept.**

Technology Assessment for TRL 7

	Solution	Near	Mid	Far
	Passive Camouflage	G	G	G
★	Active Camouflage	R		
	Decoy (hologram)	R	R	
★	Wolfpack Info Warfare			
	To Achieve Capability	R		

Fightability - Rajagopal
CSA Briefing– updated 8/2/2001

★- Critical G Adequately funded; Opportunity with D funding; R-Cannot be done

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Current Situation:

The current soldier has many capabilities to reduce his detectable signature on the battlefield. Clearly the ***"Own the Night"*** capability of the recent past provided the soldier a tremendous battlefield advantage. Now, given the proliferation of I-squared and thermal devices, our soldier is just as detectable by the enemy as the enemy is by us. Regaining that advantage requires the use of signature control in terms of low-observable materials, low-profile equipment and load packs, and stealthy TTP's.

Key Technologies:

A number of active, passive signature management and deception technologies are available to restore the OF soldier the opportunity to maintain the detectability advantage over hostile forces, I.e., realize the "See First" vision.

Passive soldier camouflage will continue to be a key technology and will continue to develop under the S&T program as new materials and techniques evolve.

Active soldier Camouflage will begin to become a powerful solution as enemy sensors become orders of magnitude more capable. The opportunity to actively reduce or modify soldier signatures will include the capability to reduce optical, thermal, radar and acoustic signatures.

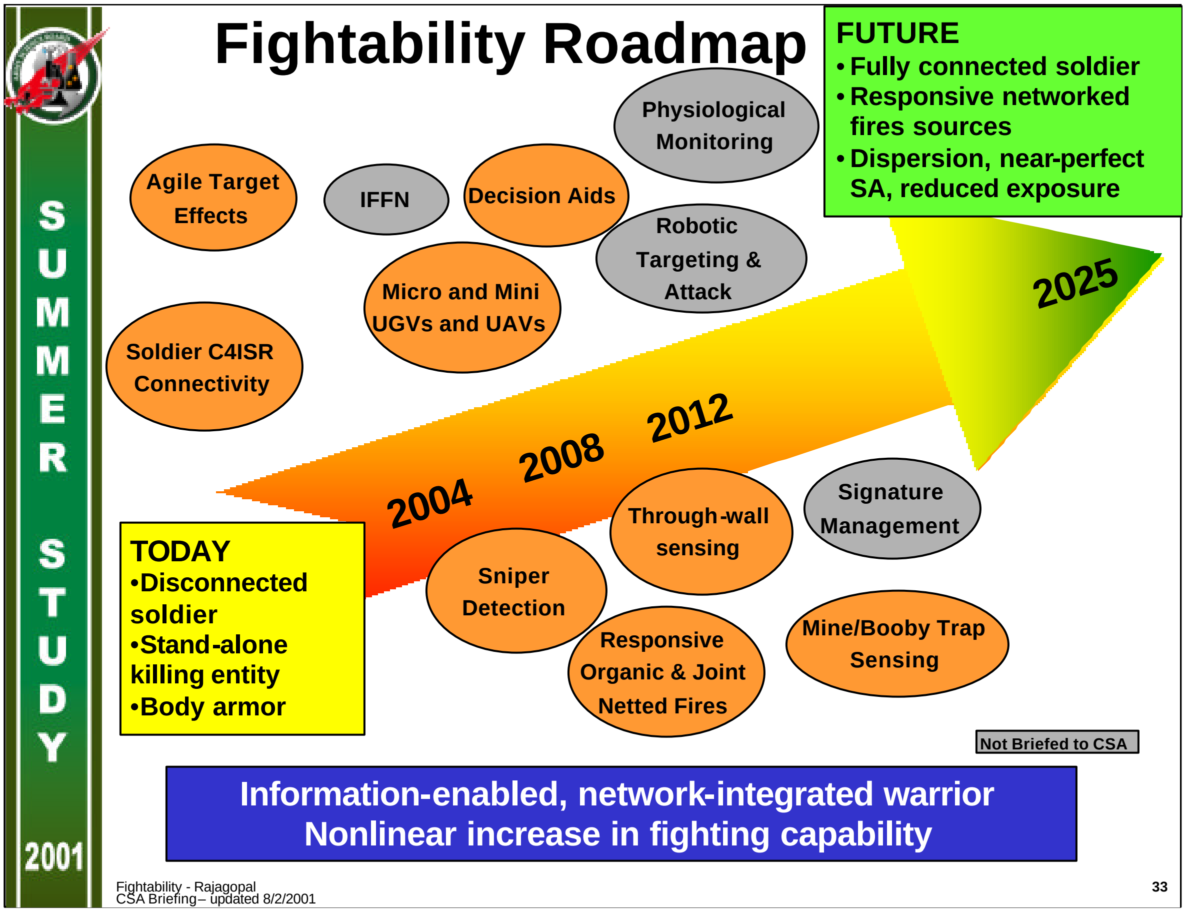
Decoys will also be a technology that will provide excellent synergy with the passive and active signature reduction technologies. The future will allow development of soldier and soldier systems (robots, UAVs, communications, weapons, etc) decoys and deception systems that can add significant degradation to hostile ISR and Target Acquisition systems reliability and information systems credibility.

Wolfpack is a technology that will provide both denial and deception of hostile SIGINT operations and can add significant confusion and degradation as the enemy attempt to exploit the soldier connectivity network.

Future:

The OF soldier will own both the day and the night as signature management and deception / decoys deny the enemy reliable and credible detection of the OF soldier under day or night, rain or clear situations.

GOOD POTENTIAL FOR MID-TERM MATURITY WITH ADDITIONAL S&T FUNDING BEYOND POM LEVEL.



Current Situation:

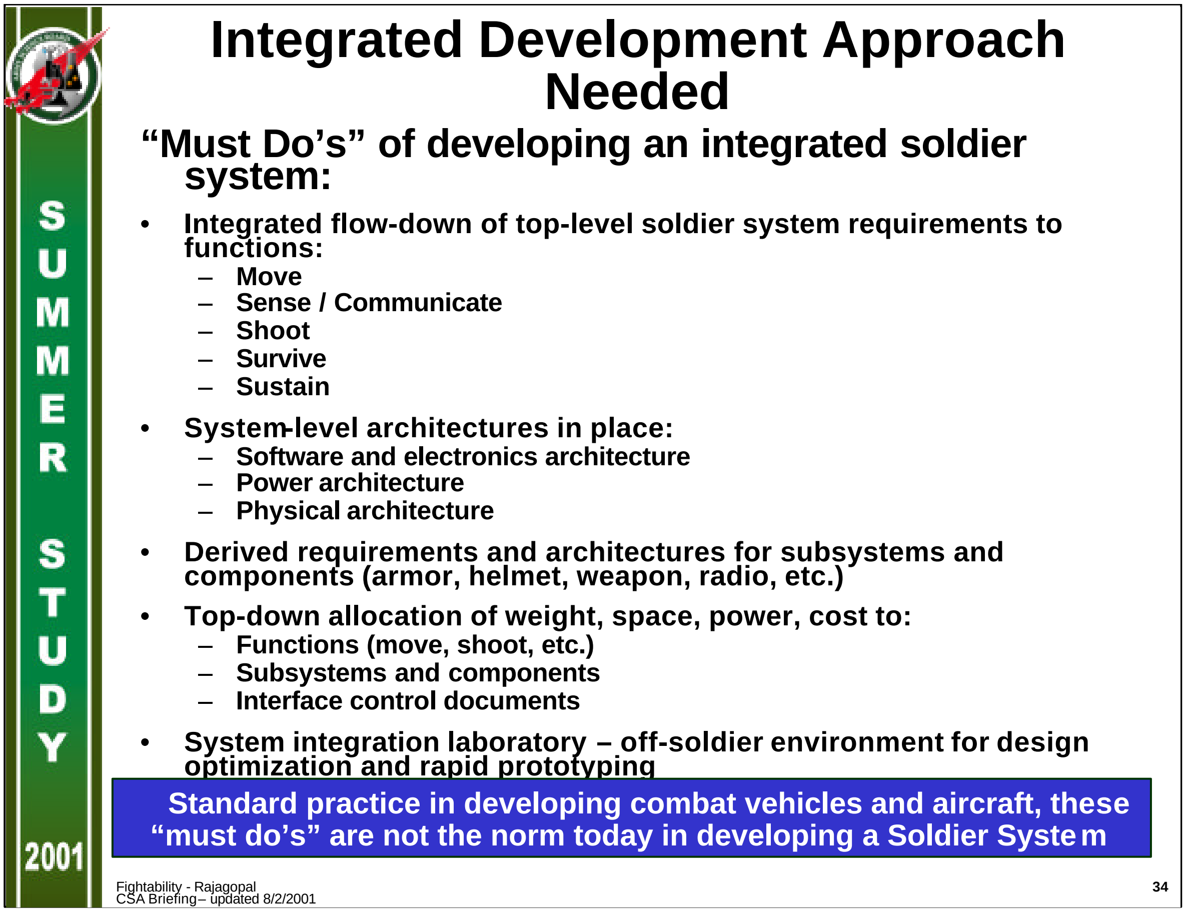
Today's soldier is not that much different from the World War II soldier; he is a stand-alone warrior with limited body armor. His weapon may have greater killing capability but is still limited by what the soldier can see enhanced by night vision. He is disconnected from the beyond line of sight fighting force and must rely on his senses for situational awareness and survivability. There is only one person in the squad with a radio to communicate with peers and upper echelons.

Key Technologies:

The technical capabilities highlighted in the ovals can make significant impact to the fightability in the midterm. The technologies shown in the orange ovals were briefed earlier in this executive presentation. The detailed quad charts for the technologies shown in the gray ovals are available in the full briefing. The position of the technology relative to time is approximate as the Technical Readiness Level is highly dependent on the funding augmentation. In order to meet the Objective Force requirements, this additional funding must be launched in 2002.

The Future:

By successfully implementing these key technologies as they mature and are available, we are moving toward a fully connected soldier who is supported with responsive, networked fire sources that are dispersed. There will be near perfect situational awareness with a significantly reduced timeline depending on the degree of automated knowledge extract vs "analysis in the loop" effort. This 10x capability offers greatly reduced exposure for the soldier, while decisively improving his effectiveness by providing him with the knowledge and support to take the right action at the right time, every time.



Current Situation:

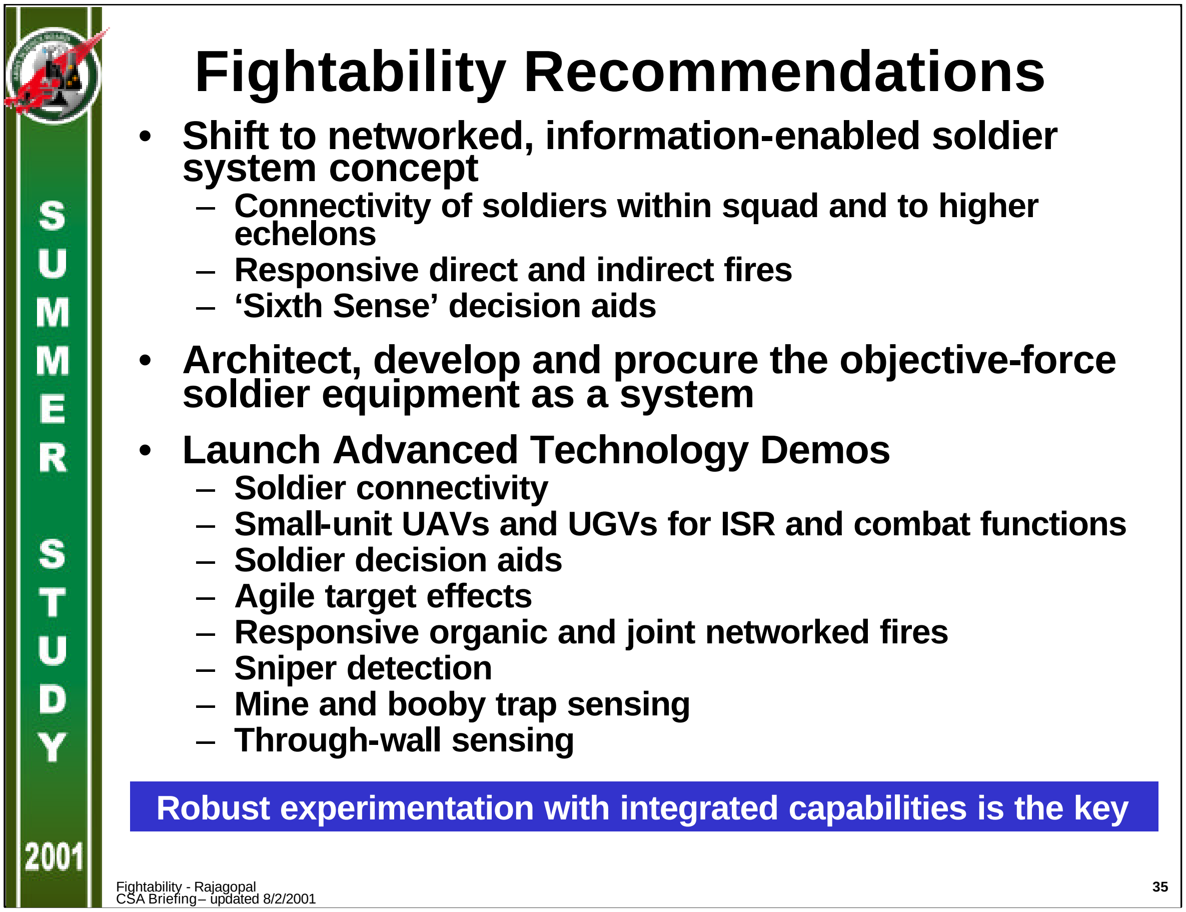
Today the phrase "soldier system" is a misnomer -- the soldier's systems are designed and developed as a series of programmatic and technical stovepipes. There is no overall systems architect who resolves the performance, weight, power, and sustainability objectives for the warrior.

Key Technologies:

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, cost can be assigned to the subsystems and components through a series of individual, yet integrated, interface control documents.

The Future:

Standard practice in developing combat vehicles and aircraft, these "must do's" are not the norm today in developing a Soldier System. The Systems Engineering will implement a System integration laboratory which will support spiral development of technology in an off-soldier environment for design optimization and rapid prototyping. The integration facility will support a development cadence that allows the Army to incorporate commercial advances in technology in a rapid refresh manner

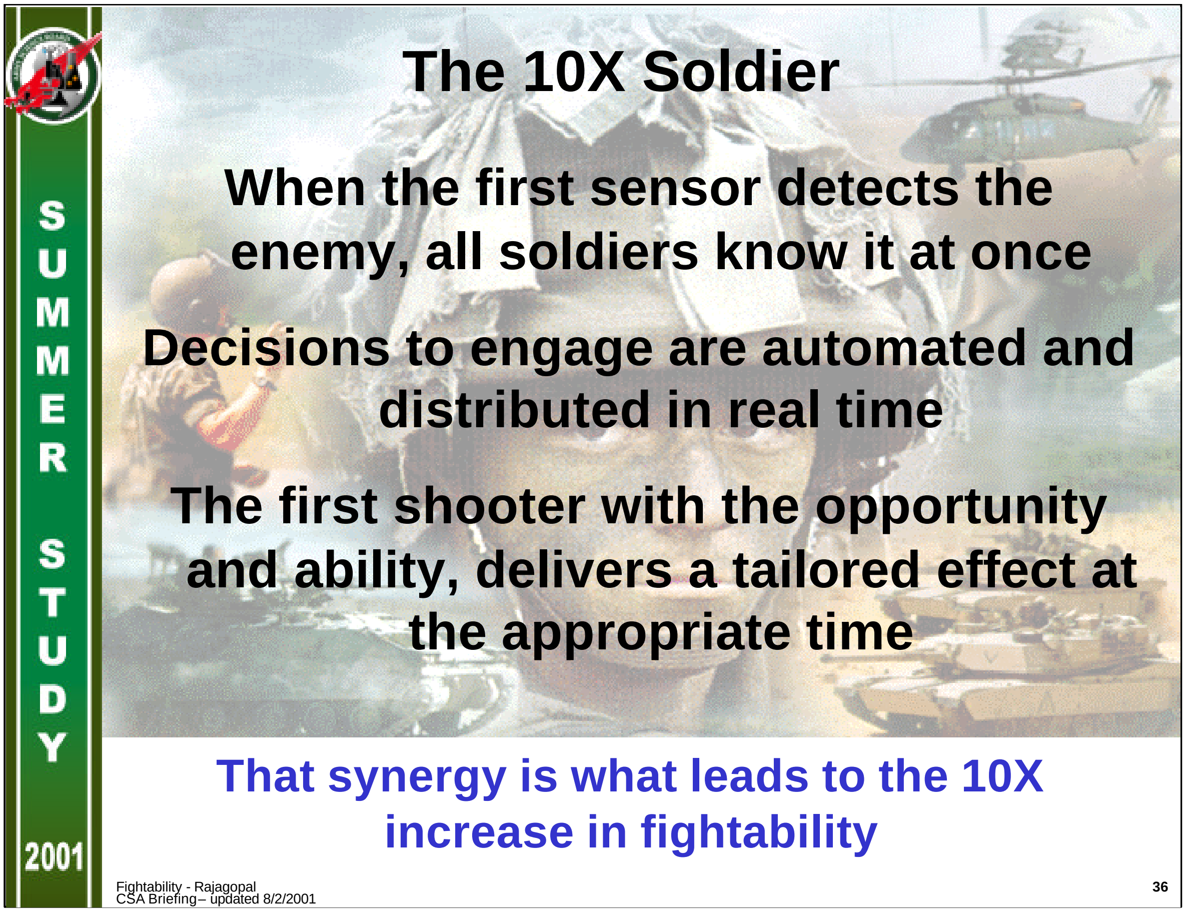


Recommendations: The panel recommends a three-pronged approach to the development of advanced fightability technologies.

First, the Army must understand, and accept into the doctrinal process, the notion of a intelligent network-centric approach to dismounted warfare. This is analogous to the process that the Army used in developing the approach to the network centric concepts for the FCS. Once this high-level concept has been accepted, it will set the framework within which the detailed requirements for the material solutions can be derived.

The panel recommends the creation of a PEO or PM position with overall architecture and acquisition authority to which all soldier system programs will report. This office should have complete oversight of all soldier systems, and a direct linkage to the objective force systems-of-systems programs (to include the FCS). The office should have the authority to perform systems trades across all materiel solutions that affect the individual soldiers. In addition, the office should also have oversight for all S&T initiatives that involve soldier systems.

The resulting S&T technologies should be investigated and extended through ATDs focused on individual components and as feeders into integrated ACTDs. Robust experimentation with integrated capabilities is the key to a successful system-of-systems program for the dismounted soldier.



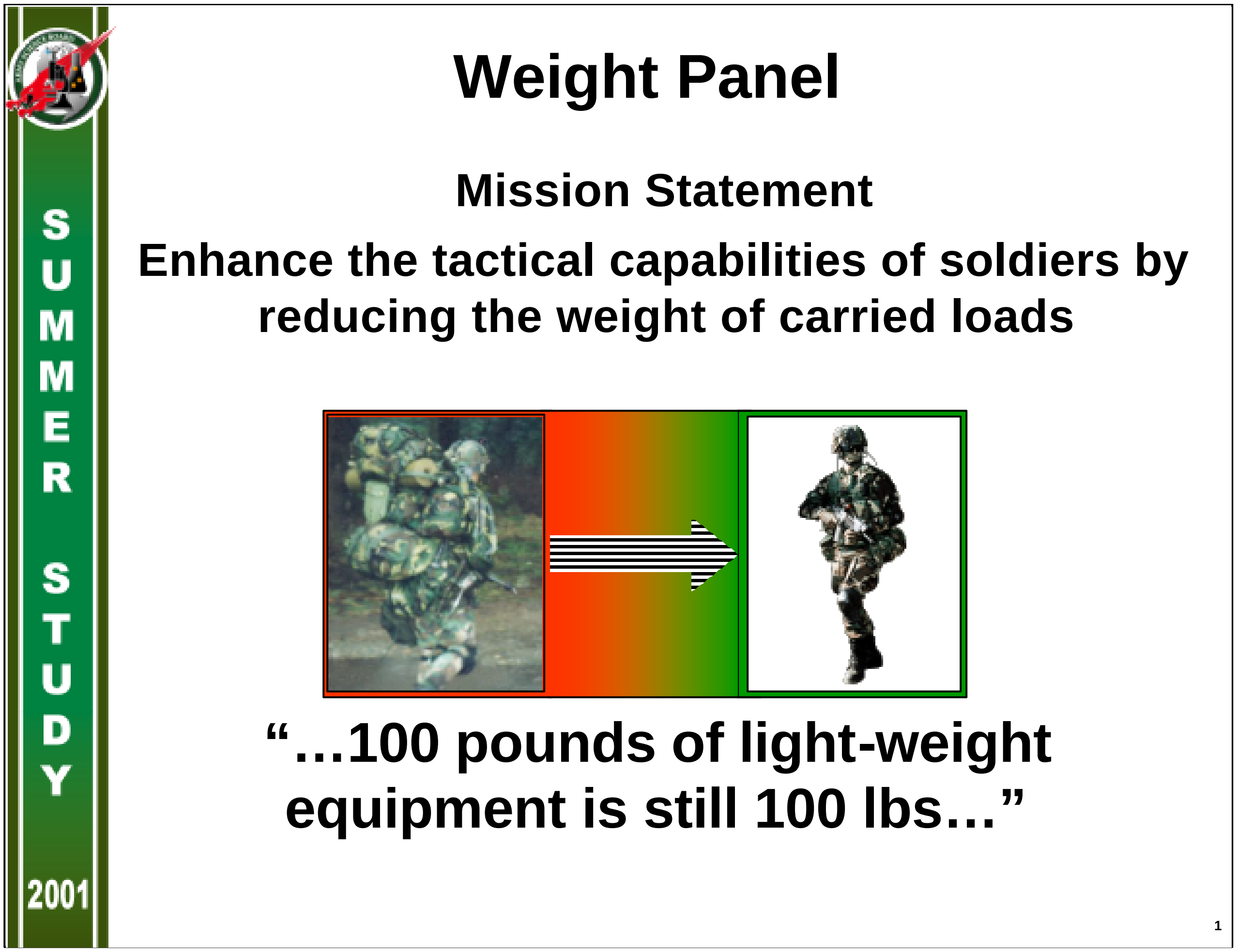
The Soldier of the Objective Force era will gain the benefit of a rich information environment that has been turned into critical knowledge which can be accessed by the soldier in a timeframe that allows his performance to be an order of magnitude or more over the current soldiers. This is accomplished by enabling a C4ISR network that provides assured, continuous connectivity to the soldier and to the knowledge sources the soldier needs to accomplish his mission. This means the soldier will have immediate access to the sensor information relevant to his activity. With this information, the soldier can "pick and choose" his engagements and "call" for the supporting organic or Joint supporting fires which will enhance his lethality by an order of magnitude, while at the same time enhancing his survivability by often allowing him to avoid situations or engagements that expose him to hostile fire, mines or booby-traps.

This **Knowledge** rich, **Network** connected, and **Lethality overmatch** combination will both deter engagement by hostile forces and provide an entirely new range of combat operations that the soldier can undertake with bounded risks.

In a network-centric battlefield, the "sensors" that detect the enemy can be humans or electronic systems, organic, legacy, or joint.

Decisions are made in a distributed environment, collaboratively between humans and automated systems that aid humans in critical decisions and make decisions autonomously where the outcome is less life-or-death.

The shooter that responds can be soldiers on the battlefield, robots, automated air or ground vehicles, or loitering attack munitions. The dial-a-kill ability can tune the weapon effect to achieve the commander's intent.



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 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.

Weight Panel

SUMMER STUDY 2001

Panel Participants

Mark Hofmann, Chair (ASB)
Tony Tether, (ASB)
Michael Krause (ASB)
Don Wajda, Government Advisor (NSC)
Don Woodbury, Government Advisor (ARL)
Ed Doucette, Government Advisor (NSC)
Tom Conway, Government Staff Assistant
Erik Wright, ASB Cadet Intern

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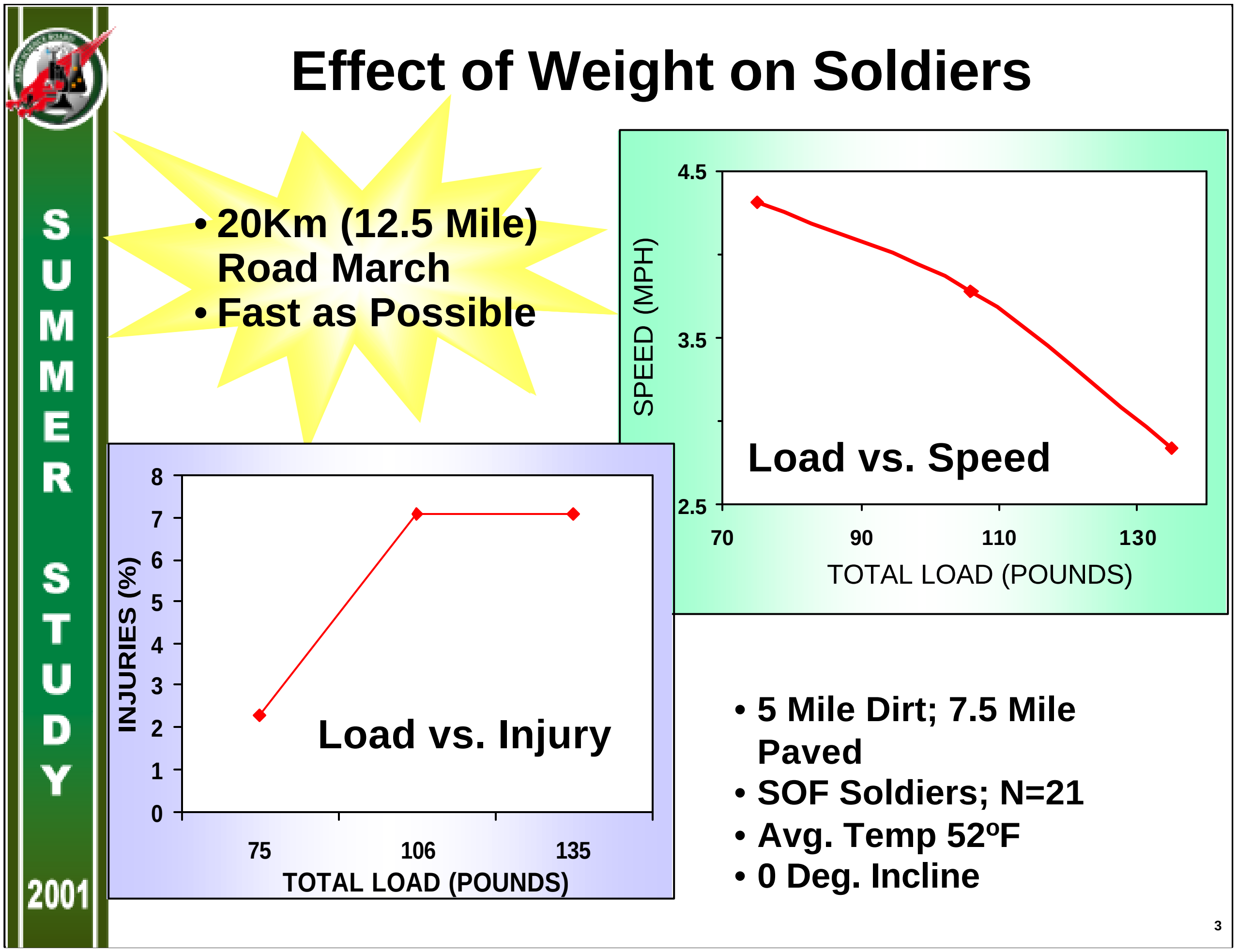
Panel Membership

The Army Science Board was fortunate to be able to gather a very knowledgeable group to grapple with this age-old issue. The members brought a wide range of experience and technical expertise to the topic at hand.



