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"TECHNICAL AND TACTICAL OPPORTUNITIES FOR REVOLUTIONARY ADVANCES IN RAPIDLY DEPLOYABLE JOINT GROUND FORCES IN THE 2015-2025 ERA"

VOLUME II
OPERATIONS PANEL REPORT

DISCLAIMER

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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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13. ABSTRACT (Maximum 200 words)

The Army Science Board was tasked to seek revolutionary possiblities for improving deployability as well as effectiveness of future joint ground combat forces. The study focused on the possibilities inherent in the Future Combat System(FCS) and also considered enhancements possible through the Future Transport Rotorcraft (FTR). Study efforts were conducted by four major Panels analyzing: Operations, Information Dominance, Sustainment and Support, and Training. The study concludes: 1) the FCS concept is sound, but senior level attention is required to ensure technologies are ready for 2006 FCS EMD; and 2) Key technologies will significantly improve force projection and combat power.

The Operations Panel was tasked to: 1) Examine the feasibility of synchronizing Future Combat System, Joint Transport Rotorcraft and Comanche requirements to provide revolutionary mobility and tactical benefits; 2) Assess capabilities gained by exploting robotics; 3) Propose an optimized suite of smart munitions and sensor combinations; 4) Determine areas of the force demanding "24/7" manning and analyze manning arrangements; 5) Identify the optimal organizational structures to best exploit future information technology.

Findings include: 1) FCS concept is solid, it addresses critical mobility, insertion and survivability issues; 2) FCS 20-ton vehicle is not a stand-alone program, must be developed with: robotic companions; appropriate munitions suites; operational, theater and strategic lift; and simulation tools. Recommendations include: 1) Press forward vigorously with FCS, develop CONOPS, develop man-in-the-loop simulations, restructure munitions priorities, expand robotics programs; 2) In the long-term, work with DoD to develop in-theater and strategic lift for FCS, and develop access to commercial lift.

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Future Combat System, FCS, Future Transport Rotorcraft, FTR, Survivability, Lethality, Robotics, Tactical Mobility, Tactical Lift, UAV, UGV, TERM, Net Fires

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- Volume I - Executive Summary
- Volume II - Operations Panel Report
- Volume III - Information Dominance Panel Report
- Volume IV - Support and Sustainment Panel Report
- Volume V - Training Dominance Panel Report

If you received only the Executive Summary, the additional volumes may be reviewed and/or downloaded by visiting

http://www.saalt.army.mil/sard-asb/ and clicking on "Studies."

Technical and Tactical Opportunities for Revolutionary Advances in Rapidly Deployable Joint Ground Forces in the 2015-2025 Era

Operations Panel Report

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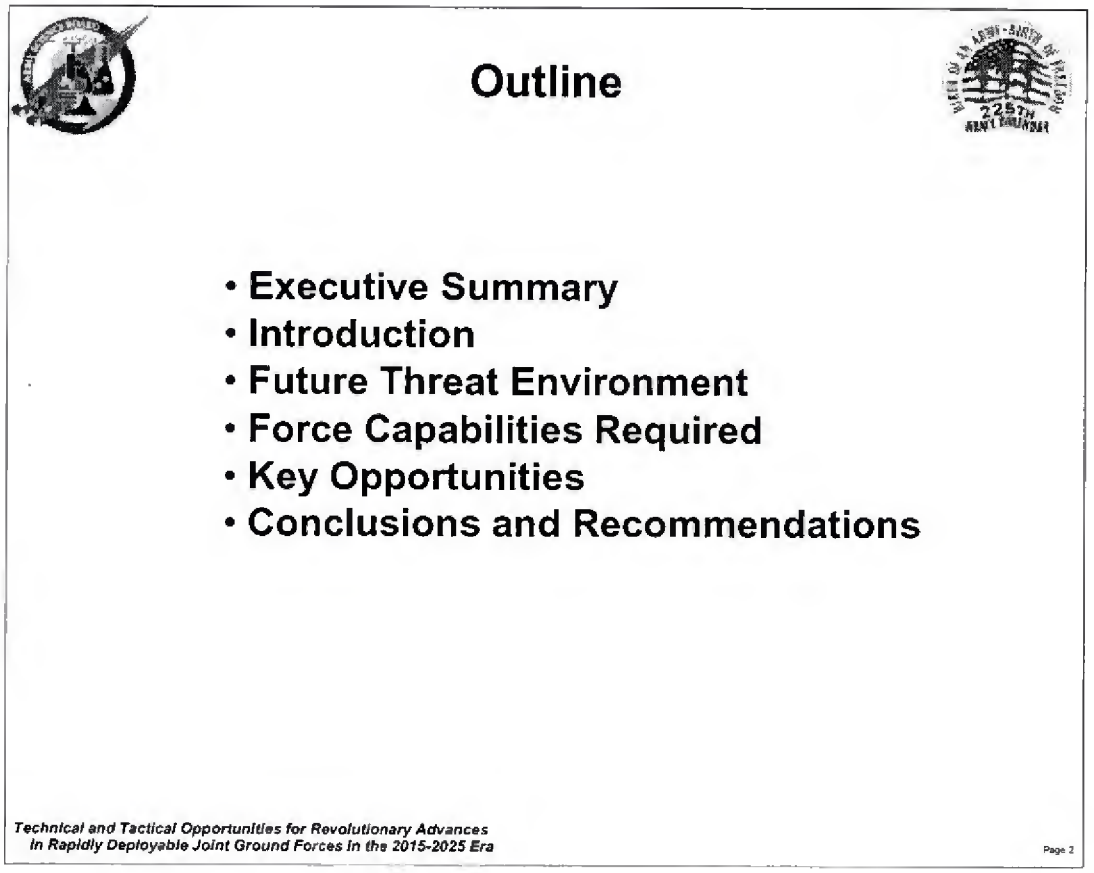
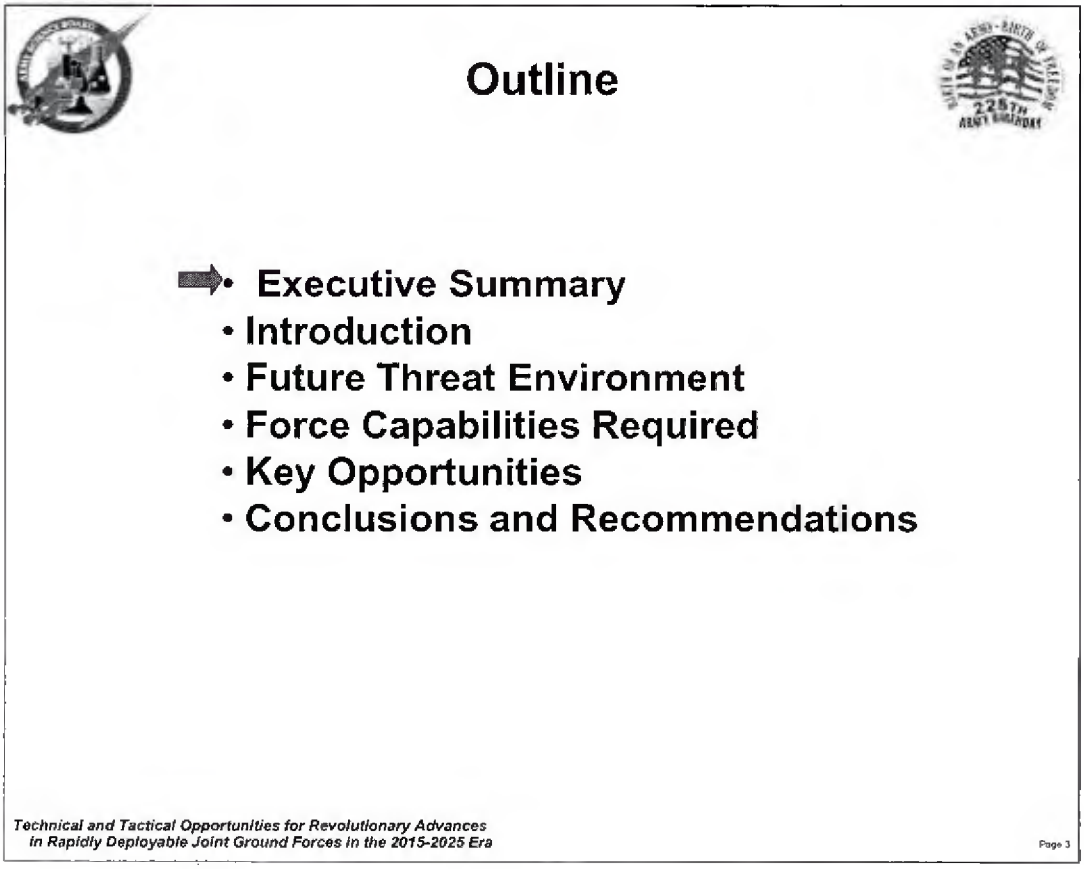
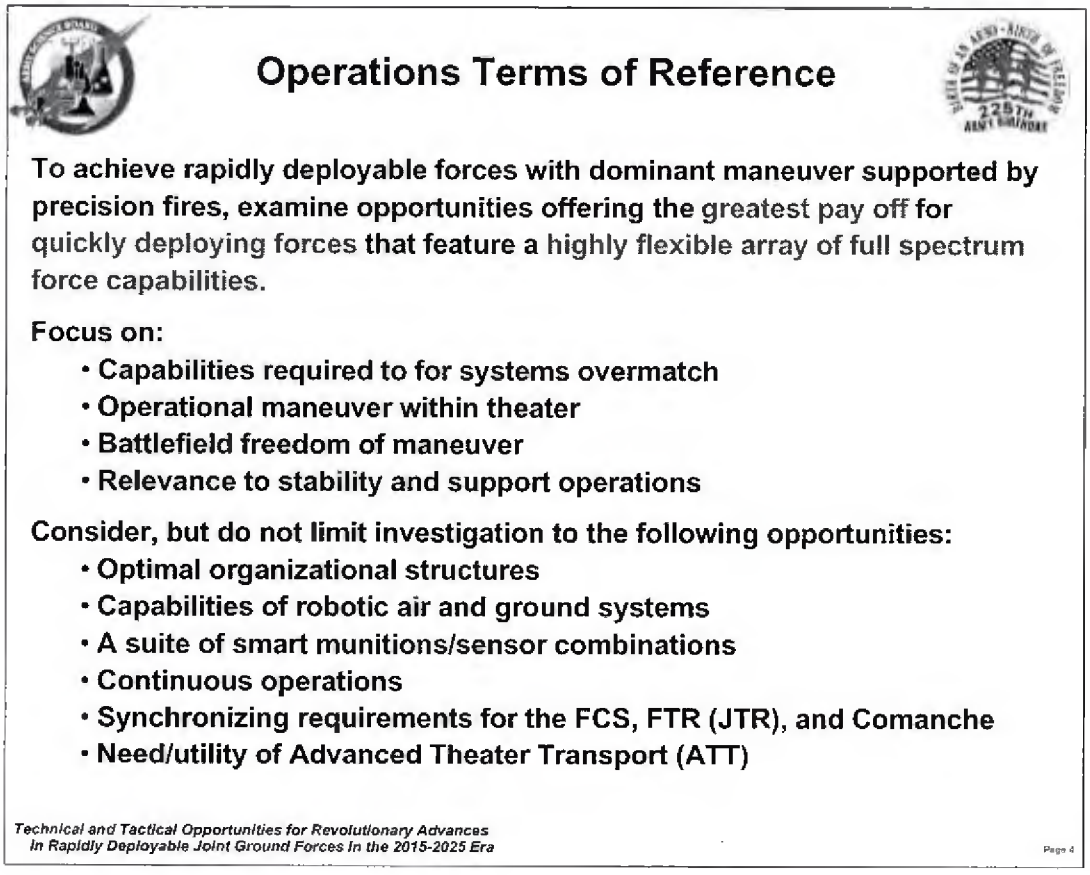
Operations Panel Report



This is an outline of the key areas discussed in this report.



This report begins with an overview of the Terms of Reference (TOR), along with a description of the panel's key recommendations.



Team 1-Operations:

Goal: Achieve rapidly deployable forces with dominant maneuver supported by precision fires.

Look at those opportunities which offer the greatest pay off for quickly deploying forces and which feature a highly flexible array of full spectrum force capabilities. Focus on combat operations, accounting for capabilities required to achieve systems overmatch as a critical component of overall force effectiveness both for initial entry into a theater of operations and to enable operational maneuver within the theater once operations begin.

Consider, but do not limit your investigation to the following opportunities:

a. Look at the feasibility of synchronizing the requirements for the Future Combat System (FCS), the Joint Transport Rotorcraft (JTR), and Comanche to provide revolutionary tactical and theater mobility and increased strategic mobility. If feasible, what are the assumed tactical benefits of this union?

b. Assess the capabilities gained by exploiting robotic air and ground systems as reconnaissance/surveillance, attack systems, and other functions. Which force capabilities or platforms appear to benefit most from this relationship?

c. Propose a suite of smart munitions/sensor combinations in our direct fire and indirect fire forces that offer the most cost effective investment and the most decisive outcome in expected scenarios.

d. Determine those areas of the force that demand robust 24 hours a day, 7 days a week manning, and portray the benefits of various manning arrangements.

e. Identify the optimal organizational structures that best exploit future information technology.

f. Determine the need for or utility of an Advanced Theater Transport (ATT) to replace the C-130 to support the operational capability and systems described above.

Summary & Recommendations

Findings:

- FCS concept is solid. It addresses critical mobility, insertion, and survivability issues
- FCS 20-ton vehicle is not a stand-alone program. To ensure its effectiveness, must consider:
  - Robotic companions
  - Appropriate munitions suites
  - Lift: operational, theater and strategic
  - Simulation tools

Recommendations:

- Press forward vigorously with FCS. In the short term:
  - Develop CONOPS
  - Develop man-in-the-loop simulations
  - Restructure munitions priorities
  - Expand robotic programs
- Over the long term:
  - Work with DoD to develop in-theater and strategic lift for FCS
  - Develop access to commercial lift

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First and foremost, from the Operations panel perspective, the FCS concept is solid. Critical concerns raised about the deployability and intratheater mobility of the legacy force and the survivability issues raised about a light force have been addressed. The brigade which we analyzed can fight and win in challenging environments.

Several important findings are:

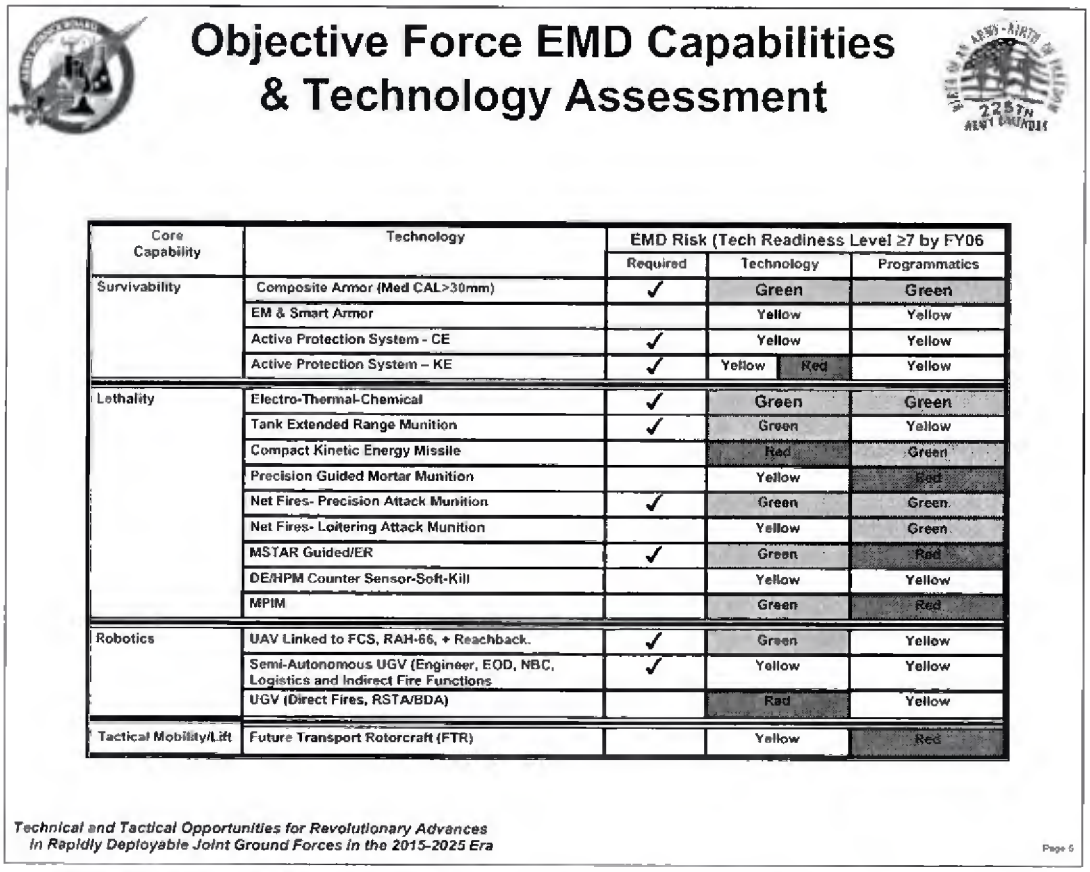
- First, the Future Combat System (FCS) is not a stand alone new combat vehicle. Rather, it is a system-of-systems which includes robotic companions, smart munitions and access to the tactical infosphere;
- Next, for timely application of the force, lift capabilities are a key consideration;
- Finally, robust simulation tools are needed to investigate among complex issues such as man-robotic interactions.

The primary recommendation is to press forward with FCS. Near term actions should include:

- Developing a CONOPS;
- Upgrading and/or developing man-in-the-loop simulations in order to be able to accurately portray the FSC CONOPS and work issues such as control of robotic companions;
- Restructure munitions priorities keeping in mind that smart munitions are a key enabler to effectiveity, deployability and sustainability of the FCS force;
- And expanding robotic programs with a view toward getting robotic ground vehicles in the hands of troops and early assigning of limited complexity tasks such as a logistic follower.

Over the longer term:

The lift issue for the FCS force needs to be studied and technologies funded that will ultimately enhance/enable vertical envelopment.



Objective Force EMD Capabilities & Technology Assessment

Core Capability	Technology	EMD Risk (Tech Readiness Level ≥7 by FY06		
		Required	Technology	Programmatics
Survivability	Composite Armor (Med CAL>30mm)	✓	Green	Green
	EM & Smart Armor		Yellow	Yellow
	Active Protection System - CE	✓	Yellow	Yellow
	Active Protection System – KE	✓	Yellow / Red	Yellow
Lethality	Electro-Thermal-Chemical	✓	Green	Green
	Tank Extended Range Munition	✓	Green	Yellow
	Compact Kinetic Energy Missile		Red	Green
	Precision Guided Mortar Munition		Yellow	Red
	Net Fires- Precision Attack Munition	✓	Green	Green
	Net Fires- Loitering Attack Munition		Yellow	Green
	MSTAR Guided/ER	✓	Green	Red
	DE/HPM Counter Sensor-Soft-Kill		Yellow	Yellow
	MPIM		Green	Red
Robotics	UAV Linked to FCS, RAH-66, + Reachback.	✓	Green	Yellow
	Semi-Autonomous UGV (Engineer, EOD, NBC, Logistics and Indirect Fire Functions	✓	Yellow	Yellow
	UGV (Direct Fires, RSTA/BDA)		Red	Yellow
Tactical Mobility/Lift	Future Transport Rotorcraft (FTR)		Yellow	Red

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Objective Force EMD Capabilities and Technology Assessment

Building on the 1999 ASB Summer Study, several high priority technologies were identified as significantly contributing to the Objective Force Capabilities listed. The required core capabilities for the initial FCS force, i.e. building blocks that should be fielded and upgraded in an evolutionary manner as the other identified technologies become available, are marked by a check. Thus we identified technologies which must be demonstrated to at least a technology readiness level of 7 in time to support a successful FY2006 EMD decision. The other technologies listed mature later than the start of FCS EMD and still deserve support because they: (1) could be available for a 2010-2012 FUE even though they are not ready for EMD in FY2006; or (2) will so greatly increase objective force responsiveness, deployability, agility, versatility, lethality, survivability and/or sustainability, that they should be developed and fielded as soon after FY2012 as feasible and affordable. Examples include FTR, autonomous unmanned ground vehicles, etc.

The 'Technology' column contains an assessment of the technical risk for the technology. The 'Programmatics' column identifies the program (current schedule and funding) risk assuming an EMD start of 2006. Technology risk categories are: Green - Low, Yellow - Moderate and Red - High.

Composite armor is require for lightweight passive protection against light arms up to 30 mm. Its requirements are established and its technology and program are on track for the FCS evaluation. The issue is maintaining that schedule.

Active protection is essential for an effective FCS. Its requirements are defined roughly. Its technology has been demonstrated in separate pieces. The program is fragmented and lacks focus. Any further drift would delay the FCS decision.

Electro-thermal chemical rounds use a combination of electrical initiation and chemical energy release to obtain greater energy from a given amount of charge, which allows them to eable FCV lethality overmatch without additional weight.

TERM permits either direct or indirect fire from current guns, which could effectively complement sensor developments to enhance overall effectiveness.

Net fires delivered by rockets in a box have the potential to provide the indirect fire support required for full FCS effectiveness if the communication and lethality need can be provided efficiently

Robotic links to UAVs are needed to provide the high resolution situational awareness and to prompt local sensors and communications needed for forces in contact.

Secure and mobile C4I is required for situational awareness and integration of FCS. The DARPA mobile network is a good testbed and possible prototype for the network required, if it can be developed in time.

Sensor and Target Acquisition Overmatch is required to detect and acquire the threat for stand-off engagement and shoot first capabilities.

Robust brigade & below is the integration of such networks at all echelons.

20 Ton vehicle is the baseline chassis for the FCS.

Hybrid electric engines have significant potential for improving the FCS performance envelope while reducing logistics requirements.

Reliability, availability, and maintainability are essential attributes of an effective FCS. Their requirements and understood and the technology required is in development, but the current program is inadequate to support the FCS decision timeline.