Effect of Weight on Soldiers

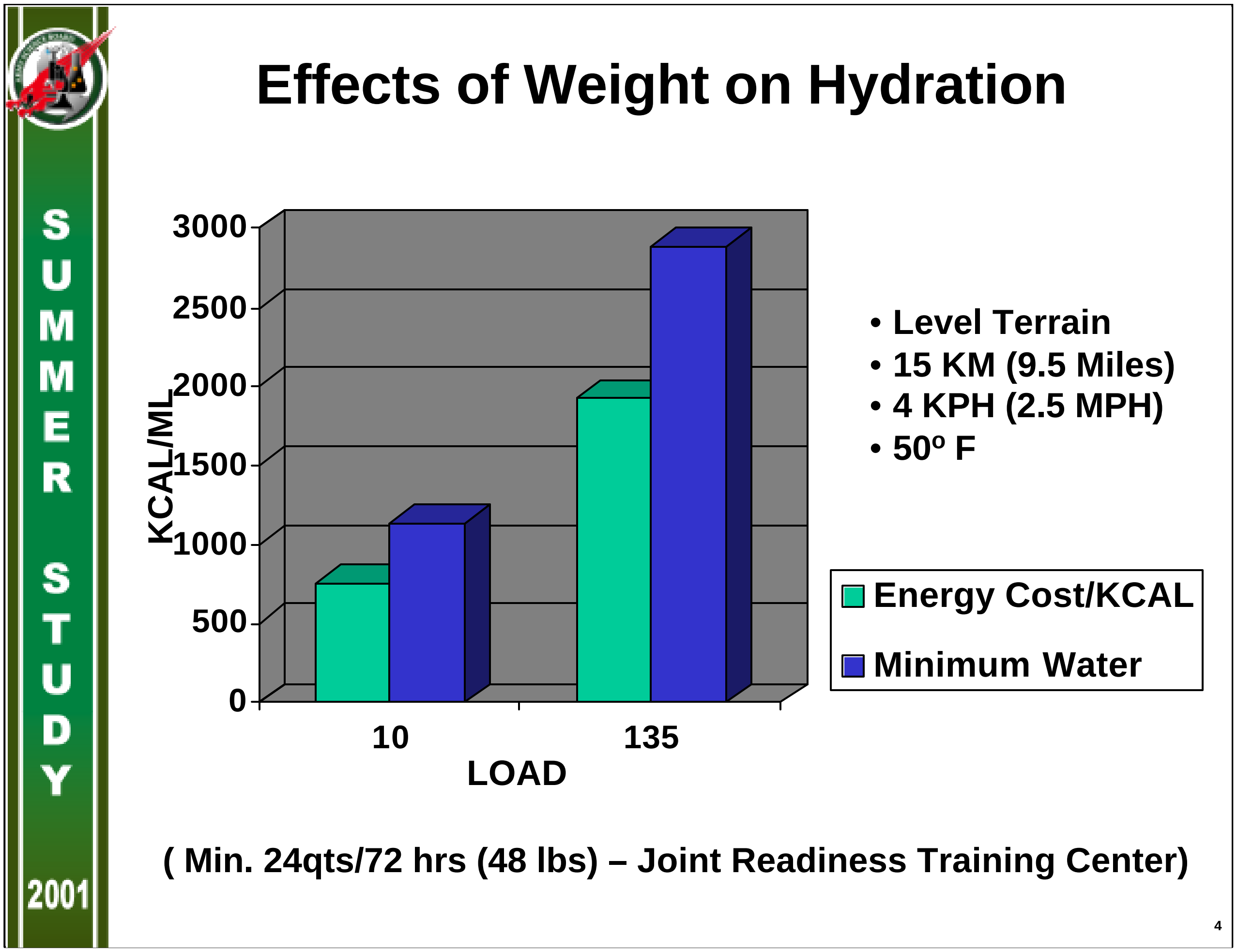
Weight affects the dismounted soldier in three primary areas: mobility, readiness, and sustainability. With respect to mobility the upper right hand quadrant of this chart shows a somewhat linear relationship between weight and speed. Increasing carried weight from 75 pounds to 135 pounds slows the average speed by 30%. This in turn adds 1 1/2 hours to a 12.5 mile march over flat terrain with a surface of dirt (5 mi.) and pavement (7.5 mi.)

Aside from this serious decrease in mobility, readiness is also adversely impacted through injury and fatigue. The lower left quadrant of this chart shows the same weight increase more than tripled the percentage of march-ending injuries.

If these data are representative of what might be expected across the warfighting force they represent a significant impact on force mobility readiness. In all likelihood, they are conservative in what might be expected because the participants were well-conditioned and motivated soldiers from the Special Operations Forces.

Report # T 14-93

U.S. Army Research and Development Command



<u>Effects of Weight on Hydration</u>

Hydration is another area impacted by increased loads. As carried loads increase, body energy expenditures increase and water requirements go up to maintain thermoregulation. Increased water demands impact sustainability and logistics. If hydration requirements are not met readiness is adversely affected because dehydration results in fatigue, dizziness, nausea and coma. These effects not only reduce soldier effectiveness but also burden the medical support system.

The above chart shows that going from the weight of clothing 135# at a slow pace over flat terrain in a moderate temperature can more that double the water uptake over a 9.5 mile march.

Soldier hydration requirements pose a severe weight burden for the individual soldier when one considers the Joint Readiness Training Center Recommends 24 quarts of water (48 #) for a 72 hour mission in hot weather. The logistics systems is also affected by hydration requirements. The Quatermaster Center and School reports that 106 of 245 tons of daily sustainment for the interim brigade will be water.

Solutions to Soldier Carried Weight

The panel arrived at several potential solutions to the weight problem. These solutions were to **Offload**, i.e. get rid of the carried weight via some means of auxiliary carrying 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.

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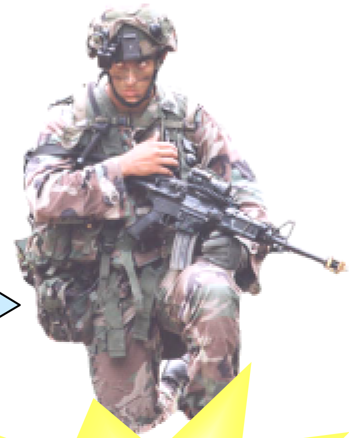
Typical Soldier Load
Land Warrior (v0.6)

DRAWERS/T-SHIRT	0.4
BDU & BOOTS W/SOCKS	9.1
MODULAR LOAD SYSTEM	5.3
INTERCEPTOR BODY ARMOR	16.4
1 QUART CANTEENS (2)	5.9
PATROL PACK	2.1
JOINT SERVICE LIGHTWEIGHT INTEGRATED SUIT TECHNOLOGY	9.6
M45 NBC PROTECTIVE MASK	4.1
MODULAR WEAPON SYSTEM W/ 30 ROUND MAGAZINE	7.4
6 X 30 ROUND MAGAZINE	6.0
GRENADES (2)	2.0
BAYONET WITH SCABBARD	1.8
CLOSE COMBAT OPTIC	1.4
THERMAL WEAPONS SIGHT	4.9
AN/PAQ-4C AIMING LIGHT	0.6
DAYLIGHT VIDEO SIGHT	0.2
IMPROVED HELMET	3.2
HELMET MOUNTED DISPLAY w/ INTEGRATED IMAGE INTENSIFICATION	1.5
COMPUTER RADIO SYSTEM	1.8
SOLDIER DIGITAL INTERCOM W/ GLOBAL POSITIONING SYSTEM	2.5
SOLDIER CONTROL MODULE	0.4
LASER DETECTOR	0.1
BATTERIES	4.0
CABLES	1.3



Net Equipment Weight: 92 lbs.

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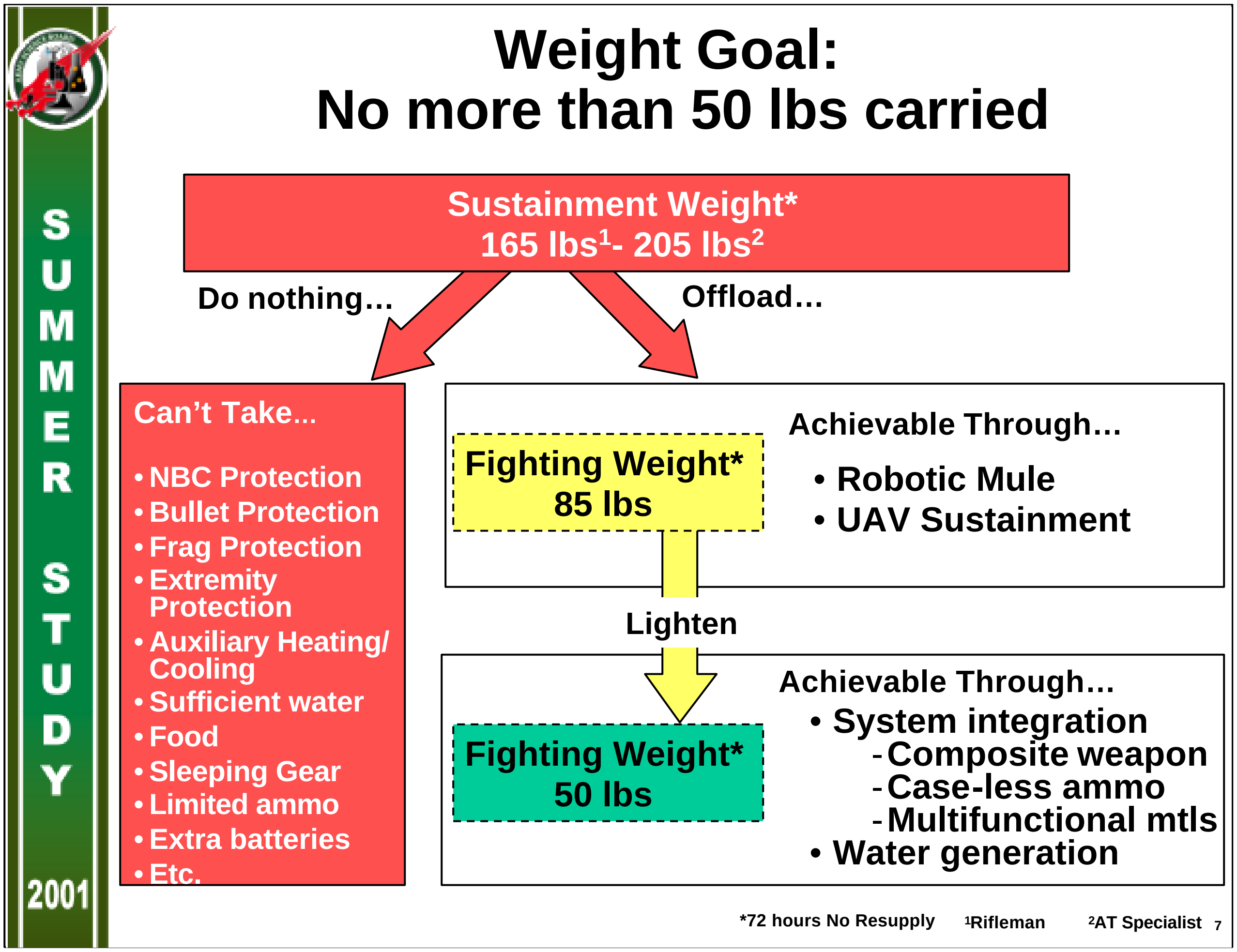
<u>Typical Soldier Load</u>

The component break-out of Land Warrior version 0.6 illustrates the typical load that a soldier carries. While many of the items carried are not, in and of themselves, a significant weight burden, in the aggregate they add up to 92 pounds.



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. The physiological, biomechanical, and kinematic considerations, were established back in the 1800s, and revalidated time and again since then. Fifty pounds equates to approximately 30% of the body weight of an average soldier (170 pounds). Fifty pounds is an upper limit for mobility and agility needs as well as physiological considerations.

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.

Robotic Mule

Offload Opportunity

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Operational Need

- Readily Available R...

Offload Opportunity

Operational Impact

- Reduced soldier load (min 80 lbs)
- Reduced squad load (min 720 lbs)
- Increased Mobility
- Potential Platform for comms relay, sensors, weapon, battery recharge, water generation

Technology Investments

- Improved All-Terrain Vehicle
- Robotic, semi-autonomous ground vehicles
- Robotic fully-autonomous ground vehicle

Technology Assessment for TRL 7

Solutions	Near	Mid	Far
Improved ATV	(hatched)	G	G
★ Semi-autonomous	(hatched)	G	G
Fully-autonomous	R	R	(hatched)
To Achieve the Capability	(hatched)	G	G

★ - Critical G -Adequately funded; -Opportunity with D funding; -Cannot be done

8

Robotic Mule

The first offload opportunity to be presented 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 implementation approach could start in the near term with improvements to the manned all terrain vehicle being used by the 82nd. This would entail providing a rudimentary autonomous capability. Greater semi-autonomous mobility could be achieved with increased funding by accelerating importing appropriate 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.

The robotic mule for the objective force soldier will have far more capability than the current manned all terrain vehicles. The robotic mule will be intelligent enough to know which soldiers it is assigned to and to take verbal directions. It will go where it is told to go and take care of its own refueling. Off road, it should be able travel at least 20 mph, negotiate 60 percent forward and side slopes, cross a four foot wide ditch, and recognize impassable terrain at least as well as a human.

Considerable progress already has been made toward achieving these capabilities. The DARPA DEMO III Reconnaissance, Surveillance, and Target Acquisition (RSTA) robots built by GENERAL DYNAMICS Robotic Systems (GDRS) show considerable ability. Funding opportunities exist to accelerate this much needed capability

Sustainment by UAV

Offload Opportunity

SUMMER STUDY 2001

Operational Need:
- On-time power, w **Offload Opportunity** food resupply
- Ground and air launch capable

Operational Impact:
- Reduced soldier load (min 80 lbs)
- Reduced squad load (min 720 lbs)
- Increased mobility
- Potential platform for remote sensors and weapons

Technology Investments:
- Low cost, payload-oriented UAVs
  - -Powered parafoil
  - -VTOL
- High horsepower, aero JP8 engine technologies
- Intelligent resupply system

Technology Assessment for TRL 7

Solutions	Near	Mid	Far
★ Payload UAV	(hatched)	G	G
JP8 Aero Engine	R	(hatched)	G
Intelligent Resupply	R	(hatched)	G
To Achieve the Capability	R	(hatched)	G

★ - Critical G Adequately funded; Opportunity with D funding; R -Cannot be done 10

Sustainment by UAV

Another opportunity for offloading and a complementary option 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. An organic capability that is transportable and launchable with existing vehicles. 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. Technologies being advanced in powered parafoils and rotary wing UAVs, integrated with soldier communications advanced technologies, could provide the core of the required capability. The technical feasibility of a powered parafoil, resupply UAV is being proven in the SOCOM PSYOPS Leaflet Delivery System (LDS) program currently in development suggesting the potential to meet the following requirements:

- 300-600 lbs total payload capacity in 6-12 separate configurable packages
- 300 km range, 8 hour loiter time

- 10-20 meter CEP accuracy
- Airdrop and ground launch (HMMWV assist) capable
- HMMWV transportable
- Return recovery of airdrop vehicle for reuse
- Multiple DZs from single UAV system

Using this approach the Objective Force Warrior on a 72-hour mission will be directly resupplied his required sustainment loads by parachute delivery from a loitering UAV, when called for, with a ten meter circular error probability (CEP), and delivered from organic units or Air Force cargo aircraft with a 300 km stand-off. In addition, the UAV serves as squad airborne sensor scout while loitering w/ addition of appropriate sensors, and it could provide a squad leader-controlled low cost, precise delivery and emplacement vehicle for ground sensors and munitions.

Recommendations:

1. Advance concept by increasing funding for Joint Army/SOCOM advancement in key technologies required for heavy payload UAVs meeting Army operational needs (powered parafoil and rotary wing).

2. Include in Objective Force Warrior (OFW) O&O development and include as part of OFW S&T Initiative.

SUMMER STUDY 2001

Lightweight Integrated Soldier System

Lighten Opportunity

Operational Need:
- Lightweight, optimally integrated soldier system

Operational Impact:
- Reduced fighting load (~30 lbs)
- Improved fightability
- Extended mission time
- Enhanced protection from emerging threats

Technology Investments:
- System Technology Integration
- Multifunctional materials
  - Electro-textiles
  - Nanotechnology
- Lightweight composite materials
  - Weapon system
  - Body armor

Technology Assessment for TRL 7

Solutions	Near	Mid	Far
★ System Integration	R	(hatched)	G
★★ Multifunctional Mat.	R	(hatched)	G
Ltwt Composites	R	(hatched)	G
To Achieve the Capability	R	(hatched)	G

★ - Critical; G - Adequately funded; (hatched) - Opportunity with D funding; R - Cannot be done

12

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 several key technologies and through "smart' integration of these technologies into an efficient system. As such, efficiencies in weight reduction can be achieved throughout the major Soldier System domains of Lethality, Survivability, Sustainment, C^4IS/R and Mobility. The following key areas for technology investment were considered in our review of lightening the soldier system:

- Breakthrough, Lightweight Power Sources
- System Technology Integration
- Multifunctional Materials
- Lightweight Composite Materials

Although Breakthrough, Lightweight Power Sources were noted as a key area, they were appropriately left to the Power Panel to investigate and make recommendations. Our findings on the remaining key areas are as follows:

System Technology Integration: The overarching goal of the Objective Force Soldier is to provide a fully integrated, modular combat system of systems with significant operational enhancement compared to Land Warrior version 1.0, and to achieve this with a significant decrease (by ~30 lbs.) in the overall system weight. The recommended approach involves smart integration of modular, plug-and-play components to not only add enhanced capabilities to the individual soldier, but also to make full use of the team concept of operation, where each soldier may have unique capabilities within the team that contribute to the overall synergy of capabilities across the team. In fact many of the Objective Force Soldier capabilities should not be considered stand-alone, but should be designed with interrelationships in mind to provide the tactical synergy and revolutionary capability we seek. Some specifics include:

- Synergy of force capabilities via scalable networked team linkage with Objective Force platforms
- Distributed Fire Control within team and with OF platforms providing overmatching lethality for all warriors
- Netted warriors and small units to achieve synergy via real-time shared situation understanding
- Human interface devices optimized for effective cognitive performance

A holistic, systematic approach to designing the body-worn system, to include protective clothing and headgear, load carriage equipment, integrated electronics/components, and other mission essential equipment is expected to yield a 10-15% weight savings. Beyond just weight reduction, a holistically designed system will be more fightable as it will be designed with the soldier at the center, optimized for human use and performance, rather than expecting the soldier to adjust to new equipment as it gets attached to an already unwieldy equipment set.

Multifunctional Materials: Advanced, multifunctional materials technology can significantly reduce the weight of the Objective Force Soldier. Much of the soldier system emphasis has tended toward integration of the system level components, but efficiencies can also be achieved through integration at the material level. Full spectrum, "smart" integration of embedded electronics, antennae, and body-worn LAN will reduce weight associated with power supplies, cables, and connectors. Additionally, integrated, individual protection approaches through advanced multi-functional materials will also contribute to significant system weight reduction in environmental and biological, chemical protection. About 25-30% of the total system weight reduction can be realized using these approaches.

Lightweight Composite Materials: Two of the heaviest components of the soldier system are the weapon systems and the protective body armor. Through advancements in composite materials technology, significant weight reduction in body armor, weapons and munitions can be achieved. The overall weight of body armor is a function of the selected material and the design/area of coverage of the protective layer. There is an existing Science and Technology Objective (STO) effort relative to lightening the weight of body armor that has a goal of 30% reduction in areal density weight which translates to a decrease of ~5 lbs for the material layers of the armor.

Nanotechnology is a novel approach to structuring materials at the near molecular level that results in materials with greatly enhanced properties for a given weight relative to their conventionally structured counterparts. Since we are at the early stages of the nanotechnology revolution, widespread application to the weight issues of Objective Force Soldier will likely not be possible. Regardless of the source, composites materials are applicable to many parts of the Objective Force Soldier System, including the ballistic protective plates and the weapon system. These approaches can significantly decrease the weight of the ballistic plates (~ 25%) and the weight of the weapon system (~20%).

SUMMER STUDY 2001

Water Purification & Generation

Lighten Opportunity

Operational Need:
- Water in all environments

Operational Impact (72hr):
- Reduced soldier load
- Water transportation weights are reduced (~432 lbs/ squad)
- Reduced logistics for water resupply

Technology Investments:
- Water Purification
- Squad level water generation

Technology Assessment for TRL 7

Solutions	Near	Mid	Far
Purification	(hatched)	G	G
★ Squad level water generation	(hatched)	(hatched)	G
To Achieve the Capability	(hatched)	(hatched)	G

★ - Critical; G Adequately funded; (hatched) Opportunity with D funding; R -Cannot be done 15

Water Purification & Generation

Water is one of the heaviest and most critically required commodities to keep the worlds most potent weapon, our soldiers, functioning. A 4% deficit in water as a function of body weight (2-3 qts.) reduces performance by 45%. Current procedures call for the individual soldier to carry 6 qts. or 12 lbs. of water as part of the fighting load for a 72 hour. This represents 1/3 of the total requirement recommendation by the Joint Readiness Training Center of 18 qts. (36 lbs.) for the same mission time conducted in hot weather. Operationally, the remaining 2/3 of the water requirement must be gained from the local terrain. Comparing the absolute need for water with the projected water availability world wide, the industrial pollutants found in water and chance of desert of operations emphasizes the need to expedite water purification and generation technologies.

With an increased investment, improved filtration technologies can be made available in the near term, which will remove viruses, bacteria, and bacterial spores, which pose a threat to the soldier's health and readiness. We must also consider the need to remove chemical contaminants from the water – whether they are industrial or military, so that water purification technologies become key to obtaining potable water. For mission areas where water is not available, water generation technologies will be key.

The most promising technologies in the near term involve increasing the amount of water available from internal combustion engines. However, for the dismounted soldier the return on this technology is not particularly high because at best making one gallon water requires combustion of one gallon of fuel. Therefore, even if a mule is available and powered in part by an internal combustion engine it will probably be of limited because of low fuel consumption. However, water generation from Future Combat System vehicles could be significant and a promising source if it can be distributed. Perhaps the distribution solution resides in the unmanned aerial vehicle.

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. Isothermal compression and super absorbent materials are two technologies that show promise.

Exoskeleton Assist Systems

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Assist Opportunity

Operational Need:

- Enable increased carrying capacity
- Enable greater mobility

Operational Impact

- Increased speed and strength Increased lethality
- Increased survivability (extremity protection)
- Increased weight carrying capacity

Technology Investments

- Compact/ efficient power
- Human motion actuators and controls
- Haptic interfaces and human motion sensing

Technology Assessment for TRL 7

	Solutions	Near	Mid	Far
★	Compact power	R	R	
★	Actuators/ controls	R	R	
	Haptic interfaces	R	R	
	To Achieve the Capability	R	R	

★ - Critical G Adequately funded; D - Opportunity with D funding; R -Cannot be done 17

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.

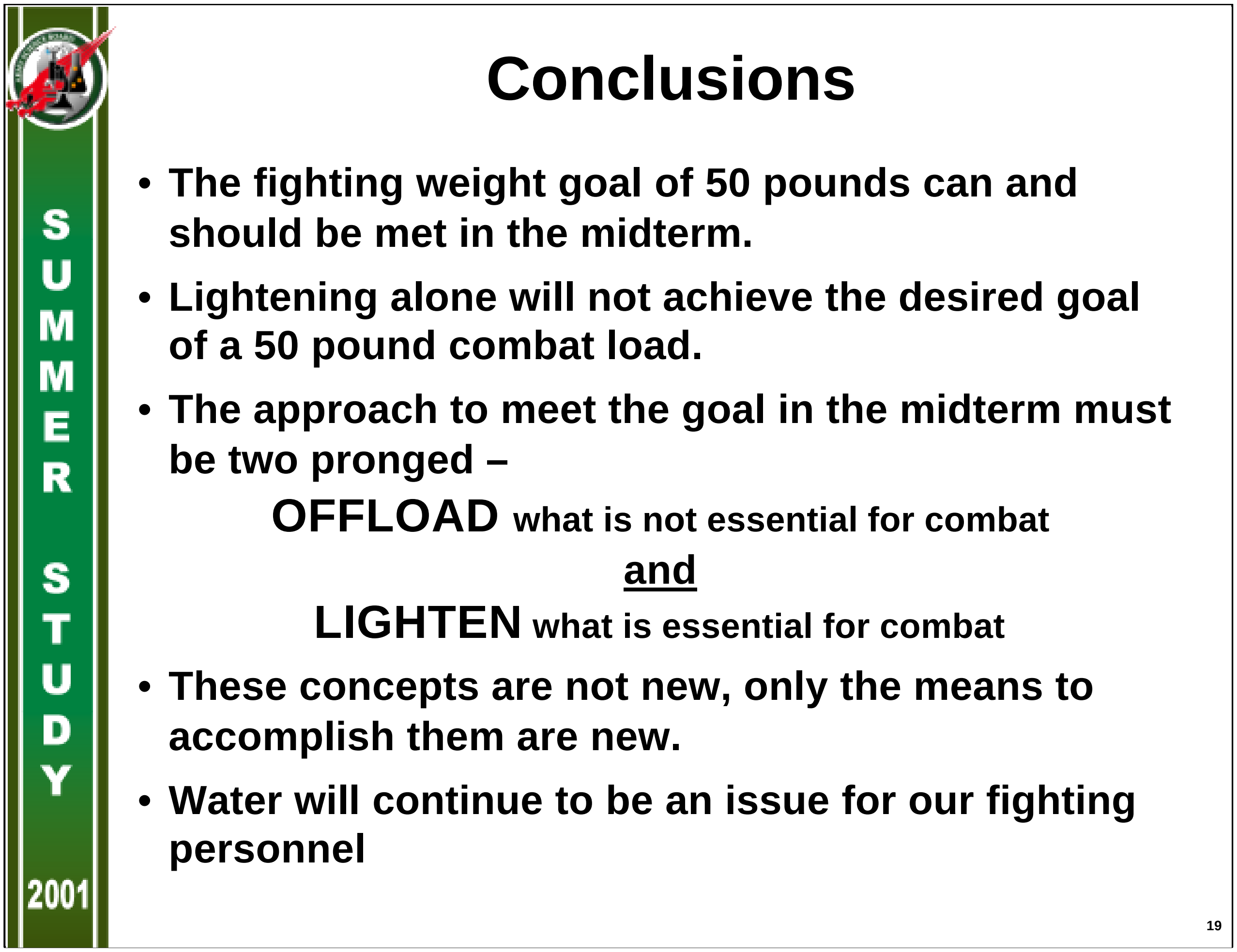
Through use of the exoskeleton system the objective soldier can carry larger caliber weapon – with greater lethality - using intelligent ammunition. The soldier will have greater strength and speed. He can "jump" obstacles. He can achieve better protection by the use of more – heavier – armor.

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.

Initial testing of lower extremity mobility enhancers are promising. Two powered legs with an integrated power unit and a back-back like frame are being used. The soldier is being assistyed in motion to squat, bend, swing from side to side, twist, walk and run on ascending and descending slopes, and step over and under obstructions.

Performance enhancement technology includes the controlled amplification of human motion and carrying capabilities. The Objective Soldier will wear a structure to increase motion and carrying capacity through an outer garment. There will be human motion sensing interfaces through haptic mediums.

In summary, there is no question that this is a high development risk concept. However, it probably has the highest mobility payoff of any concept so far suggested for the individual soldier in direct contact with the enemy. If an exoskeleton can be designed to conform to the soldier's body and constructed from body armor materials, there is potential in the concept for combining enhanced mobility with armor protection of the extremities. The exoskeleton effectively would become a modern, powered suit of armor, albeit one that enhanced its wearer's mobility and comfort rather than degrading them. It would combine much of the equipment the soldier must carry into an integrated warrior fight-ability enhancing machine.



Conclusions

The fighting weight goal of fifty pounds can be met and should be met.