The following are high technical risks:

Compact kinetic energy missile (CKEM) – unproven high specific impulse with low vulnerability propellant

Directed energy/high power microwave counter sensor-soft kill – engineering scaling

Autonomous UGV – Sensor fusion, signal processing and software for autonomy

Programmatic risk assessments refer to the funding and schedule risk of the current funded Army program: Green - Funding and schedule are adequate to achieve TRL of 7 by FY2006 EMD start; Yellow – Moderate risk due to inadequate funding and/or schedule; Red – unacceptable schedule &/or funding to get to TRL7 by FY2006 EMD start.

The following are high program risk:

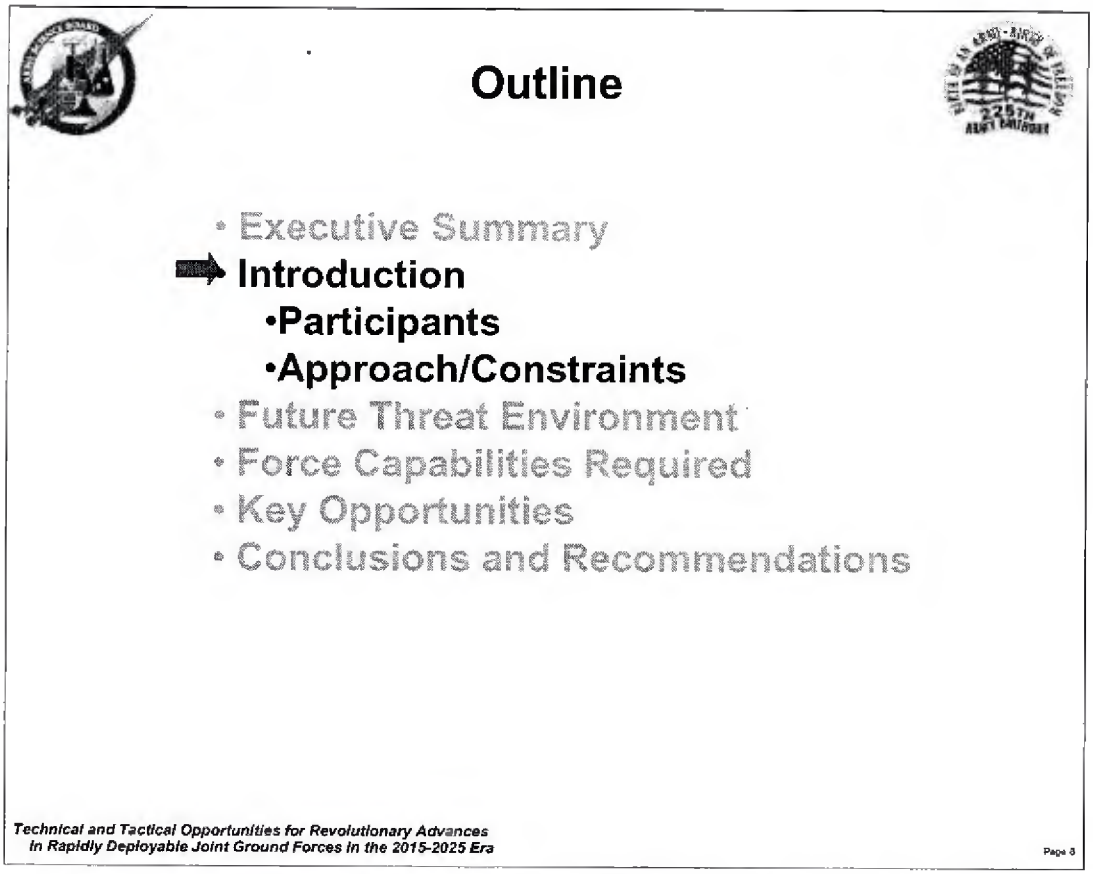
Multi-purpose individual munitions (MPIM) - Procurement unfunded

Precision guided mortar munitions (PGMM) - No funded transition and ATD stretched

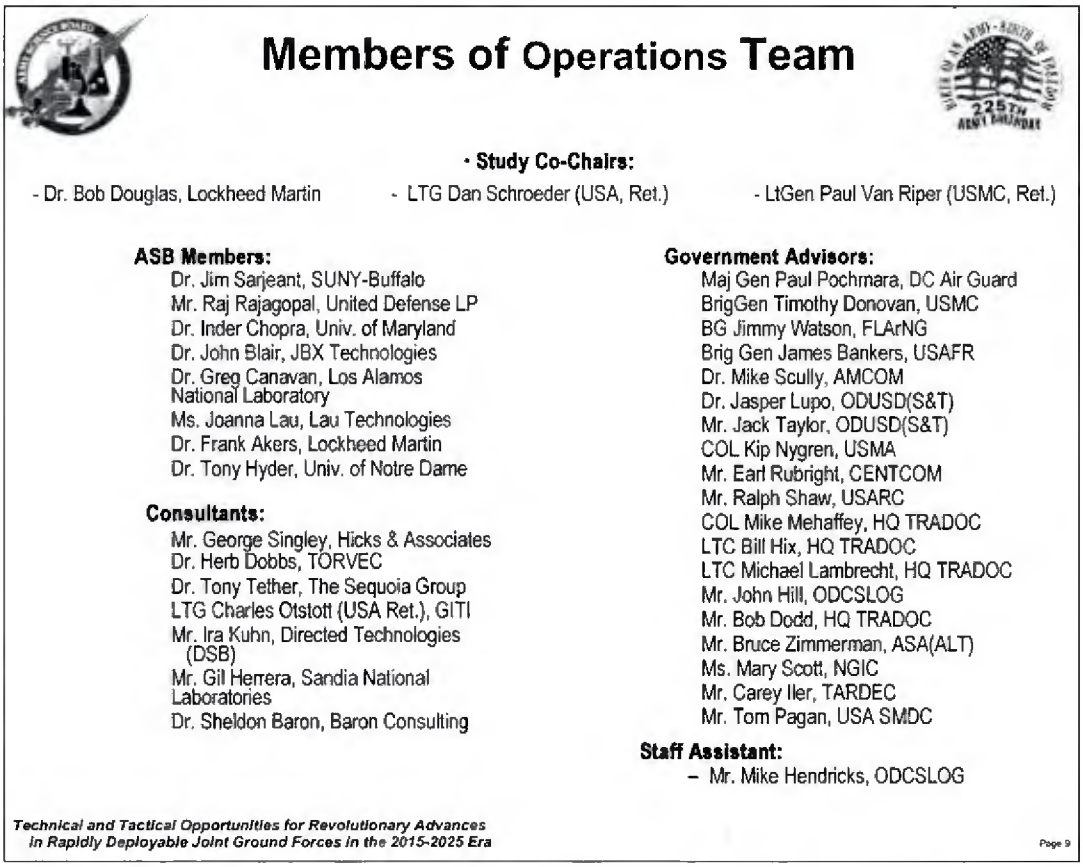
MSTAR guided, extended range 270mm missile – MSTAR killed

Ten ton (10T) vehicle – no funded program

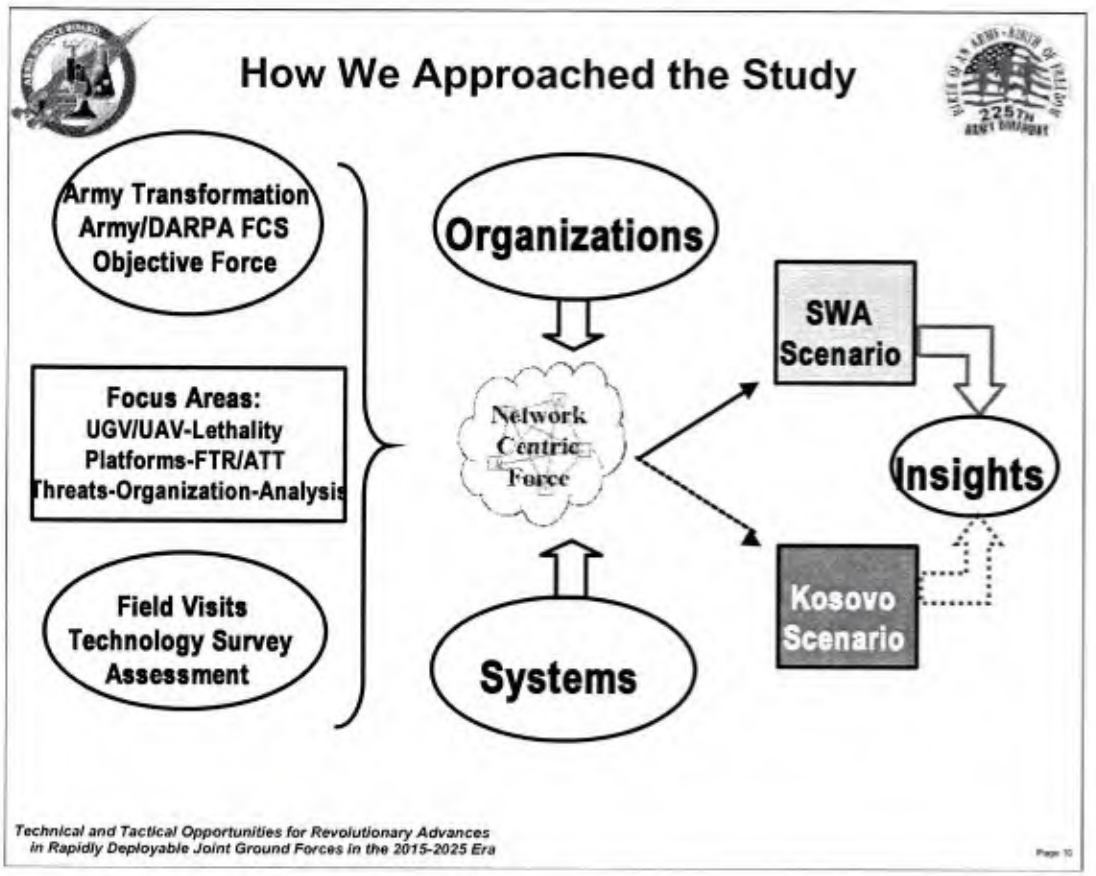
Reliability, availability & maintainability – Needs to be required now. No threshold metrics.



This section lists the participants in the study. It also describes how the panel approached the study and addresses the limitations and constraints encountered in the study.



The study group consisted of both ASB members and select consultants. It also included support from various government and Army staff agencies.



Based on the key issues and focus areas provided in the ASB terms of reference (TOR), the operations team started with a review of key Army warfighting concepts, the Army Transformation Strategy and major Army and DoD program including the DARPA / Army Future Combat System (FCS) program. A series of site visits to key installations and agencies were made to collect additional details and information on future science and technology initiatives and opportunities. Notional organizational designs were developed to allow supporting analytical assessments of benefits and trade-offs for emerging science and technology options. Future system possibilities were defined as representative examples available for the force in the 2015 to 2025 time frame. The notional force was then constructed to evaluate various force, systems and technologies issues relative to the overall force objectives and constraints.

Two scenarios (South West Asia and Kosovo) were used to get insights relative to the merits / challenges of selected technology options in different environments. A "system of systems" approach to the force provided a wide range of potential future systems and employment strategies. Insights were used to develop overall team recommendations supplemented by additional briefings and discussions from subject matter experts from both government, industry and academia organizations.

Scope/Study Limitations

- Organization structure is representative, but NOT optimal. For example:
  - Span of control of supervised robotic devices (ground and air) cannot be specified at this time.
  - Number/type of robotic devices required within the organization will be dependent on scenario, commercial development, etc.
- Cost aspects have not been considered in detail.
- Validated analysis of requirements vs. capabilities and investment strategies of FTR and ATT have not been fully evaluated.

This chart highlights the principal limitations in addressing the terms of reference.

First, we were tasked to "identify optimal organizational structures …". Three organizational structures were examined which spanned low-risk to high-risk. They will be described in subsequent charts. These organizational structures are representative, but not suggested to be optimal. A much more detailed analysis is required in order to arrive at an "optimal" organizational structure than could be completed in the time available to the operations panel. An example where more thorough analysis is required is in the area of robotics.

Next, costs were by and large not addressed

Finally, a more thorough analysis of future transport Rotorcraft (FTR) and Advanced Tactical Transport (ATT) is needed. However, a detailed discussion is provided.

Outline

- Executive Summary
- Introduction
- Future Threat Environment
- Force Capabilities Required
- Key Opportunities
- Conclusions and Recommendations

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The Future Threat Environment is examined in the next three charts.

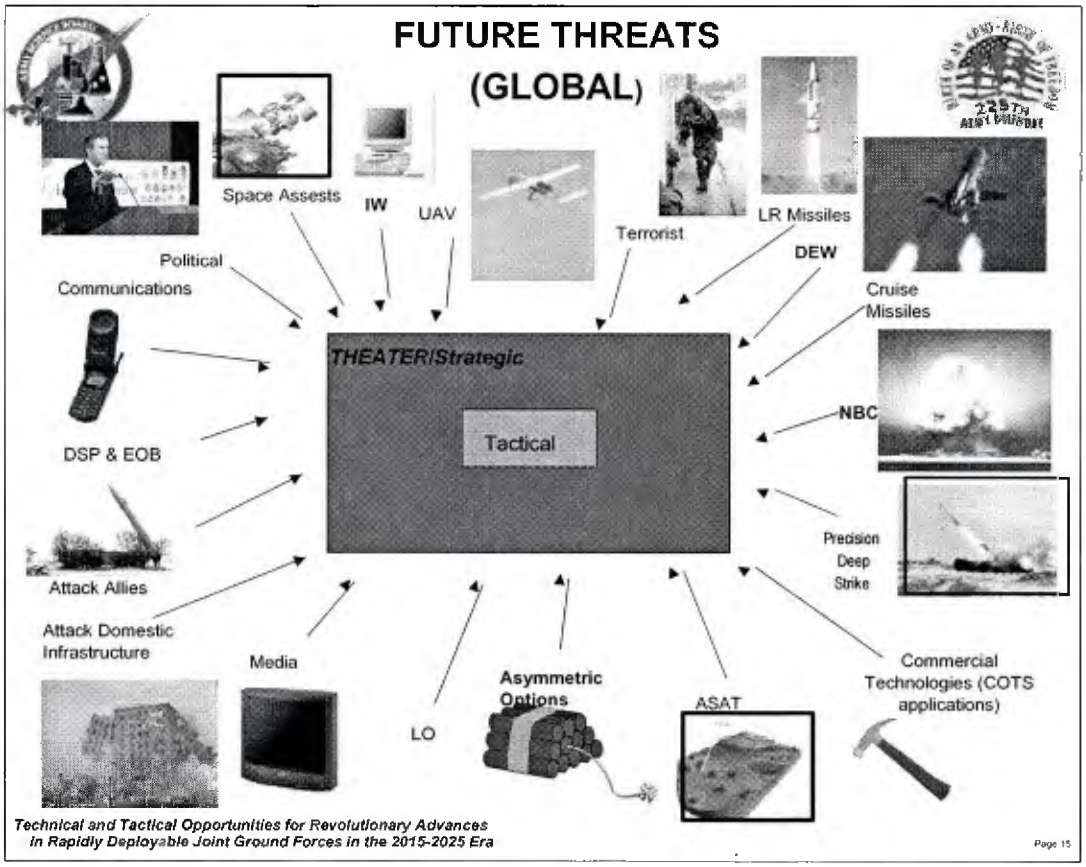
The future threats that our tactical theater operations will face in the post 2015 era will be varied in sophistication, lethality, and impact. All of the varied sophisticated and non-sophisticated weapon systems and their tactical applications will be available to any potential adversary from a large number of countries and manufacturers. Most adversaries will have a mixture of older systems and hybridized upgrades of older systems (providing near-state-or-the-art capabilities in key aspects), and a limited number of modern state-of-the-art weapon systems. Though unable to match the US system for system, the potential of these militaries for inflicting unacceptable damage in specific scenarios will demand that US and Allied forces take the necessary actions to counter their efforts.

No adversary will want to meet us in a conventional battlefield environment—the first goal will be to force engagement in complex terrain or in other asymmetric tactical positions and situations. The range of threats in these situations can be divided into two general classes: those capable of inflicting physical damage and those capable of making our forces more susceptible to attack. In the first category, the traditional, but sometimes surprisingly modernized threats such as tanks, artillery, mines, and infantry-fired weapons will be seen. These will be augmented with a variety of other hard-kill threats such as artillery-delivered PGM (Precision Guided Munitions, "poor man's air force") and tactical missiles. UAVs will be widely available and incorporated into surveillance and targeting. Simple means such as cells phones plus GPS will also be employed. The threats from lasers (sensor blinding) as well as the potential of NBC weapons (especially chem and bio) will expand to more and more countries. In the second category, allied forces will face a number of threats aimed at degrading their capability—enemy CCD, asymmetric operations, EW (including GPS-jamming) and IW, and an increased use of sophisticated obscurants.

Urban operations will carry with them a unique set of threats, many of which we have not yet appreciated and most of which we have no answer readily in hand. The enemy will take advantage of the greatly reduced engagement ranges, 3-dimensional conflict space (underground tunnels, alleys, buildings), our inability to distinguish adversary (13-year old RPG gunner) from innocent civilian, and co-locating military

assets next to "no strike" humanitarian sites. While the US may increasingly use robotic platforms for operations, we may also expect to see the adversary take advantage of this growing technology.

Urban warriors, asymmetric operations, and increased adversarial access to new and emerging technologies will characterize threats in the battlefield in the post-2015 era.



US forces, with their technological, organizational, and strategic capabilities, will dominate regionally-focused militaries in a conventional land battle. Adversaries are therefore driven to asymmetric, adaptive alternatives whose scope extends far beyond the tactical and operational level. Coordinated activities are conducted at the theater and global levels to influence the outcome of the conflict. Anticipating the need for this global approach, the adversary will use the media before and during the conflict to influence public opinion worldwide and especially the US populace's will to engage, thence US political and military decisions. Knowing the US is casualty-averse, the enemy may embrace a specific strategy to cause early American casualties.

Should the US intervene, the adversary may now attack military logistics and points of debarkation with conventional or Information Operations weapons and target theater landing zones and ports with conventional weapons or Chemical/Biological weapons. In addition many adversaries believe the best way to avoid, deter, or offset US military superiority is to threaten the US homeland—"no sanctuary." In addition to strategic nuclear/missile threats, the national (civilian) infrastructure is vulnerable to disruptions by physical and computer attack. Civilian communications disruptions also affect the military systems for which they are a backbone. While conventional munitions attacks are the most likely today, widely available hardware and software tools provide the adversary with a growing capability for Information Warfare.

Commercial space assets provide an enemy with Indication and Warning (I&W) on US activities. In addition, by 2015, future adversaries will be able to employ a wide variety of means to disrupt, degrade or defeat portions of the US space support system. A number of countries are interested in or experimenting with technologies that could be used to develop counter-space capabilities—for example DEW-ASAT.

Theater-range ballistic and cruise missiles are widely proliferating. These systems are becoming increasingly accurate and destructive, so that they have far more than the psychological impact of SCUDs used against Israel in the Gulf War. Such long-range missiles, conventionally or WMD-armed, can be used against US allies in the region, against fixed targets in the theater, or be sea-launched against the CONUS.

Consequences of the Threats

The broader range and increased potential lethality of the threats and improved enemy countermeasures will create more unpredictability and a more complex environment at every point in the spectrum of operations.

TACTICAL	OPERATIONAL	STRATEGIC
•Limited SA/corrupted SA	•Anti-Access	•Imprecise IPB
•Degraded IPB/restricted maneuver	•Trans-national threats	•Degraded I+W
•Uncertain targeting	•TBM Threats against allies and coalition partners	•Interrupted connectivity
•Imprecise unit coordinates		•Uncertain BDA
•Loss of traditional I+W		•Non-secure communications
•Reduced sensor effectiveness		•Loss of initiative (reactive operations)
•Inability to fuse sensors and data		•Expanded battlefield (CONUS)
•Non-robust communications		•Unexpected (unacceptable) casualties
•Forced close combat in complex terrain		•Loss of public/allied support
•Susceptibility to inexpensive PGM		•Loss of surprise
•Loss of surprise		
•Urbanization		

Remember,
Adversaries will have access to the same technology suite as US forces
They don't have to win; they need only persevere

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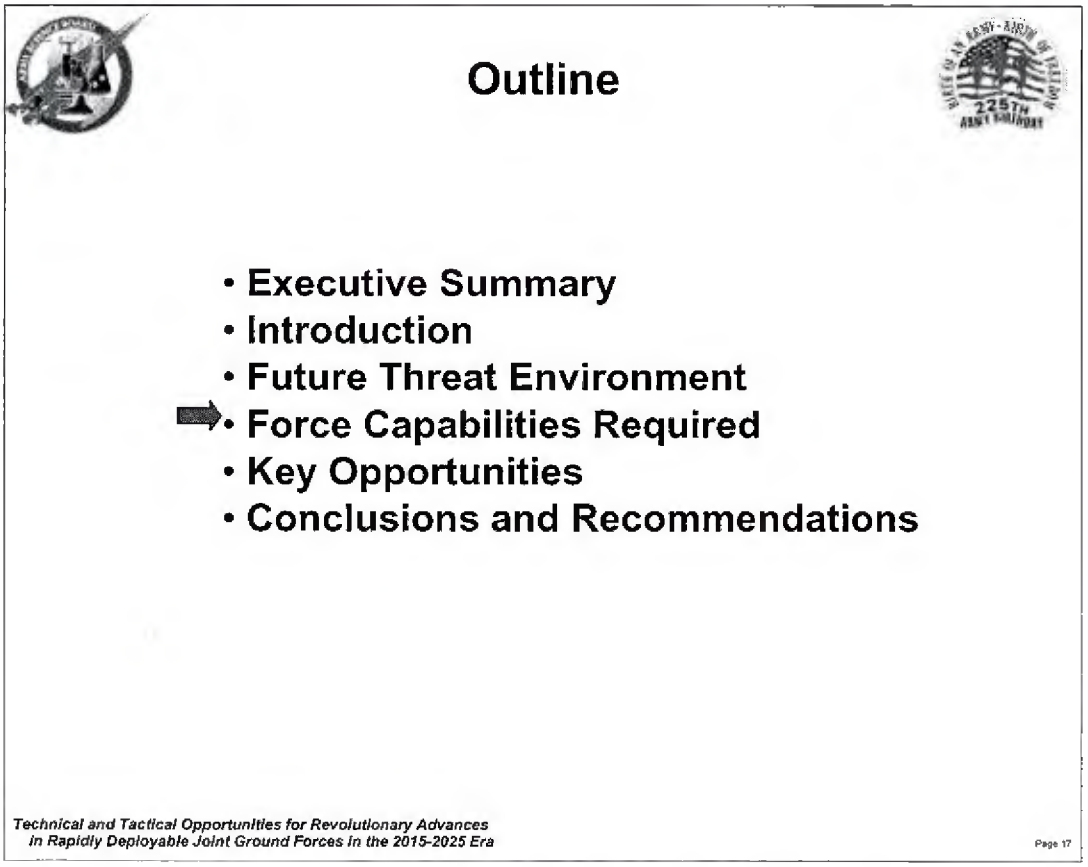
The previous two slides outline the nature of the threats that can be anticipated at the tactical, operational and strategic levels in the post-2015 era. In some cases, these threats are similar while there are also threats unique to each operational environment. Each of these threats will present the warfighter with certain consequences if the threat is not addressed.