The approach to meet the goal in the midterm must be two pronged –

OFFLOAD what is not needed to fight.

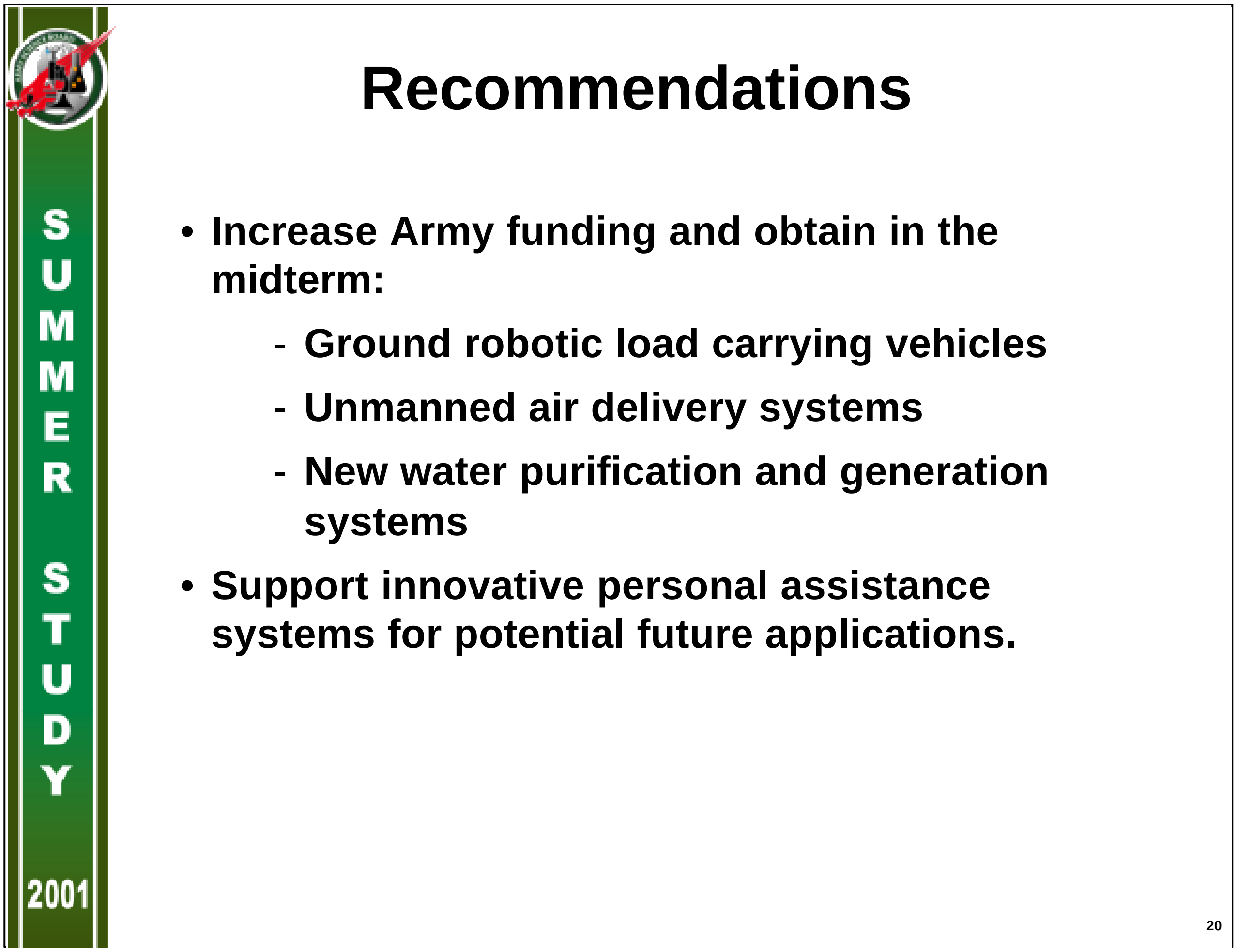
and

LIGHTEN what is needed for the fight.

These concepts are far from new, only the means two accomplish them are new.

Lightening alone will not work and has not worked.

Water has and will continue to be an issue for our fighting personnel



Recommendations

- Increase Army funding and obtain in the midterm:
    - Ground robotic load carrying vehicles.
    - Unmanned air delivery systems
    - New water purification and generation systems
- Support innovative personal assistance systems for potential future applications.

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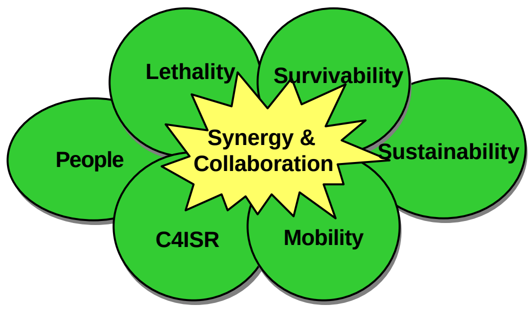
Bottom Line

- Solving weight issues significantly contributes to the vision of a 10X gain in effectiveness
- Solving weight issues enhances survivability, sustainability, mobility, lethality, C4ISR and soldier endurance



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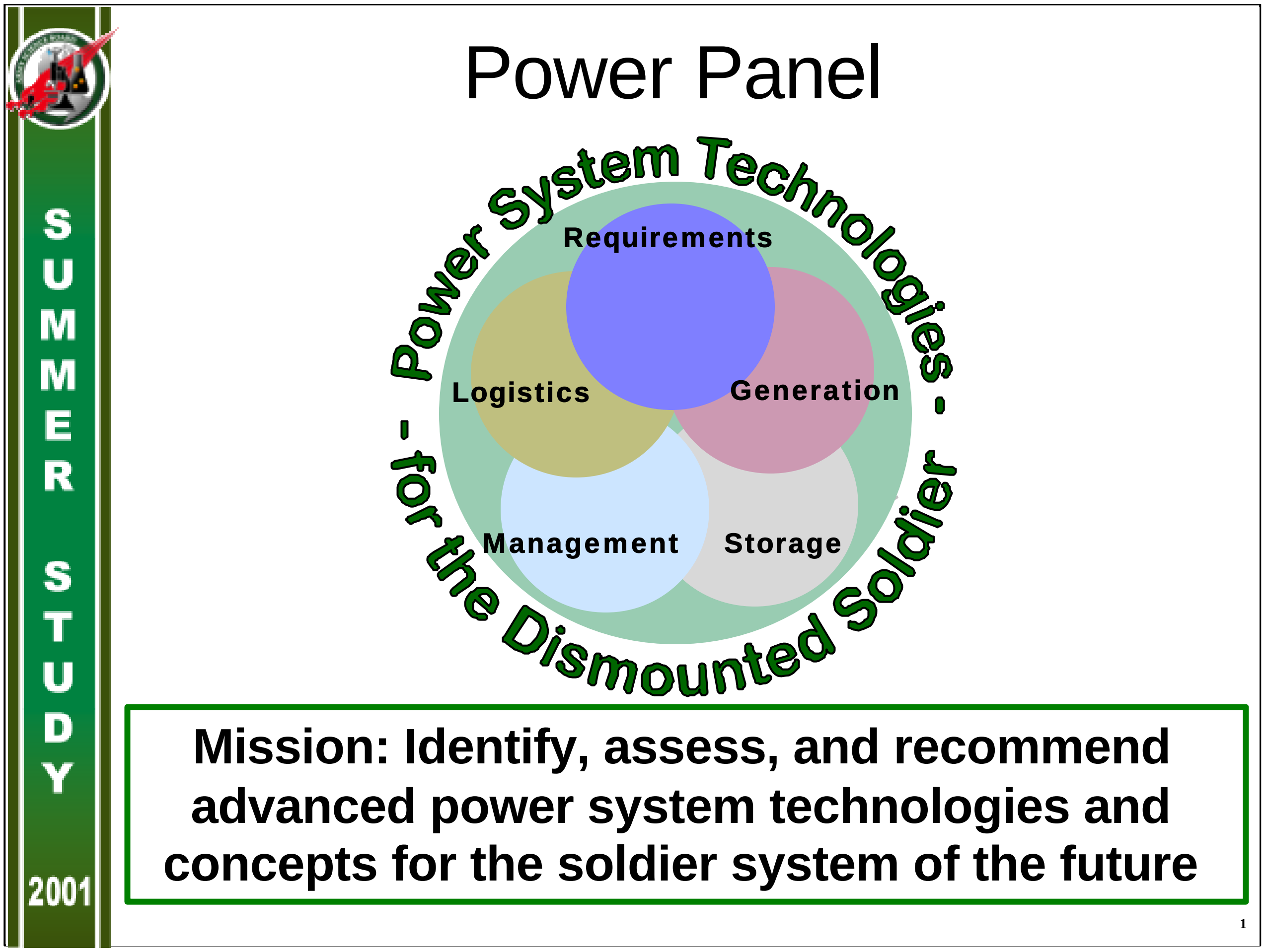
The Bottom Line

The bottom line is that weight reduction in synergistic with the "ilities" before you thus producing more of a positive effect than might other wise be expected. This concludes my remarks and I will be followed by Dr. Herrera who will discuss the all important issue of power on the modern battlefield.



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.

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Contributors to this panel report are listed above. The panel members, consisting of ASB members and consultants, provided a multidisciplinary team for the panel's deliberations. The diversity of the team assured that consensus was achieved with a wide spectrum of perspectives. The government advisors from Natick, ARO/ARL, PM-Soldier and TSM-Soldier provided key information on requirements, systems, and research programs. They were invaluable in assuring the completeness of the study. The staff assistant, LTC Tom McWhorter, supported the study in many ways and provided an important TRADOC perspective. CDT Kevin Mattern, of Wake Forest University, our cadet assistant, greatly assisted LTC McWhorter and the panel members during the two-week effort at the Beckman Center.

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Power versus Energy

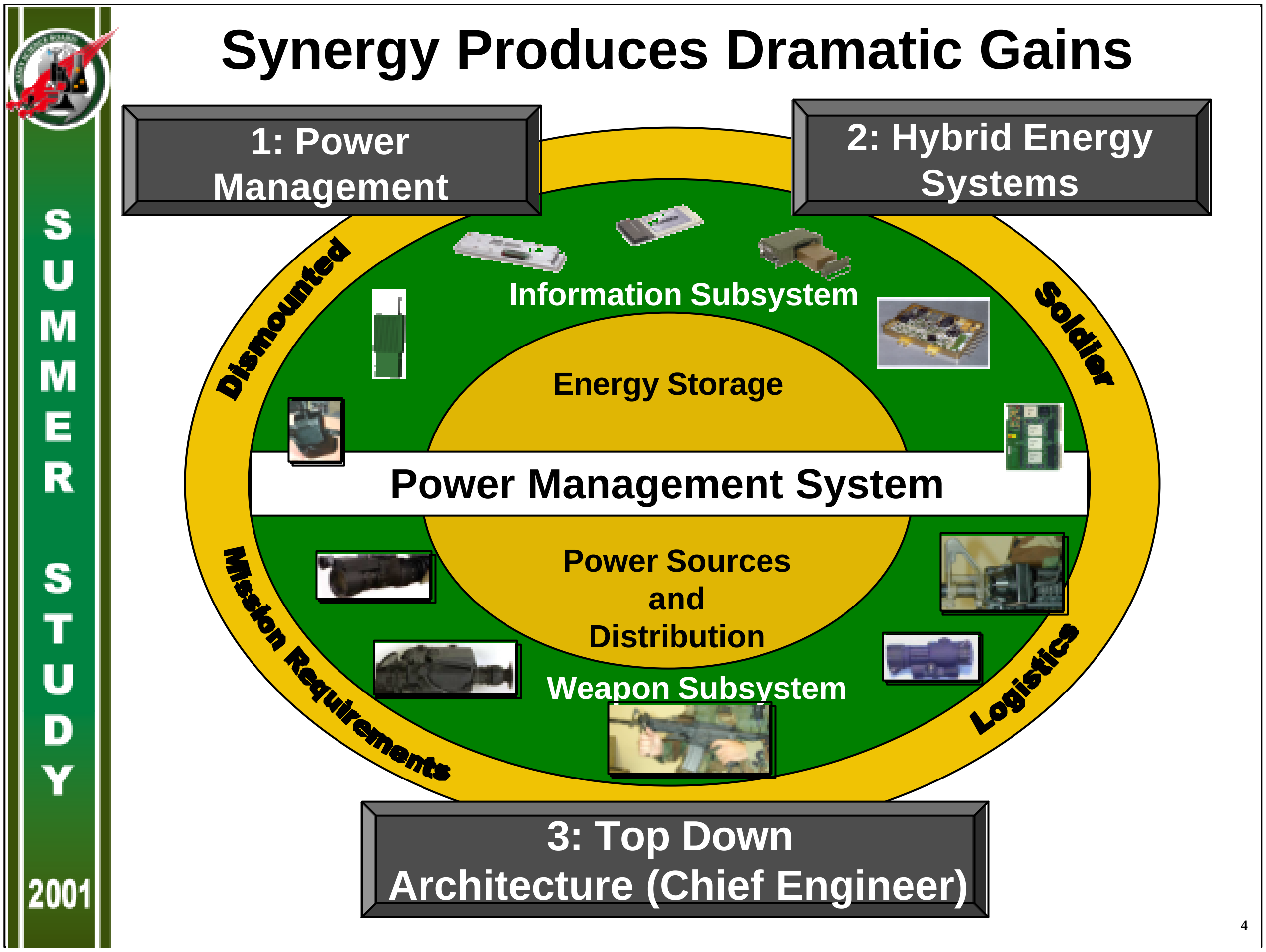
$$P = vi$$

$$e = \int P(t)\,dt$$

Energy is what you store
Power is the rate you take it out

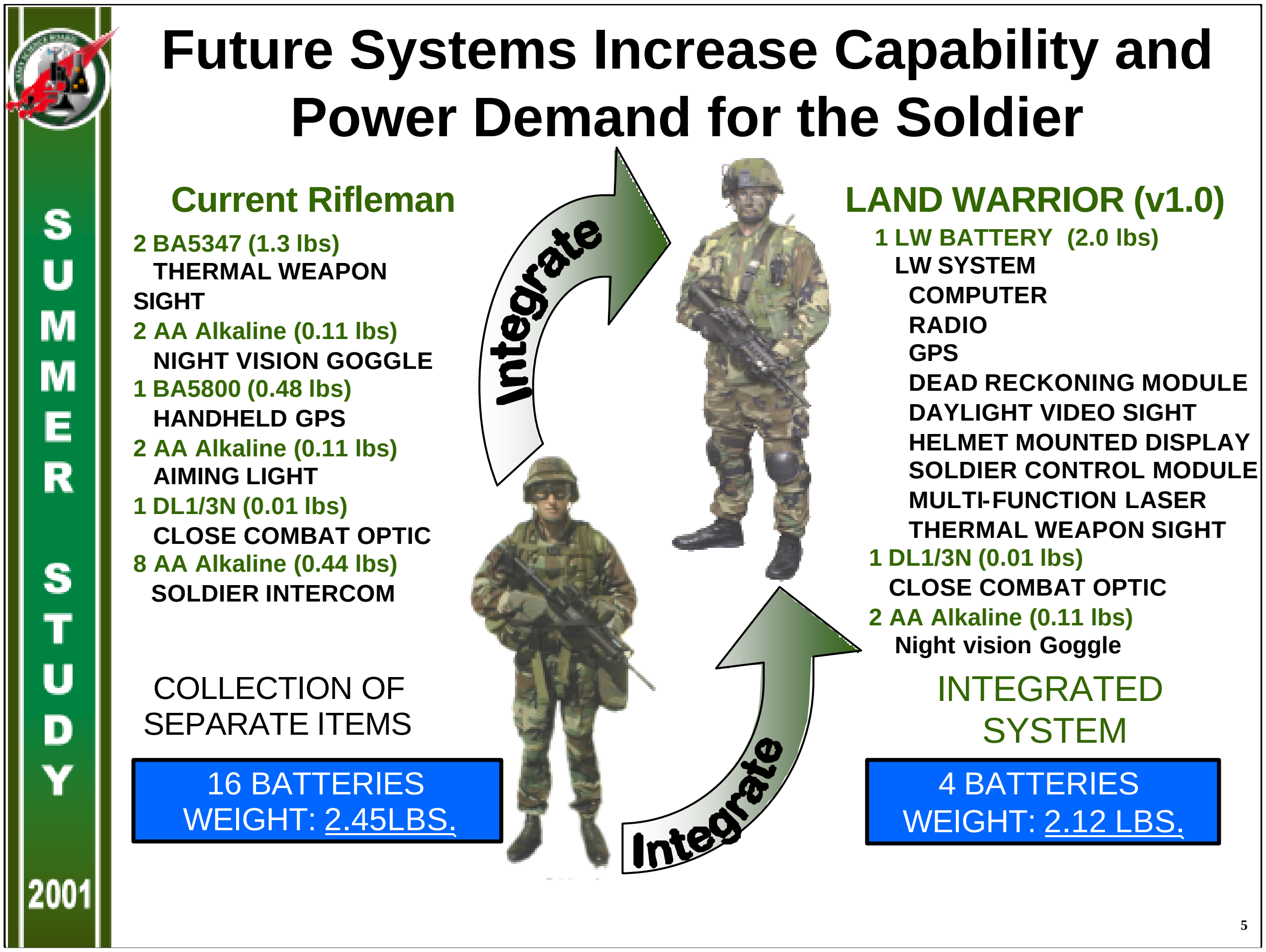
3

Power and energy are oftentimes regarded improperly as synonymous. It is imperative that the distinction between power and energy be maintained in the decision process affecting the power subsystem for the soldier system. Power is the measure of the rate at which work is done. Energy is the total capacity for performing work. Energy is stored in batteries, fuel, and other storage devices. Power is withdrawn from storage. Power is the rate at which energy is used to power devices such as computers, scopes, laser illuminators, night vision equipment, etc. One simile is that the fuel gauge of your automobile corresponds to the energy content and the tachometer corresponds to current power being produced by the engine. Frequently optimizing storage devices for efficient energy storage leads to systems with very limited capabilities to draw power from them. On the other hand optimizing on high power delivery capabilities frequently results in systems which do not store energy efficiently.



This chart represents a decomposition of the soldier system as it relates to power. Our study indicates that the major enabler for extending the life of these various sources of power will be a good power management system. That system will take the various soldier-worn devices and deliver power to them in such a way that the "energy drawdown" and the use of power for the various tasks that the soldier must do will be held to a minimum. The optimal implementation of power management for soldier electronic systems, judging by the degree of success that similar systems have had in the personal computer world, should give a factor of between 5 and 10 improvement over the ways that power is managed today.

Three themes were identified. First, power management is the most critical theme. Proper design and use of power management systems will extend the useful life of the components of the soldier system the require power, enabling the soldier to do more tasks because his sources of power will last longer in combat. Second, we have identified hybrid systems, consisting of rechargeable batteries and wearable rechargers as the recommended solution. Third, we see a need for a top-down architecture and chief engineer to ensure a pervasive systems engineering effort. We believe this will yield an optimum system design, incorporating power management considerations into the design at an early stage. The chief engineer should have the authority to assure the Army that power management will be properly done and that these principles of design are carried out through development. We believe that a chief engineer, with associated authority, is needed, since many of the design principles are now unfamiliar to many Army designers.



Today the current rifleman (equipped with the full electronics suite) carries 16 batteries of 4 different types weighing 2.45 pounds. This provides an interim successful mission capability. Land Warrior, Version 1 will carry 4 batteries of 3 types weighing 2.12 pounds. This will provide a 12-hour nominal mission capability. In addition, the Land Warrior will have available a computer, radio, dead reckoning module, daylight video sight, helmet mounted display, soldier control module and multi-function laser. The future Land Warrior will require a 72-hour nominal mission capability with increased functionality demanding power while decreasing the overall system weight by 20%. Clearly, the demand for power will always outpace the ability to provide it. Thus, alternatives to the power demand/supply race need to be found and exploited.

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Emerging Technologies

Mid-Term	Challenges
• Power Management	⇒ Systems Integration, Cost/Time
• Hydrogen/Air Fuel Cell	⇒ Hydrogen supply
• Direct Methanol Fuel Cell	⇒ Catalysts and membranes; size?
• Alternative fuels (e g,ammonia)	⇒ Safety, acceptance
• Heel Strike	⇒ Power density; power distribution
• Microchemical Systems	⇒ Chemical Modeling; materials/fab
• Microdiesels	⇒ Signatures, lifetime, efficiency
• Microcombustor	⇒ Materials, scaling, heat transfer

Far-Term	Challenges
• Microturbine	⇒ Materials, fabrication, reliability
• Mesoscale turbine	⇒ Bearings, efficiency
• Solid Oxide Fuel Cells	⇒ Materials, startup times
• Direct Oxidation HC Fuel Cells	⇒ Catalysts, heat transfer, materials
• Metal/air batteries	⇒ Materials, disposal, safety
• MicronGap Thermophotovoltaics	⇒ Basic physics, thermal management
• Biomimetic systems	⇒ Lifetime, interfacing
• 'Nuclear' batteries	⇒ Materials, disposal, safety

There are many emerging technologies with enormous potential

6

We have listed here some of the emerging technologies that are expected in both the mid-term (2007) and the far-term (2014), together with their associated challenges that the Panel expects they will present to implementing PMs and PEOs.

The emerging technologies judged to be critical for providing power to the objective soldier are listed in a table found near the end of this presentation with recommended funding increases above the baseline in the FY02 POM.

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Increased Funding For Critical Technologies in FY02 POM to Achieve TRL7

Technologies / Time and Funding Lines	NEAR TERM	MID TERM	FAR TERM	$ MILLIONS
Soldier Wearable Technologies				
Batteries				
• Militarize Rechargeable		G	G	8
• Next Generation Primary (LiM_nO_2)	R	R		5
Air Breathers				
• Zinc-Air		G	G	5
• Lithium- Air	R	R		3
• Hydrogen-Air PEM F/C		G	G	3
• Direct Methanol	R		G	7
Hydrogen Sources for F/C				
• Micro-chemical Reformers (for synthetic diesel fuel, methanol/ethanol)	R		G	10
• Solid Reactants	R		G	2
Small Engines and Turbine (20W)	R	R		4
Hybrid Power System Integration	R		G	5
Squad Level Technologies				
• Improved JP-8 Burning Engines and Turbine Recharger (1-3kw)	R		G	5
Solid Oxide Fuel Cells for JP-8				
• Recharger (1-3kw)				4
• "Mule" Power (~25kw)				4

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The table represents the panel's selection of enabling power generation and storage technologies to support the evolving ORD of the Land Warrior program. The table also includes an estimate of increases in S&T funding needed to achieve the objectives in a timely manner.

A detailed discussion of enabling technologies can be found in the notes accompanying the viewgraph entitled Power Generation and Energy Storage.

ASB Power Panel members can also be consulted regarding the estimates and assumptions.

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Future Power Requirements

- Like bandwidth and memory, the desire for power is insatiable
- Militarization of new power source technologies is challenging

- Proposed soldier capabilities require very high power

How much power is needed, for how long, and under what conditions

8

Power requirements must answer the question: How much power do you need, for how long, and under what conditions.?

With the Land Warrior, requirements were originally written to achieve ever-greater operating time between re-supply, and specified maximum allowed battery weight to meet this requirement. This was viewed as too restrictive to the design space, so more recent versions now specify a maximum allowed total system weight carried by the soldier for various mission durations. The trade-off between power source weight other items is made during the research, design, and development phase of the project.

The ASB's recommendation to develop squad-level battery rechargers immediately lightens the soldier's load. For most dismounted infantry, the "mule" - which will have a recharger on it - will never be far away, making the use of rechargeable batteries quite practical. Additionally, we recommend that battery rechargers be installed on HMMWV's and FCS.

For the infantry that has no mule or recharger readily available (for example, rangers and scouts), the ASB recommends developing a man-wearable hybrid system whose total weight does not exceed about 4 pounds for a 24+ hour mission. Additional fuel would extend mission duration.

Developing the hybrid system is challenging since it relies on using high energy-dense sources. In the case of hydrogen fuel cells, fuel must be "reformed" to capture hydrogen. In micro generators, fuel is burned in a combustion chamber. Such a wearable hybrid system would require significant engineering to accommodate the necessity for air, the management of thermal and sonic signatures, and other complications. A somewhat heavier alternative can be achieved more quickly using Zn-air instead of a liquid fuel.

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Estimated Power Requirements

Capability	Peak (Watts)	Time Average (Watts)
Physiological Status Monitoring	2	1
Intra-Squad Communication	4	3
Land Warrior Leader 0.6	na	23
Land Warrior Leader 1.0	39	19
Micro Climate Conditioning (Chem/Bio Mission)	>150	>75
Exoskeleton (Load assist, P >> maneuver)	4000	750

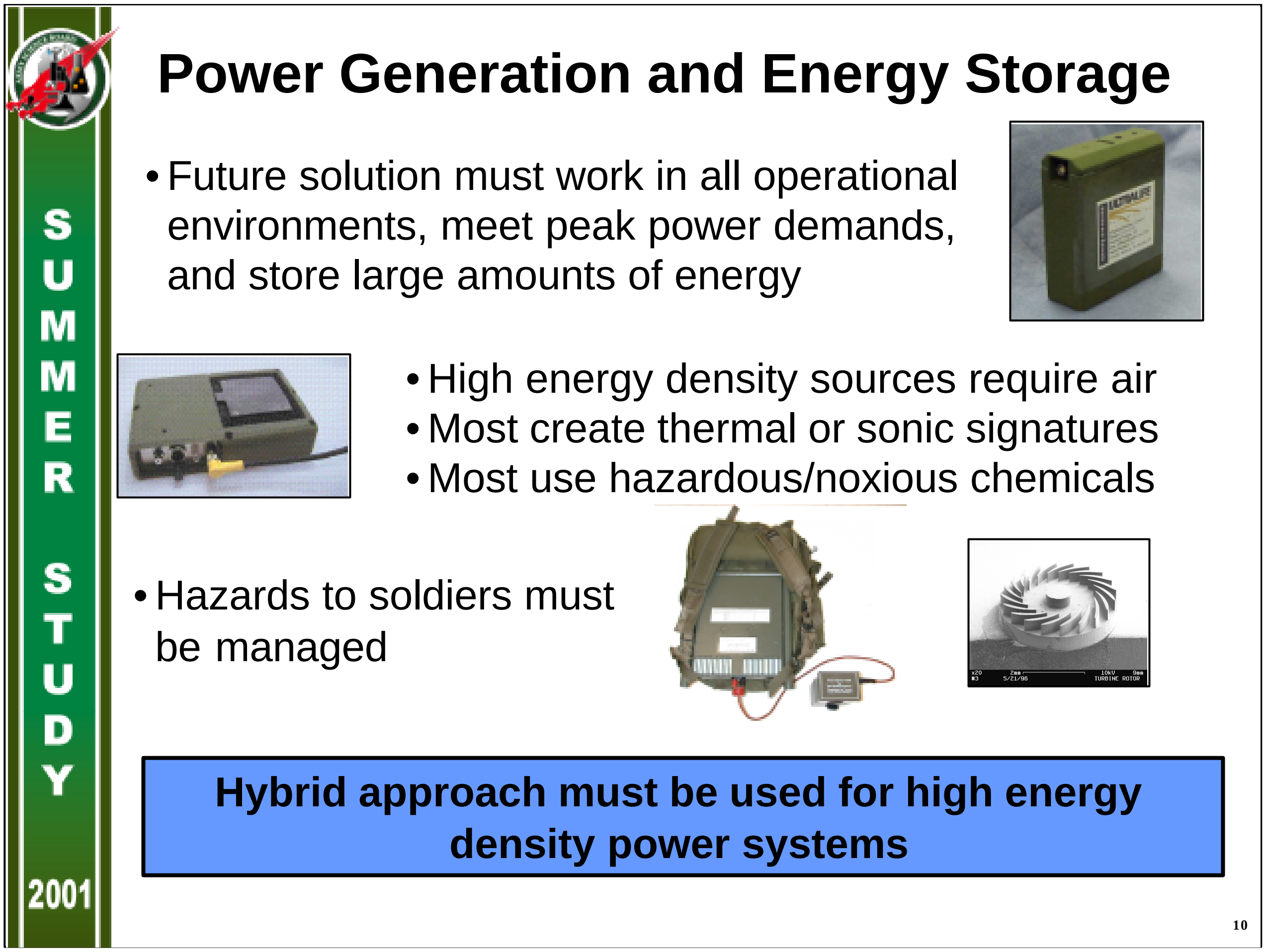
Proposed capabilities require large amounts of power

9

The above data are estimates only, and not intended as design criteria. They were developed based upon available information. In the case of the first four entries, we solicited data from project managers, and therefore believe the data are reasonably accurate.