While no adversary may choose to meet the US and its allies head-on, opportunities for shaping the conflict to his advantage may encourage the enemy to develop tactics and threats that challenge US forces. For example, force deployment that is dependent on robust ports and airfields will be challenged by enemy abilities to target those facilities. Further, our inherent assumption of battlefield information dominance will be tested as adversaries become equipped with electronic and information warfare technologies allowing them unprecedented capabilities. These capabilities when combined with a range of enemy camouflage, concealment, and deception may lead to uncertainties at both the tactical and theater levels in our intelligence preparation of the battlefield, I&W, and battle damage assessment.

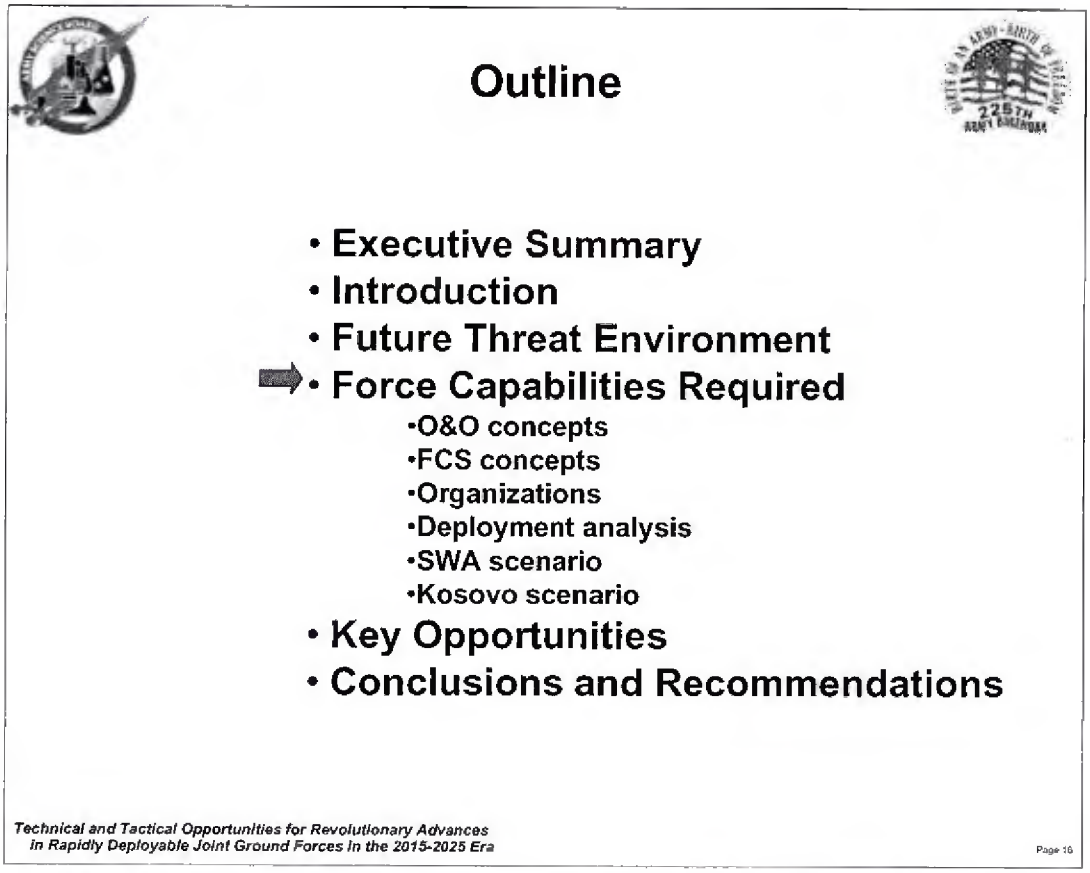
The assumed connectivity from secure and robust communications networks may also be threatened as adversaries with little or no technological infrastructure acquire capabilities in the world marketplace. For example, lasers capable of blinding US sensors and jammers capable of denying GPS data will level the battlefield to an unprecedented extent.

Worldwide proliferation of PGM and RPG weapons will also exacerbate the issue. Component upgrades to existing inventories of weapon systems will create hybrids with near-US capabilities. Basically, we must be prepared to meet an adversary with access to the same technology suite that we employ. This will place a premium on strategy, tactics, and training.

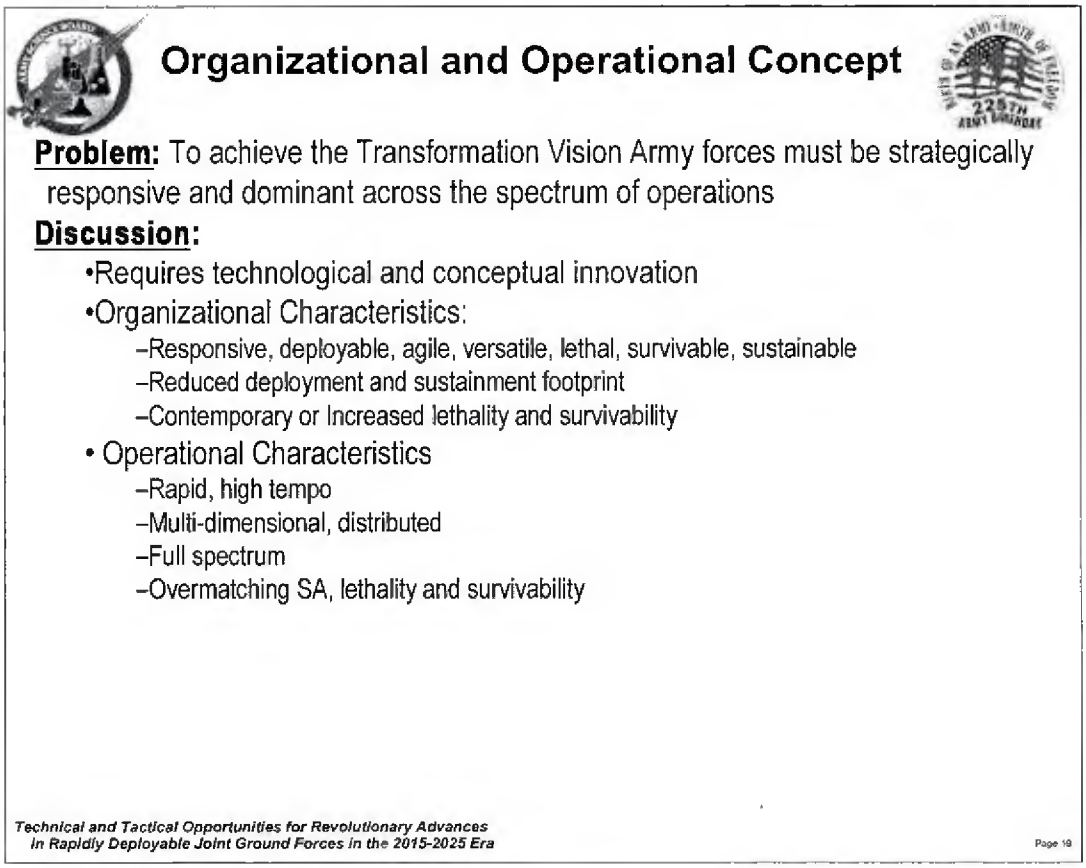
Finally, the adversary will make every use of complex terrain, especially urban environments, to degrade our areas of overmatch, and increase the likelihood of inflicting US casualties



Force capabilities requirements are examined in the following charts.

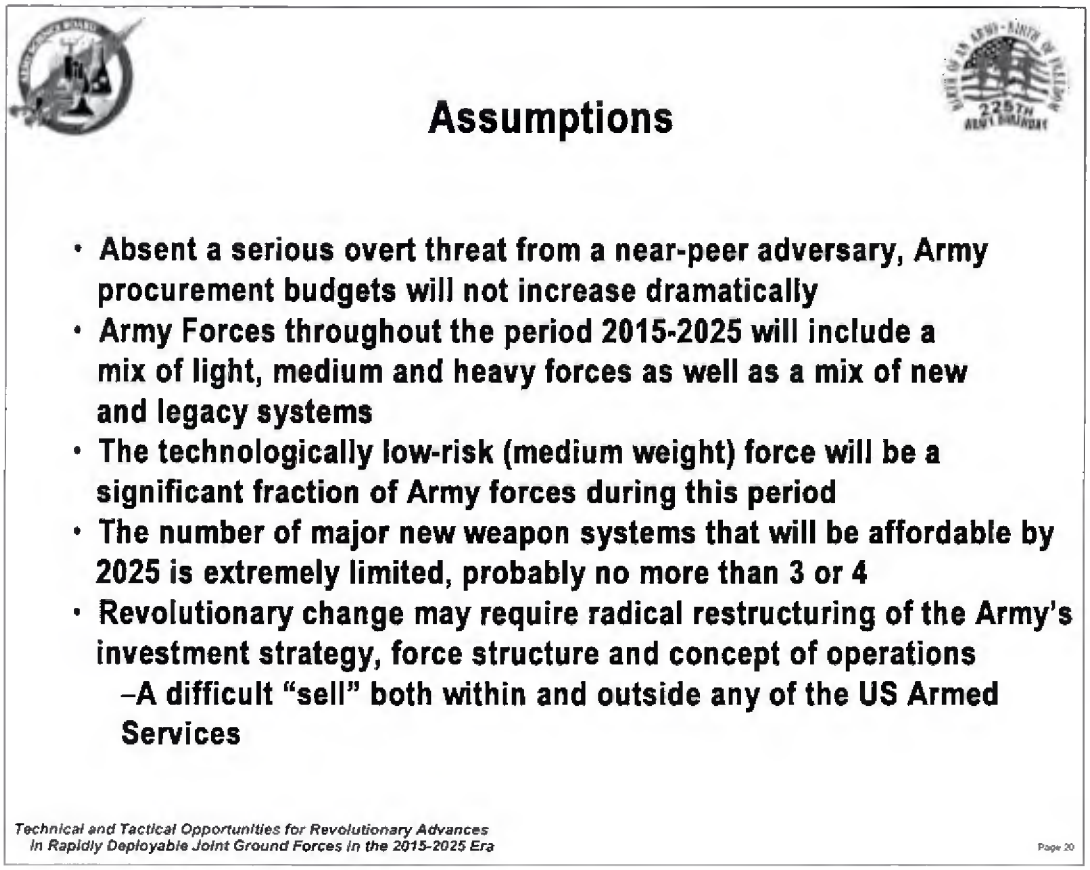


The study examined three force designs populated with the same equipment set. The Notional FCS force based on a Fort Knox MMBL experimental "vehicle"-- was the force chosen for simulation and analysis.



The Army vision presents a challenging endstate for the future Army.

To be strategically responsive and dominant across the spectrum demands full realization of the characteristics outlined in the Secretary of the Army and CSA's vision. This will demand revolutionary approaches to operational concepts, organizational designs and force capabilities (materiel).

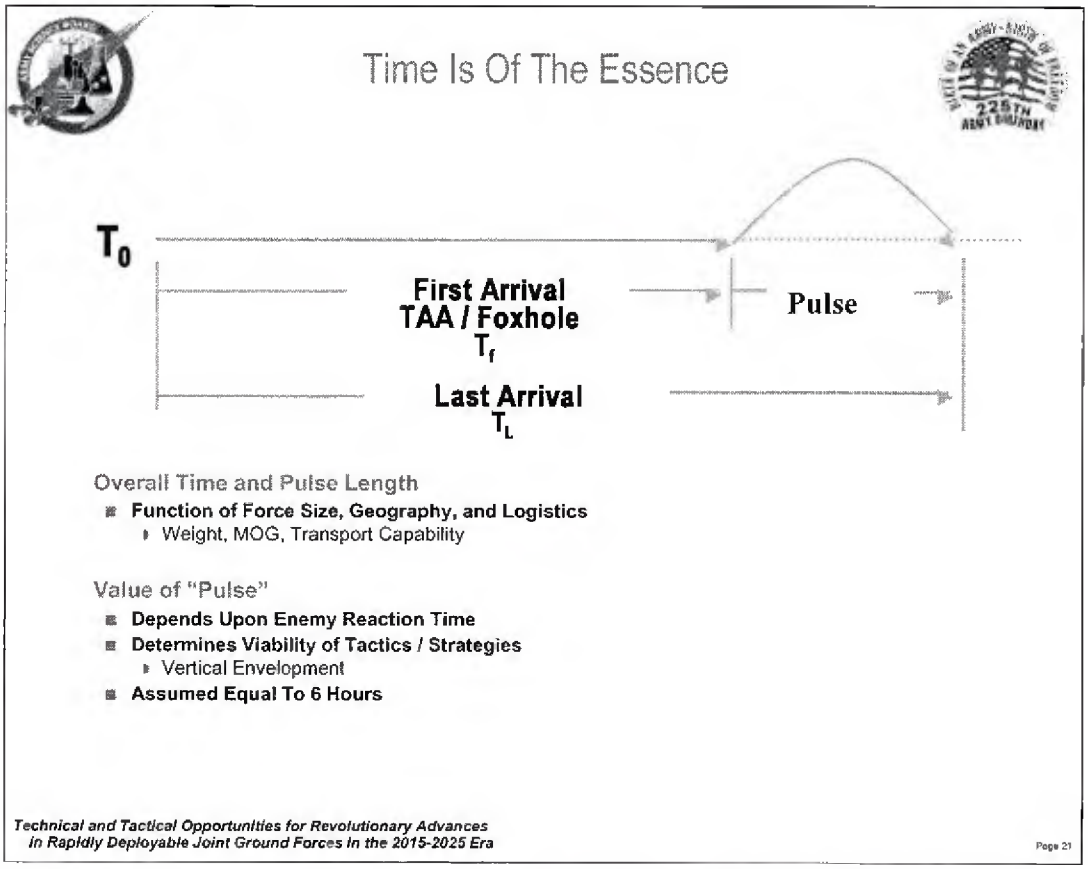


Absent a serious threat from a near-peer adversary, Army procurement budgets will not increase dramatically. The transformation process, even on the most optimistic funding profiles, will take 30-40 year to completely field the Objective Force. Therefore, Army forces throughout the period 2015-2025 will include a mix of light, medium and heavy forces as well as a mix of new and legacy systems.

The medium weight forces being developed at the front end of the transformation process will be useful in the early entry phase of any near term crisis response operation. Formation of 6-7 medium weight brigades in the initial and interim brigade programs will insure that the low-risk (medium weight) force will be a significant fraction of Army forces during this period.

Given the assumption that procurement programs are not likely to increase dramatically between now and 2025, no more than three or four major new weapons systems will be affordable by 2025.

The Objective Force appears to be headed in the direction of eliminating heavy armored forces and relying on agility, robotics, killing at great ranges, and total situational awareness to guarantee the same lethality and survivability that heavy armored forces enjoy today. This means that structure and doctrine will change. Change in a conservative institution such as the Army is very difficult. Radically shifting the force structure and the concept of operations of any of the US Armed Forces will be a difficult "sell" both within and outside the Service.



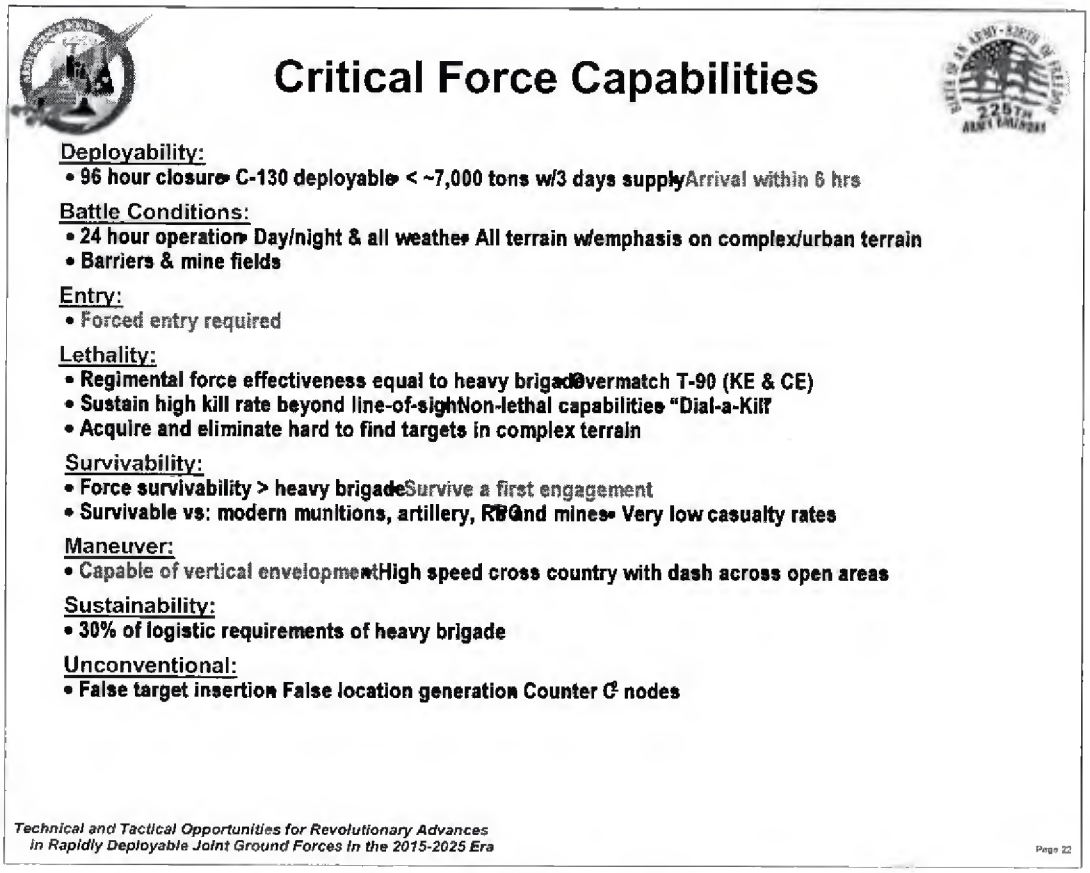
A major reason motivating FCS stemmed from the realization that Army heavy forces were not strategically mobile enough to meet emerging timelines and that Army light forces while very mobile, were not lethal enough.

The challenge voiced by the CSA in October 1999 was to develop a Future Combat System which would have the lethality of heavy forces but be as deployable as light forces. A criteria set by the CSA was that a brigade would be deployed within 96 hours of initial departure, followed by closure of a division in 120 hours and 5 divisions in 30 days. In all cases these forces are immediately employable upon closure.

This compressed time line recognizes that the time between the first arrival of the force to the next is as important as the closure of the first brigade in 96 hours. And it may be more compressed than the Army objective of 96, 120 and 30. We choose to define this time as the "pulse."

The overall time from deployment start to the last arrival is a function of force size, lift capability, and geography. The "Pulse" however will determine the viability of tactics/strategies such as Vertical Envelopment where, for example, a force is inserted behind the enemy to facilitate achieving the real objective without having to fight to it, or to prevent the enemy force from retreating to a safe haven such as a city.

The numerical value of the pulse needs to be studied further and is undoubtedly dependent upon the particular situation. However, a value of 6 hours is believed to be a reasonable nominal value. In order to meet this value, a capability to vertically insert is mandatory.



Highlighted areas of emphasis:

- Projecting forces into a contested area demands that early arriving forces deploy in coherent operationally capable force packages. In order to seize the initiative and signal resolve, the panel assessed that the first force pulse should arrive within the first 6 hours.
- Asymmetric approaches to US force projection include anti-access strategies where opponents seek to deny entry into the area of operations. This will include the denial of air and sea ports and beach heads. Additionally, critical assets and centers of gravity may be located inland. These conditions will continue to demand a forcible entry capability.
- Even in an era where information superiority is expected, surprise engagements and engagements by enemy stand off weapons will continue to be a challenge. The FCS force must be able to survive these first round engagements and respond with overwhelming violence to defeat the immediate threat and carry out its assigned mission. The ensemble approach to system and force design, coupled with emerging technologies for protection, survivability and lethality will enable FCS forces to survive these engagements without the pervasive and heavy protection of current approaches to system protection and survivability.
- Trends suggest that enemy approaches to US intervention will include seeking stalemate and attempting to cause heavy US casualties. Additionally, the operational environment challenges US mobility given austere infrastructure. Further, emerging constructs suggest a more distributed, rather than linear and contiguous battlespace. Finally, terrain continues to influence the course of operations, often becoming as much a factor as the enemy we seek to confront. In the past, only light forces were able to routinely conduct vertical envelopment operations to avoid intervening terrain and strike from unexpected directions. In the future, this capability will become more significant, and with the advent of new capabilities including the FCS and FTR, the capacity for vertical envelopment will increase both in scope and in capability. Teaming of the FCS and FTR will link light force agility with contemporary heavy force lethality, survivability and ground mobility, substantially increasing the options of the joint and operational commander.