For micro climate conditioning, we assumed a vapor compression device with a coefficient of performance (COP) of 2, and assumed that a soldier under high exertion dissipates 1000 watts and a soldier carrying a standard load 600 watts. This is consistent with a commercial air conditioner. Using this method, we calculated a peek of 500 watts, with a time average of 300 watts. The data in the table reflects Army requirements for a candidate system. The panel viewed the Army requirements to be optimistic.

For the exoskeleton, we assumed the end-use was load assist and not maneuver. Therefore, the nominal use is to carry ~200lbs. of equipment, the exoskeleton, and its power supply. The time average is the electrical equivalent of one horsepower, and the peak is an estimate of the ratio of energy used to walk on level terrain vs. energy used to walk up a steep incline. It is the view of the panel that running, bearing the weight of armor, or tactical maneuver would greatly increase the required power.



Current Army portable military systems are powered by a mixture of primary (disposable) and rechargeable batteries. Improved primary and rechargeable batteries with a more desirable form factor, higher energy density, and integrated "smart battery" electronics to facilitate power management are being developed for the Land Warrior.

Hybrid systems worn on the soldier provide longer periods of autonomous operation (i.e., Li-ion rechargeable coupled to a zinc-air battery. A 1 kg rechargeable battery with 120 Wh/kg would provide about 6 hours of operation, while a 1 kg zinc-air battery with 340 Wh/kg coupled directly to it would extend the period of operation by an additional 17 hours.

The main charging options are: Near term: Batteries recharged from vehicles and other sources. Mid term: Rechargeable batteries plus man-wearable zinc-air batteries and squad-level light weight generator. Long Term: Rechargeable battery recharged by man-worn fuel cell or advanced metal-air battery (e.g., Li-air).

Long-term research needs include better membranes for rechargeable polymer batteries; new higher energy cathodes for primary batteries (Lambda MnO_2,CFx); higher energy metal-air batteries (Li-air could surpass hydrocarbon fuel cell); and improved electrocatalysts.

Some of the longer-term options, such as the hydrocarbon fuel cell, the microturbine and the lithium-air battery likely have modest probabilities of success for the year 2012.

Specific Energies

SOURCE	PRACTICAL SPECIFIC ENERGY (Watt-hr/kg)	THEORETICAL SPECIFIC ENERGY (Watt-hr/kg)
Li/SO_2	121 - 260	1,175
Li/MnO_2	230 - 325	1,001
Zn-Air	360 - 500	1,066
Methanol	1,000 - 3,100	6,200
Diesel	1,320 - 5,000	13,200
Hydrogen	1,000 - 23,000	33,000
Nuclear	190,000	2,800,000

High energy density sources are "air-breathers"

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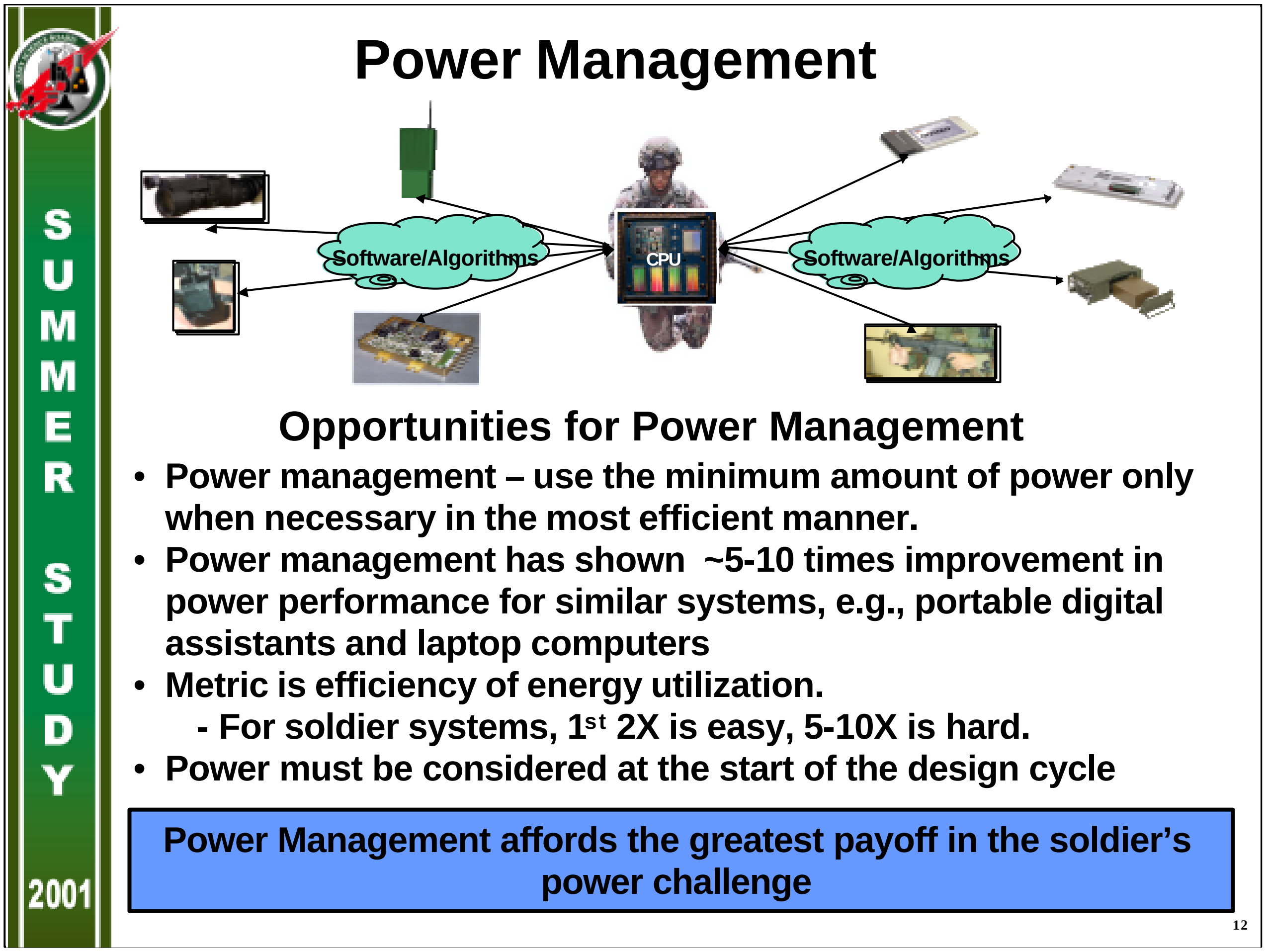
Specific energy is the amount of energy contained in a unit of mass (watt-hours per kilogram). The theoretical limit is the amount of electrical energy that would result from a 100% efficient conversion. The practical specific energy is a best estimate assuming the best realistic device output that can be achieved that includes both conversion efficiency and overheads of peripheral equipment and packaging. The "real world" dictates that achievable system solutions yield practical specific energies of the order of one-fifth (1/5) that of the theoretical limits. Those sources which are boxed and shaded gain their advantage by oxidizing a fuel where the oxygen source is the atmosphere ("air breathers"). The fuel burning sources (i.e. methanol, diesel, hydrogen) afford an order of magnitude advantage over those (batteries) listed above because of the hydrogen content of the fuel and the lack of oxidizer. For contrast, the nuclear option which provides multiple orders of magnitude improvement over fuel oxidization is shown. Of course, the nuclear option is not a realistic solution due to hazard and safety considerations associated with sources of sufficient energy density to provide useful power.



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.

Elements of Power Management

- **Minimize software overhead**
  - **- Operating system**
  - **- Inefficient/unnecessary software modules**
- **Efficient power management architecture**
  - **- optimize $P=\frac{1}{2}(CV^2)f$**
  - **- ¯voltage, ¯capacitance, minimize frequency**
- **Accommodate control of modules**
  - **- Tailor power to performance needs**
  - **- Power full/partial/standby/off**

Pocket digital assistants and laptop computers are enabled by power management

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Most general purpose operating systems do not employ power management. However, commercial operating systems used in embedded and portable hardware do employ power management. One can gain significantly by avoiding excessive overhead in instruction handling, memory data blocks fetching, effective use of internal CPU cache, etc. The software can be substantially simplified if it is optimized for the specific subsystems associated with the overall soldier system.

The 5-10 x improvement will come after designing the power management as an integral component of the overall system architecture. This step will include effective management of capacitance, frequency, voltages, and hardware explicitly supportive of power management operations, as well as the management of subsystem status (on/degraded/suspend/off).

It has been demonstrated by several examples within the DARPA PAC/C (Power Aware Computing/Communications) program that the energy utilization can be tailored to the algorithms running in the system. For example, acceptable encryption can be achieved at lower bits of precision without degradation and saving Energy/bits. Another example shown within the PAC/C program is the level of precision and computing needed for images. Again one can save substantial Energy/bit by accommodating what is “good enough” accuracy and precision.

There are also effective subsystem controls available in several of the soldier subsystems. For example, displays can be shut off when not used. The radio transmitter can control the power required to reach the destination according to the distance of the receiver. This approach is presently used in today’s cellular phones.

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Logistics

Replenishment Options

- Individual recharge systems
- Small-unit recharge
- Recharge on “Mule”, FCS, or HMMWV
- Power/Energy sharing
- Part of larger unit supply chain

Challenges

- **Type/diversity of soldier power solutions have tremendous logistics impact**
- **Recharge vs. disposable battery issue significant**

Rechargeable/refuelable systems greatly reduce cost but change logistics (+/-)

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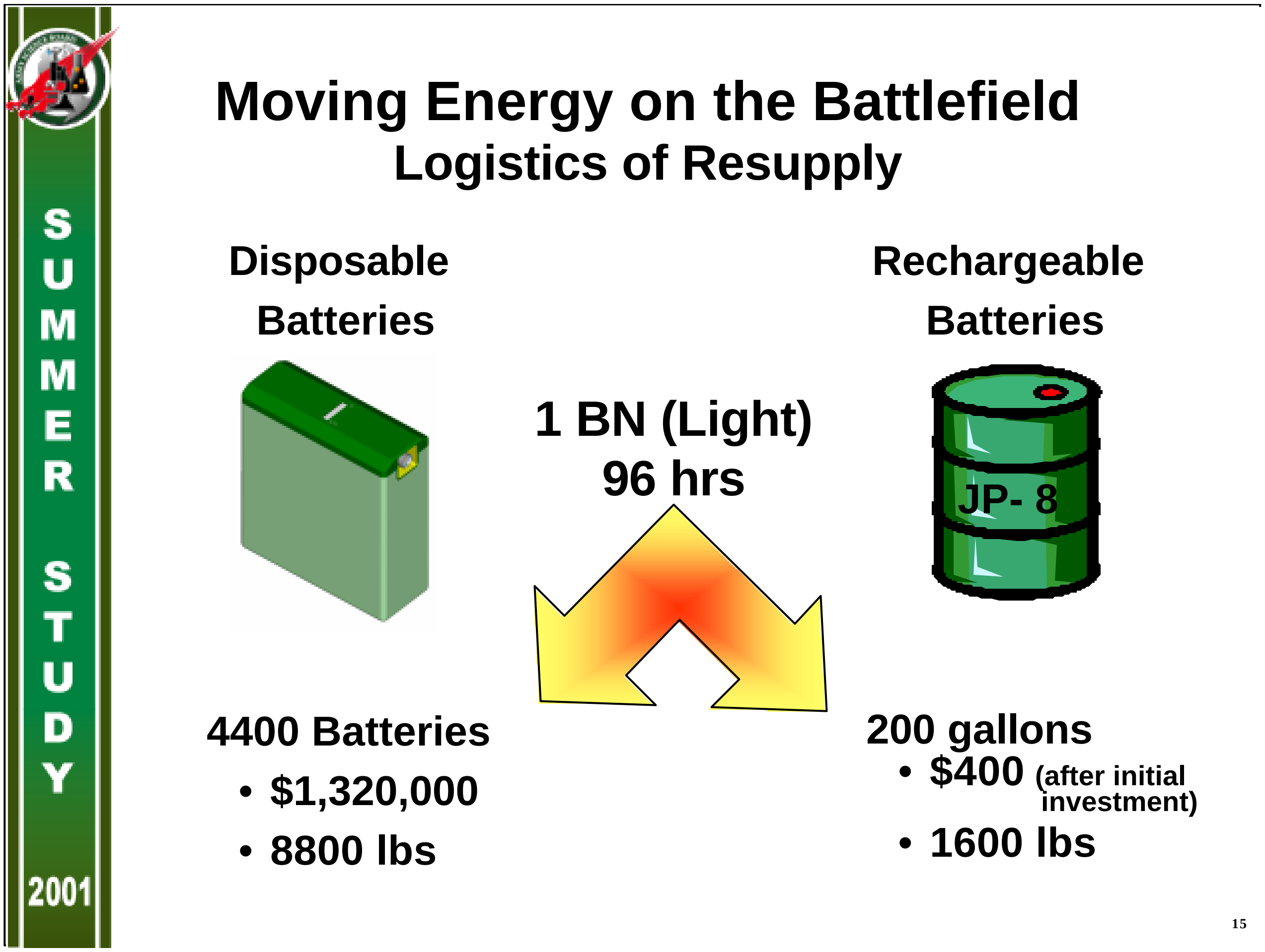
REPLENISHMENT OPTIONS

The various options for replenishment in combat are listed.

CHALLENGES

One of the critical issues for soldier support is the distribution of power and energy on the future battlefield. Recent guidance states that rechargeable batteries are to be used during field exercises and disposable batteries are to be used in combat situations. Using the two types of batteries simultaneously will significantly impact logistics. We advise that the logistics and operational trade-offs between the two approaches be further analyzed, but our panel’s strong recommendation is that the Army make the transition from disposable to rechargeable batteries, ultimately leading to hybrid power systems. We believe that in the future the power and energy logistics train will consist more and more of components that will need to be recharged, and the experience gained in the beginning with rechargeable batteries will set the stage for the planning of future logistics trains as newer technologies that provide energy and power are incorporated into the Army’s soldier support system.

We give high marks to Army efforts to reduce the number and types of batteries that support soldier systems and we urge that the effort continue in order to minimize the variety of different types that now exist. Narrowing the number and types will make logistics more tractable and simplify both storage and transportation.

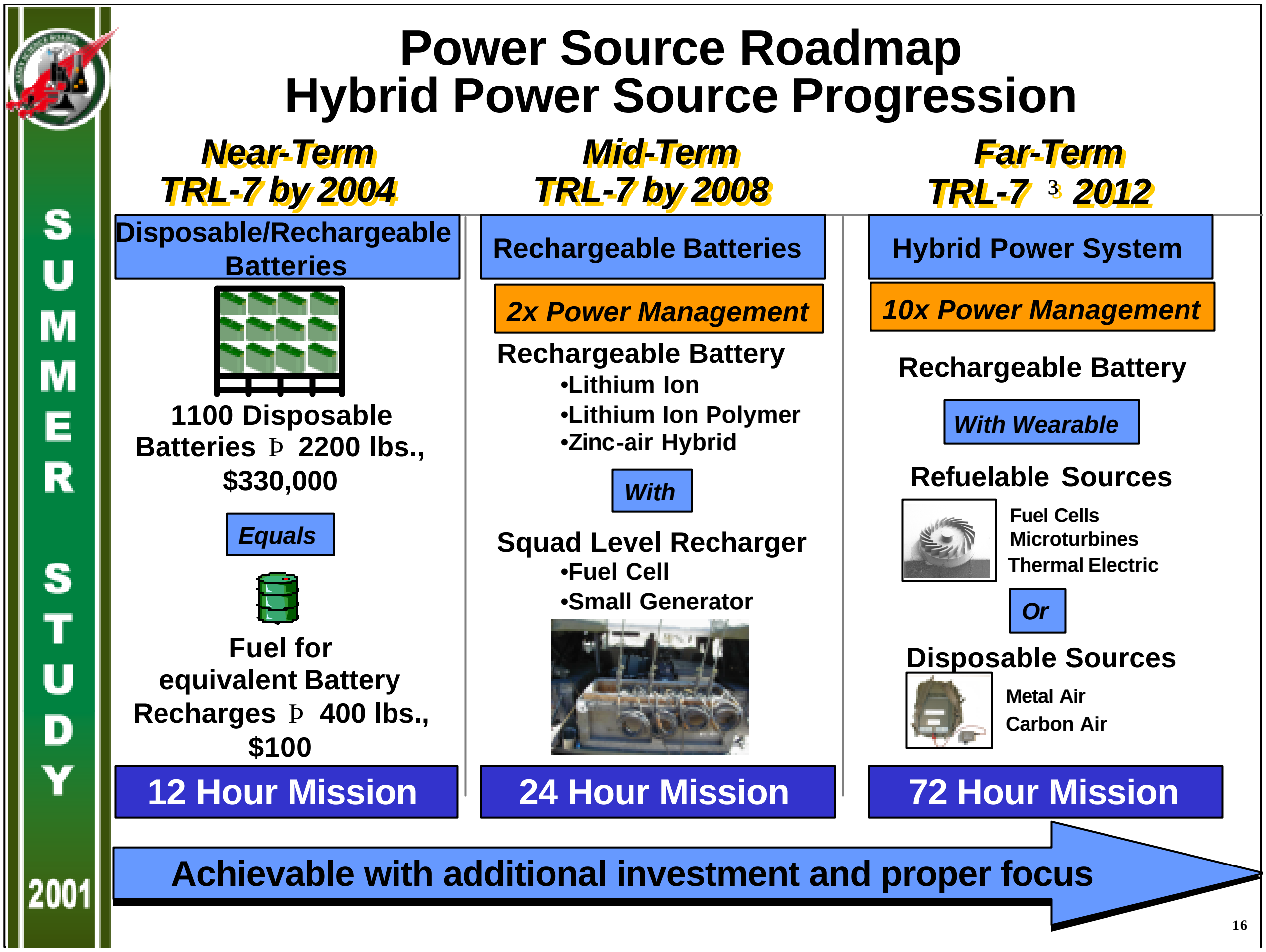


It is instructive to compare two options for the logistics burden needed in order to supply one battalion (Abn/light ~ 550 soldiers) on the battlefield over a period of 96 hours (4 days). These two options are (1) disposable batteries and (2) rechargeable batteries.

Using disposable batteries will require 4400 batteries at a cost of about $1.3 million and will involve moving a load of about 8800 pounds.

If the Army evolves to rechargeable batteries, it will require fuel to power a recharger which will be used to recharge the batteries. Here we have chosen the fuel JP-8 for the example, although other fuels are possible. If JP-8 is used as an illustration, it will require 200 gallons of fuel weighing 1600 pounds, costing only $400 after the initial investment is made in batteries and recharge systems.

We recognize that the system costs for these two options are different. The disposable battery option is usually paid by the operators while the cost of components of the rechargeable battery option is a cost borne by the acquisition community. We suggest that the Army consider these costs in terms of the total budget involved and not by the units who must pay the cost.



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.

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Technical Findings/Recommendations

- **Expect evolutionary rather than revolutionary improvements**
  - Basic chemistries have long been known
  - Significant progress made on some technologies exploiting basic chemistries
  - New technologies (e.g. MEMS) may provide breakthrough
  - Safe, reliable, efficient, manufacturable power systems pose significant engineering challenges
- **Emphasize transitioning technologies from demonstration into systems**
- **Power management can extend endurance by 5-10X**
  - Eliminate non-mission essential power demands
  - Include energy conservation in Tactics, Techniques, and Procedures (TTP)

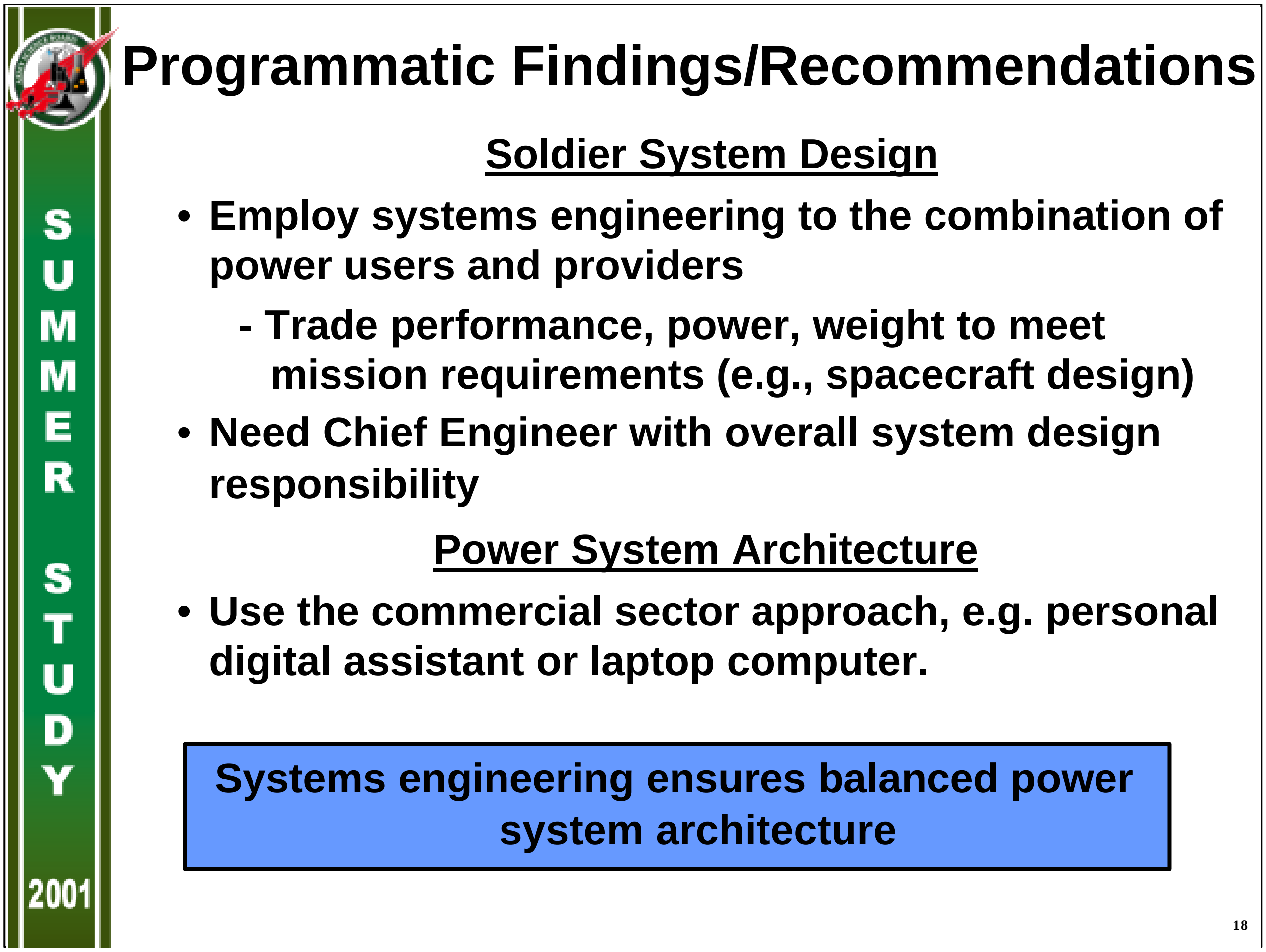
Power management provides revolutionary opportunity

17

Expect evolutionary rather than revolutionary improvements in the technology base for the soldier system power systems. Given the insatiable demand for energy there is a temptation to seize on a panacea or a proposed technological solution. Prudence and skepticism is necessary in the power arena due to its maturity of development. The basic chemistries have long been known. The challenge is in the engineering details. On the other hand, significant progress has been made on a number of technologies that has been painfully slow and costly. MEMS (micro-electric-mechanical-systems) and micro-turbine technologies afford the possibility of a breakthrough in "wearable" devices to convert fuel into electricity. In all cases, safe, reliable, efficient, manufacturable power systems pose significant engineering challenges.

One of the fallouts of evolutionary progress in power technology has been an inadequate number of technologies taken to full system demonstrations. This severely limits the number of options that can be pursued for the near and mid terms. A major technical recommendation is to significantly increase the emphasis on transitioning promising technologies into systems.

The efficient use of energy affords a means of extracting the greatest utility from what will always be a limited resource for the soldier system. The Tactics, Techniques and Procedures (TTP) are a major driver of power management. Power needs to be treated in TRADOC's development of the TTP the same as other expendables. The panel believes that TTP's will help conserve power because of the desire to limit signature (i.e., radio frequency, thermal, and sonic emanations from soldier systems or from power generated for soldier systems. The bottom line is that the full spectrum of power management provides the revolutionary opportunity in the power arena.

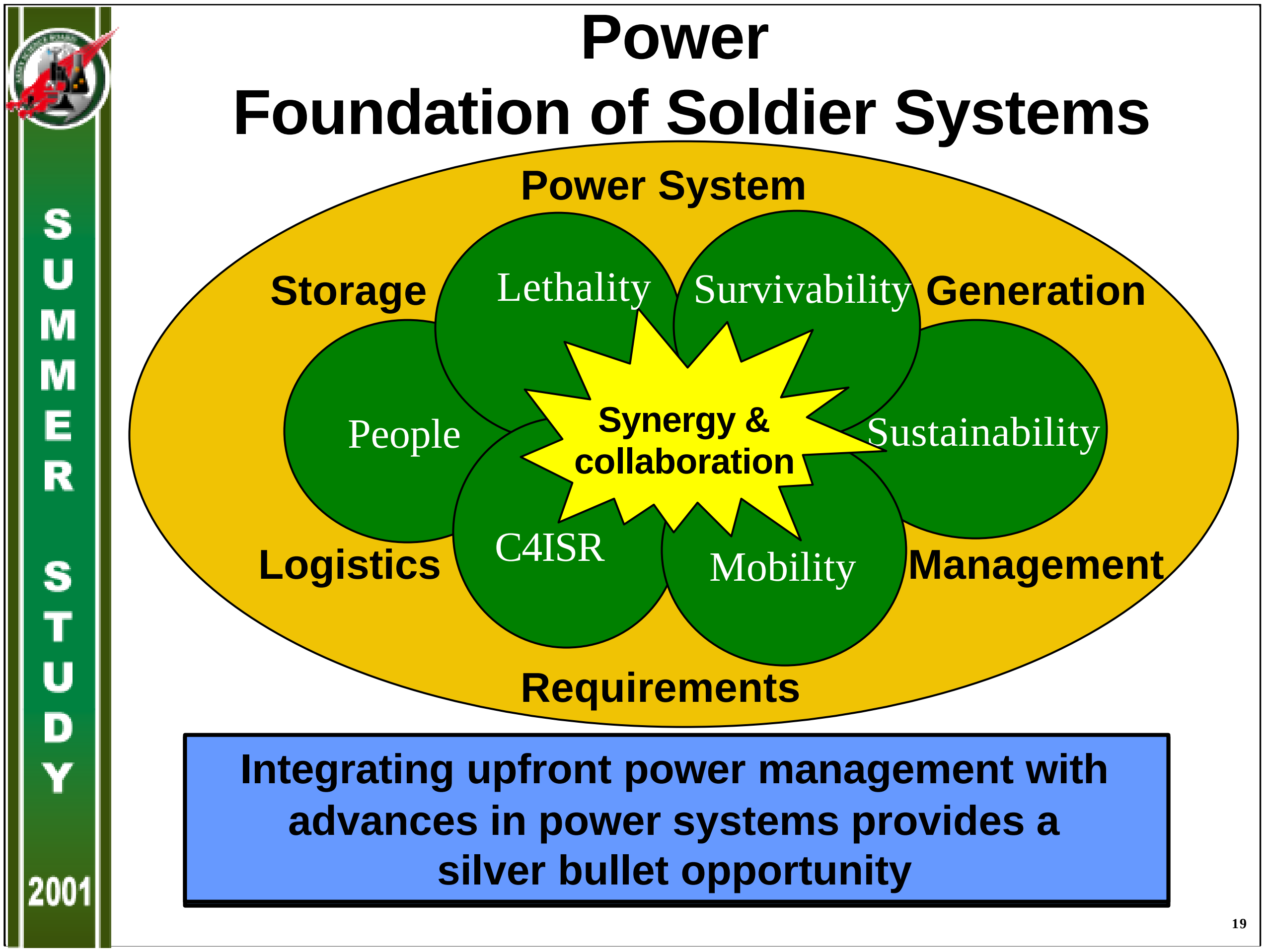


Energy is and will always be a very dear resource in the design of the soldier system. There are no panaceas. Thus, the design of the soldier system must recognize this fact and be done accordingly. This is a change from the classical approach where the power users are optimized for performance, cost and weight and the power system is tasked with meeting the demand. The panel strongly recommends that systems engineering be applied to the combination of power users and providers. Power must be integrated into the soldier system design.