Organizational and Operational Concept

Problem: To achieve the Transformation Vision which requires a family of light, lethal, survivable fighting vehicles transportable by C-130

Discussion:

- Organizational Characteristics:
  - Combined arms organization to company level
  - Vehicular mounted LOS/BLOS weapons
  - High % infantry
  - Conventional artillery replaced by Net Fires (Rockets in a box)
  - UAV/UGV at battalion and brigade for situational awareness
- Operational Characteristics
  - Situational awareness essential
  - Precision engagements throughout battlespace
  - Networked/collaborative engagements
  - Tactical/operational intra-theater mobility
  - Robotics and protection technology for survivability

Recommendation: Develop the FCS O&O and pursue S&T associated with core elements

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The Army Transformation Vision requires a family of light, lethal, survivable fighting vehicles transportable by C-130. The Joint DARPA/Army FCS program is addressing this need.

Organizational Characteristics include:

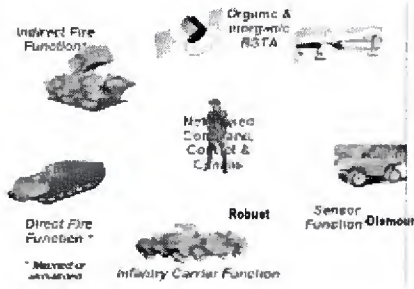
- Combined arms organization at the company level
- Vehicular mounted LOS/BLOS weapons
- High % infantry
- Conventional artillery replaced by AFSS (Rockets in a box)
- UAV/UGV at battalion and brigade for situational awareness

Operational Characteristics include:

- Situational awareness essential - Precision engagements throughout battlespace
- Networked/collaborative engagements - Tactical/operational intra-theater mobility
- Robotics and protection are technology required for survivability

Recommendation: Pursue the most promising S&T that enables a 2010-2012 FCS FUE and the implementation of a modern organizational and operational concept.

Principles That Influenced Force Design and Analysis



- **Low-risk force with quick deployability and early entry capability.**
- **Exploit air dimension to dominate strategic, operational and tactical maneuver .**
- **Maintain echelons of force structure.**
- **Infantry capability remains essential.**
- **Vehicular mounted LOS & BLOS weapon systems capable of destroying enemy armor and fortified positions.**
- **Combined arms organizations down to company level.**

A Collaboration Centric Force

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The force used in the analysis is a medium weight force whose purpose is to deploy quickly in a crisis response and add formidable capability to early entry (light) forces. It is composed of low risk technology components which have a reasonable chance of fielding in the early stages of the Army transformation process. Therefore, this is a low-risk force with quick deployability and early entry capability.

Early crisis response requires force projection. Force projection requires strategic movement of forces by air and surface means. Once in the theater, forces must have the capability to reposition by air in order to achieve dominant maneuver. Therefore, we must exploit the air dimension to dominate strategic, operational and tactical maneuver.

There is no compelling evidence to suggest that elimination of one or more echelons will increase combat effectiveness. The Army transformation will be difficult enough to realize without trying to radically change the organizational echelons of the institution. The Army should maintain the current echelons of force structure until detailed analysis is conducted.

Because we believe that combat in urban/complex terrain will be more likely in the future, there must be a significant number of infantrymen in the force structure. Infantry must be available to dismount and operate in close proximity to other human beings, whether hostile or not. That is, there must be infantry to work humanitarian or peace keeping operations in a non-hostile environment; and there must be infantrymen to fight house to house in urban conflict to defeat an enemy who has chosen to fortify a city. Therefore, for the foreseeable future, infantry capability remains essential.

While the majority of the killing of enemy armored systems will take place at ranges beyond line of sight, largely by indirect fire means, there must be the capability to engage and destroy enemy tanks at close range in under three seconds by direct fire means. We also must preserve direct fire capability for reduction of strong points in urban combat. Therefore, there must be vehicular mounted LOS & BLOS weapon systems capable of destroying enemy armor and fortified positions.

The study examined combined arms organizations down to and below company level. It is apparent that life on the future battlefield will be difficult for the lieutenant platoon leaders and may become more inordinately complex if they must master the employment of several major weapons systems. Platoons should be organized around single major weapons systems. The Army should not push combined arms below company level until detailed analysis is conducted.

Core Capabilities Insights

Problem: To determine core capabilities that are critical to a FCS system of systems to constitute a viable, collaborative centric force

Discussion:

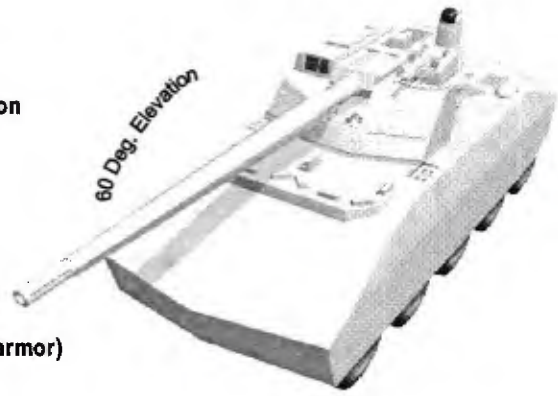
- FCS is a system of systems with critical components
  - 20 ton vehicle essential capabilities:
    - Survive first engagement via situational awareness, APS, advanced armor
    - Lethality overmatch, via ETC cannon + advanced EFP and TERM
  - Net Fires: autonomous launch and precision attack munitions
  - UAVs: multipurpose, adverse weather, with links to FCS vehicles, RAH-66, reachback
  - UGVs: integrated into OPS concepts; start with follower
  - Infosphere: secure, mobile, robust commo to brigade and below
- Future Transport Rotorcraft (FTR) to be developed after FCS bow wave

Recommendation: Ensure adequate funding of core elements and give command attention to critical technologies

FCS (AT)

System Description
- 20 ton vehicle
- Crew of 2

Key Capabilities
- Lethality
  - Direct and indirect fire ETC cannon
  - KE overmatch T-90
  - TERM with ~ 15 km range
  - Hyper-spectral sensors
- Survivability
  - Netted situational awareness
  - Signature management
  - Active Protection System
  - Passive (EM, ceramic and smart armor)
- Mobility
  - Hybrid electric
  - High speed cross country
  - Dash/Silent operation
  - Precision air insertion



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The FCS Anti-Tank variant is a 20-ton vehicle with a 2-man crew and a direct fire ETC weapon capable of beyond-line-of-sight fires with the Tank Extended Range Munition (TERM) round. The gun elevates up to 60 degrees to enable precision fires at elevated targets in urban environments with programmable levels of lethality.

Survivability is enabled by enhanced situational understanding and long-range fires to avoid close combat with enemy tanks, signature management to avoid or delay detection, active protection against tank-fired and larger munitions, and passive armor to defeat all lesser threats.

Ground mobility is enabled by a fuel-efficient hybrid-electric drive system, and at 20-tons, the vehicle can be inserted precisely via parasail.

FCS (IFV)

System Description
- **20 ton vehicle**
- **Commander, driver, + 9 man squad**

Lethality
- **4 CKEM Missiles + reload**
- **Advanced 30 mm cannon**
- **Advanced fire control (FLIR, MMW, ERASER)**
- **Coordinated fires**

Other
- **Common mobility platform with FCS (AT) with the same survivability factors**

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The Infantry Fighting Vehicle variant of FCS is also 20 ton with several features in common with the AT vehicle. It is operated by a 2-man crew with room for 9 troops.

The lethality suite includes a medium-caliber ETC cannon (30 mm or higher) together with a Compact KE Missile (CKEM) launcher with four ready rounds. Designated FCS variants work with one another, and with unmanned vehicles and unattended sensors to provide netted fires.

Survivabillity and mobility features are identical to the AT variant.

Destroyer

System Description

- 10 ton
- 2 man crew
- Multi-purpose:
  - Destroyer
  - C^2
  - Mortar

Features

- Hyper-spectral sensors
- Signature management
- Small arms armor protection with selective up-armoring
- Armament various:
  - Javelin or MPIM
  - Mortar w/PGMM
  - Advanced machine gun
- Hybrid electric drive

Destroyer variant shows promise if it can be employed consistent with the protection and payload limitation of a 10-ton vehicle

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While the main FCS vehicles (AT, IFV) weigh 20 tons to provide adequate crew protection and payload capacity, a 10-ton vehicle could fulfill useful roles. The benefits and limitations of a 10-ton vehicle receive more thorough treatment below.

As a Destroyer, the 10-ton vehicle would be tele-operated or sent semi-autonomously to flush the enemy out of concealed locations in wooded areas and other potential ambush sites. The C2 variant (command and control) would have enough payload at 10 tons to accommodate a robot control panel and sensors. A mortar variant may also be possible, provided it is unmanned or, if manned, does not get exposed to threats larger than small arms fire.

Hybrid-electric drive and signature management are standard for all the 10-ton variants. Depending on the specific variant, additional crew armor or an armament suite are possible.

FCS (Robotic Weapon Carrier)

System Description
- 10-15 ton mobility platform
- Semi Autonomous Control
- NLOS Communications

Features
- Rocket in Box or Direct Fire Weapon
- Fire Control Sensors
- Protection for key sub systems
- Externally similar to manned

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As robotics technology matures, unmanned ground vehicles (UGVs) will be introduced to the force to ease the task burden on humans and increase their effectiveness and to minimize their exposure to overmatching threats. UGVs will initially be tele-operated, and some may be semi-autonomous in the 2015-2020 period. True autonomous operation will not be available until after 2020.

Robotic weapon platforms could be 10-ton vehicles, or, if additional armament payloads are required, 15 tons or higher (with a maximum of 20 tons). External profile would be kept similar to manned vehicles. Non-line-of-sight communications will be a critical requirement. The weapons suite can be Rockets-in-a-Box or a direct fire cannon or missile, although the short engagement timelines for direct fire may preclude robotics for technical or doctrinal reasons.

FCS (Net Fires)
(formerly AFS$)

System Description

- **'Munitions in a box'**
- **Could be carried by destroyer or towed by robotic re-supply.**
- **~ 30 munitions**
  - **20-40 km precision attack munitions (PAM)**
  - **30 minute/200 km loitering munitions**
  - **Programmable warhead based on target type.**

Key Features

- **Fully autonomous**
  - **Receives fire commands through comm. network.**
  - **Computes firing solution on board.**
- **Box very cheap – throwaway?**

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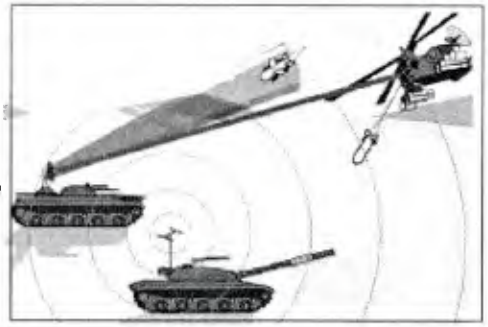
The DARPA Net Fires program offers a method of delivering precision, long-range indirect fires autonomously. The "Rockets-in-a-Box" can be a stationary element, placed in the back of a HMMWV (as shown on the slide) or carried by the FCS weapon carrier shown on the previous one. Rocket boxes can be resupplied with a robotic "mule."

Warhead options include programmable precision attack and long-range loitering munitions, to handle different types of targets.

The weapon system can be remotely controlled, and the launch mechanism (the box) can be designed to be a throwaway.

FCS (DE)

High-power microwave weapons (RF)
Mega/gigaWatt power level.
Can be used to disrupt enemy communication.
Threat vehicle's RF systems vulnerable to HPM.
Vehicle self defense.
- Attack threat weapon's RF.



Laser directed energy weapons
Threat vehicle / threat missile EO systems vulnerable to laser DEWs.
Megawatt class laser sufficient to cause spalling/melting of target.
- Attack threat vehicles
- Platform self defense: destroy threat missiles.

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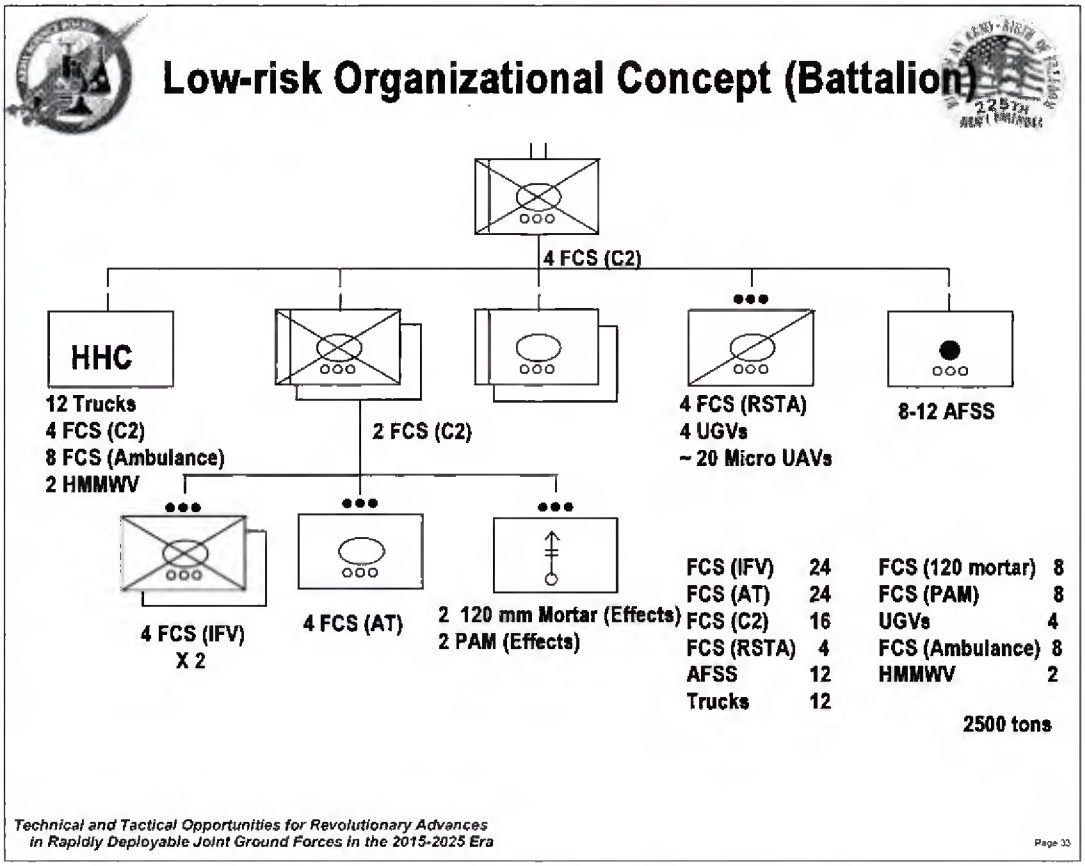
A directed-energy variant of FCS would use the on-board hybrid-electric system to power microwave and laser weapons.

The high-power microwave would disrupt enemy RF communications and inbound threat RF links.

Force protection against long-range threat missiles is enable by a high-power laser. Recent test results against a live Russian Katushya rocket are very encouraging. The technology can be adapted to mobile ground applications provided that the laser and its support equipment can be shrunk in weight and cube without much loss in power.

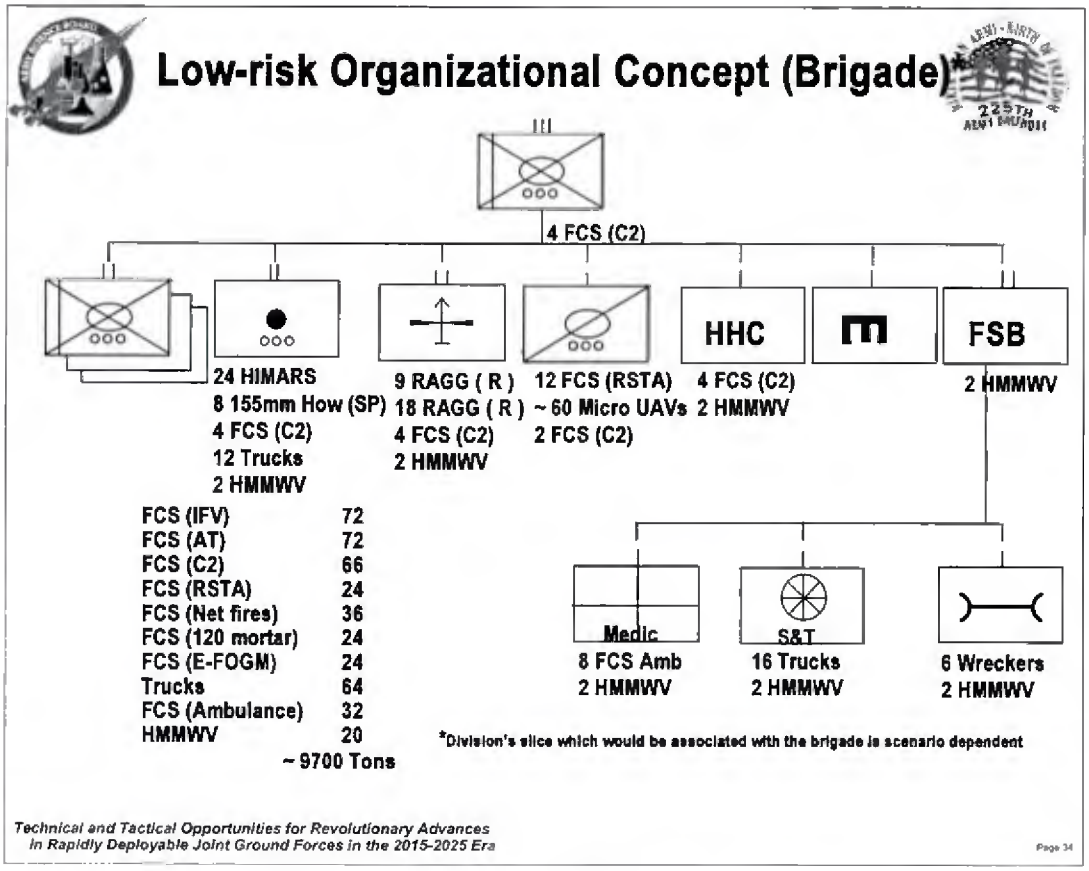


The Medium Weight Battalion-Low Technology Risk Organizational Concept adheres generally to current organizational structures, but organizes combined arms teams at company level. It includes:

- Four companies of three platoons in the battalion.
- 24 infantry squads with fighting vehicles and 24 anti-tank vehicles in each battalion.
- The fighting vehicles are 20 ton FCS variants with composite armor.
  - The infantry fighting vehicle carries the infantry squad and mounts a tank killing direct fire rocket system.
  - The anti-tank fighting vehicle has a two man crew and has a weapon capable of LOS and BLOS kills.
- Company teams include 120mm mortars capable of firing precision guided munitions and E-FOGM, both capable of destroying enemy armored forces at range before the close fight is joined.
- Battalion reconnaissance platoon employs multiple UAVs and has some semi-autonomous UGVs.
- Battalion has Advanced Fire Support System (AFSS) which provides 12 systems of 30 rockets in a box with range of 20 Km, unmanned launch and terminal guidance.
- Battalion weighs out at approximately 2500 tons with only the 20 ton variant of the FCS. Replacing 24 of the vehicles that do not have to survive in the front line with a 10 ton variant of the FCS reduces the weight to about 2200 tons.

In the Operational Concept:

- The Battalion Commander fights this force as a combined arms team.
- He depends on assured networked communications and excellent situational awareness from his organic means (UAVs, UGVs, E-FOGM) as well as that provided by his parent headquarters.
- His enhanced situational awareness allows him to engage the enemy force at long range and destroy the majority of threat forces before they close to disadvantageous range.
- The primary killing systems will be AFSS, E-FOGM, and precision guided mortars for the destruction of the enemy beyond line of sight.
- At closer ranges, the LOS and BLOS systems carried on the fighting vehicles become decisive.

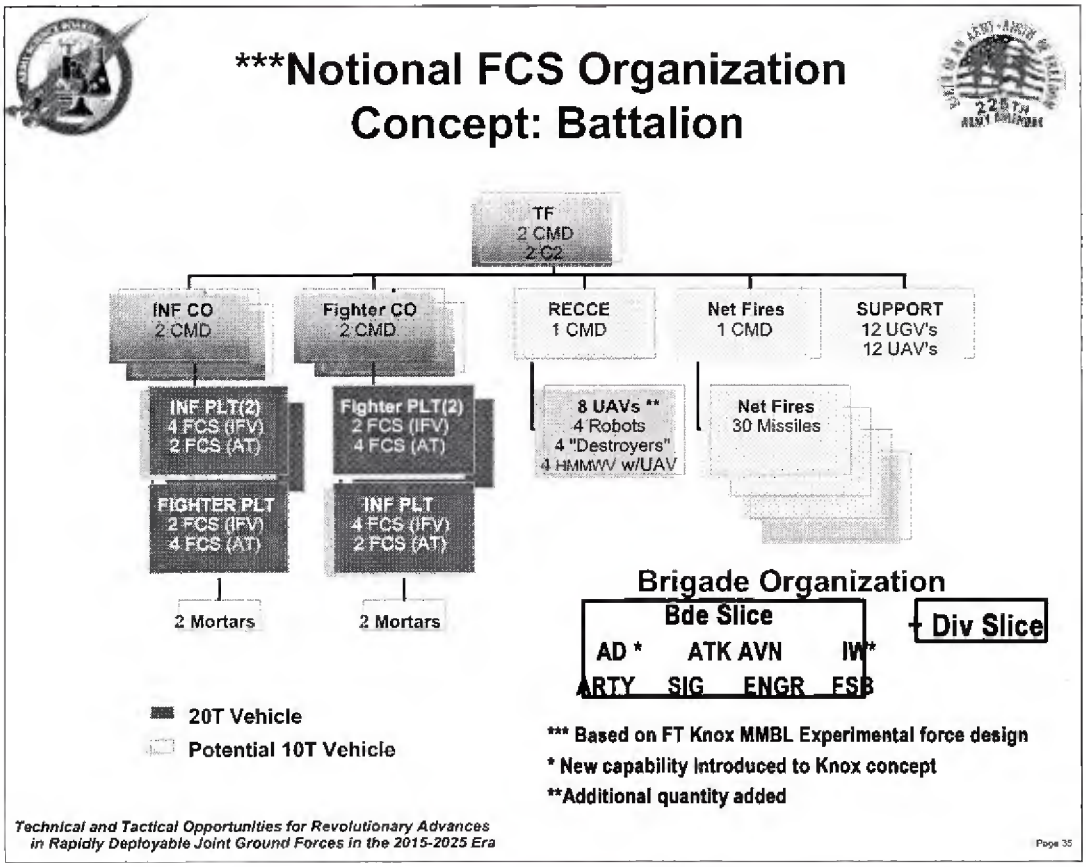


The Medium Weight Regiment-Low Technology Risk Organizational Concept:

- Adheres generally to current organizational concept of the armored cavalry regiment
- Artillery battalion has 24 HIMARS and 8 soft recoil, light weight 155 mm howitzers mounted on the FCS chassis
- Aviation battalion has 27 Comanches: 9 in the reconnaissance role and 18 attack aircraft
- RSTA troop has 60 micro UAVs and 12 FCS RSTA vehicles
- An engineer company and an austere forward support battalion complete the force package
- The regiment weighs out at approximately 10,000 tons with only the 20 ton variant of the FCS. Replacing 92 of the vehicles that do not have to survive in the front line with a 10 ton variant of the FCS reduces the weight to about 9,000 tons

In the Operational Concept:

- The regimental commander fights this force as three relatively independent, highly potent, combined arms taskforces.
- He influences the battle by applying the RSTA troop to find the enemy main forces, and by applying the attack helicopters and the artillery for attrition of the enemy at range.
- The 155 mm artillery can be used in direct fire role in complex/urban terrain to reduce strong points with high explosive ordnance.

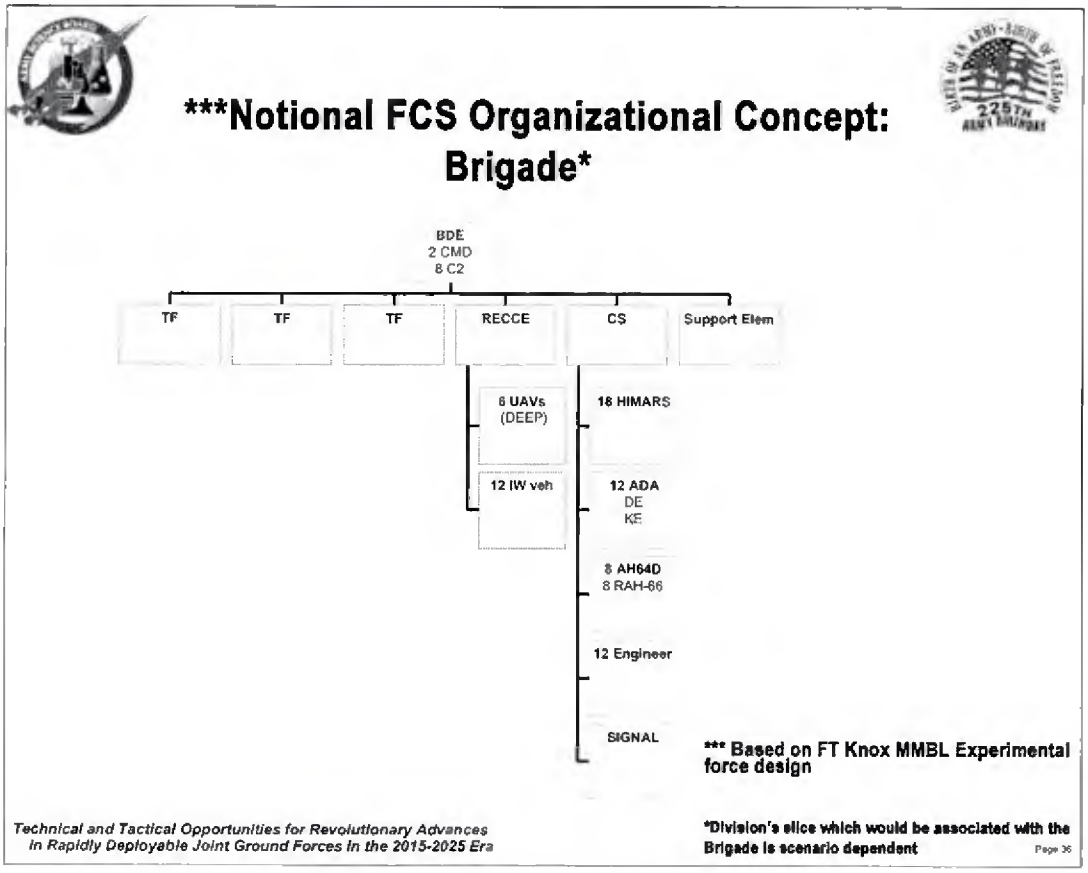


The Notional FCS Force (Ft. Knox MMBL Based Structure) Organizational Concept features four company combined arms teams that have three platoons of six vehicles, each containing both the infantry fighting vehicle and the anti-tank variants of the FCS.

- There are 36 infantry squads with fighting vehicles and 36 anti-tank vehicles in each battalion.
- The fighting vehicles are 20-ton FCS variants with composite armor and enhanced protective suites.
  - The infantry fighting vehicle carries the infantry squad and mounts a tank killing direct fire rocket system.
  - The anti-tank fighting vehicle has a two man crew and has a weapon capable of LOS and BLOS kills.
- Each company team includes two tubes of 120mm mortar.
- Additional fire support is provided by four AFSS systems, each consisting of 30 rockets in a box capable of firing to 20 km range.
- Reconnaissance troop employs multiple UAVs and UGVs to bring enhanced situational awareness to the commander.
- The battalion weighs out at approximately 2800 tons with only the 20 ton variant of the FCS.

Operational Concept

- Battalion Commander fights this force as a combined arms team.
- He depends on assured networked communications and excellent situational awareness from his organic means (UAVs and UGVs) as well as that provided by his parent headquarters.
- His enhanced situational awareness allows him to engage the enemy force at long range and destroy the majority of threat forces before they close to disadvantageous range.
- The primary killing systems will be AFSS and precision guided mortars for the destruction of the enemy well beyond line of sight.
- At closer ranges, the LOS and BLOS systems carried on the fighting vehicles become decisive
- Critical Enablers -
  - Assured network C2
  - Rapid communications and net fires
  - Multiple UAVs and robotic scouts
  - Enhanced air defense



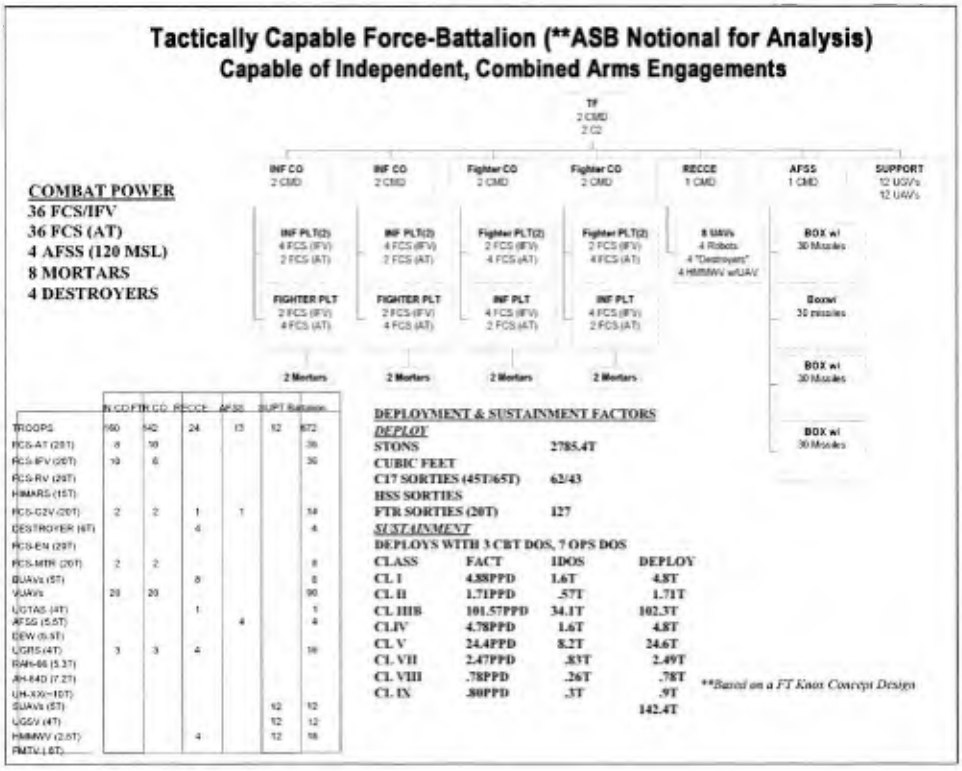
Notional FCS Force (Ft. Knox MMBL Based Structure)Organizational Concept adheres generally to current organizational concept of the armored cavalry regiment and includes:

- A combat support battalion with HIMARS, 12 Directed Energy air defense weapons systems, 8 AH64 Apaches, 8 RAH-66 Comanches, engineers and signal capabilities.
- RSTA troop has 6 UAVs which operate deep and 12 information warfare systems which are capable in offensive and defensive IW.
- An austere forward support element completes the force package.
- The regiment weighs out at approximately 7,000 tons with only the 20-ton variant of the FCS.

Replacing some of the vehicles that do not have to survive in the front line with a 10-ton variant of the FCS will reduce the weight to about 6,600 tons.

Operational Concept

- The regimental commander fights this force as three relatively independent, highly potent, combined arms task forces
- He influences the battle by applying the RSTA troop to find the enemy main forces, and by applying the attack helicopters and the artillery to attack the enemy.

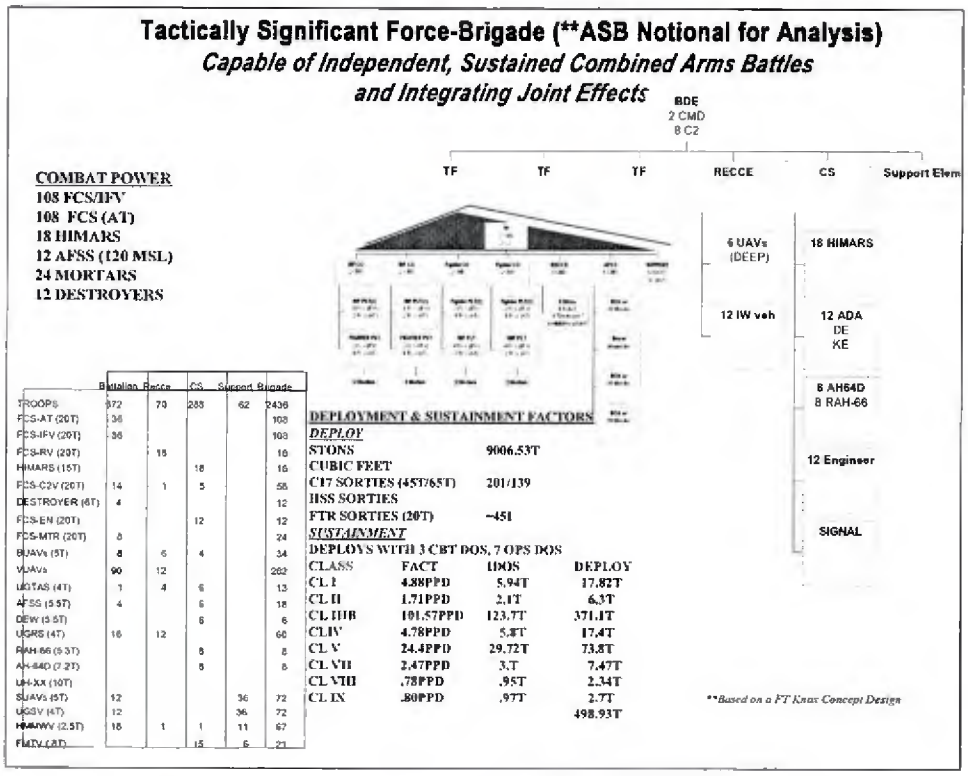


This chart illustrates systems density and deployment and sustainment footprints of the force used for analysis.

•Systems weights are notional for planning

•Sustainment footprint is based on CASCOM study consumption factions

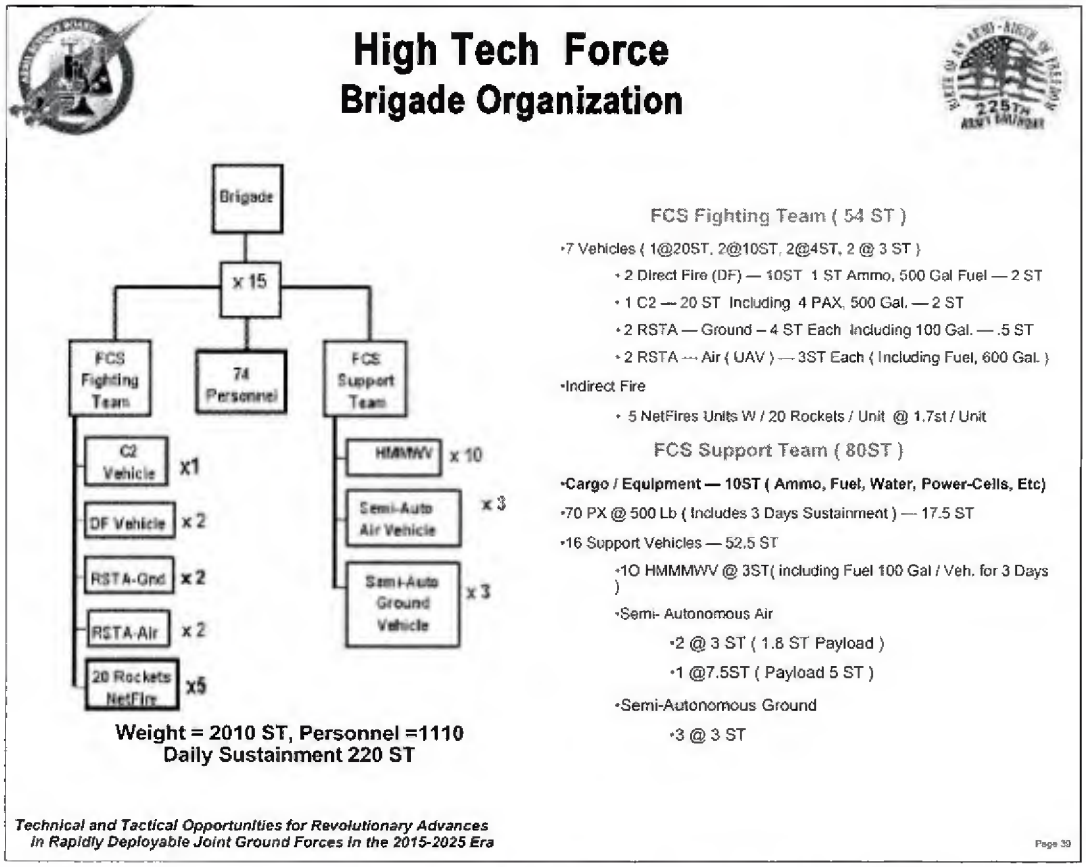
It was assessed that this battalion-sized force was capable of an independent tactical action, and with sustainment and support from its parent organization, it is capable of multiple actions/engagements



This chart illustrates systems density and deployment and sustainment footprints of the force used for analysis.

- Systems weights and Sustainment footprint are consistent with the Battalion

It was assessed that this brigade sized force was capable of conducting sustained independent tactical engagements and battles.



A High-Tech Force was developed which took extreme advantage of technology. It is not expected that technology will have matured sufficiently to support the initial FCS FUE in 2010-2012 be comparable to this force. However, as technology matures, it is believed that FCS will and should converge to the High-Tech force described above.

The High-Tech Force's lethality and survivability are directly related to the networking of all elements in the force. The RSTA UAV and UGV's, and the Indirect Fire weapons allow the High Tech Force to engage enemy forces at ranges beyond current and projected adversary capabilities

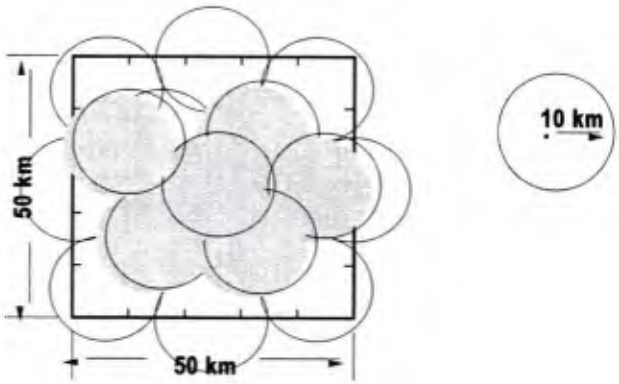
In addition, the situation awareness provided by the networked RSTA units allow the Force to maneuver enemy forces at a disadvantage and possibly into an ambush situation.

The 1110 personnel results from the use of robotic vehicles performing tasks that otherwise would have to be done by humans.

This force was not analyzed in a warfighting scenario.

High-Tech Force Brigade Area Coverage

- Everyone Networked; Information, Fire Call and Logistics
- Firepower Equivalent to M1's with a 20+ km kill range
- Each Team Covers 10 KM Radius
- 15 Teams Cover 50Km x 50Km



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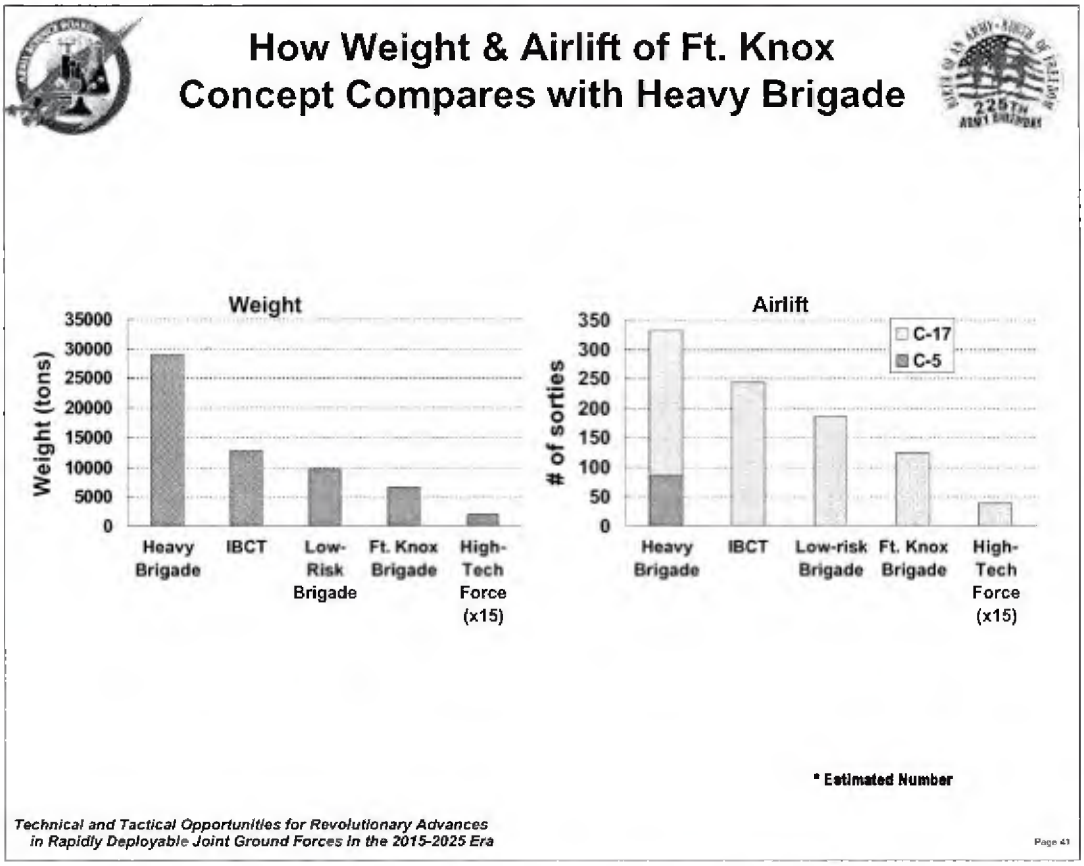
Each of the Teams detailed on the previous slide have an Area Of Control (AOC)defined by a circle with a 10 Km radius. For this analysis, a Brigade's AOC was defined to be a 50 Km by 50 Km area.

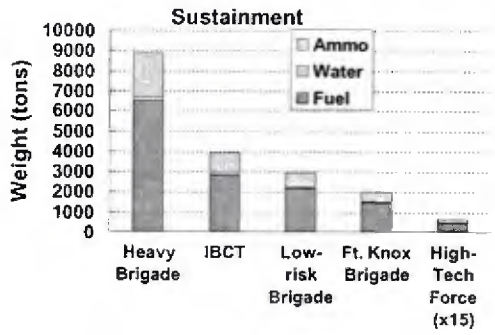
A total of 15 Teams distributed across the 50x50 Km area defines the size of the Brigade. Note that only 9 Teams are required to cover this area. However, if a Team's C2 vehicle was lost, a noticeable gap would appear within this area. Six extra teams is conservative since it adds more redundancy than required. More simulation and analysis is required to determine the precise size of the force.

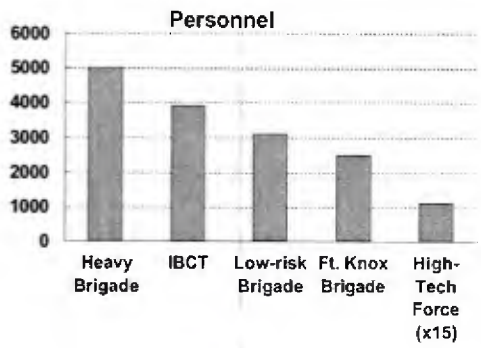


This slide illustrates the deployment footprint of the various force designs considered as compared to other current Army forces.