The panel recommends that a Chief Engineer with overall system design responsibility 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 power subsystem design is technically feasible, affordable and manufacturable. It is important to note that the Chief Engineer is responsible for the total system architecture, and not only for the power system.

Relative to the power system architecture, the panel recommends that a commercial sector approach be taken. Examples include the personal digital assistant or laptop computer. In the case of the personal digital assistant this meant the incorporation of a tailored operating system. The result is a system that performs a specified set of functions very well and is extremely power efficient.

The overarching finding of the panel is that integrating upfront the power management with advances in power systems provides a silver bullet opportunity.



The power provides one of the most important foundations of a soldier system. The soldier power system is composed of a number of considerations and we have pointed out five of them – requirements, power generation, power storage, power management and the logistics associated with energy and power distribution on the battlefield. The synergy and collaboration between those five factors and the lethality, survivability, sustainability, and mobility of a soldier system, coupled with good C4ISR techniques, promises to produce dramatic gains by properly equipped and trained individual soldiers in future warfare.


SUMMER STUDY
2001
S&T PANEL
INVESTMENT STRATEGY

SUMMER STUDY 2001

Soldier System Study S&T Panel

- **Mission Statement: Provide an S&T investment strategy for enhancing the soldier system**
- **Process**
  - **Military Utility Assessment – What should the Army do?**
  - **Technology Assessment – When can the Army do it?**
    - * **Near-Term: TRL7 by 2004**
    - * **Mid-Term: TRL7 by 2008**
    - * **Far-Term: TRL7 after 2008**
  - **Cost Assessment – What will it cost the Army?**
    - * **"First Cut" of $ needing to be added to POM 01-05**
  - **S&T Roadmaps – How can the Army do it?**

1

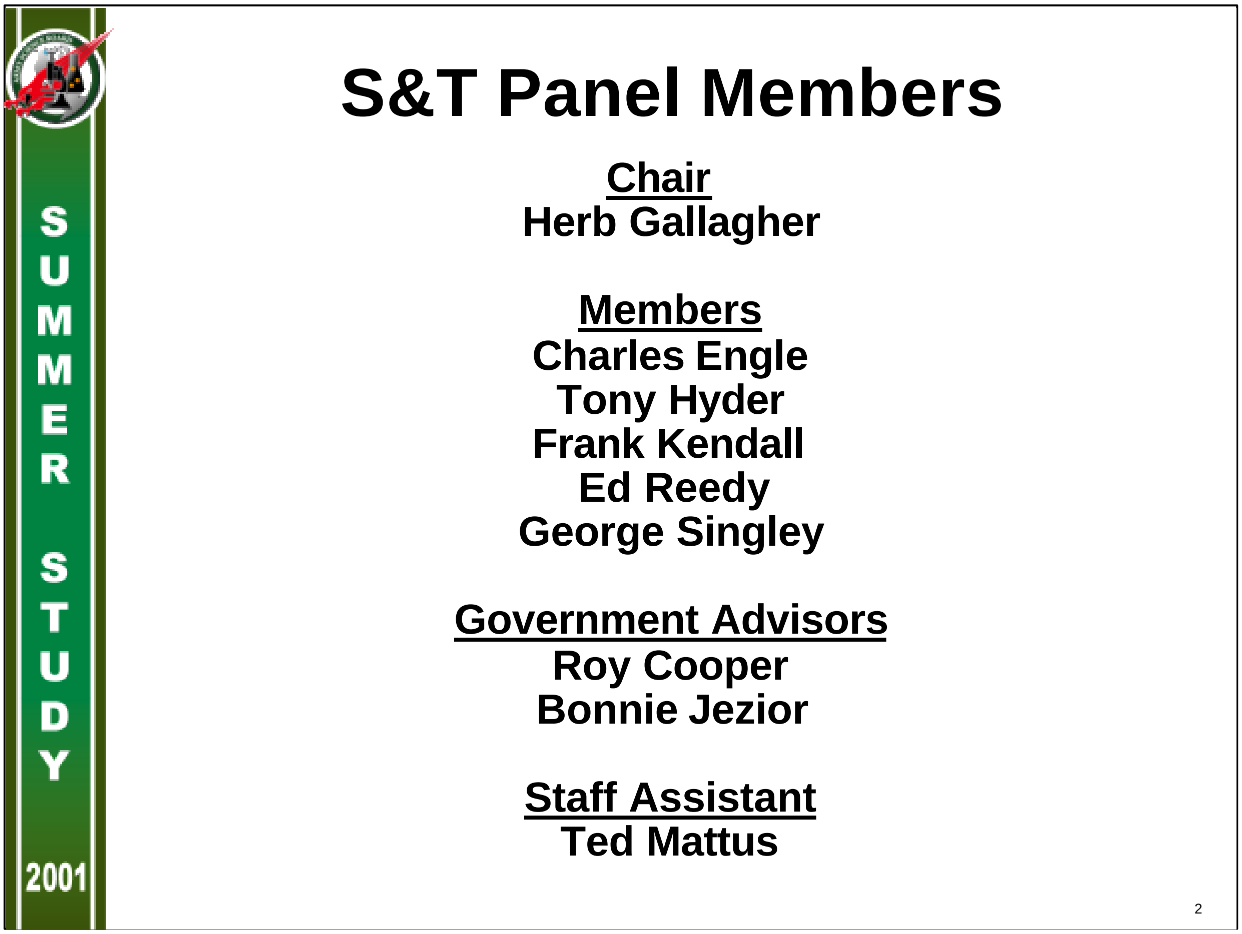
The S&T Panel integrated and prioritized the study results, formulating an investment strategy for the soldier system. Specifically, the panel coordinated the evaluation and prioritization of more than 100 technologies that were identified by the four technology panels (fightability, weight, power, and people) to identify the top 24 enabling technologies. These 24 Major Enablers were subsequently integrated into a candidate S&T investment strategy.

The evaluation process involved the following assessments:

- <u>Military Utility</u> – Subjective estimate of the relative impact of each technology on the military performance of the dismounted soldier.
- <u>Technology Maturity</u> – Review of the maturity of each technology and its potential to reach Technology Readiness Level (TRL) 7 to support fielding in the near-term (2008), mid-term (2012), or far-term (beyond 2012).
- <u>Cost</u> – Estimate of the additional Army S&T investment beyond those investments in the FY 01 – 05 POM to achieve TRL 7 maturity to support fielding in the three periods described above.

The results of these assessments were integrated into a candidate S&T roadmap that provides an evolutionary capabilities-based approach to significantly improving the capabilities of the soldier system.

Recommendations on management structures and innovations that will enable success in executing this roadmap have also been provided along with a "road ahead" for follow-up actions by the Army.



The Panel Membership consisted of individuals from Industry (Gallagher and Engle), Academia (Hyder and Reedy), and ex-senior government officials (Kendall and Singley).

Government Advisors that assisted the Panel Members were from the Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology (Cooper) and the Army Soldier and Biological Chemical Command (Jezior).

The Government Staff Assistant who supported study activities was from the Natick Soldier Center (Mattus).

SUMMER STUDY 2001

The Qualities of “First”

Major Enablers

- **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

3

As discussed earlier, the Panel developed and implemented an evaluation process that identified the top 24 enabling technologies for the soldier system. As many of these Major Enablers cut across multiple “ilities”, it was difficult to organize them along these lines. Instead, they have been organized into six “Quality of First” areas. The concept of “Firsts” comes from preliminary work conducted by TRADOC to support Army transformation. This concept is to 1) See First, 2) Understand First, 3) Act First, and 4) Finish Decisively. To this list the Panel added 5) Endure (to capture the sustainability aspects of the soldier system), and 6) People.

The choice of which Major Enabler to align with each “First” was not always straightforward as some Major Enablers could logically be placed under several “Firsts.” Subjective judgment was used to determine the most logical “First” for each Major Enabler. The important point is not the specific alignment of the Major Enablers with the “Firsts” but that these 24 Major Enablers can provide significant enhancements to the “First” concepts that are supporting the Army’s transformation.

Major Enablers

(1 of 2)

SUMMER STUDY 2001

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
$	Δ POM $(M)	50	50	60	50	100	70	50	100	10	20	25

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

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

Δ $M are S&T additions to the 02-07 POM based on the 01-05 POM Soldier System S&T funding levels

4

These next two charts summarize the results of the Military Utility, Technology Maturity, and S&T Cost assessments for the 24 Major Enablers. 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 estimate 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.

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Major Enablers

(2 of 2)

++ 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				
$	D POM S&T $(M)	40	50	100	100	50	50	25	40	10	55	11	24	60

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

Δ $M are S&T additions to the 02-07 POM based on the 01-05 POM Soldier System S&T funding levels

5

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

The People Major Enablers are not discussed further in this section of the report as additional detailed information is available in the Army Science Board Special Study entitled “Manpower and Personnel for Soldier Systems in the Objective Force” dated June 2001.

SUMMER STUDY 2001

Major Enablers - Total ΔS&T Costs

Major Enablers	"Firsts"	Total	Near	Mid	Far
Mine/Booby Trap Sensing	See First	50	0	25	25
Micro & Mini UGVs & UAVs	See First	50	25	25	0
Through Wall Sensing	See First	60	0	35	25
Sniper Detection	See First	50	10	40	0
Soldier C4ISR Connectivity	Understand First	100	0	100	0
Decision Aids	Understand First	70	0	0	70
Identification Friend/Foe/Neutral (IFFN)	Understand First	50	10	40	0
Exoskeleton Assist Systems	Act First	10	0	0	10
Robotic Mule	Act First	20	20	0	0
Sustainment by UAV	Act First	25	0	25	0
Responsive Organic & Joint Netted Fires	Act First	100	0	30	70
Signature Management	Finish Decisively	40	0	10	30
Agile Target Effects	Finish Decisively	100	0	60	40
Robotic Targeting & Attack	Finish Decisively	50	0	50	0
Physiological & Environmental Monitoring	Finish Decisively	100	0	30	70
Power Management	Endure	50	0	25	25
Rechargeable Energy Systems	Endure	50	25	25	0
Wearable Fuel Cells	Endure	25	0	10	15
Lightweight Integrated Soldier System	Endure	40	0	40	0
Water Purification & Generation	Endure	10	5	5	0
Total Δ S&T Cost		1050	95	575	380

This chart amplifies the S&T cost information that was provided on the previous two charts (excluding the People Major Enablers). It provides a break-out of the increase to the FY 02-07 POM (from the FY 01-05 POM) necessary to accelerate the maturity of the Major Enablers to TRL 7 in the three different timeframes.

These costs represent the S&T costs associated with maturing the technologies of the Major Enablers which can provide increased capabilities for the Land Warrior ($95M), the Objective Force Warrior (OFW) ($575M), and follow-on upgrades to the OFW ($380M).

SUMMER STUDY 2001

Opportunities To Reduce The S&T Investment Bill

Major Enablers

Micro & Mini UGVs & UAVs	➳
Mine/Booby Trap Sensing	➳
Through-Wall Sensing	
Sniper Detection	➳
Soldier C4ISR Connectivity	➳
Decision Aids	➳
IFFN	➳
Responsive Netted Fires	➳
Exoskeleton Assist Systems	
Robotic Mules	➳
Sustainment by UAV	➳
Robotic Targeting & Attack	➳
Signature Management	➳
Agile Target Effects	➳
Physiological Monitoring	➳
Power Management	
Rechargeable Energy Systems	
Ltwt Integrated Soldier System	
Wearable Fuel Cells	
Water Purification & Generation	➳

✓ ***High commonality with Objective Force & FCS S&T can be exploited***

- **~ $250M unique to Soldier System**
- **~ $800M "shared" with Objective Force & FCS**

- **Relative return on investment analysis can further identify highest payoff S&T enablers**
  - **Detailed military utility analysis**
  - **Detailed assessment and prioritization of technical approaches**

Integrated Management Of Objective Force, FCS, Soldier System and Aviation Is Needed To Realize These Opportunities

6

As the previous chart shows, the development of the 24 Major Enablers could require the addition of approximately $1,050M to the Army S&T program in the FY 02-07 POM. Two considerations were identified that can reduce the S&T investment cost necessary to realize a revolutionary soldier system capability.

First, 14 of the 20 Major Enablers (excluding the People Major Enablers) were found to have high commonality with the technology needs of the Objective Force and/or Future Combat System (FCS) initiatives. Specifically, only $235M is associated with soldier unique technologies while the balance of $815M is applicable to the Objective Force, including FCS and manned/unmanned Aviation.

A second opportunity to reduce these S&T costs can be realized through an in-depth analysis of the Major Enablers' technology options relative to the respective soldier system capabilities they enable. In many cases, multiple competing technologies have been identified for Major Enablers which offer significantly different performance payoffs. Prioritization of these competing technologies with regard to their anticipated soldier system payoff is expected to identify cost reduction opportunities.

It must be emphasized, however, that the realization of these cost reduction opportunities will require a management process that integrates the needs and technology solutions for the soldier system with those of the Objective Force, FCS, and aviation systems.

SUMMER STUDY 2001

Major Enablers – "Unique" Δ S&T Costs

Major Enablers	"Firsts"	Total	Near	Mid	Far
Through Wall Sensing	See First	60	0	35	25
Exoskeleton Assist Systems	Act First	10	0	0	10
Power Management	Endure	50	0	25	25
Rechargeable Energy Systems	Endure	50	25	25	0
Wearable Fuel Cells	Endure	25	0	10	15
Lightweight Integrated Soldier System	Endure	40	0	40	0
Total Soldier System Δ S&T Cost		235	25	135	75

This chart amplifies the S&T cost information that was discussed on the previous chart for soldier system unique Major Enablers. It provides a break-out of the increase to the FY 02-07 POM (from the FY 01-05 POM) that is unique to the soldier system and is necessary to accelerate the maturity of the Major Enablers to TRL 7 in the three different timeframes.

These costs represent the Soldier System program costs associated with potential improvements to Land Warrior ($25M), the OFW ($135M), and follow-on upgrades to the OFW ($75M).

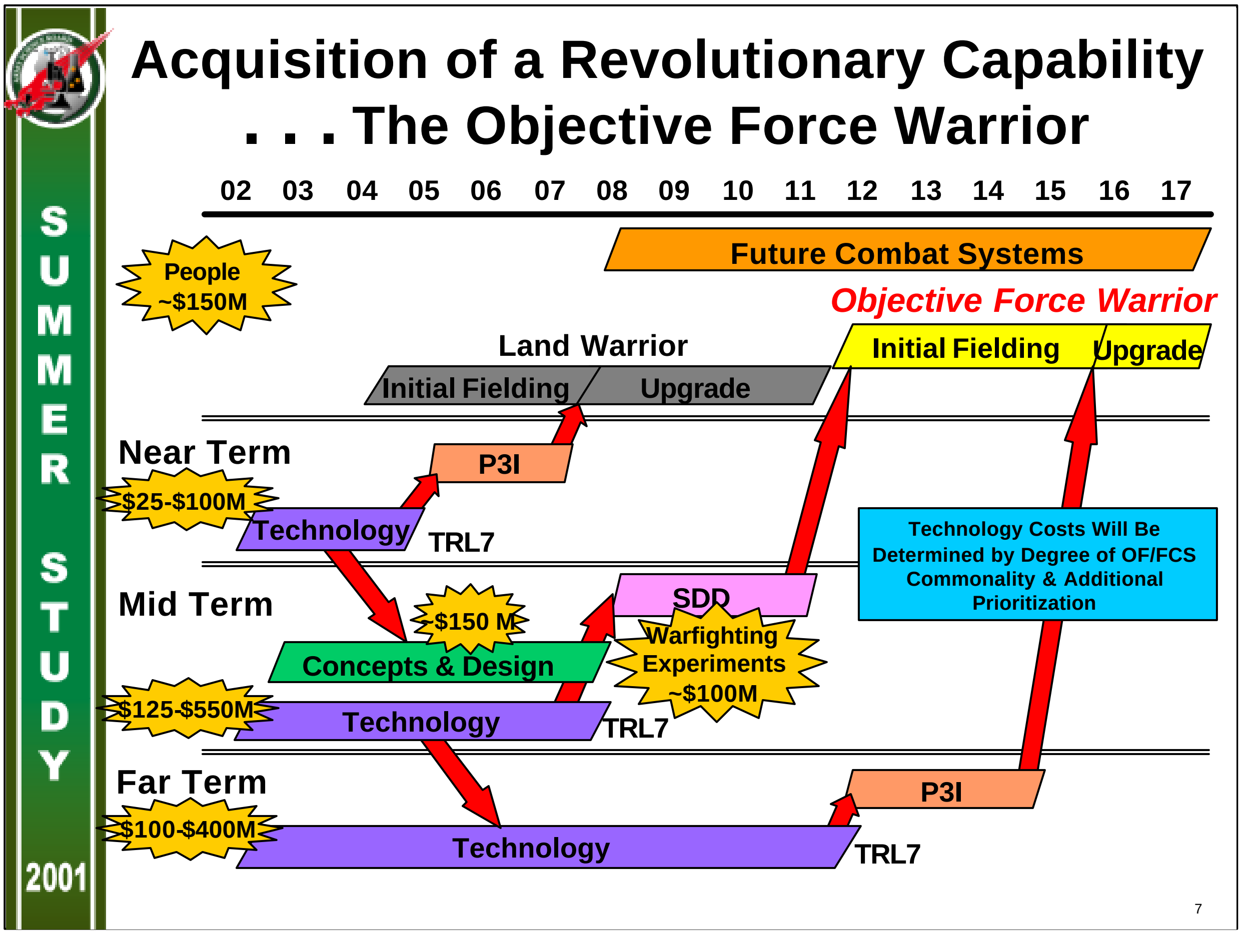
SUMMER STUDY 2001

Major Enablers – "Shared"Δ S&T Costs

Sniper Detection	See First	50	10	40	0
Identification Friend/Foe/Neutral (IFFN)	Understand First	50	10	40	0
Soldier C4ISR Connectivity	Understand First	100	0	100	0
Decision Aids	Understand First	70	0	0	70
Sustainment by UAV	Act First	25	0	25	0
Responsive Organic & Joint Netted Fires	Act First	100	0	30	70
Robotic Mule	Act First	20	20	0	0
Signature Management	Finish Decisively	40	0	10	30
Robotic Targeting & Attack	Finish Decisively	50	0	50	0
Agile Target Effects	Finish Decisively	100	0	60	40
Physiological & Environmental Monitoring	Finish Decisively	100	0	30	70
Water Purification & Generation	Endure	10	5	5	0
Total S&T Cost Shared with FCS		815	70	440	305

This chart amplifies the S&T cost information that was discussed previously for soldier system enablers found to have high commonality with the technology needs of the Objective Force and/or FCS initiatives. It provides a break-out of the increase to the FY 02-07 POM (from the FY 01-05 POM) necessary to accelerate the maturity of the Major Enablers to TRL 7 in the three different timeframes.

These costs should be shared among the soldier system and other Transformation Programs, representing the Transformation Program costs associated with potential improvements to Land Warrior ($70M), the OFW ($440M), and follow-on upgrades to the OFW ($305M).

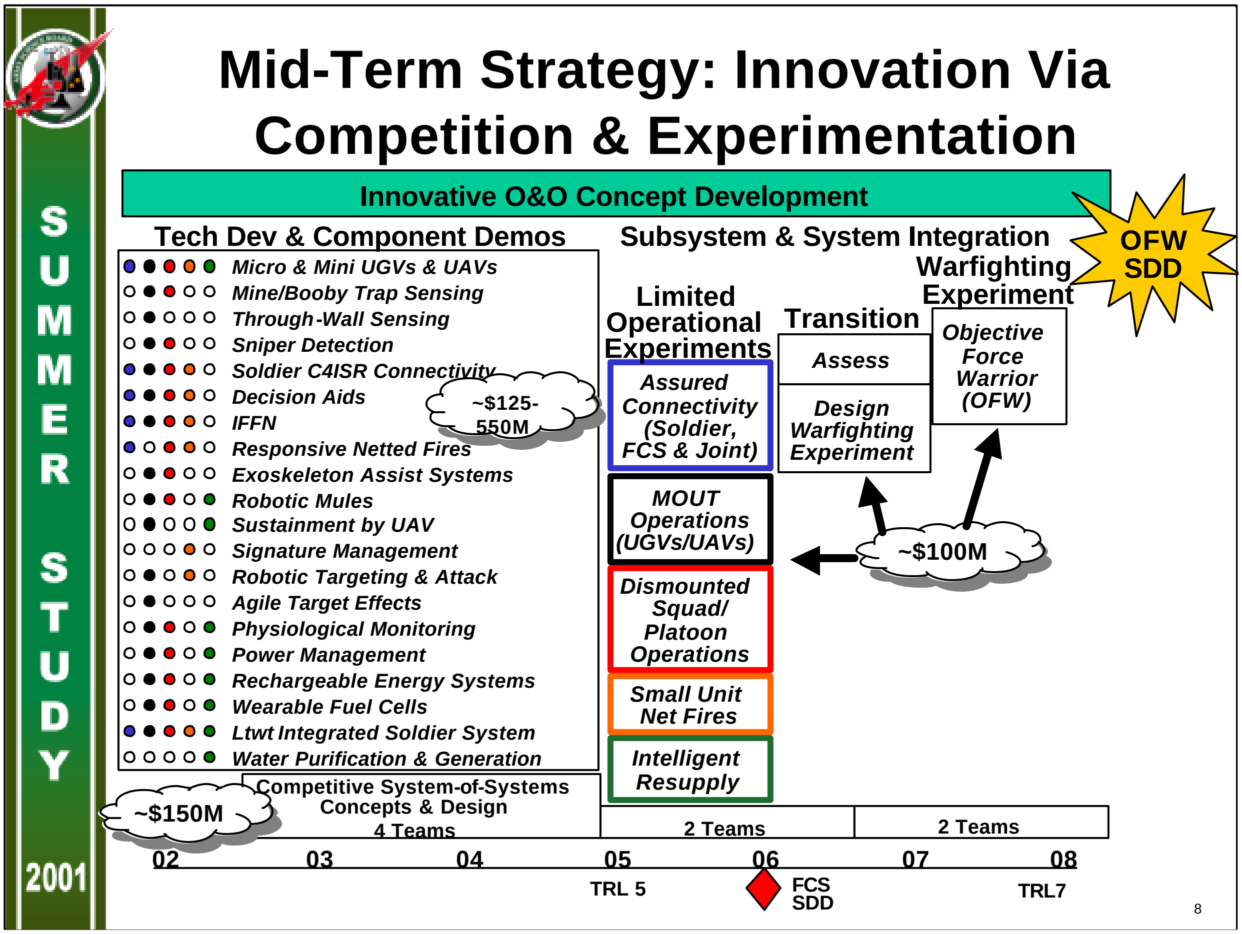


A capabilities-based Acquisition Strategy for realizing a revolutionary capability was developed. This strategy provides for a significant performance upgrade to the Land Warrior in the near-term, a revolutionary capability for the OFW in the mid-term, and a dramatic enhancement to the OFW in the far-term.

Near-term: Relatively mature technologies can be developed and demonstrated to TRL 7 by FY 2004. These technologies can be transitioned to a Pre-Planned Product Improvement (P3I) program for subsequent fielding of an upgraded Land Warrior system. This S&T program will require an increase of $25-100M, depending on the cost savings that can be realized from the two considerations previously discussed.

Mid-term: Emerging, innovative technologies can be developed and demonstrated to TRL 7 by FY 2008. This effort should be closely linked to competitive concepts and design activities that can develop and evolve innovative concepts to final integrated system designs. The products of these activities should be put in the hands of the Warfighter in a number of Limited Operational Experiments (LOEs) and a capstone Army Warfighting Experiment (AWE) that exploit live, virtual and constructive simulations. This building block approach allows the Warfighter to experiment with the technologies, determine how to integrate them into the Objective Force, and determine the best innovative warfighting concepts and tactics, techniques and procedures (TTPs). Upon completion of the AWE, the program should be ready to transition to SDD for subsequent fielding in FY 2012. The estimated increase in S&T funding is $125-550M with additional funding of $150M for integrated Concept/System Design and $100M for Warfighting experiments.

Far-term: Pursuit of basic and early applied research opportunities can lead to the development and demonstration of an enhanced OFW capability with significant overmatch in the period beyond FY 2012. These technologies can be transitioned to a P3I program for subsequent fielding of an upgraded OFW system. This S&T program is estimated to require an increase of $100-400M.



A more detailed mid-term Acquisition Strategy based on innovation, competition, and experimentation was developed. This S&T strategy integrates four key elements.

Innovative Operational and Organizational (O&O) Concept Development: The realization of a revolutionary soldier system capability requires the synergistic application of innovative materiel solutions with innovative TTPs. This strategy calls for the robust, concurrent development of competitive soldier system O&O concepts, built from evolving technologies, which guide the design of advanced concepts.

Technology Development and Component Demonstrations: Technology development needs to include defense laboratories, industry, and academia. In many cases, alternative technical approaches exist for Major Enablers where evaluations and Advanced Technology Demonstrations (ATDs) should be used to prioritize and identify optimal approaches.

Competitive System-of-Systems Concepts and Design: The design of the soldier system should be based on integrated, innovative system-of-systems concepts developed through competition. This strategy funds four teams to develop preliminary concepts. The best two of these concepts should be selected to compete through the subsystem and system integration phases, providing prototype subsystems to be tested during this phase. An essential element of the design approach must be system integration. Each team should be expected to use a system-of-systems approach, performing system trades and optimizations that balance system fightability, weight, power, and costs.

Subsystem and System Integration With Experimentation: A number of LOEs followed by an AWE is recommended as a means to ensure the resulting soldier system concept provides the overmatch capability required. Five candidate LOEs are proposed where prototype systems and subsystems would be provided to soldiers for field testing and system design optimization. A proposed mapping of the Major Enablers and the LOEs is shown through a color code. The capstone experiment would be the OFW AWE.

SUMMER STUDY 2001

Objective Force Warrior Acquisition/Management/Funding

- **Option 1: Part of Objective Force Program**
  - **Allows for synergistic development of soldier system Major Enablers in concert with other Objective Force programs in an integrated, cost-effective fashion**
  - **Preferred approach to achieve a “Soldier Centric” force**
- **Option 2: Part of FCS Program**
  - **Aligns soldier system development activities with FCS but makes integration with other Objective Force programs more difficult & higher risk**
- **Option 3: Separate Land Warrior Follow-On Program**
  - **Separation from other Objective Force programs precludes cost-effective development of “shared” technologies & inhibits integration with Objective Force**
  - **Least desired approach**

Several alternatives were considered for managing and funding the Objective Force Warrior Program.