- Planning considerations must consider realistic airlift inventory assets vs actual airlift allocations given for individual service requirements.
- The heavy brigade exceeds the capacity of the entire military strategic fleet.
- The Ft. Knox Brigade requires most—if not all—C-17 operational aircraft.
- C-17s must be supplement by other military airlift (C-5, C-130, ATT) assets or a combination of military and commercial aircraft.
- If commercial aircraft are used, the mobility packaging and the deployment planning must be exercised and tested before an actual contingency movement.

Concept Comparison with Heavy Brigade (Sustainment/Personnel)





Technical and Tactical Opportunities for Revolutionary Advances in Rapidly Deployable Joint Ground Forces in the 2015-2025 Era

This data underpins deployment footprint data on the preceding slide.

FCS Force Deployment Analysis

Decisive, Employable Combat Capability Delivered in 4 Days

FCS Force Analysis

Requirements

- Deploy 9,000 STON force
- In-flight refueling

Constraints

- Throughput
  - – APOE (MOG 15): 7,200 STONs/day (C-17 only fleet, 24 hr contingency ops)
  - – APOD (MOG 3): 1,851 STONs/day (C-17 only fleet, 24 hr ops, expedited offload-1.75 hrs)
- Distance
  - – Mileage: 5,080 nm
- Aircraft:
  - – 150-200 C-17 sorties
  - – C-17 capacity: 45 STONs/430 knots; load and unload time -- 2.25 hrs/1.75 hrs

FXXI Brigade Analysis

Requirements

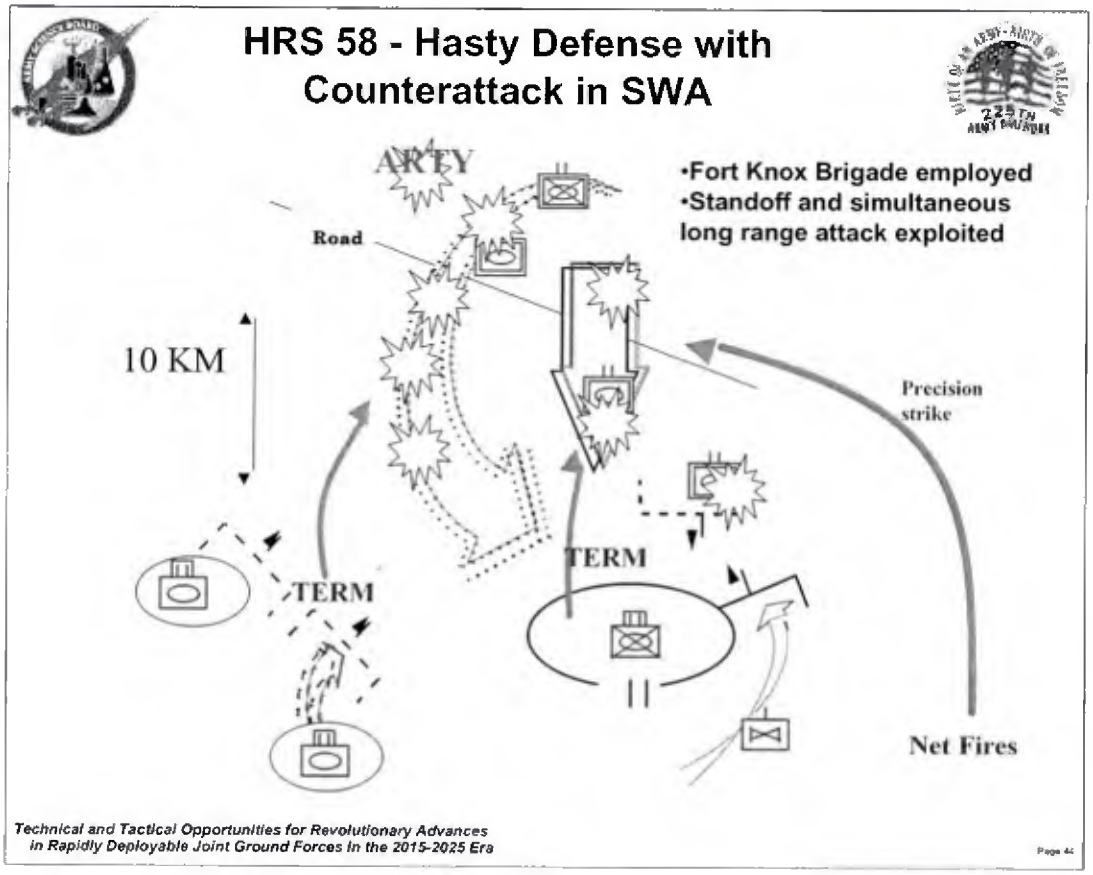
- Deploy 29,580 STON force
- In-flight refueling

Constraints

- Throughput
  - – APOE (MOG 15): 7,200 STONs/day (C-17 only fleet, 24 hr contingency ops)
  - – APOD (MOG 3): 1,851 STONs/day (C-17 only fleet, 24 hr ops, expedited offload-1.75 hrs)
- Distance
  - – Mileage: 5,080 nm
- Aircraft:
  - – 657 C-17 sorties
  - – C-17 capacity: 45 STONs/430 knots; load and unload time -- 2.25 hrs/1.75 hrs

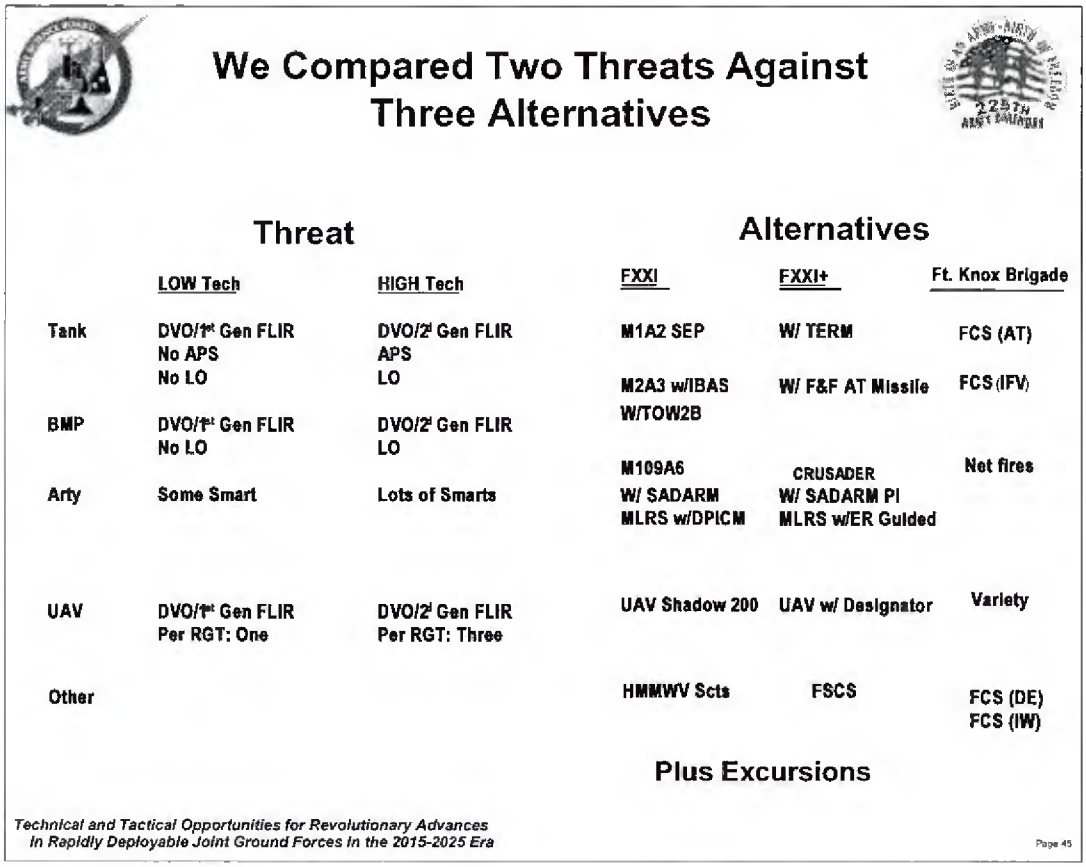
This slide reflects deployment analysis of the Notional FCS force as compared to a FXXI brigade.

Contrasted with the FXXI brigade, the Notional FCS force demands about half the lift while delivering dramatically increased combat power.



HRS 58: Hasty Defense with Counterattack in SWA Phase II

- This analysis was done by TRAC-WSMR using the Notional FCS brigade force based on the Ft. Knox design against an FXXI brigade baseline.
- The scenario featured the employment of the medium brigade against an attacking red regiment in open desert terrain in SWA.
- While the general posture of the blue forces is "hasty defense", this mission is being accomplished by maneuver which is best characterized by the term "counterattack".
- The key to the defeat of the red force is the ability to engage the advancing armored forces with precision weapons at long range and kill them well before they close to the range of LOS, direct fire engagement.
- This is accomplished by superior situational awareness provided by UAVs, capability to engage at ranges of 5-20 kilometers with Net Fires, BLOS ERM rounds, HIMARS, attack helicopters, and other non-Army fire support means.
- Blue was able to
  - Shoot down enemy UAVs and some enemy rocket artillery with Directed Energy Air Defense Artillery weapons.
  - Spoof the enemy GPS system to reduce the effectiveness of their guided munitions.
  - Achieve survivability through the killing of the enemy systems at long range, before enemy direct fire systems could be employed.



Threat Capabilities:

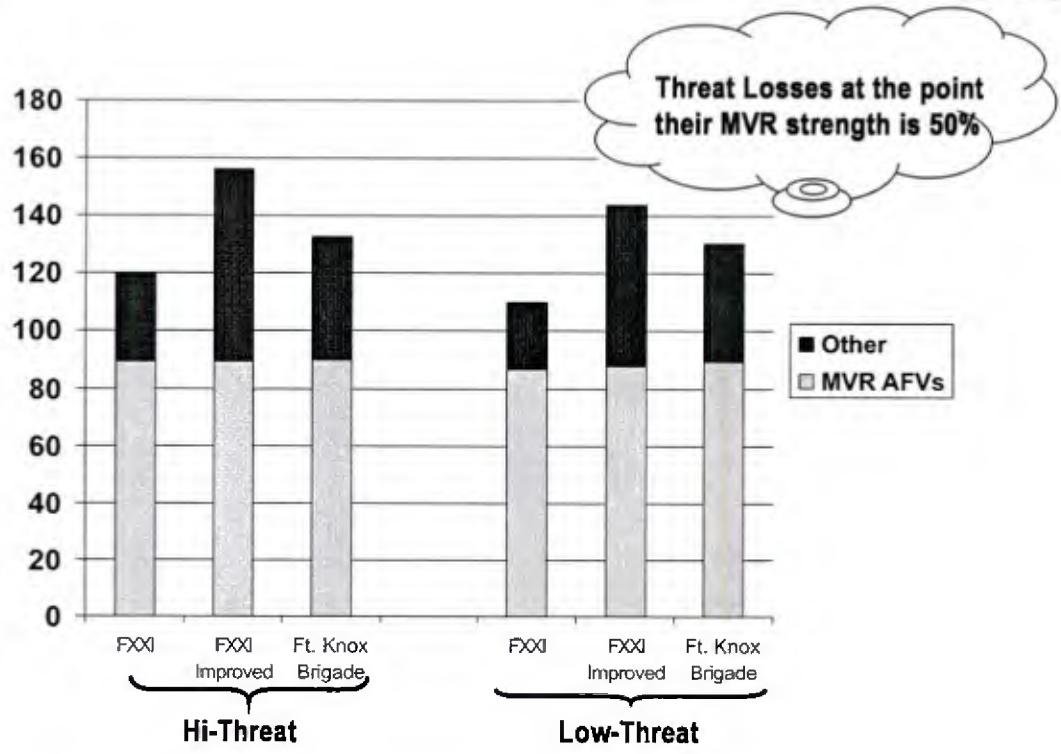
- Two levels of threat capabilities were played against the three forces. The low level threat was essentially the technology available to threat forces today. The high level threat assumed 2nd generation FLIR on principal ground vehicles and on UAVs, low observable technology on ground vehicles, APS system on the tanks to defeat kinetic energy rounds, and a lot of smart munitions.

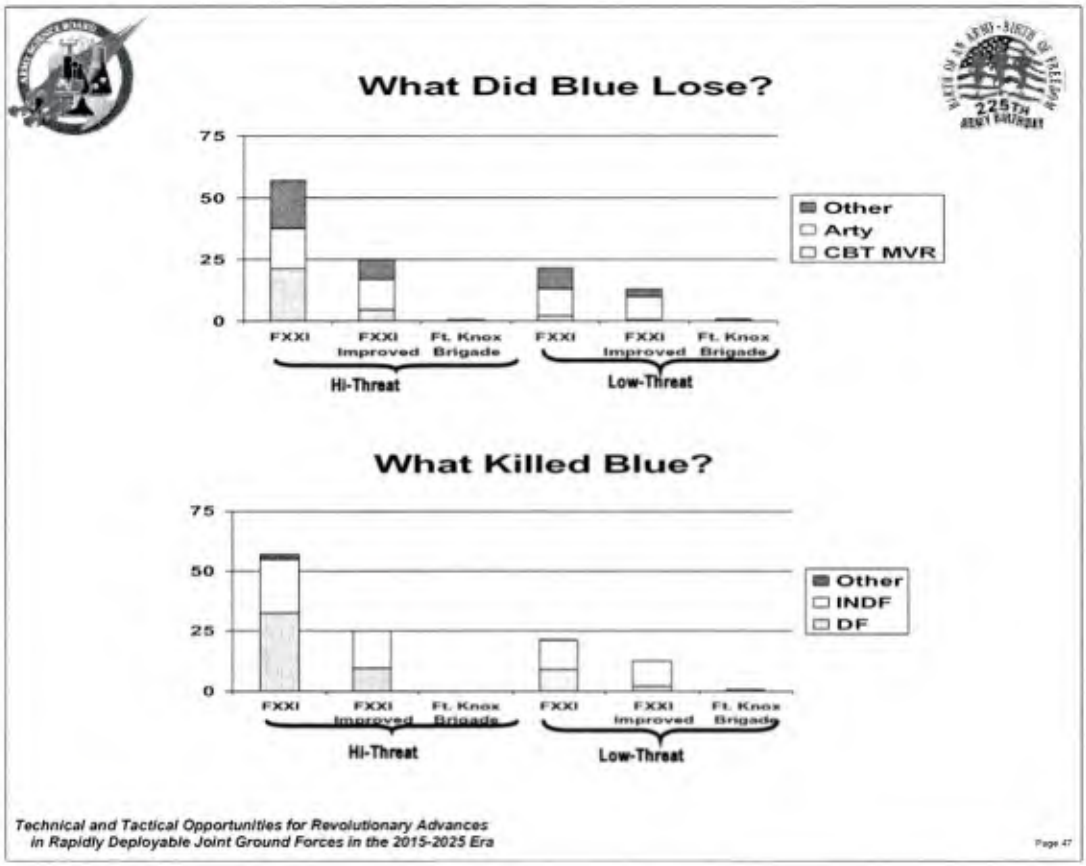
Blue Alternatives:

- **Force XXI:** Essentially today's force with today's technology
- **Force XXI+:** This force is today's force enhanced by Tank Extended Range Munitions (TERM), fire and forget AT missiles launched from Bradley's, CRUSADER with product improved SADARM,MLRS with extended range guided munitions, UAV with target designator, and the Future Scout Combat System.

Fort Knox Brigade: The FCS achieves high lethality and survivability with net fires, multiple UAVs, the capability to kill enemy UAVs with DE, and the ability to spoof enemy GPS guided munitions.

Threat Losses





The Blue Force prevailed in all cases in this scenario run by TRAC-WSMR.

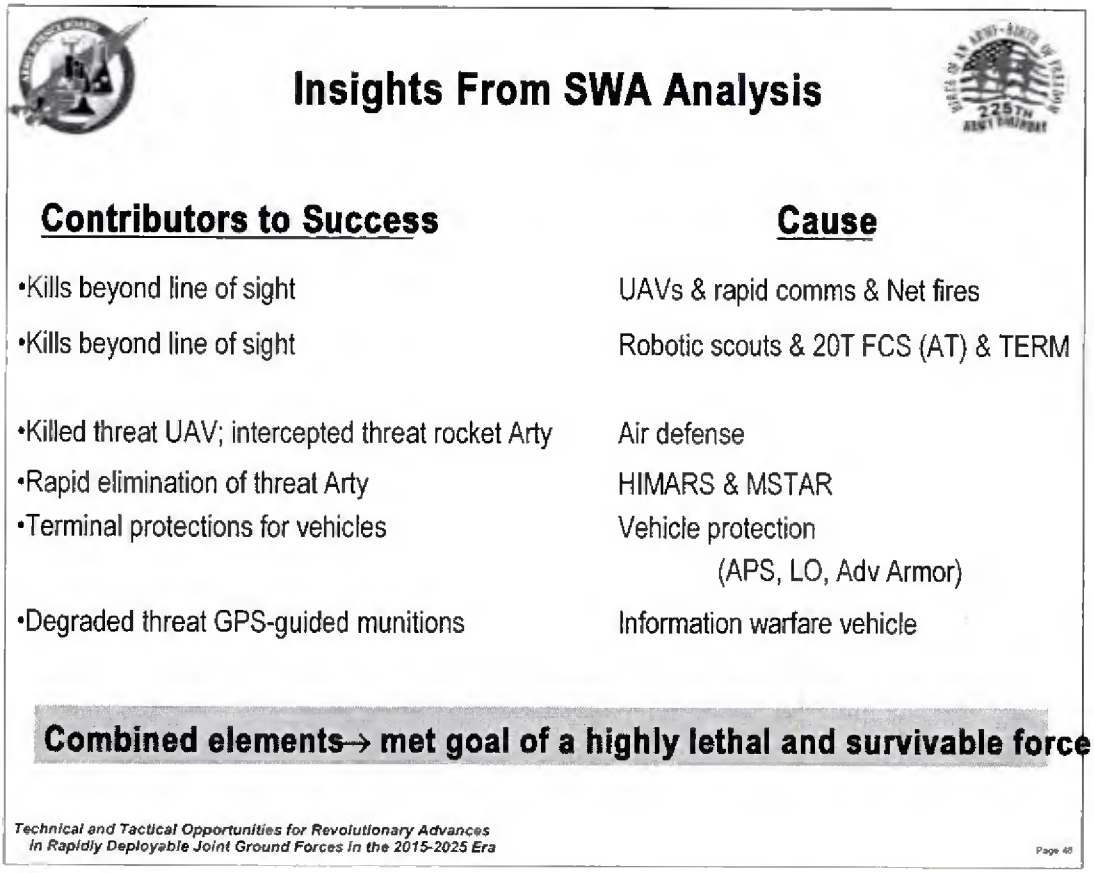
What Did Blue Lose?

- The number of system losses sustained by the Blue force in each of the runs of this scenario are shown in the chart above. Against the hi-threat Red force, the Blue FXXI force lost a high number of ground maneuver vehicles (Abrams tanks and Bradley IFVs) because a high percentage of the killing took place in the very close direct fire exchange battle. The improved FXXI force took fewer losses because it killed Red forces at greater range with TERM and MLRS with SADARM. The Ft Knox force sustained very few casualties because it was able to destroy the enemy force before the maneuver forces closed to direct fire LOS range.

- Blue did generally better against the low-threat red force than against the hi-threat force. This was to be expected.

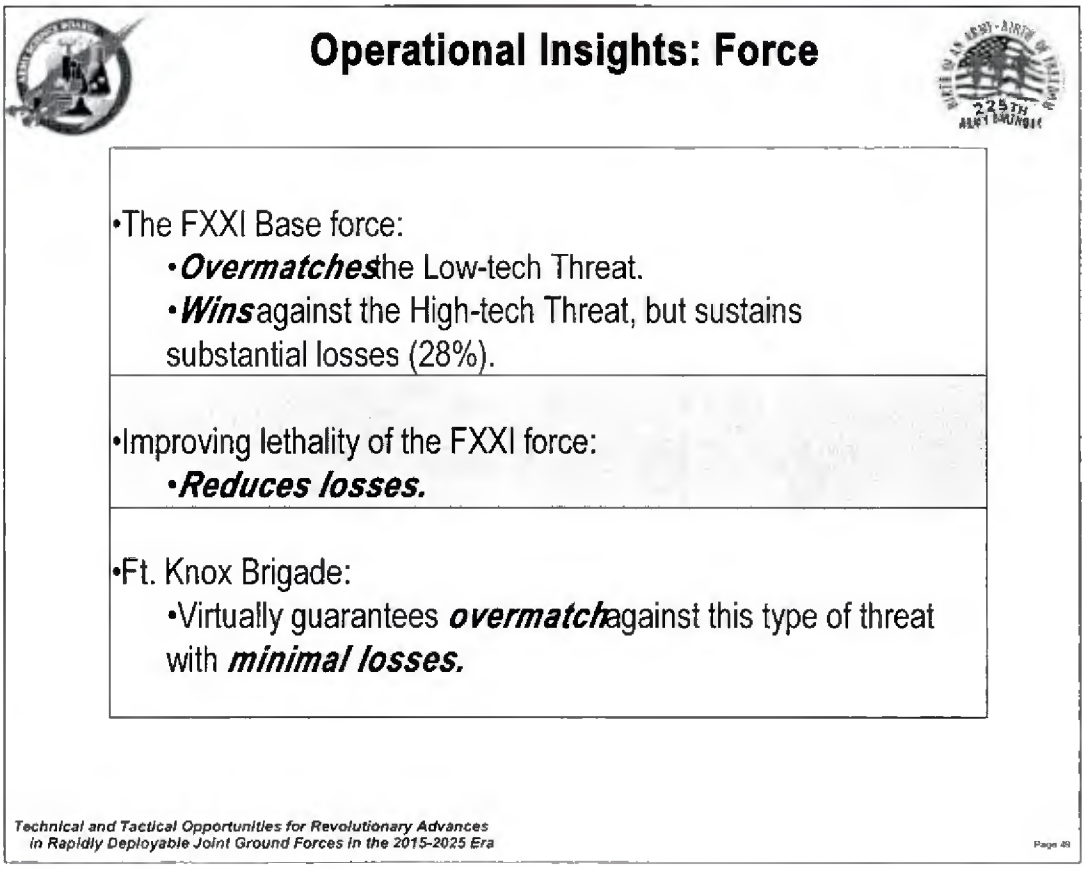
What Killed Blue?