The preferred approach would be to incorporate and fund the OFW Program as part of the overall Objective Force Program, thereby enhancing the probability of adequate funding priority and force integration. If this approach is taken, the OFW Program should have its own funding line item(s) to retain visibility and reduce the likelihood of it becoming an inadvertent bill payer. This approach ensures that the Objective Force will be a “Soldier Centric” force.

The second preference would be to make the OFW Program part of the FCS Program. While this would be preferable to a stand-alone OFW Program, this approach makes integration with the Objective Force, including Army Aviation (manned and unmanned), more difficult and higher risk.

The least desired approach would be for the OFW Program to remain a separate program, like the current Land Warrior program. This will preclude realization of many of the cost savings previously discussed, prevent efficient integration with the Objective Force, and put at risk the “Soldier Centric” concept of the Objective Force.

SUMMER STUDY 2001

Innovation Essential for Success

- **Research/Discovery**
  - **Required now for Far-Term Major Enablers**
  - **Must include Defense & Commercial technologies that are integrated into focused programs**
- **Concept Development**
  - **Systems-of-Systems approach must be utilized concurrent with technology development**
- **Early Experimentation**
  - **Key for effective integration of technologies & concepts**
- **Modeling, Simulation & Analysis**
  - **New tools are required to understand the synergy of new technology & concept developments**
- **Training**
  - **The cornerstone for success, requiring tailoring for the new "soldier centric" environment**

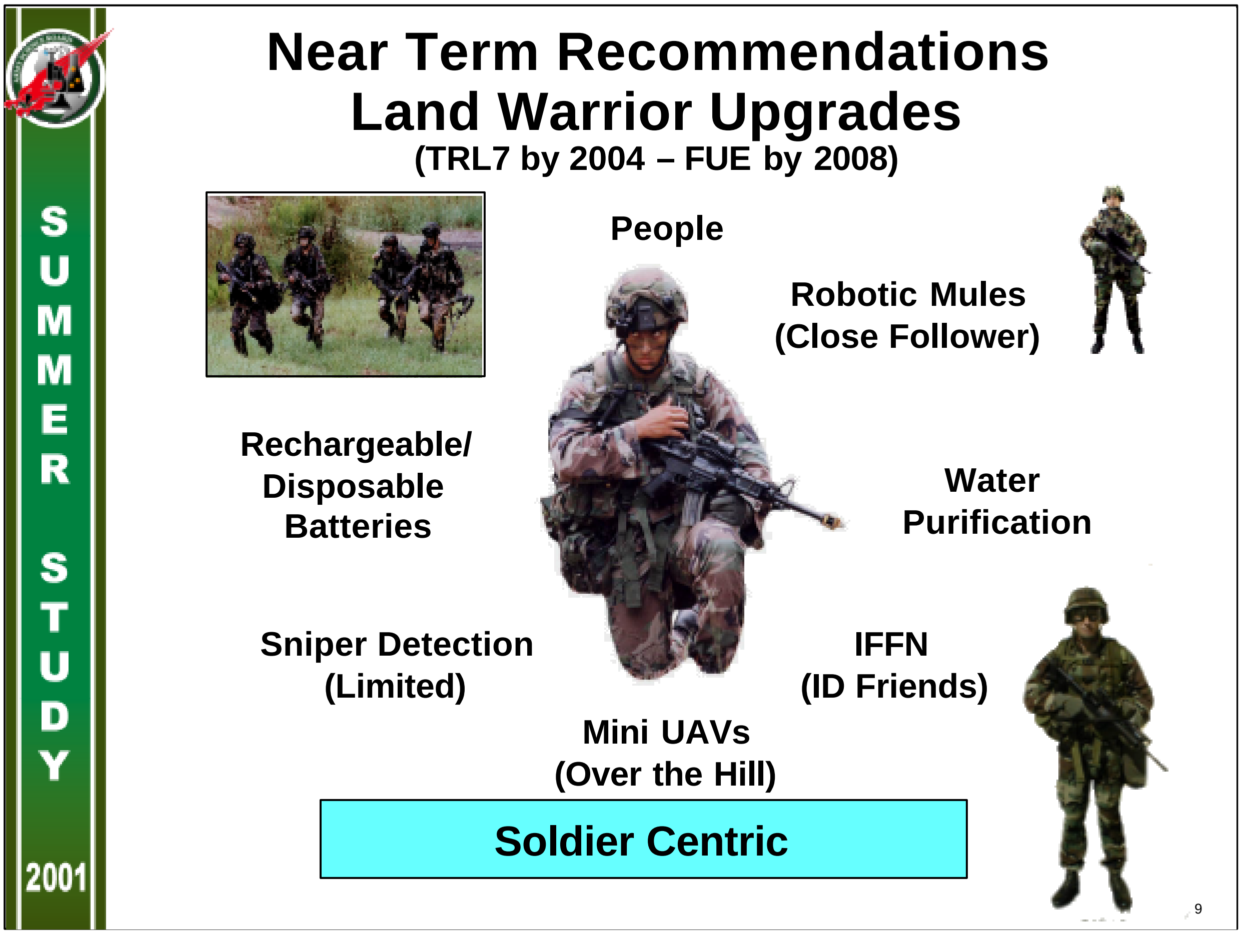
To achieve the revolutionary collaborative soldier system capabilities postulated, innovation is essential in a number of different soldier system areas.

Basic and applied research must be focused on the individual soldier, as it has been on major weapons platforms. The realization of a number of far-term enablers and the development of the requisite soldier system M&S tools requires investment now in new research. DoD research must be supplemented with the best from industry and academia. These research activities must be integrated into focused programs that lead to evaluations and downselects that advance the technologies needed for the Major Enablers.

As previously mentioned, the successful exploitation of new technologies requires the robust, concurrent development of innovative soldier system concepts which take a system-of-systems approach to optimize fightability, weight, power and cost. Extensive early experimentation that exploits live, virtual and constructive simulation is required to determine how to best integrate these technologies with innovative warfighting concepts.

As mentioned by the Analysis Panel, considerable improvements in soldier system capabilities can be achieved by analyzing alternative technologies and the synergies that result from their combination. However, current M&S tools are inadequate to allow for their proper analysis. Development of new tools and analysis capabilities is essential to exploit these new technologies and concepts that can synergistically provide enhanced capabilities.

Finally, like today, training will remain a cornerstone for success. Innovative training approaches that address how soldiers must function in a "soldier centric" environment need to be developed and provided in a tailored, "just in time" fashion.



If the recommendations for S&T funding increases are realized and development is performed with the proposed innovative approaches, the fielding of new capabilities which can significantly 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. Advances in Identification Friend or Foe (IFF) will allow for the positive identification of friends, enhancing survivability. Soldiers could also have technologies that increase their ability to detect snipers - a capability that will continue to improve over time.

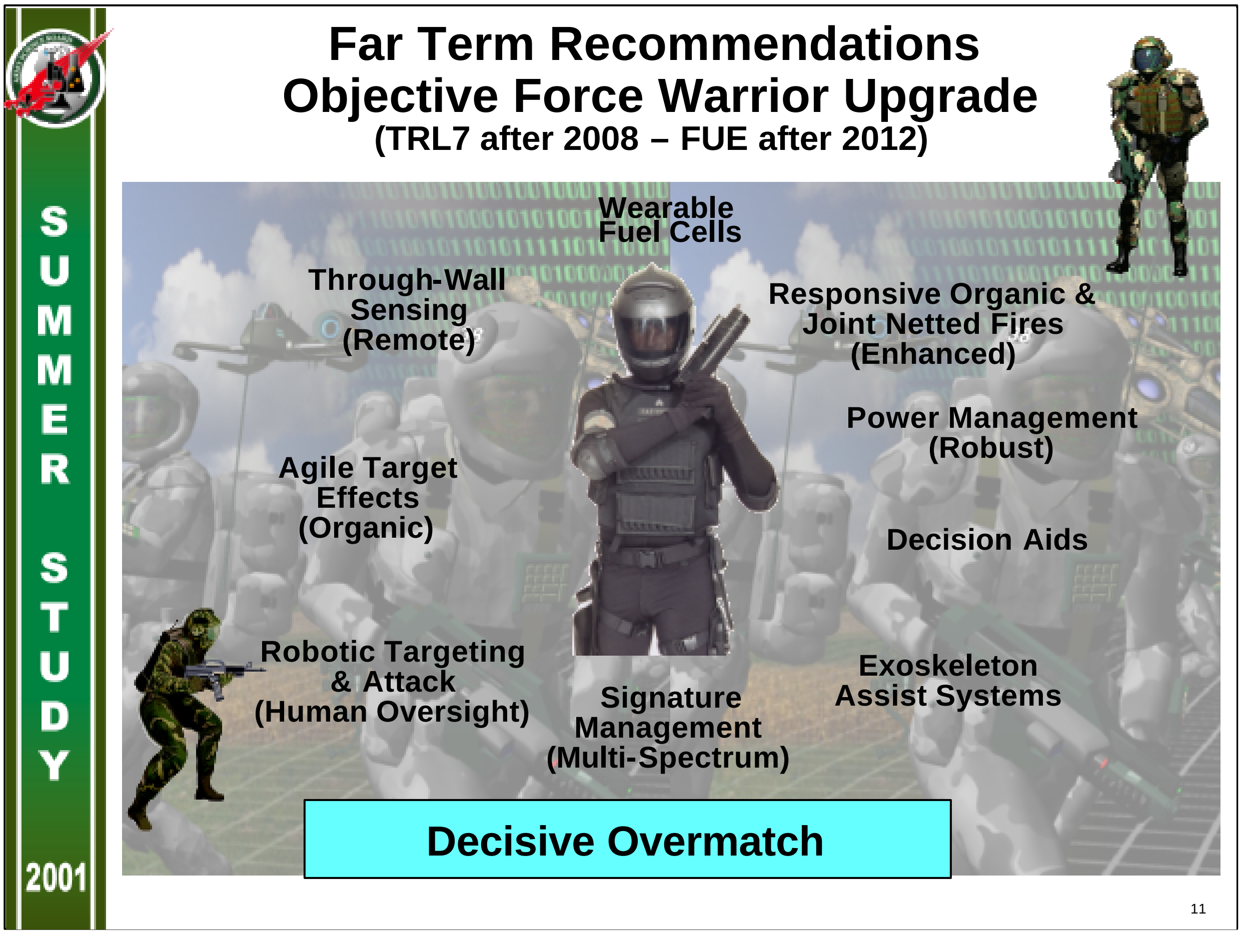
Significant improvements in soldier sustainment and support can also be realized. A robotic mule can emerge, which will have limited autonomy but can assume a major role in load-carrying. Water supply can also become less of a logistics' issue with new water purification technologies emerging. The soldier will be able to 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 Objective Force Warriors fight, and, even more significantly, increase their chances of survival through the collaborative advantages of multiple technologies.

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

The ability to "see first" and "understand 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" and "finishing decisively" can now be a function of responsive joint netted-fires, agile (lethal and non-lethal) target effects, and human-in-the-loop robotic targeting and attack. Enhanced mine and booby trap sensing can also be added to the list of operational capabilities. For complex terrain operations, soldiers can have limited see-through-walls capabilities and much more sophisticated sniper detection capabilities.

"Enduring" enhancements will include reduced weight via the application of integrated power management techniques and the use of rechargeable energy systems. Finally, new water generation capabilities, and both semi-autonomous robotic mules and UAVs can make "just in time" logistics a reality.

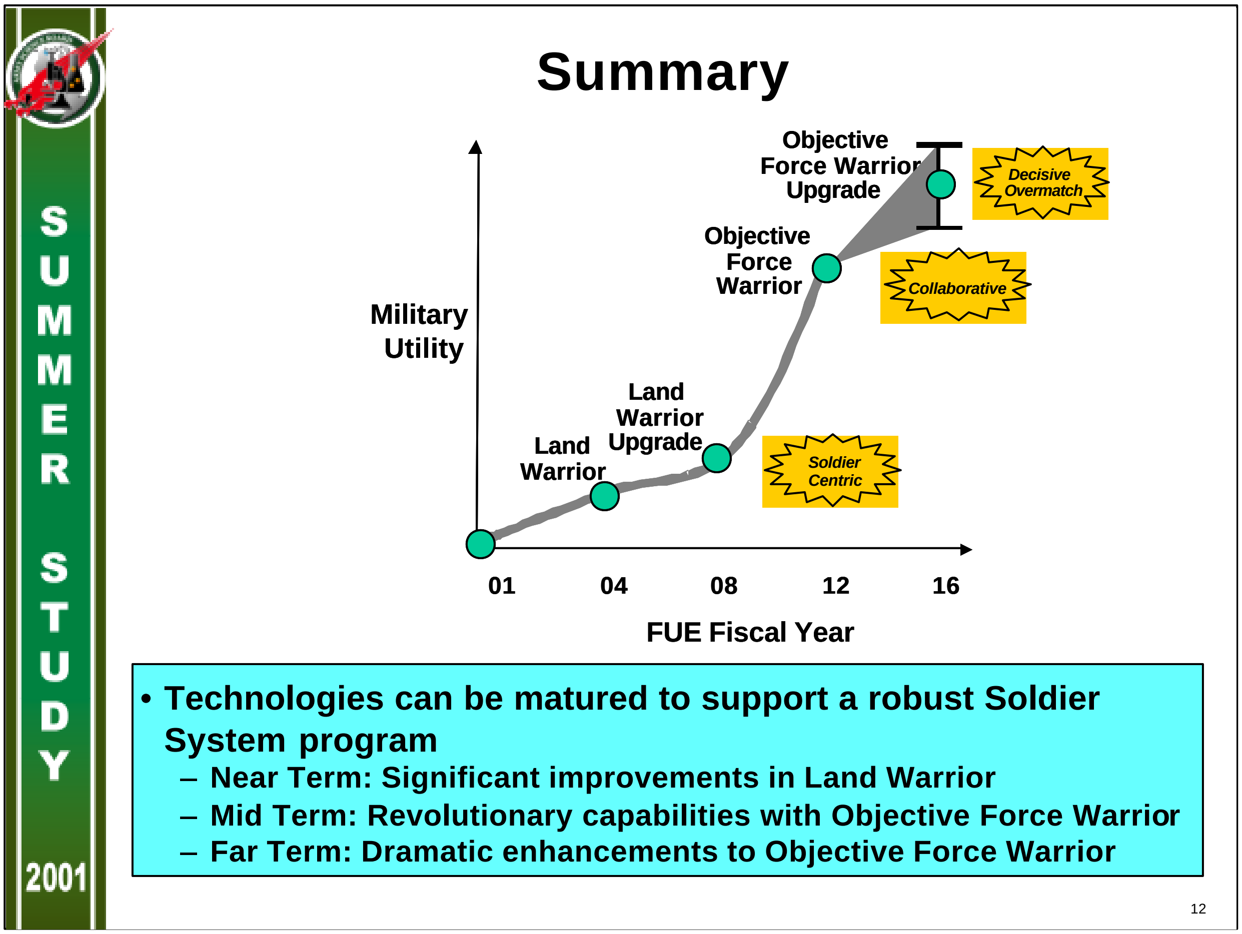


Far-term upgrades to the Objective Force Warrior can be realized after 2012. The recommended investments are expected to yield dramatic enhancements that can increase the soldier systems' overmatch capabilities.

Agile target effects organic to small units can be a reality, as can more enhanced, responsive organic and joint netted fires. Robotic targeting and attack can be greatly improved as human oversight replaces the need for human-in-the-loop.

Soldiers will now have advanced decision aids which can make real-time battlefield knowledge management a reality. The ability to see through walls from remote locations along with multi-spectral signature management capabilities will continue to improve survivability in complex terrain environments.

Continued sustainment advances can be expected in the far-term. Robust power management, wearable fuel cells, and exoskeleton assist systems are among the possibilities, increasing the operating envelop of soldiers in dismounted operations..



The figure on this chart conceptually illustrates the dramatic improvements in soldier system warfighting capabilities that can be realized over the next 15 years. In summary:

- Major Enablers have been identified that can provide these leap-ahead improvements in warfighting capabilities.
- Opportunities exist as soon as 2008 to start fielding these improvements, with additional capabilities becoming available as their technologies are matured in a phased capabilities-based acquisition strategy approach.
- However, investments are needed now to advance the prerequisite technologies and to develop the M&S analysis tools needed to focus their development.
- In addition, innovative warfighting concepts and TTPs must be concurrently developed and put in the hands of the Warfighter in a series of experiments that exploit live, virtual, and constructive simulation.
- Finally, management of the soldier system program as part of the overall Objective Force Program is necessary to fully exploit the technology synergies between soldier system and other Objective Force programs, and ensure effective force integration.

The implementation of these recommendations will put the Army on the path of truly revolutionizing the soldier system in concert with the transformation of the remainder of the Army.

SUMMER STUDY 2001

Soldier System – Next Steps

- **Conduct detailed military utility analysis**
- **Perform additional prioritization & assessments of technical approaches**
- **Determine "shared" capabilities with Objective Force & FCS programs**
- **Refine POM funding estimates for S&T programs**
- **Execute the Soldier System program, integrating it with the Objective Force, FCS & Aviation programs**

13

As a follow-up to the work conducted in this Summer Study, additional actions on the part of the Army are recommended to focus and prioritize activities necessary for the efficient and effective development of the soldier system:

- Conduct a detailed military utility analysis to verify and/or adjust the military utility analysis conducted by the ASB.
- Assess and prioritize the candidate technologies for the Major Enablers to determine those with the largest operational impacts and identify where cost reduction opportunities exist.
- Complete a rigorous analysis of the Major Enabler technologies to identify those that share commonality with the Objective Force, including FCS and manned/unmanned Army aviation. This analysis should identify the cost-leveraging that can permit funding by non-soldier system S&T programs. This will allow the existing soldier system S&T programs to focus on those efforts that are unique to the soldier system.
- Execute the proposed evolutionary acquisition and integrated management approaches to acquire the revolutionary soldier system capabilities in a time-phased approach which leverages the best available advanced technologies from both defense and commercial/academic sectors.

SUMMER STUDY 2001

Affordability and Cost Control Panel

1

Our panel mission was initially to assess affordability for the Soldier System. However, as we visited the PM Soldier Office and the various Laboratories and started our analysis, we realized there was a need to expand our perspective to include Cost Control. There exists today, no single point of contact for cost control across the entire Soldier system.

Affordability Panel Members

Carl Fischer	Chair
Mg (R) Chuck Drenz	Panel Member
Dick Ladd	Panel Member
Chérie Smith	Administrative Advisor
Col. John Smith	Government Advisor
Mateo Chino	Cadet Support

SUMMER STUDY 2001

2

The panel members (shown above) provided a wide range of management experience from the private sector and government covering executive management, program management at all levels, budgeting at all levels, cost estimating, contracting and major command operations.

Affordability Panel Mission

- **To achieve improvement in Performance While Cutting The Life Cycle Cost**

3

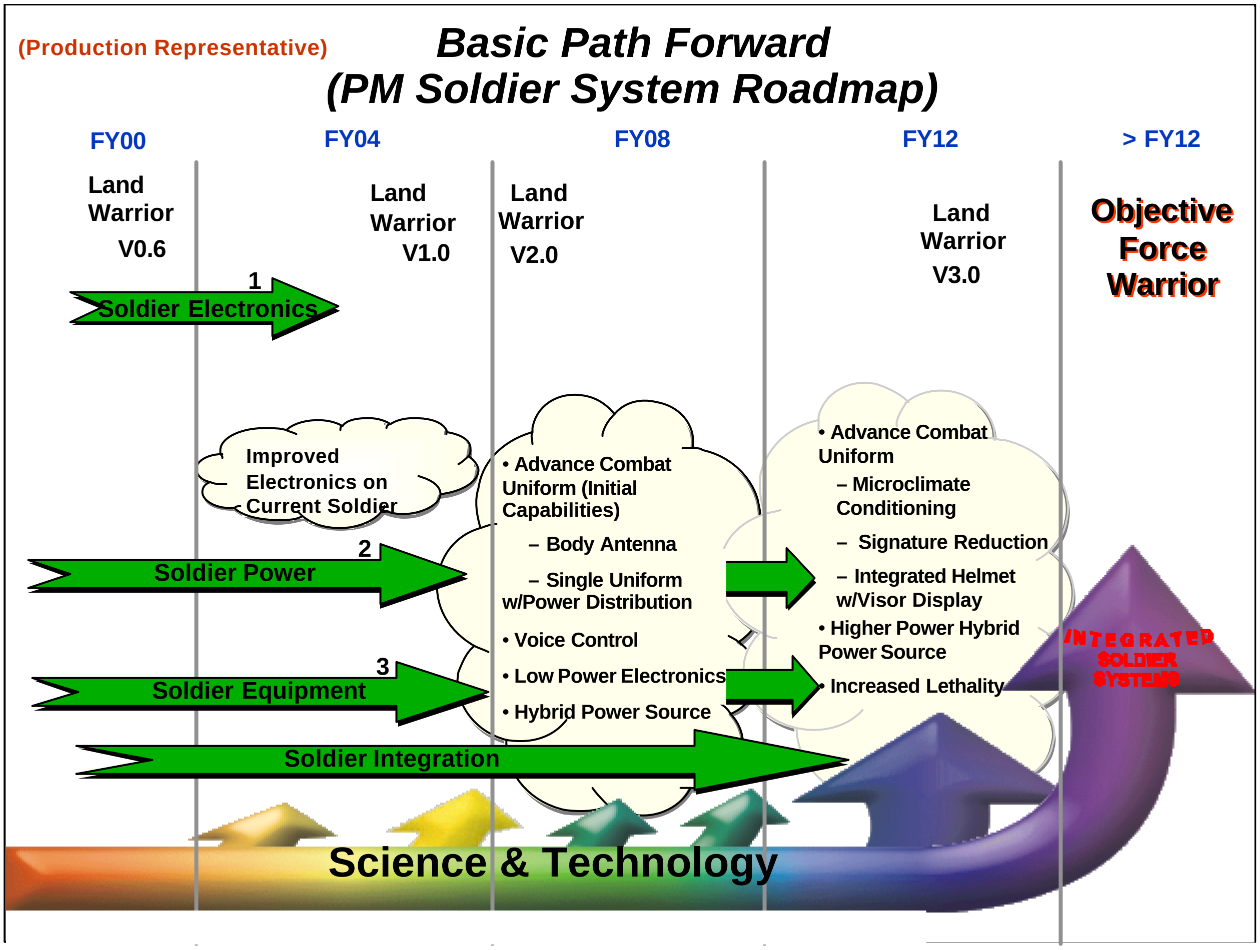
Given the fiscal challenges faced by all future military systems, the affordability panel's basic task was to investigate potential reductions in total lifecycle costs. We note up front that life cycle cost estimates are management tools, often of a long range nature, and not budgetary estimates.

The objective was to identify savings in the near term (2008) of 10%, mid term (2012) of 25 percent and long term (>2012) of 50 percent. While this initially appeared inconsistent with the concurrent objectives of ten-fold (10X) improvements in system capability, areas where significant gains were needed and possible have been identified.

The panels analysis was based on a basic fighting team of 9 infantry soldiers using cost data contained in PM Soldier Systems data base which was found to be the single most reliable source of cost data. This team would be equipped with 2 Objective Infantry Combat Weapons with the remaining team members equipped with other weapons as determined by combat scenario. The basic organization of the team was assumed to remain unchanged through 2012 and beyond.

Three separate 72- hour combat scenarios were evaluated to determine the costs associated with different tactical situations in which the objective force soldier would be employed. Two of the scenarios involved Military Operations in Urban Terrain (MOUT), one with a close combat mission and one with a peacekeeping mission. The third scenario involved intense operations in mountainous, difficult terrain.

For analysis purposes system costs were categorized into five separate "bins": lethality, C4ISR, Mobility, Survivability and Sustainability. This approach allowed the panel to focus on cost drivers which emerged in the lethality and C4ISR areas independent of scenario or mission.



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 from version 0.6 (FY00) to V2 (FY12) significant capabilities enhancements are 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 3.0 or depending on programmatics, held for integration into the penultimate combat soldier system, the Objective Force Warrior. The red area shown on this slide reflects the central challenge the overall system faces beyond FY 2004.

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.

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.

SUMMER STUDY 2001

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

5

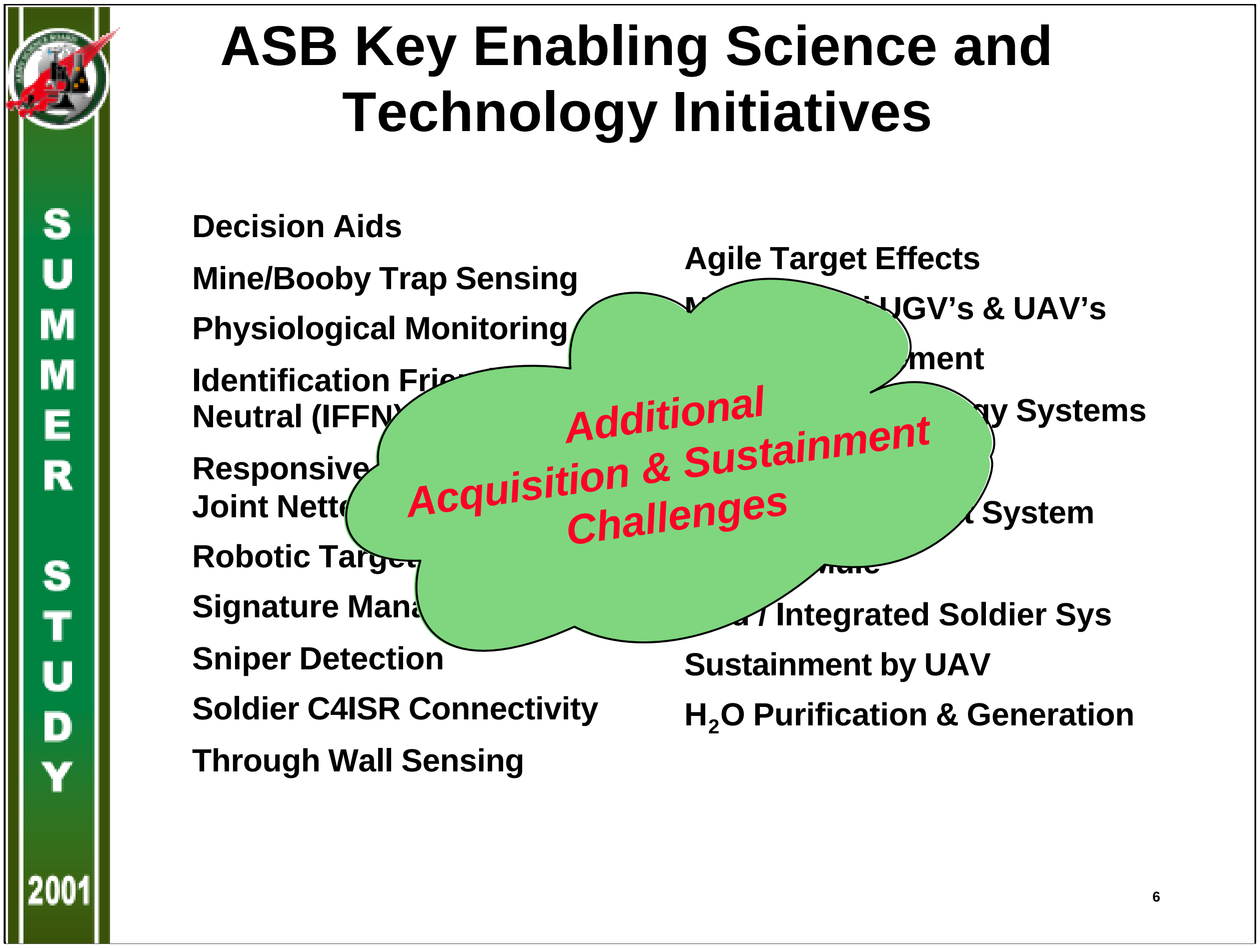
The Soldier System we evaluated is a system of systems evolving through a spiral development strategy. The back bone of the system is the Land Warrior System and is complemented by an emerging Science and Technology (S&T) program which could lead to a revolutionary new, integrated system or a very robust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



The Army Science Board has identified 20 technologies that have the potential of improving or revolutionizing the capabilities of the base line PM Soldier System program and record -- either in improved functionality or through reduction of Sustainment costs.

Some, if not all of these, are not likely to be available until implementation of Objective Force Warrior; others could be sufficiently mature for incremental integration into Land Warrior. Of those ready for insertion into the soldier system, they are unlikely to represent a procurement savings. They will most likely require additional acquisition monies over the lifecycle estimate, However, in some cases (e.g., Power Management) there are potential for overall lifecycle savings in Sustainment dollars.

Since these are un-programmed at this point in time, another challenge will be to secure necessary procurement dollars to get these advanced technologies in the hands of the combat soldier. While new technologies have the potential to actually reduce Sustainment costs, the overall impact of these initiatives on the Sustainment cost of the system cannot be predicted with any accuracy at this time. It is safe to assume that in most areas if they are additive to existing capabilities, they'll also add to Sustainment costs.

Four Approaches to Affordability

- **Exploiting potential synergisms in FCS**
  - **Commonality in technologies**
  - **Balanced force structure**
- **Lowering Sustainment costs:**
  - **Improve Mean Time Between Failure (MTBF) and Mean Time Between Replacement (MTBR)**
  - **Maximize use of rechargeable batteries**
- **Managing affordability and cost control**
- **Exploiting C4ISR to bring about a revolution in Army structure**

SUMMER STUDY 2001

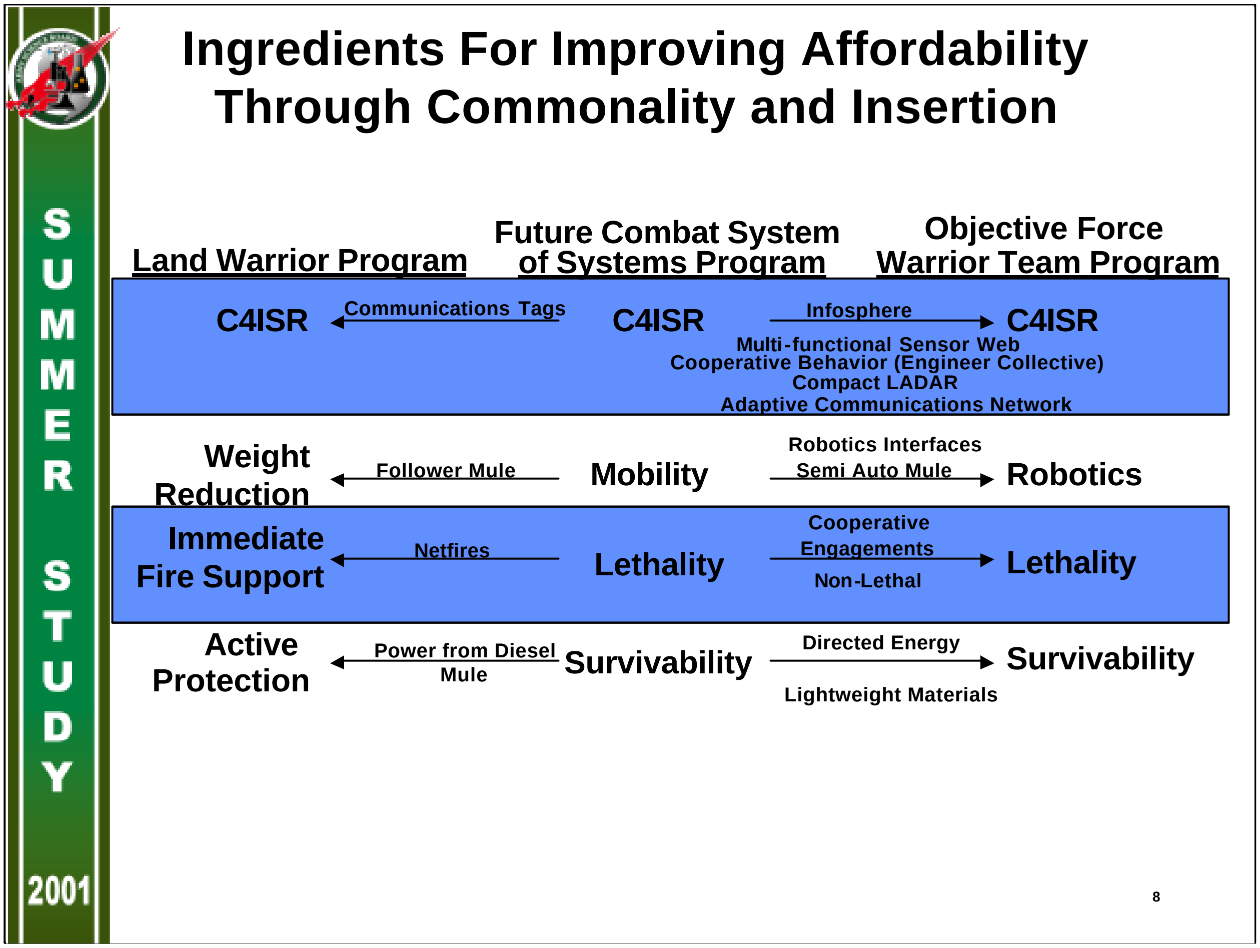
7

Our analysis suggests four approaches to enhance affordability which will be discussed in turn.

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.

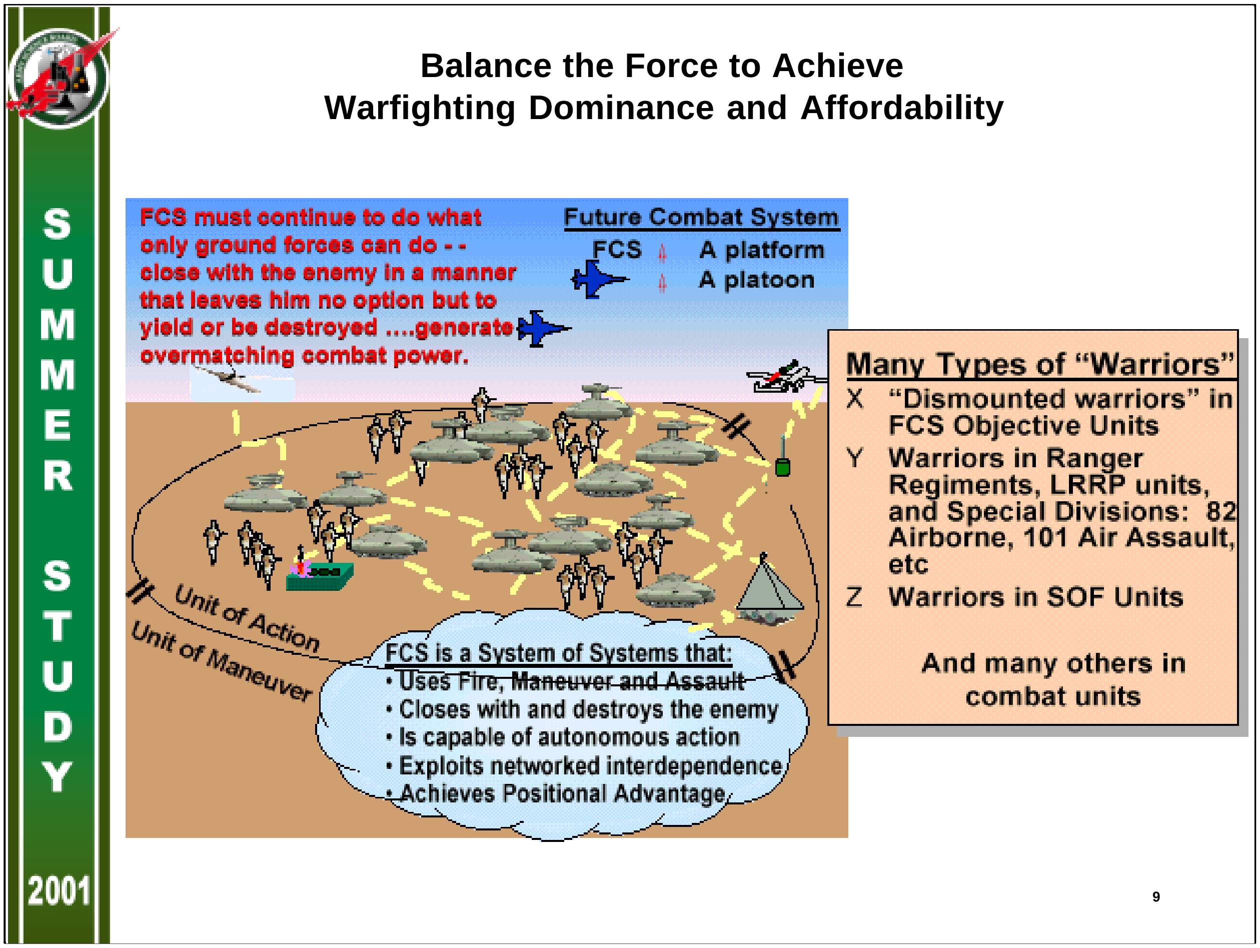
As in any successful program the ability to manage across the entire system and its respective components is vital. It is critical to establish a single individual responsible for cost and affordability, to manage trade-offs and determine viable options.



This slide further identifies the potential areas where leveraging work between Land Warrior, Future Combat System, and Objective Force Warrior could result in approving affordability, creating common baselines, and leveraging work initiated from one program into another.

Continuing with the Robotics topic discussed previously, this slide illustrates the requirement for greater mobility of the dismounted soldier. By using a "Follower Mule" to off load equipment and reduce the weight requirement on the individual soldier, you achieve the Performance Parameters in the Land Warrior Program. Then adding additional requirements to the robotic infrastructure, the potential to semi-automate the Mule would enhance the mission capabilities and effectiveness of the Objective Force Warrior.

These types of potential initiatives are apparent across many areas with increases in capabilities and cost savings in all areas of the Soldier System.



The typical battlefield of the future will not be characterized by massed forces opposing each other on open battlefields. Corps and Divisions will continue to play in the Major Theater War of tomorrow.

The "Futures/Threats Panel" analysis noted that with world population growth and continued movement into urban environments, urban terrain will dominate the landscape much more than in any time in the past. The very nature of MOUT makes the dismounted soldier the weapon of choice. This complex environment represents a unique set of threats, which only Land Warrior and it's successors can assure total tactical success and minimum casualties.

Our analysis suggests that with the 10x improvement in soldiers lethality and effectiveness that tradeoffs within the force could improve Soldier System affordability and increase force effectiveness.

SUMMER STUDY 2001

Life Cycle Cost Overview

	LW **1	Other LW	S&T
S&T for Objective Force Warrior			$0.5 – 1.0B
Research and Development	$0.8B	?	
Initial Fielding			
Land Warrior (LW)	$1.4B		**2
OICW (Less Training Ammo)		$0.7B	**2
Government Furnished Equipment		$1.0B	
Operating Costs			
Procurement (replacement)	$1.7B		**2
Operation and Maintenance	$3.9B	$0.6B	**2
Total	$7.8B	$2.3B	$0.5 – 1.0B

1 From Army Approved PM Soldier Cost Estimate

2 Assumed Not More Costly Than Land Warrior

Acquisition = $3.9 B | **Sustainment = $6.2 B** | **Total = $10.1 B**

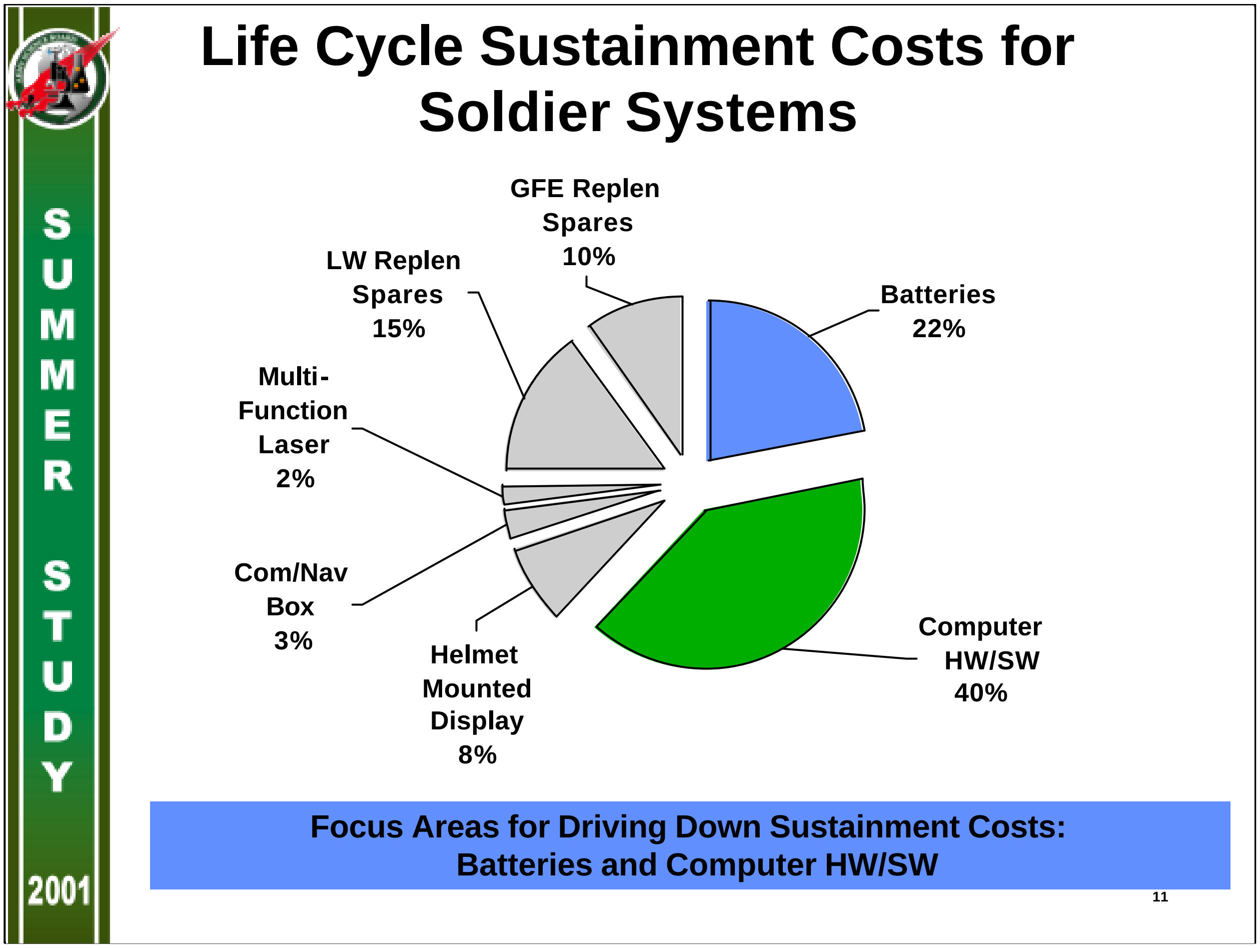
10

A quick look at Life Cycle Costs illustrates the importance of system Sustainment costs, which are typically the major portion of life cycle costs.

As no single life cycle cost estimate exists for the complete soldier system, the panel added an estimate of the initial acquisition and operating costs of government furnished items required for the PM Soldier managed Land Warrior program. This addition of $2.3 billion to the official $7.8 billion estimate for the Land Warrior program suggests an approximately $10 billion life cycle cost.

Just over 60 percent of the life cycle costs are Sustainment costs.

This $10 billion estimate is likely the best case estimate for the more revolutionary approach which could flow out of the envisioned S&T program. The estimate will increases unless some of technologies suggested by this study will provide net reductions in acquisition and operating costs. The panel notes that advanced military technologies rarely cost less than replaced technologies or have lower operating costs because increased capabilities are usually added.



A quick look at Life Cycle Costs illustrates the importance of Sustainment costs, typically the major portion of life cycle costs. As no single life cycle cost estimate exists for the complete soldier system, the panel added an estimate of the initial acquisition and operating costs of government furnished items required for the PM Soldier managed Land Warrior program. This addition of $2.3 billion to the official $7.8 billion estimate for the Land Warrior program suggests an approximately $10 billion life cycle cost with Sustainment cost being just over 60 percent of the life cycle costs. (This $10 billion estimate is likely the best case estimate for the more revolutionary approach, which could flow out of the envisioned S&T program. The estimate will increase unless some of technologies suggested by this study will provide net reductions in acquisition and operating costs.)

The panel allocated Sustainment costs into the major categories above. Two of these -- Computer Hardware/Software and Batteries -- constitute 62 percent of Sustainment costs and are viewed as the major “focus areas” for reducing Sustainment costs. The panel examined what the basic cost drivers were in these 2 areas and developed a number or options or steps that could be taken to reduce costs. A number of these are under active consideration in the Land Warrior program today. Informal estimates suggest that substantial reductions in life cycle costs can be achieved. It is the panel view that aggressive action should be taken now in order to maximize those savings.

In computers, a number of cost reduction steps merit consideration for both hardware (H/W) and software (S/W). Most of the computers and operating S/W are being purchased as commercial off the shelf items. Prices can be reduced by buying later in the market cycle rather than early in the production runs when demand exceeds supply. The current support strategy assumes that H/W and operating system S/W will be replaced and disposed of on 6 year cycles based on market place cycles of support and availability. Apply strategies which increase the useful life e.g., strategies that selectively assign the fastest computers to high priority units can lengthen the useful life of preceding generations of equipment, special deployment computer packages or having hi-lo mixes within units, and some h/W might be upgradable by careful use of spares/LRUs, requiring computer vendors to provide for upgrades. Reliability growth plan needs to be established to force longer mean time between failures and increase mean time between replacement of repair items. A shift to wireless technology can eliminate many cables and connectors which constitute a major failure points. Contractual provisions requiring reliability and upgrades need to be examined.

For Batteries the key points are to reduce power requirements though use of power management strategies. Eliminate organizationally redundant capability within a unit. Shift from disposable to rechargeable batteries to the maximum extent possible. The argument that we must train as we fight must be challenged. In fact the need to reduce the weight carried by the soldier suggests that using rechargeable batteries may be the preferred way of fighting whenever there is a recharge point accessible which should be case very often for the FCS based soldier system. There should be a progression started towards JP8 energy systems using fuel cells and rechargeable batteries.

SUMMER STUDY 2001

Computers: A Step-By-Step to Lower Sustainment Costs

- **Lower Unit Costs**
  - **Buy Units Later in Production/Market Cycle**
- **Lower Total Buy**
  - **Consider Strategy of Pre-deployment System Upgrades**
  - **Allow for Hi-lo Computer Capability Within Squad**
  - **Upgrade Thru Spares**
- **Lower Repair Costs**
  - **Use Wireless Technologies Vs. Wire Harness**
  - **Increase LRU Reliability**
  - **Review Hardware Management/Configuration Control Plans**

12

In the area of computers, a number of options or cost reduction steps merit consideration for both hardware and software.

Unit Costs: Most of the computers and operating software are being purchased as commercial off the shelf items. As such, the issue is more market price than cost. Prices can be reduced by buying later in the market cycle rather than early in the production runs when demand exceeds supply. Such a strategy can save money.

Lower Total Buy: The current support strategy assumes that computers and operating system software's will be replaced and disposed of on 6 year cycles based on market place cycles of support and availability.

Most of the computers will still be useable beyond 6 years as our experience with our home computers clearly demonstrates. Strategies which increase the useful life will reduce the number of replacements. As the military unique, functional software evolves separately, strategies that selectively assign the fastest computers high priority units can lengthen the useful life of preceding generations of equipment. Such strategies might include special deployment computer packages or having hi-lo mixes within units. Additionally, some computers might be upgradable by careful use of spares/LRUs, requiring computer vendors to provide for upgrades.

Lower Repair Cost. Reliability growth plan needs to be established to force longer mean time between failures and increase mean time between replacement of repair items. A shift to wireless technology can eliminate many cables and connectors which constitute a major failure points. Contractual provisions requiring reliability and upgrades need to be examined.

Batteries: A Step-by-Step Progression to Lower Sustainment

SUMMER STUDY 2001

- Lower Energy Requirements
  - Lower Energy On a Given Soldier
    - ∗ Power Management
    - ∗ Better Systems Design
      - Energy Consumption KPP
      - Doing More With Less
      - Standardization and Commonality
  - Lower Number of Soldiers With High Energy Needs
    - ∗ Rational Number of Land Warrior Systems Required within FCS
- Increase MTBF and MTBR
  - Packaging, Ruggedization, Training
    - ∗ Current Heuristic: 3 yr Life
    - ∗ Expected Life In Normal Use: 6 yrs.
  - Rechargeable Batteries

13

Batteries and power sources are a major issue addressed separately by the ASB. The next 2 charts jointly prepared with the power panel summarize several steps to reduce costs.

The key points are to reduce power requirements though use of power management strategies on computers and software systems. Organizationally, redundant functionality and capability within a unit must be eliminated consistent with operational risks, I.e., rationalize power consumers with operational needs.

There should be a shift from disposable to rechargeable batteries to the maximum extent possible. The argument that we must train as we fight, i.e., use disposable batteries, must be challenged. In fact the need to reduce the weight carried by the soldier suggests that using rechargeable batteries may be the preferred way of fighting whenever there is a recharge point accessible which should be case very often for the FCS based soldier system.

There should be a progression started towards JP8 energy systems using fuel cells and rechargeable batteries

SUMMER STUDY 2001

Batteries: A Step-by-Step Progression to Lower Sustainment (Cont.d)

- Optimize Peace Time Expenditures
  - Commercial Rechargeable Batteries
  - Inexpensive Primary Batteries For Training
  - Provide Inexpensive Generators for Recharging
  - Use Hybrids of Rechargeable Batteries Combined with Low Cost Primary (Zinc-Air) Batteries
  - Use Solar Power When Available
- Begin Progression to JP8 Energy Systems
  - Use Hybrids of Rechargeable Batteries Combined With Fuel Cell Or MEMS Power Units
  - Build An Overall Energy System Where the Prime Fuel Source is JP8, Using Generators, Rechargeable Batteries, etc.

14

SUMMER STUDY 2001

Management Considerations

- **Centralized management for the soldier system**
  - **PEO or Super PM: I.E., PM Soldier Systems**
  - **Under PM Soldier there should be a Chief Systems Engineer responsible for:**
    - **An aggressive Cost As an Independent Variable (CAIV)**
    - **Total Soldier System Configuration Management**
    - **One Synchronized S&T program to assure that the Soldier System is fielding in lock step with the over all needs of the Objective Force**

15

As stated earlier, a System of Systems/Family of Systems approach needs to be brought to this effort. This can be done through the establishment of a Super Program Manager (PM) for all elements within the Soldier System or by placing all the various elements within a single Program Executive Office (PEO) for control and integration. Within this responsible entity, there needs to be a Chief Systems Engineer with responsibility for integration across the Soldier System. Additionally, this provides a single voice to Objective Force and FCS Overarching Integrated Process Teams (IPT).

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. The Chief Systems Engineer would ensure total Soldier System Configuration Management and a single synchronized Science and Technology (S&T) program that assures the Soldier System is fielding in lock step with the overall needs of the FCS Force.

Acquisition and Sustainment Cost Drivers

Lethality

- **Multifunction Laser/Digital Compass**
- Thermal Weapon System (TWS) (med/lt)
- MILES 2000
- OICW/Ammunition
- **Thermal Image Intensifier (I^2)**
- **Target Laser/Identification**

C4ISR

- **Helmet Mtd Display**
- **Computer Assembly**
- MBITR Radio
- Joint Digital Radio
- **Computer/Navigation Assembly & Soldier Radio**

Other

- Battery & Power Sources
- Gator/Robotics
- **Global Positioning System (GPS) Cards/Antenna**
- **Armor**
- **Exoskeleton**

[highlighted] PM Soldier Managed

SUMMER STUDY 2001

16

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. The areas not highlighted in this slide are found outside of the PMs control and influence. 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 offs.

Integrated Affordability Management and Control

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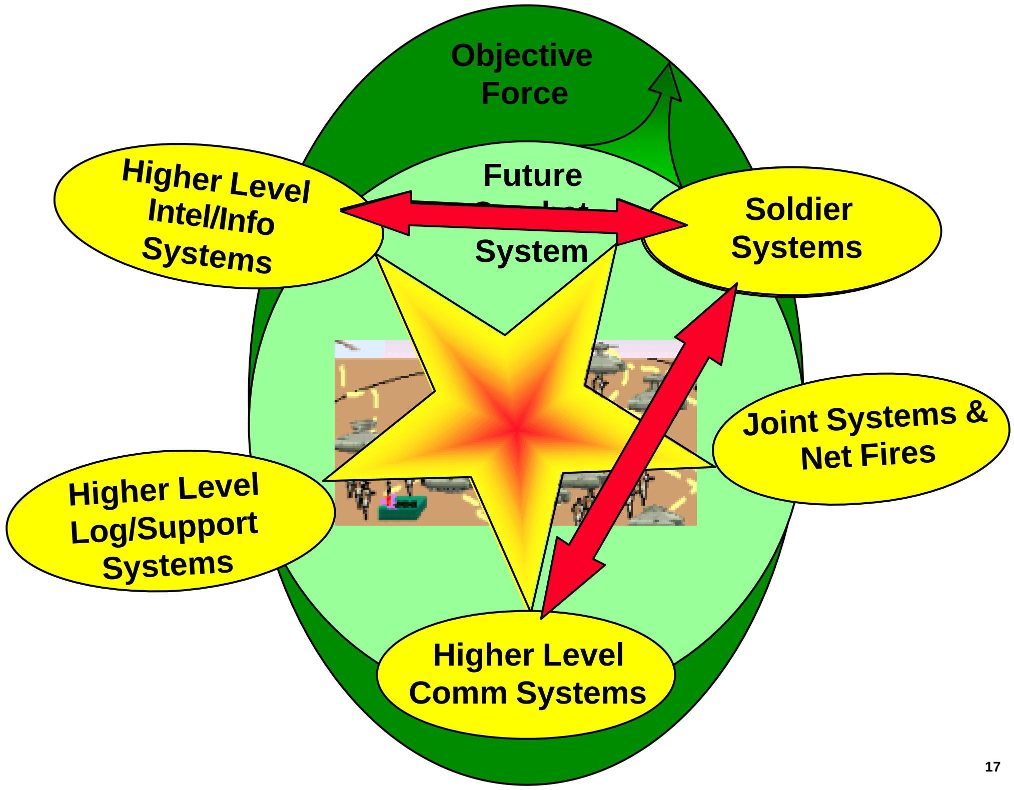

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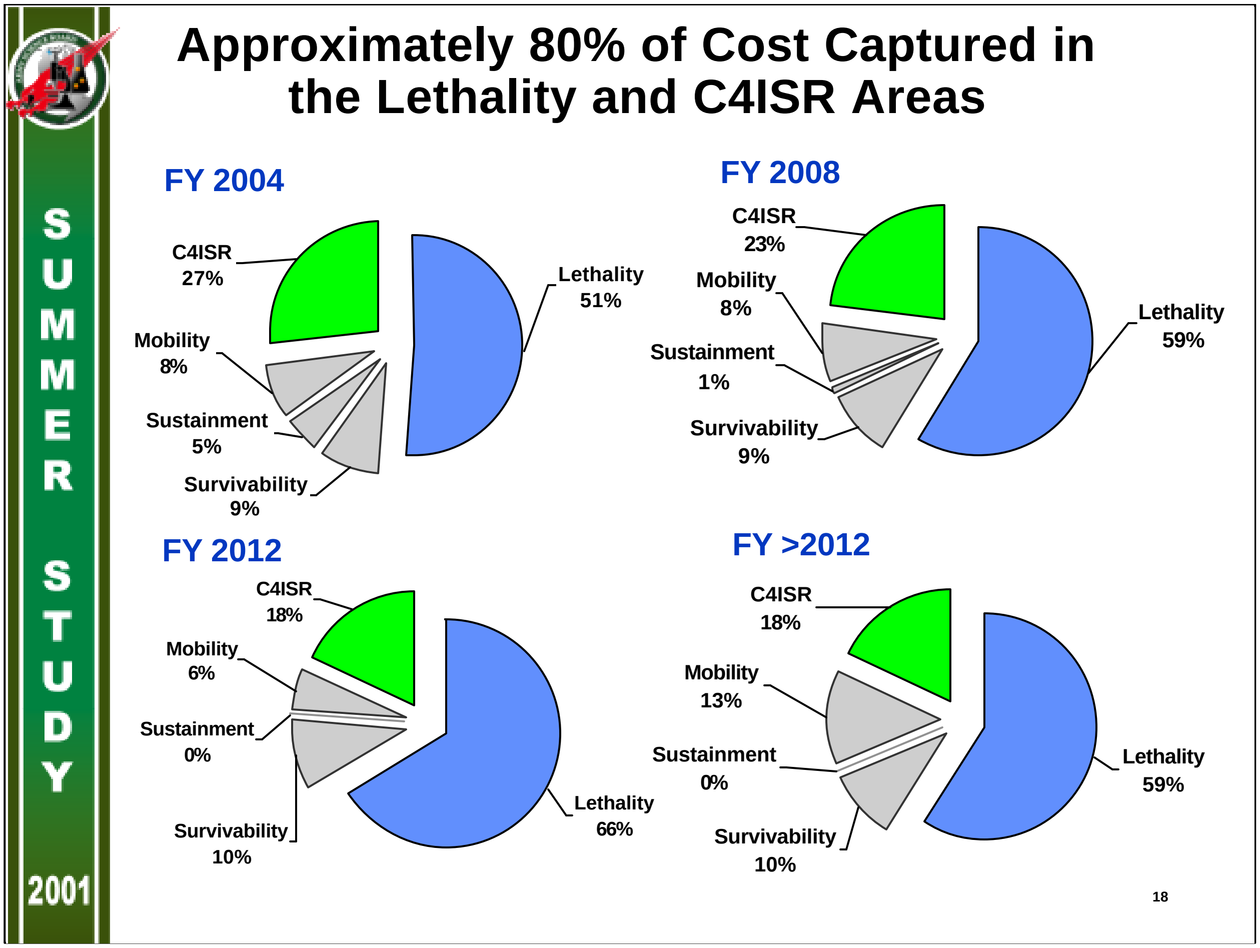

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Three separate 72- hour combat scenarios were evaluated to determine the costs associated with different tactical situations in which the objective force soldier would be employed. Two of the scenarios involved Military Operations in Urban Terrain (MOUT), one with a close combat mission and one with a peacekeeping mission. The third scenario involved intense operations in mountainous, difficult terrain.