- The chart shows that the majority of the Blue FXXI force losses were due to the direct fire engagements in the close battle. As the Blue stand off capability improved in the FXXI+ force, the proportion of losses caused by Red indirect fires increased sharply as the direct fire engagement caused fewer losses. In the case of the FCS force, the enemy was destroyed before they could cause significant Blue losses. The minimal losses that did occur were due to Red indirect fires.



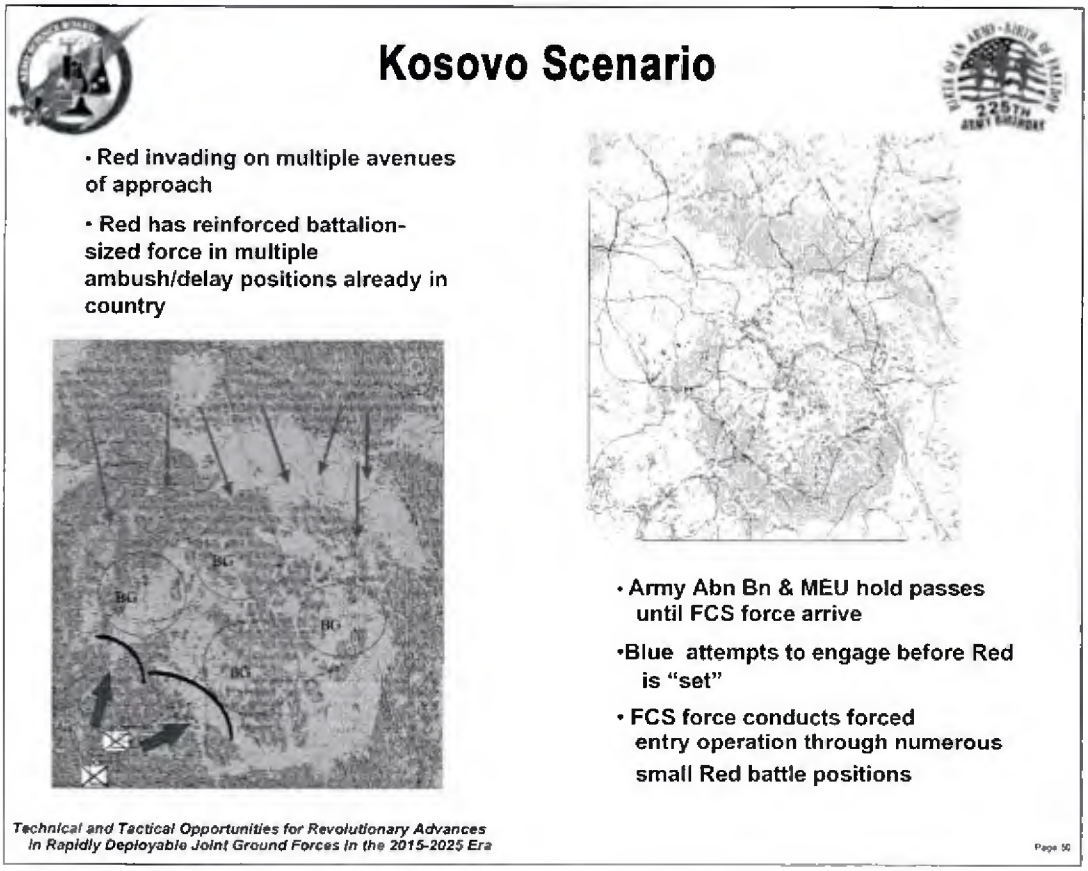
The remarkable success of the Notional FCS Force was due to the following reasons:

- Kills beyond line of sight were enabled by enhanced situational awareness provided by UAVs, rapid communications, and robotic scouts
- Kills beyond line of sight were made primarily by Net Fires (Rockets in a Box) and TERM munitions fired by the FCS anti-tank vehicle
- Enemy UAVs were destroyed and threat rocket artillery rounds were killed by Blue air defense directed energy weapons
- Rapid elimination of the threat artillery was due to HIMARS and MSTAR
- Superior blue vehicle survivability and protection was achieved with SA, stand-off engagements, Active Protection System (APS), Low Observability technology, and advanced armor (composites) technology
- The implications of networked forces in a global, operational and tactical infosphere, building SA from the top down and bottom up and enabling collaborative operations appears to be a dramatic force multiplier
- The effectiveness of the threat GPS guided munitions was degraded by spoofing the threat GPS system using an Information Warfare vehicle



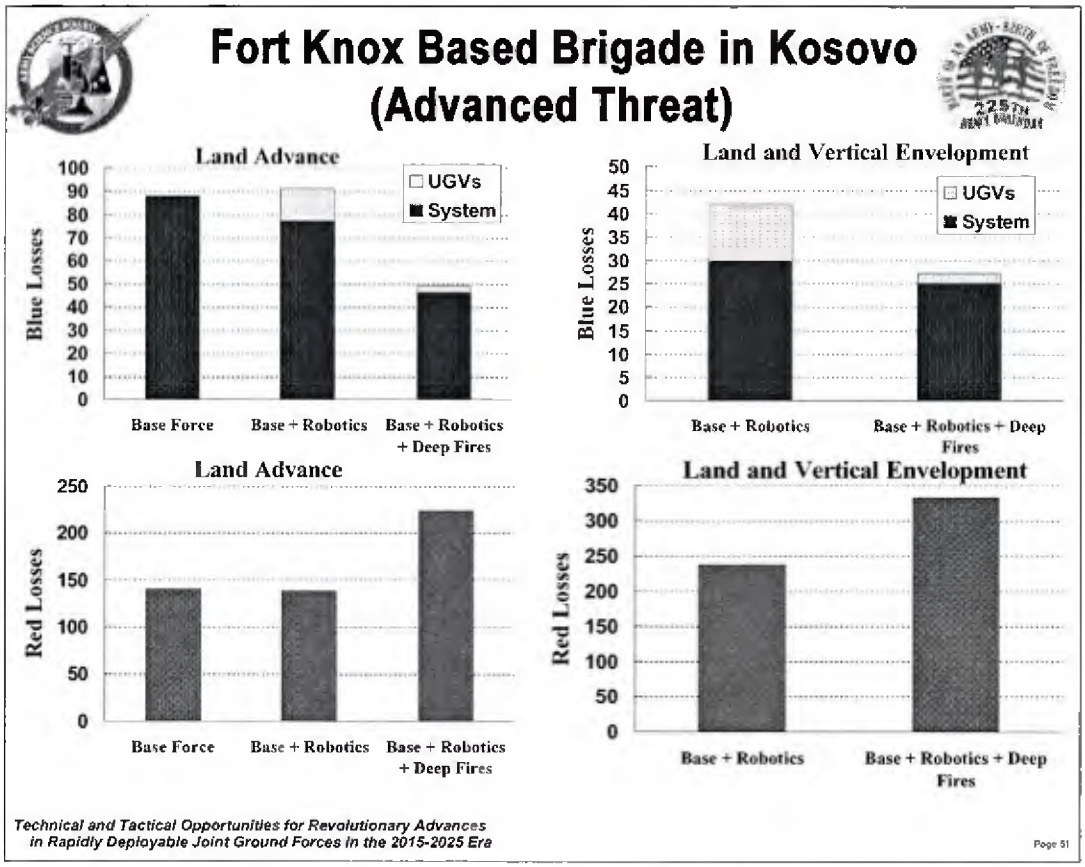
This slide summarizes insights from SWA HRS 58 analysis of the Notional FCS force base-lined against a FXXI brigade

- Selected enhancements of FXXI improves force effectiveness against all threats. High tech threats increase the risk of a product improved approach to upgrading FXXI
- In this analytical example, increases in lethality increased survivability of the FXXI force. This insight is consistent with ARL analysis.
- Concepts and capabilities embodied in the Knox based brigade provided unquestioned overmatch of all threat forces in this open terrain scenario.



Rand Kosovo Scenario

- The Red forces introduced a reinforced battalion sized force early to establish ambush and delay positions to hamper the advance of Blue forces. The main body of Red forces advanced on multiple avenues of approach from the north.
- Blue forces used an Army airborne battalion and a Marine Expeditionary Unit (MEU) to hold the two passes until the Blue FCS brigade could arrive. Blue attempted to move to blocking positions astride the main avenues of approach before Red could gain its objectives. Blue was successively delayed and attrited by Red as it fought its way through the various small pockets of resistance which became effective ambush/delay positions.

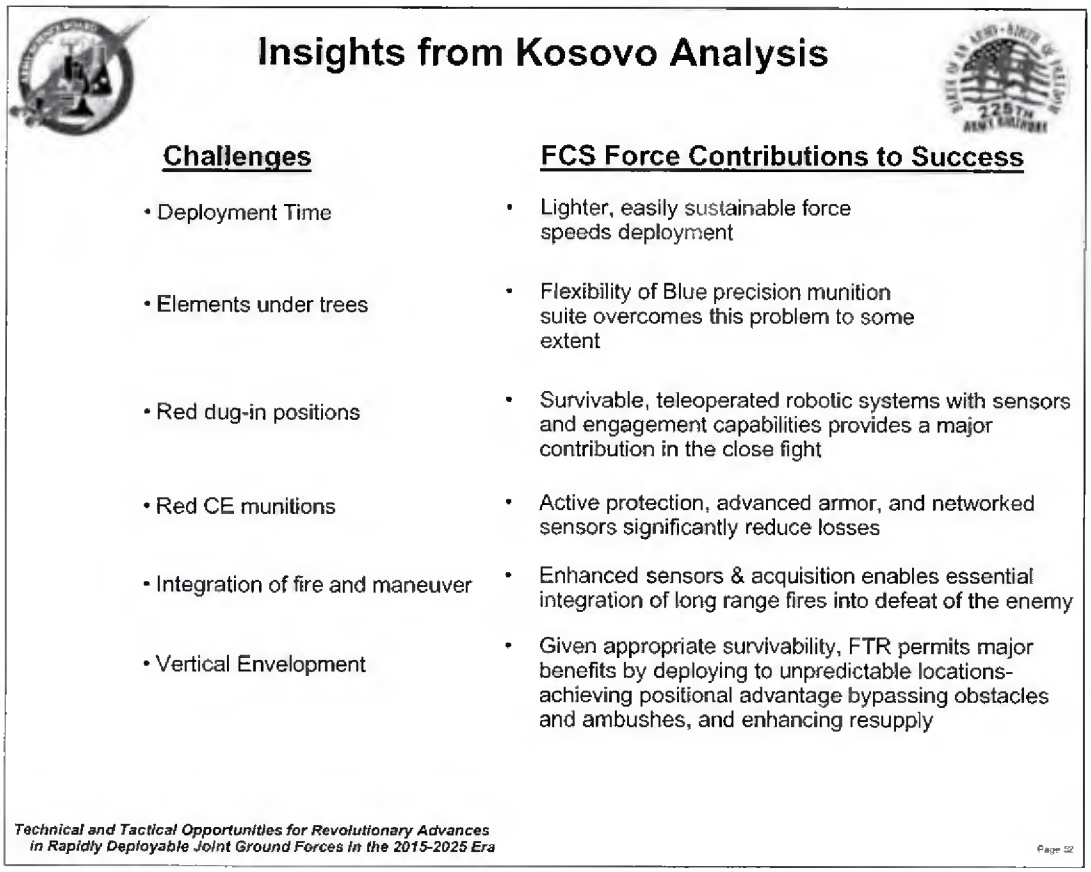


The Blue and Red losses for the Kosovo scenario are depicted on this chart. Note that this Ft. Knox based force was employed against an advanced threat.

The 'Base Force' was built around the FCS(AT) and FCS(IFV) shown earlier. When this force was used along ground routes of approach into Kosovo, an exchange ratio of 1.59 resulted. (Note: exchange ratio is total Red losses divided by total Blue losses) When ground robotic elements were added to the force, the exchange ratio improved to 1.79, however, a total of 14 UGV's were lost. When UAV's were used with sensors such as foliage penetration radar (FOPEN) to detect hidden threat elements and smart munitions were used against these elements, the exchange ratio improved to 4.87, reflecting cutting Blue loss by approximately a factor of 2 while significantly increasing Red losses. Note that this killing before the direct fire battle would be consistent with the envisioned CONOPS.

The right hand side charts reflect the use of a FTR in conjunction with the ground elements. The FTR was used to lift Blue elements to blocking positions to counter advancing Red elements. This vertical envelopment had a significant effect on the overall exchange ratio.

The conclusion drawn from this analysis is that the postulated FCS force would be able to accomplish the mission while sustaining modest losses. Further work needs to be done, however, to refine employment of the UGV's and to ensure proper representation of the technologies which are envisioned for FCS. These results were viewed as very encouraging.

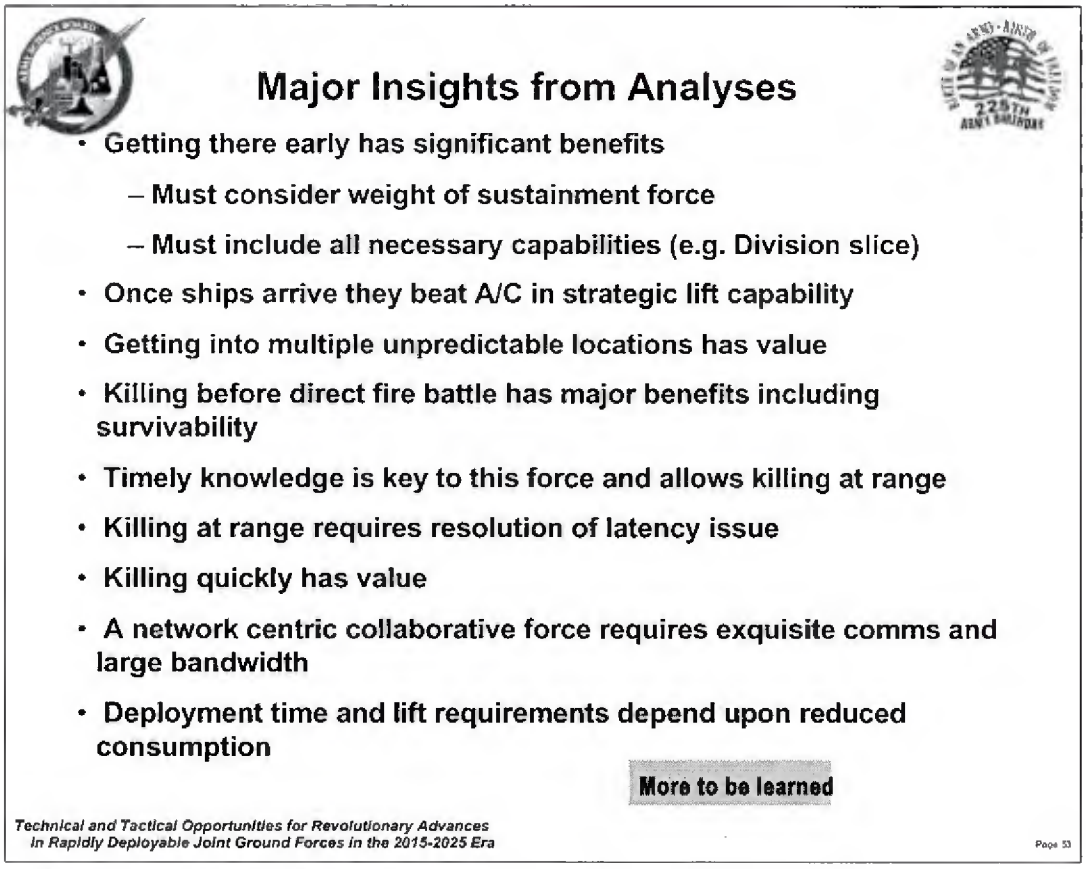


Insights from Kosovo Analysis

This chart depicts the challenges to the FCS force and the advantages that we believe the FCS force will enjoy based on the insights derived from Rand analysis of the Kosovo scenario.

Critical capabilities exploited in this FCS analysis included:

- rapid deployment;
- application and integration of strategic/operational and tactical multi-spectral sensors;
- rapid and precise engagement of identified targets;
- robotics with target detection and engagement capability;
- the integration of long range fires and maneuver;
- vertical envelopment to achieve positional advantage and time advantages.



Major Insights from Analyses

Getting to the fight early allows significant advantages to Blue, but we must not underestimate the weight and cube of the sustainment force and the various slice units that must go with, or very soon after, the FCS force.

Once the sea lift begins to arrive in theater, the amount of materiel that can arrive by ship far exceeds what can be strategically lifted by air. (Note: this insight comes from previous ASB studies.)

Positional advantage can be achieved by insertions of forces into multiple unpredictable locations by not being tied to APODs and SPODs.

Killing the enemy at long range before the direct fire battle is joined has major benefits in survivability for the FCS force.

Very good situational awareness is crucial to allowing this killing at long range.

Blue must resolve the latency issue of information transmission if the situational awareness is to be current.

Killing the enemy quickly and simultaneously has great benefits in survivability.

We must possess exquisite communications and bandwidth to make the network centric collaborative force work.

Deployment time and lift requirements depend upon reduced consumption.

Additional Force Design and Effectiveness Analysis

Study insights limited to a single organization design and scenario; further analysis required to fully evaluate implications of missions and environments on systems capabilities and organizational constructs.

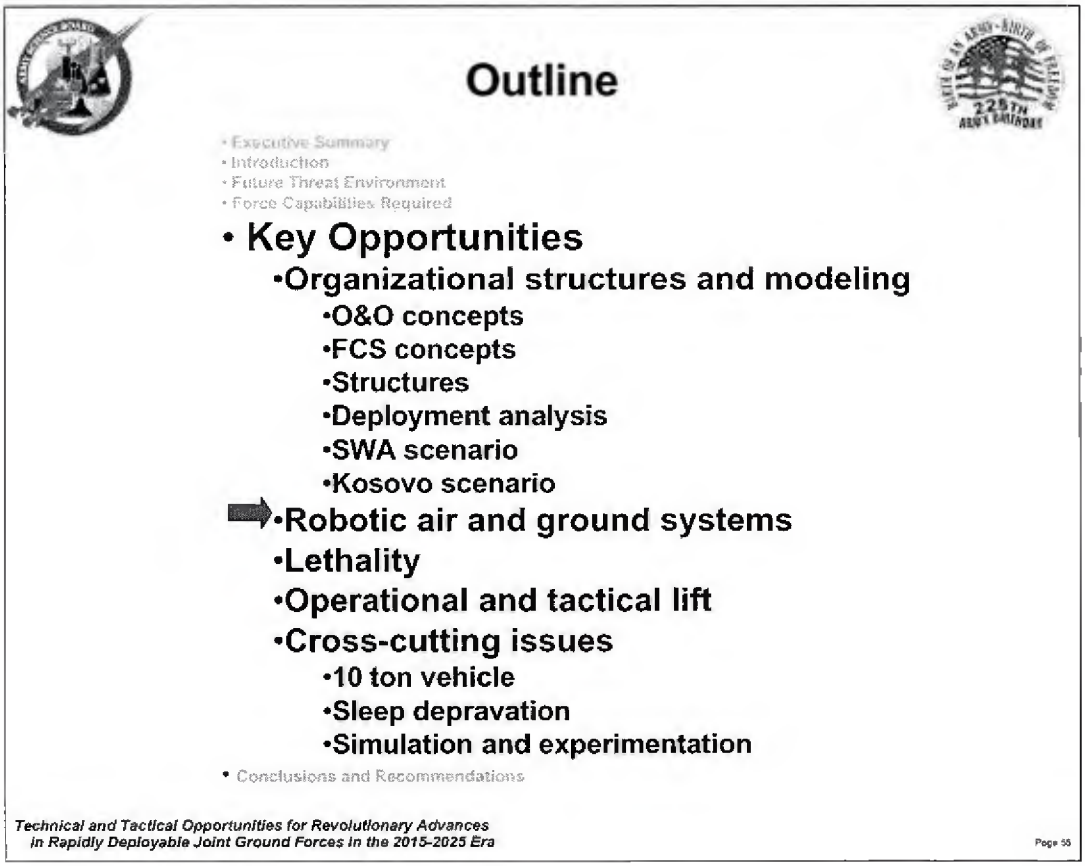
	OFFENSE	DEFENSE	STABILITY	SUPPORT
OPEN	LIMITED	LIMITED	X	X
COMPLEX	LIMITED	LIMITED	X	X
URBAN	X	X	X	X

Analysis to date provides significant insights into the potential payoff of future capabilities examined by the operations panel--ISR, Stand-off fires, robotics, etc. Additional analysis required to gain insights into implications of full spectrum capabilities (the other 11 of 12 scenarios) across a variety of force designs.

Technical and Tactical Opportunities for Revolutionary Advances In Rapidly Deployable Joint Ground Forces In the 2015-2025 Era

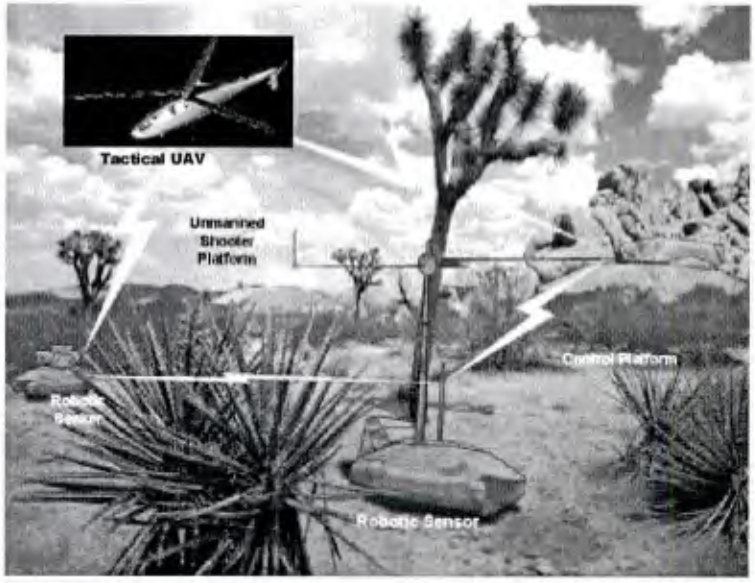
Force effectiveness and capabilities analysis was limited to two scenarios (HRS-58, SWA counterattack/defense and Kosovo attack and defensive blocking positions) due to time and resource constraints.