For analysis purposes system costs were categorized into five separate “bins”: lethality, C4ISR, Mobility, Survivability and Sustainability. This approach allowed the panel to focus on cost drivers which emerged in the lethality and C4ISR areas independent of scenario or mission.

Reviewing each of the cost bins within the scenarios suggests that relative costs for the system, when operating in various environments, are not substantially different. As expected from the overall analysis, costs peak during the MOUT Intense scenario; with Sustainment and Survivability being the largest components of the cost difference. (The spike in survivability due to increased consumption of disposable batteries. Due to the very nature of the tactical environment, the combat team will be placing extensive reliance on situational awareness and target acquisition and engagement capabilities. Similarly, mountain intense also increased use of batteries, although somewhat less than MOUT, likely due to decreased reliance on power hungry components of the system. When engaged in intense contact with the enemy, a small increase in survivability is demonstrated. Increased dependence on survivability components to minimize losses accounts for this increase.)

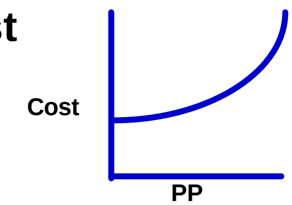
Given the minor difference between costs for a given scenario, our panel performed our assessment using the MOUT Intensive scenario as the baseline. This represents the most component intensive scenario and the results from which can be assumed to accurately extrapolate to the other scenarios. Evaluation of the contribution of each of the bins over the lifecycle of the system clearly isolate Lethality and C4ISR as the principal cost drivers, regardless of the timeframe investigated. In the out years the other bins, Survivability and Mobility have slightly increased impact on costs, however increases are relatively insignificant due to the overall percent they contribute to the whole. Mobility has the largest such growth, this is due to introduction of exoskeleton and/or robotics in the out years.

For the initial procurement, 2004, the Multifunction Laser/digital compass contributes over 50% to the Acquisition cost of the system. This followed by Thermal Weapon Sight (TWS) light and medium. By 2008 the OICW has been introduced and consumes a significant portion of the cost; however, the TWS remains a major cost driver. This situation does not change by 2012; however, at this point TWS has been replaced and thermal/i2 fusion which is one of the more significant components of the cost breakdown. After 2012 target laser/identification is introduced which contributes greatly to cost.

Cost As an Independent Variable (CAIV) and Design to Cost Program Essentials

SUMMER STUDY 2001

- **Firm commitment to cost objectives – acquisition & Sustainment**
- **Cost Czar with authority to optimize mission effectiveness for a given cost objective**
- **Performance Parameter (PP) vs Cost relationships**



- **High resolution Performance Parameter versus military utility models**
  - **Soldier system**
  - **Soldier system/objective force**

Affordability – Leading Cause of Failure to Field
Unfielded Systems Do Not Improve Combat Effectiveness

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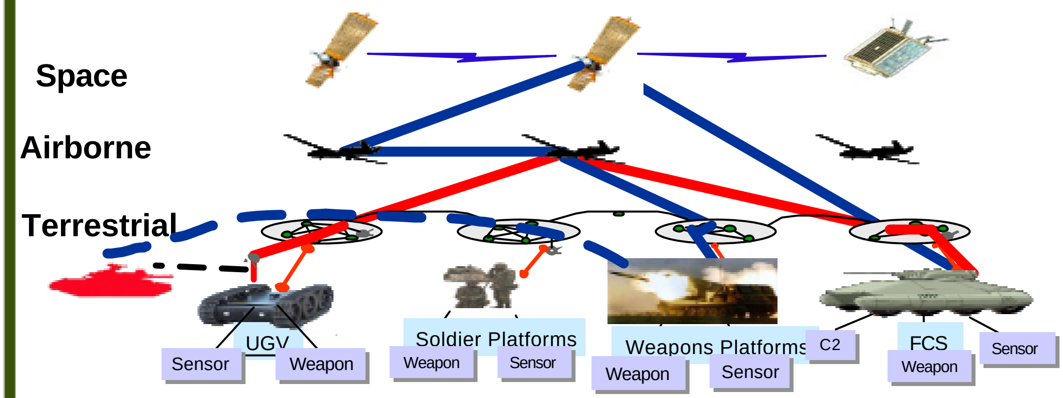
Cost as an Independent Variable (CAIV) is currently applied to only pieces of the over all Soldier System. This would be unacceptable in the commercial environment. For example, if you were responsible for designing and building a future car model, one of the first things you would be told is the price at which the car most leave the factory. As the Program Manger for this new vehicle you could conceivably put in any items you wanted as long as the overall cost was within your cost baseline. You could then perform trade offs of capabilities against each other and items would "Buy their way" into the completed car baseline.

This type of cost control must be implemented within the Soldier System. The Cost Czar must have authority to optimize the mission effectiveness across the Soldier System Baseline for a given cost objective. They must assess the performance parameter they are trying to meet with the cost of meeting that requirement.

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.

SUMMER STUDY 2001

C4ISR Will Lead to a Revolution in Warfare



- **Many of this years recommendations add to last year's ASB study**
- **"Close-the-last mile" - give the dismounted soldier the ability to see first, shoot first**

C4ISR Should Enable a New Balance in Force Structure With More Tooth and Less Tail

20

SUMMER STUDY 2001

Four Approaches to Affordability

- **Exploiting potential synergisms in FCS**
  - **Commonality in technologies**
  - **Balanced force structure**
- **Lowering Sustainment costs:**
  - **Improve Mean Time Between Failure (MTBF) and Mean Time Between Replacement (MTBR)**
  - **Maximize use of rechargeable batteries**
- **Managing affordability and cost control**
- **Exploiting C4ISR to bring about a revolution in Army structure**

Lack of Affordability - leading Cause of Failure to Field

21

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.

SUMMER STUDY 2001

Bottom Line

- **ASB key enabling Science and Technology initiatives recommended for technology insertion**
- **Four approaches to affordability**
  - **Share technology development with FCS**
  - **Improve MTBF And MTBR**
  - **Establish a single point of leadership for Soldier Systems to manage affordability**
  - **Use C4ISR to lower cost of force structure**
- **In combination - These approaches should allow better allocation of resources to the Army's Centerpiece of Battle - The Dismounted Soldier**

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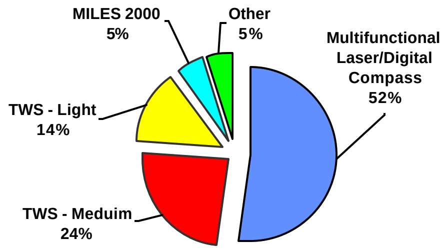
- Sad Reality: Cost is Often a "Neglected" Variable Rather Than an Independent Variable
- Program Management Is Not Currently Organized Properly to Field an Affordable Soldier System

SUMMER STUDY 2001

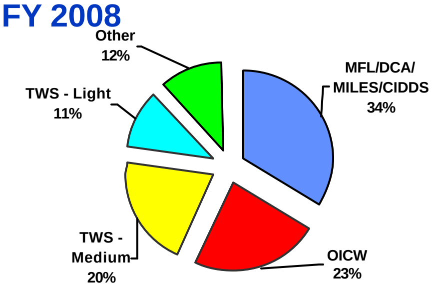
Lethality
Acquisition Cost Drivers

FY 2004



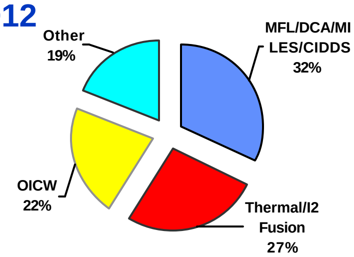
Total Dollars Lethality	$ 164,588.00
Total Soldier System Dollars	$ 315,100.06
Lethality % of Total	51%

FY 2008



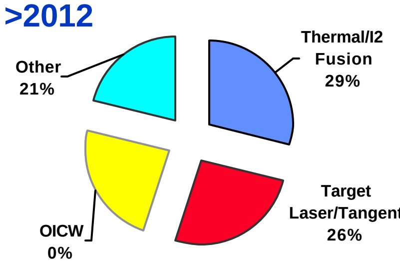
Total Dollars Lethality	$ 176,288.40
Total Soldier System Dollars	$ 298,045.29
Lethality % of Total	59%

FY 2012



Total Dollars Lethality	$ 178,288.00
Total Soldier System Dollars	$ 276,225.95
Lethality % of Total	66%

FY >2012

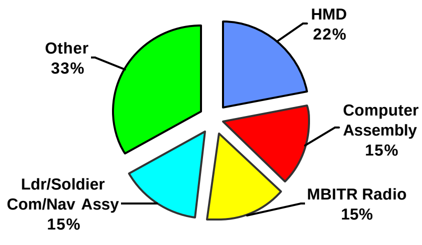


Total Dollars Lethality	$ 167,801.72
Total Soldier System Dollars	$ 283,739.67
Lethality % of Total	59%

SUMMER STUDY 2001

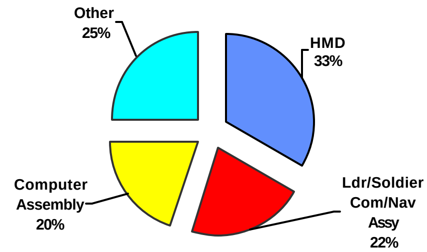
C4ISR
Acquisition Cost Drivers

FY 2004



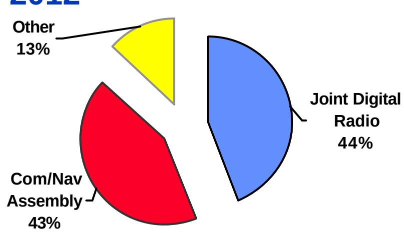
Total Dollars C4ISR	$ 84,351.00
Total Soldier System Dollars	$ 315,100.06
C4ISR % of Total	27%

FY 2008



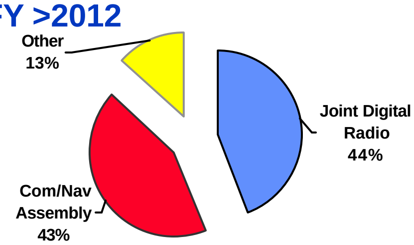
Total Dollars C4ISR	$ 67,719.00
Total Soldier System Dollars	$ 298,045.29
C4ISR % of Total	23%

FY 2012



Total Dollars C4ISR	$ 50,730.60
Total Soldier System Dollars	$ 276,225.95
C4ISR % of Total	18%

FY >2012



Total Dollars C4ISR	$ 50,730.60
Total Soldier System Dollars	$ 283,739.67
C4ISR % of Total	18%

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OICW Thermal Weapon Sight

SUMMER STUDY 2001

Requirements

- Detection/Engagement Range 1000m
  (Cost Estimate Basis) 750M
- Ruggedness Demonstrate (Drop, Vibration, etc) Note:Current Medium Thermal Sight only meets these requirements in it's packing container
- Laser Steering & Video Tracking
- CIDS/MILES
- Operating Life 20 Years

Current Cost Projections

- Thermal Weapon Sight (TWS)
  - Thermal Imaging/ Visual $16,000
  - Other $4,000
  - Subtotal $20,000
- Test Bore Sight, Align $2,300
- Government (Ratioed) $1,500

Total $23,800

Current MM&T Cost Reduction Programs

Initiation	Risk	TRL	Available
Multifunction Laser	High	6	FY04
Uncooled Focal Plane Array	High	6	FY03
Combined Optics	High	4	FY02

Note: These Reductions Are Already Factored Into The Projected Cost of $20,000/sight

CAIV Considerations

- Move Electronics to LW $1,500/sight
- Move Digital Compass to LW $1,160/sight
- Drop Req for Laser Steering and Video Tracker $2,195/sight
- Range Reduction (750m to 500m) $3,780/sight
- Drop Req for CIDDS/MILES $1,160/sight

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Requirements: The requirements for the sight are currently for acquisition of targets at 1000 meters, day – night, video tracking, digital compass, range funding, embedded training, stand alone weapon. Expectations are the user will reduce requirements to a range of 750 meters and drop embedded training (CIDDS/MILES).

Comments: This chart has costs portrayed based on a 750 meter not a 1000 meter requirement and assumes the currently funded high risk MM&T's will be successful. There are some potential CAIV areas if the user is willing to reduce his requirements. These are: (1) Moving the electronics and digital compass to the Land Warrior (LW). This however will limit issue of the OICW to LW equipped soldiers. (2) The greatest cost can be saved by simply reducing the acquisition range from 750 to 500 meters. This change will also insure that development production and fielding by FY09 can be met as the technical risk is reduced. (3) Dropping the laser steering and video tracker and the CIDDS/MILES embedded training requirement. These requirements should be revisited as to need and how much improvement is provided.

OICW Ammunition

SUMMER STUDY 2001

Requirements

- High Explosive Air Burst (HEAB) Ammo
  - Pi Exposed Stationary .50 @ 450-500 mm
  - Pi Defilade .35 @ 450-500 mm
  - Safety Storage/Handling/Transformation/Use
- 5.56 mm Ammunition – Standard Round

Current Cost Projections

- 20 mm High Explosive Air Burst (HEAB) $16,320/weapon
  - $34/Round
  - 480 Rounds Per Weapon = Basic Load and War Reserve

    ($34/Round *480 rounds = $16,320)

Current MM&T Cost Reduction Programs

Initiation	Function Type	Risk	TRL	Available
Warheads (Tungsten)	MM&T	Med	7	FY01
MEMS Fusing	6.2/DARPA	High	6	FY04

Note: These Reductions Are Already Factored Into The Projected Cost of $34.00/Round

CAIV Considerations

- Trade Pi vs. Cost

	HEAB Geometry	
HEAB Shell	Front	Back
Current HEAB	Tungsten	Steel
CAIV HEAB-1	Steel	Steel
CAIV HEA B-2	Tungsten	Tungsten

CAIV HEAB-1
- Projected savings = $7.00/round or $3360/system
- Reduce Pi by 30%

CAIV HEAB-2
- Projected cost addition = $4.50/round or $2160/System
- Increased Pi by 15%

- ASIC Fuse $2.00/fuse = $960/system

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Requirements: Current requirements are Probability of incapacitation (Pi) for exposed stationary troops is .50 @450-500 meters and Pi = .35 @ 450-500 meters for troops in defilade. This requirement was based on a red/blue loss exchange ratio using a CAS FORUM model.

Comments: Current requirement has not been demonstrated and is in testing now using combinations of the current design (tungsten – front/steel-rear), a steel-front/steel-rear version and a tungsten – front/tungsten-rear version. Analyses showed steel/steel was about Pi = .2 stationary and less than Pi = <.2 in defilade, which did not satisfy the users' desired loss exchange ratio. This testing should validate this fidelity of the models and allow a more realistic decision as the real requirement for lethality should be.

Helmet Mounted Display

SUMMER STUDY 2001

Requirements

- Provide primary visual information output & complete access to computer information
  - –Multi-spectral day/night
- Support map display
- Monocular night vision sensor for improved mobility and target detection
- – Target detection (Meters):

Current	Min Acceptable	Goal
160/0*	320/210*	450/300*

* High visibility, night/poor visibility

Current Cost Projections

- HMD
  - – Thermal/ LLV (60%)
  - – Display (20%)
  - – Electronics (20%)

$2533

Current MM&T Cost Reduction Programs

Initiation	Risk	TRL	Available
Uncooled Thermal Imager	High	5	FY05
Miniature & Conformal Elect	Low/ Med	5	FY05
Orient & Cueing Sensor	Low	5	FY05
SXGA Color Display	Med	5	FY05
Shared aperture MS optics	Med	5	FY05

CAIV Considerations

- Display
  - –Shared Aperture/ Multi-spectral (1280x1024)
  - –HDTV (1920x1080)
- Horizontal FOV
  - –Reduce requirement from 40 to 30 degrees
- Un-cooled Micro-bolometer
  - –Alpha Silicon vs Vanadium Oxide (baseline)
    - *Similar performance with significant unit cost reduction

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Requirements: The Helmet Mounted Display is to provide both visual displays and access to computer information. The visual information is for multi-spectral day and night. The HMD must also support a map display. Monocular night vision for improved mobility and target detection is also required. The target detection requirements, in meters, are for both high visibility night and poor visibility. The current requirement is 160 meters for high visibility, night and 0 meters for poor visibility. The minimally acceptable requirements are 320 meters and 210 meters respectively. The goal is 450 meters and 300 meters respectively.

Current Cost Projections: The HMD will cost $2533 per unit. Although the specific cost breakdown is not provided, there are assumptions provided as to the relative per cent of cost of the major sub-systems. These are thermal/ low-light level (60%), the display (20%), and the electronics (20%).

Current Cost Reduction Programs: The objective is to mature the technology in those areas where there is a payoff in cost reduction while minimizing risk and uncertainty prior to committing to the next phase of the program. Five specific cost reduction areas are identified. These are: (1) Un-cooled thermal imager, (2) Miniature & conformal electronics, (3) Orientation and Cueing Sensor development, (4) SXGA color display, (5) Shared aperture Multi-spectral optics,. All of the cost reduction related efforts fall under the research and development type, and all provide a TRL 5 when available in 2005. The un-cooled thermal imager is the only item considered to be high risk, with the SXGA color display, and shared aperture multi-spectral optics being medium risk. The remaining items are considered relatively low risk.

CAIV Considerations: CAIV analysis could provide savings in a couple of areas. In the display area where there are two displays under consideration. The shared aperture/multi-spectral provides a 1280 x 1024 display, whereas the HDTV capability will provide a 1920 x 10809 display.

A second consideration involves the horizontal field-of-view (FOV). It is understood that the more critical FOV is in the vertical, so no consideration should be given to relaxing that requirement. However, it may be worth considering relaxing the horizontal FOV requirement from 40o to 30o.

Another possible CAIV analysis would consider changing the baseline for the un-cooled micro-bolometer from vanadium oxide to alpha-silicon. This could provide significant cost reduction with little or no performance degradation.

SUMMER STUDY 2001

Joint Digital Radio

Requirements

- Multi-band/multi-tier peer-to-peer ad hoc network topology for secure voice and data services
- Multiple modes to defeat detection & jamming
- Wearable, broadband antenna
- Multi-functional/programmable modem/network processor
- Scaleable/expansible RF for Leader-level, multi-channel/multi-net ops

Current Cost Projections

Squad-Level		Leader-Level
$250.	User Interface/apps processor	$450.
$250.	INFOSEC	$750.
$700.	Prog modem/net processor	$1400.
$100.	Software waveform	$200.
$850.	Expansible waveform	$1250.
$100.	Broadband antenna	$200.
$150.	Packaging & interconnects	$300.
$100.	Power supply	$200.
$2500.		$5000.

Current Cost Reduction Programs

Initiation	Function Type	Risk	TRL	Available
JTRS Dismounted/ Handheld	R&D	High	6	FY06-08
Prog Modem/Proc	R&D	High	5	FY05
Multi-band RF	R&D	High	4	FY05
Soldier antennas	R&D	High	5	FY05

Note: These Reductions Are Already Factored Into The Projected Cost

Considerations

- Squad vs Leader-Level Component reuse and logistics
- Expansive RF
  - Channels, frequency range
- Broad-band antennas
  - Gain, efficiency, frequency range
- Programmability, multi-function
  - Reduced memory/processing capability

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Requirements: The requirements for the Joint Digital Radio (JDR) include the following. It must have the capability for multi-band/multi-tier peer-to-peer ad hoc network topology for secure voice and data services. In order to defeat detection and jamming it should be capable of multiple modes. The antenna needs to be wearable and broadband. The radio must be multi-functional, with a programmable modem and network processor. The radio needs to have scaleable.expansible RF for Leader-level, multi-channel/multi-net operations.

Current Cost Projections: The current cost projection for the JDR is broken into two parts. One is for the squad-level, the other for the Leader-level. For the squad-level, the cost projection is $2500 per unit; for the Leader-level, the cost projection is $5000 per unit. The cost projection is further broken down by specific category, such as, INFOSEC, broadband antenna, expansible waveform, etc. The major cost drivers are the programmable modem network processor and the expansible waveform.

Current Cost Reduction Program: This chart depicts a list of some of the cost reduction programs underway. All are considered high risk and, except for the JTRS dismounted/handheld initiative, are available in 2005. It is worth noting that the JTRS dismounted/handheld availability is somewhere between 2006 and 2008. The uncertainty may be related to funding more so than technology uncertainty.

CAIV Considerations: There may be several areas where one could effect cost reduction through smart buying or trading off of requirements. For the former, an example would be to look at squad versus Leader-level component reuse and logistics. In the area of trading off of requirements a couple of examples are presented here. One would consider the channels and frequency range for the expansive RF. Another would be to look at the gain, efficiency, and frequency range for the expansive RF. Another would be to look at the gain, efficiency, and frequency range requirements for the broad-band antennas. Lastly, for the requirement for programmability and multi-function, one could consider the effect of reducing the memory and processing capability.

SUMMER STUDY 2001

Computer/Nav Assembly

Requirements

- Lightweight, low power, wearable computer with integrated navigation capability
- 72 hour mission duration
- Robust Nav capability in all terrain
  - Primary Nav via Y-code GPS
  - Backup Nav
- Real-time situational awareness

Current Cost Projections

- Computer/Nav Assembly
  - GPS receiver $2000.
  - Dead reckoning Module $1000.
- Wearable computer w/ low power proc $3000.
- Ruggedized computer $8700.

Total: $14700.

Current Cost Reduction Programs

Initiation	Function Type	Risk	TRL	Available
Integ Power Gen & Mgmt	R&D	Med	5	FY05
Army GPS HTI	R&D	Low	9	FY04
Relative Squad Na	R&D	High	5	FY04
Wearable Computer Sty	R&D	Low	6	FY04

Note: These Reductions Are Already Factored Into The Projected Cost

Considerations

- Squad vs Leader-Level Component reuse and logistics
- Expansive RF
  - Channels, frequency range
- Broad-band antennas
  - Gain, efficiency, frequency range
- Programmability, multi-function
  - Reduced memory/processing capability

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Requirements: Currently the baseline under LW 1.0 has a separate computer and navigation assembly. The goal is to combine these into a single unit. Specific requirements include: (1) a lightweight, low power, wearable computer with an integrated navigation capability, (2) a robust all terrain navigation capability providing primary navigation via the Y-code of GPS with a nominal 10M accuracy and a backup capability (dead reckoning), (3) mission duration of 72 hours, and (4) real-time situational awareness. These requirements need to be accommodated in a wearable, modular, scaleable, and expansible open systems design.

Current Cost Projections: A combined computer/navigation assembly will be $14, 700 per unit. This is breaks down to: $2000 for the GPS receiver, $1000 for the dead reckoning module, $3000 for the wearable computer with low power processor, and $8700 for ruggedizing.

Current Cost Reduction Programs: There are two funded initiatives in the computer area and three related to navigation. The two in the computer area are the Dismounted Warrior C4I wearable computer study and the Integrated Power Generation and Management effort. These are R&D initiatives of low to medium risk, with TRLs of 6 and 5 respectively in the 2004/2005 time frame.

The three navigation initiatives are: Army GPS HTI, New Dead Reckoning Module, and relative squad navigation. Both the GPS and dead reckoning module are considered low risk, not requiring R&D for availability in the 2004 timeframe. The relative squad navigation is an R&D item with a high risk driven by the need to reach a TRL 5 by 2004.

CAIV Considerations: Realizing that the overall objective is to reduce cost, there are some CAIV considerations worth investigating. Examples are provided, but are not meant to be exhaustive. As one can see, the largest payoffs are in the area of ruggedization and replacement of the GPS with a relative navigation module on two-thirds of LW. It is believed there may be as much as a 3:1 reduction in cost by using standard COTS in lieu of a ruggedized unit. By replacing GPS on two-thirds of LW there could be savings on the order of $10K per squad. Other areas worthy of consideration include eliminating the GPS security module and elimination of the backup navigation requirement in buildings.

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

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

Study Co-Chairs

Dr. Robert Douglas
DRS, Electro-Optical Systems Group

GEN Wayne Downing (USA, Ret.)
Downing and Associates Incorporated

LtGen Marty Steele (USMC, Ret.)
Intrepid Sea, Air and Space Museum

ASB Panel Chairs

The Future Threats Panel
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
Sandia National Laboratories

Dr. James Sarjeant
State University of New York at Buffalo

The Manpower and Personnel Panel*
BG James Ralph (USA, Ret.)
Ralph Consulting L.L.C.

Dr. Harold O'Neil
University of Southern California

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.)
Downing and Associates, Inc.

* The Manpower and Personnel Study was conducted as an independent Special Study and then integrated into this study.

ASB Panel Members

The Future Threats Panel

Dr. Anthony Hyder
University of Notre Dame

Dr. Roberta-Diane Perna
Norwich University, Mezzogiorno Consulting

Government Advisors

Ms. Kathleen Kinsella
NGIC

Mr. Earl Rubright
CENTCOM

Ms. Mary Scott
NGIC

Cadet Assistant
CDT Kenton Justice
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The Conceptual Framework Panel

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Global Infotek , Inc.

Mr. Thomas Kelly
TPL, Inc.

Mr. Richard Ladd
Robinson International, Inc.

Government Advisors

Mr. Chris Christenson
Institute for Defense Analyses

COL Gary Engel
MTMC

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Battelle Memorial Institute

Lt. Col. Douglas Jerothe
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MITRE

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Mr. Dan Rondeau
Sandia National Laboratories

Dr. Randy Steeb
RAND

Mr. Mike Tobin
Lawrence Livermore National Laboratories

Staff Assistant
Ms. Karen Williams
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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	
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

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