Final decisions on capabilities and technology should be underpinned by further analysis and hands on experimentation including distributed integrated simulation.



This section looks at robotic and ground systems.

Issue 2: Robotic Equipment



Technical and Tactical Opportunities for Revolutionary Advances in Rapidly Deployable Joint Ground Forces in the 2015-2025 Era

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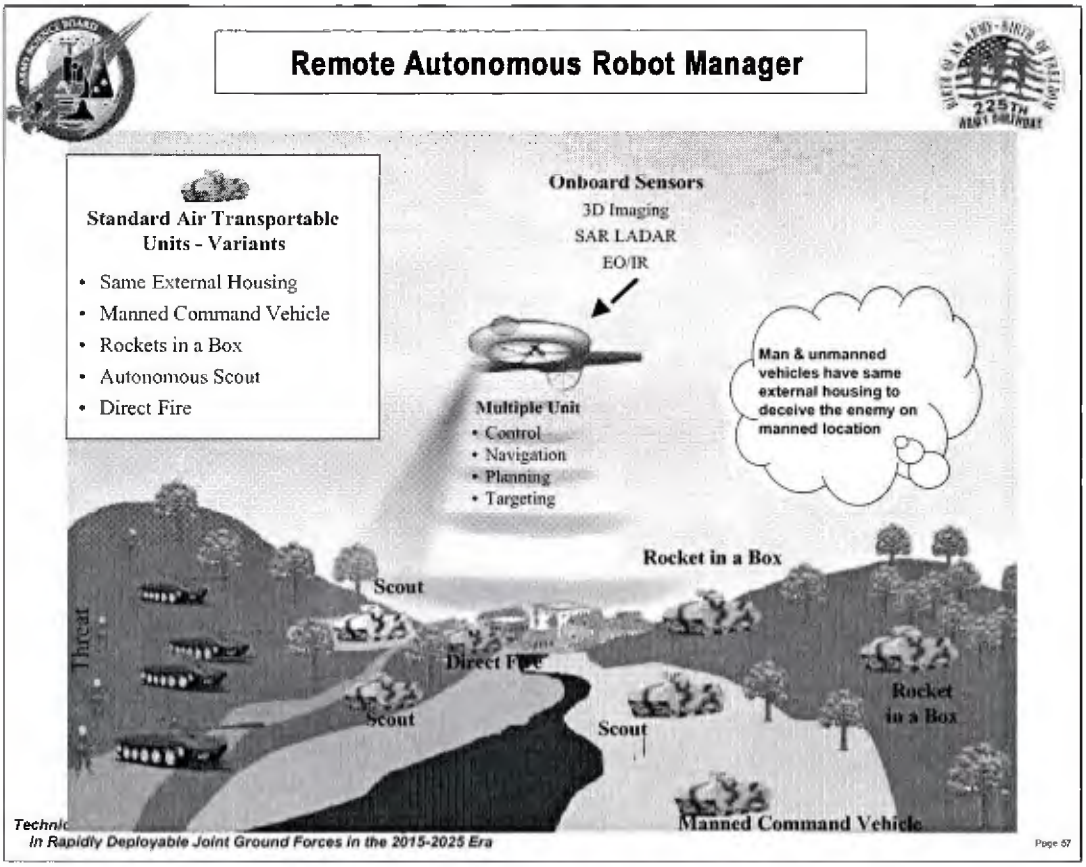
The following pages describe the Army's ground robotics program, assesses the status of UAV activities applicable to FCS, and shows application examples in terms of current and expected Technology Readiness Levels. The appendix contains a detailed discussion of technological challenges that need to be addressed to move the program toward autonomous robotic operation. Aspects of the integration of automated robotic elements into manual operations are discussed.



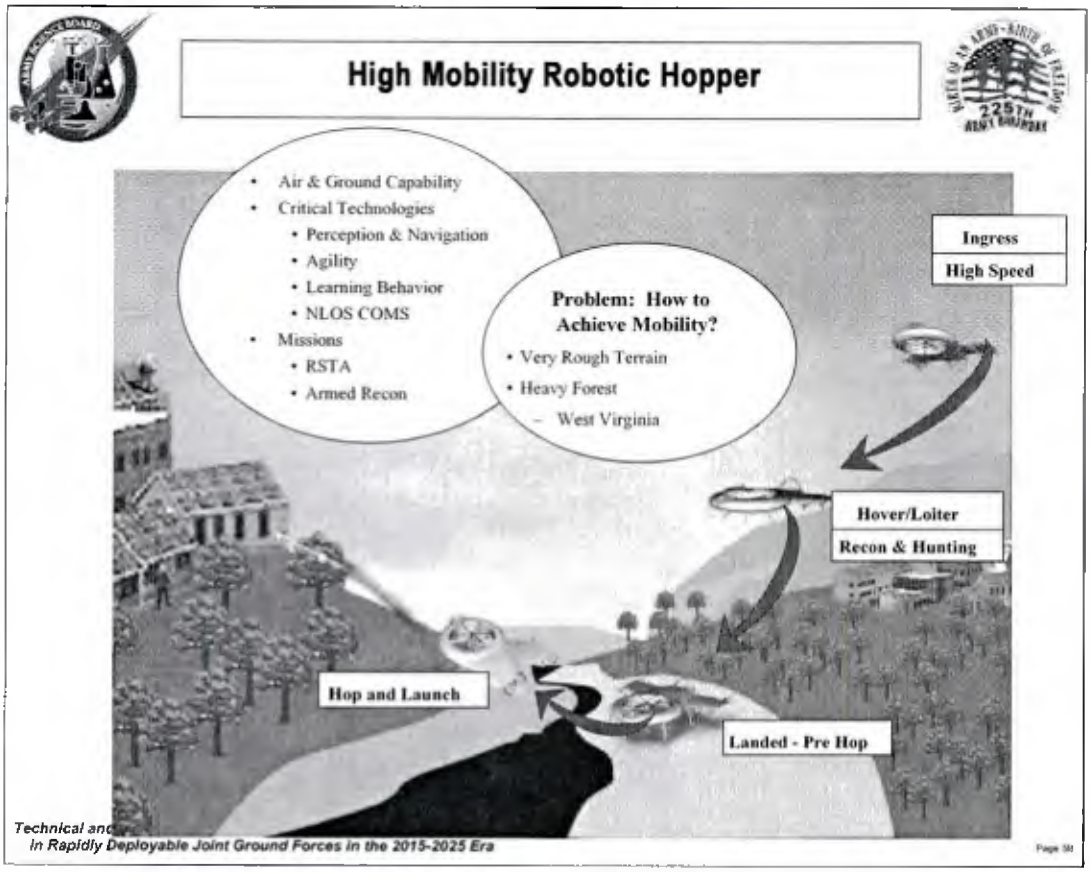
Concept: Remote Autonomous Robot Manager (Eye in the Sky)

This concept:

- relies on a modular ground system
- permits respectable battlefield behavior, allowing better visibility and access to remote computing/mapping.

The role of the aerial unit is supervisory.

This concept permits more robust tactical behavior with the ground robotic units. By knowing the oncoming terrain, and possible opponents, the "supervisor" can plan ahead for the appropriate actions. Overall mobility will be increased.

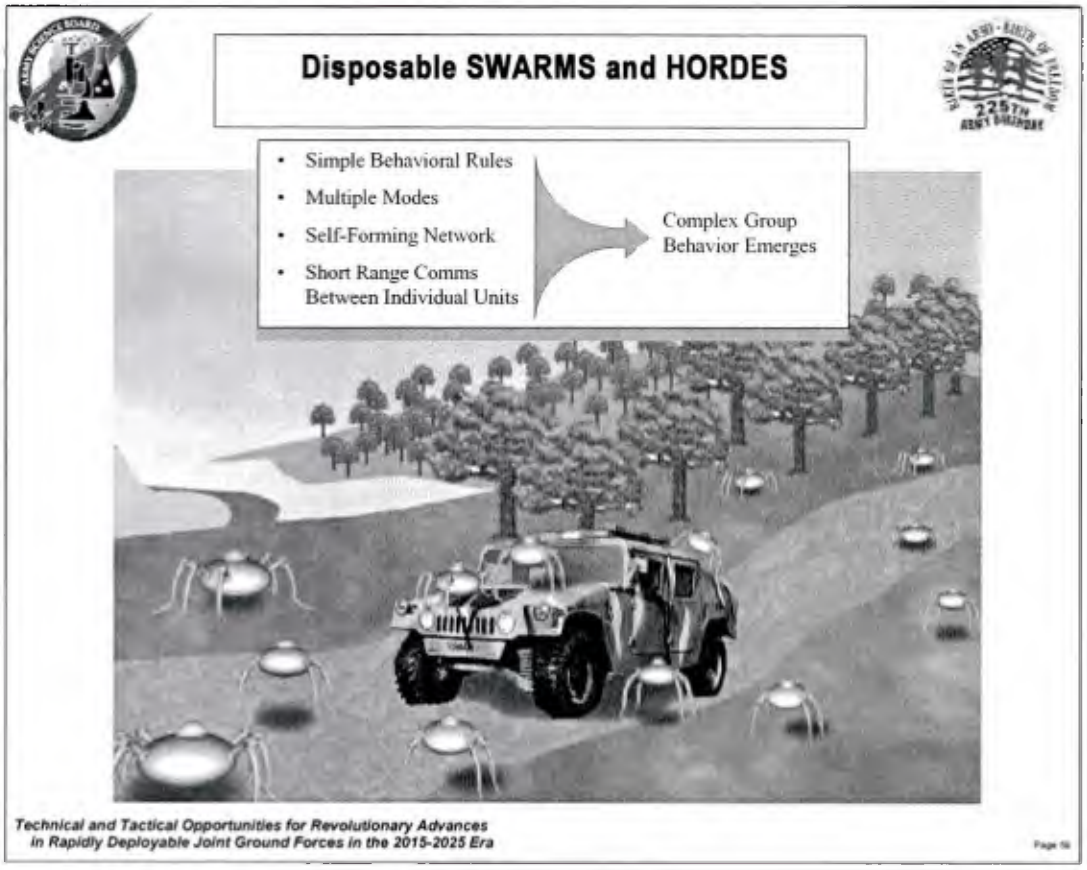


Concept: High Mobility Robotic Hopper

This concept addresses the problem of handling high speed ingress.
The problem is, when confronted with W.Va-type terrain, how to move in quickly.
The assumption is that you already know where you want to go.

The combined air/ground system has the advantages of :
-high speed
-land and lurk
-could be passive until activated

The systems could be built relatively small, depending on the mission.



Concept: Disposable Swarms and Hordes

This concept depends on a large number of throwaway – simple robotic mechanisms.

Perhaps not all of these would be the same.

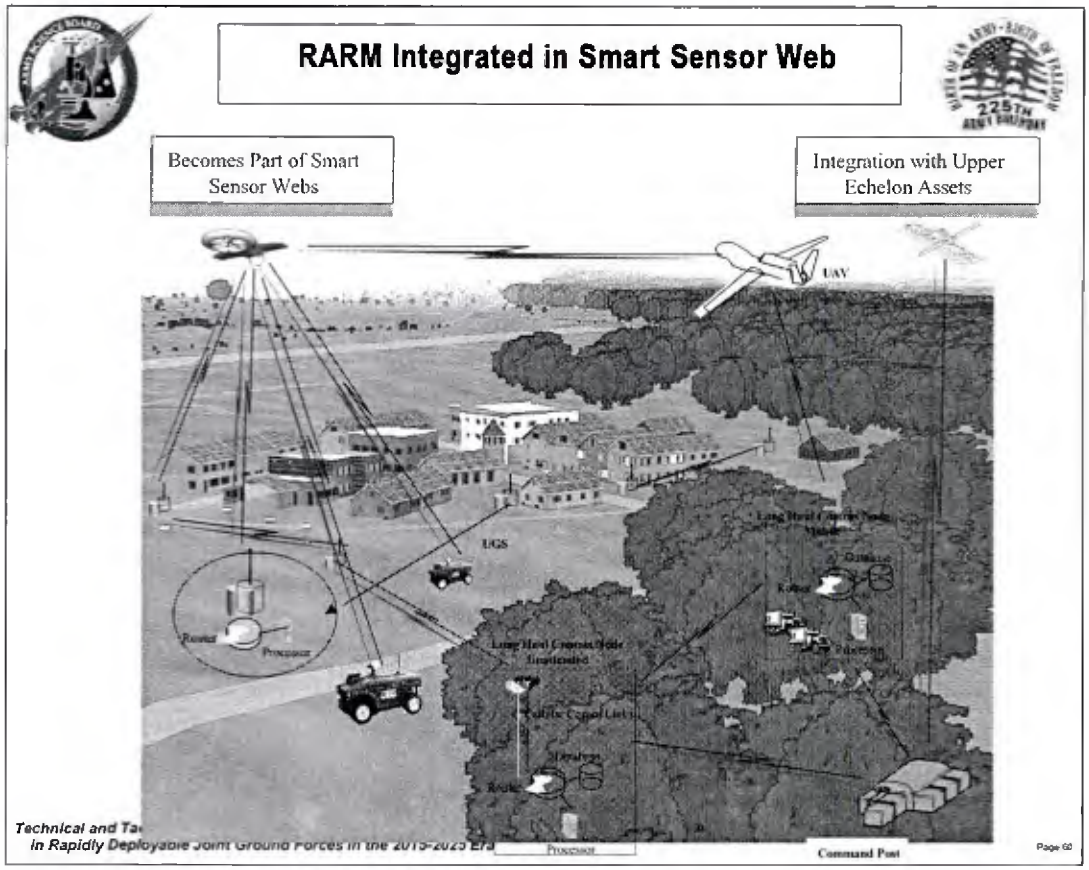
- One could hunt magnetic signatures.
- One could use acoustics.
- One could hunt vehicle exhaust or movement

The comms would not have to be long range. There is recent evidence that networked mechanisms can be formed using relatively simple behavioral rules to produce "hordes" which exhibit potentially useful behavior.

One option for deployment is a air/rocket launch. Creative use of this concept could solve some tough problems.

- Area Denial
- Vigilance; impede the enemy
- IFF

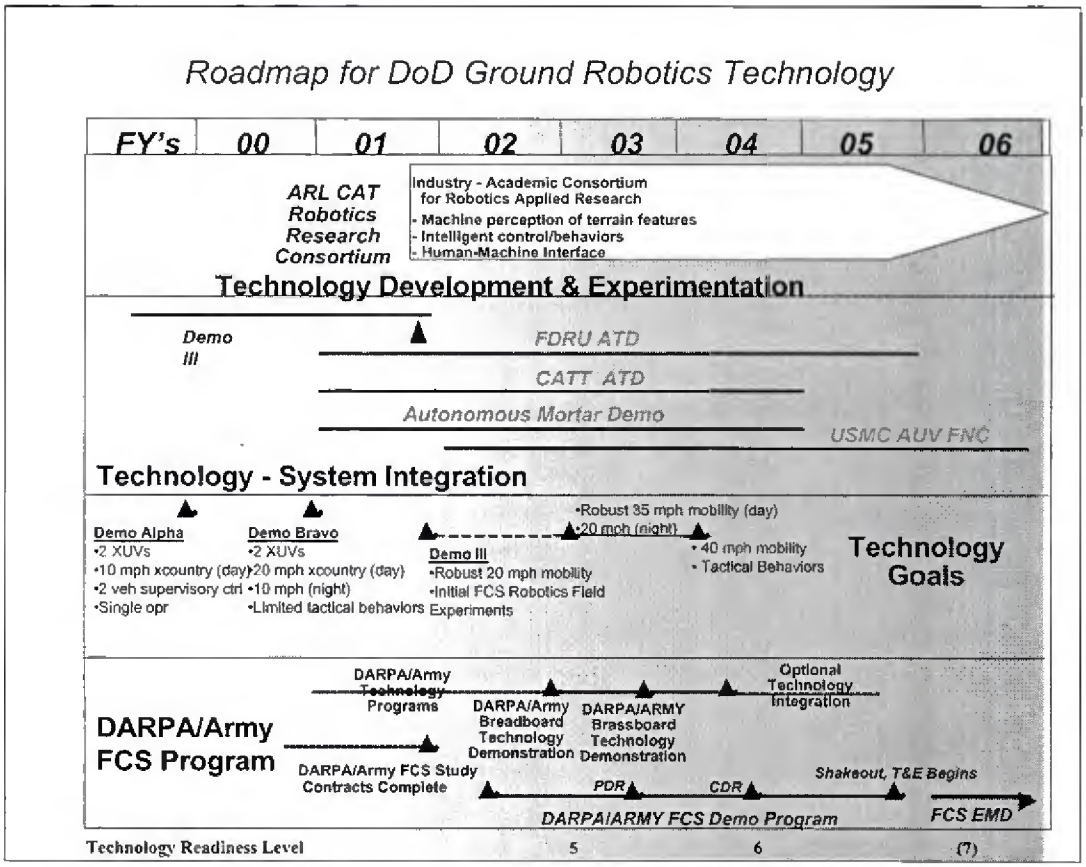
This concept needs a serious look by the user. With MEMS and micro-sensor costs coming down, the cost per unit could be reasonable.



Concept: RARM Integrated with the Smart Sensor Web

This pulls information off the Smart Sensor Web SSW to provide even greater capability for autonomous operation.

The SSW is a recent DUSD(S&T) initiative. The vision for SSW is an intelligent, web centric distribution and fusion of sensor information that provides enhanced situational awareness, on demand, to lower echelons. Emphasis is on multi sensor fusion of large arrays of local sensors, joined with other assets, to provide real-time imagery, weather, targeting information, mission planning, and simulation.

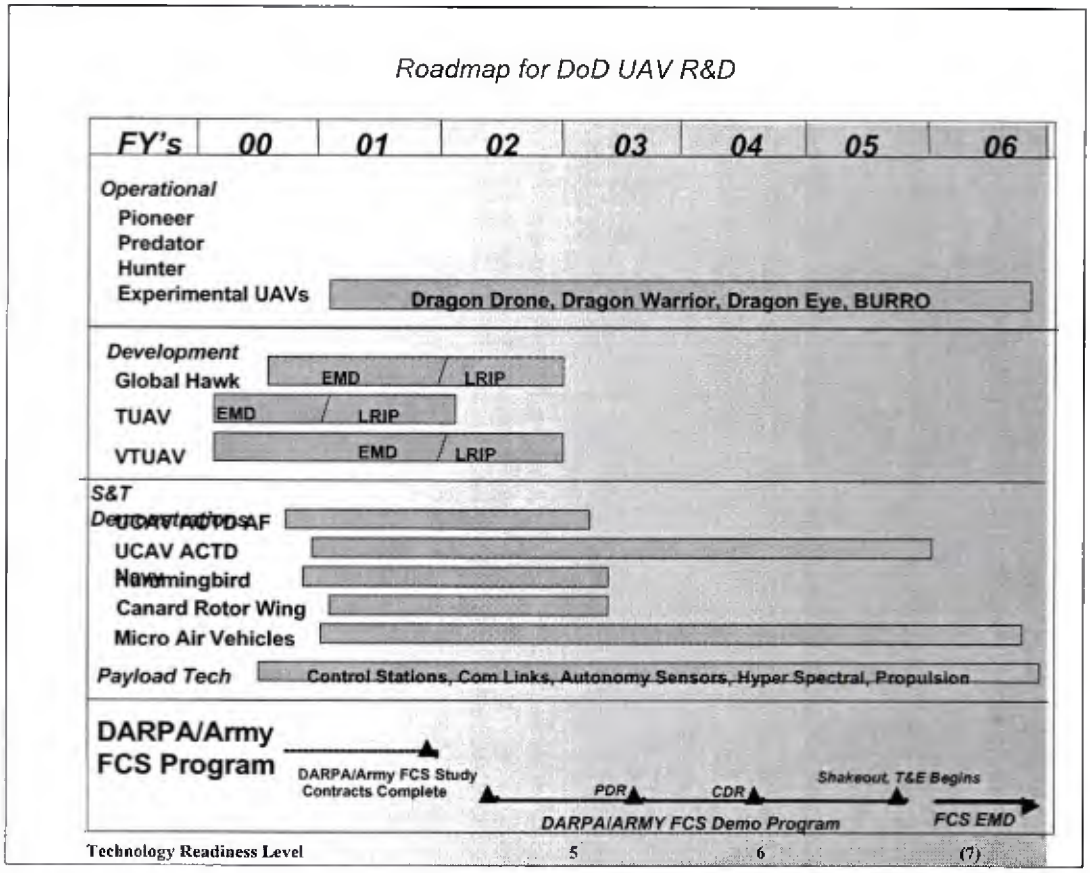


The unmanned ground vehicle S&T program has mostly occurred in the past year. Prior to this time, almost the entirety of the program was encompassed by the OSD Joint Robotics Program (JRP), an EMD program. The JRP also included the Demo 3 program. The other program was the DARPA Tactical Mobile Robotics program. In FY 00 the Army 6.2 and 6.3 program was initiated, as well as the start of the DARPA FCS robotics program.

The Army 6.2 program will primarily consist of the Robotics Research Consortium, to address critical technical challenges in perception, and human machine interface. The Army 6.3 program will consist of the Forward Deployed Robotics Unit (FDRU) ATD,(focused on a 10-20 ton robotic platform, the CATT (a crew reduction demonstrator), and an Autonomous Mortar tech demo.

The USMC is also involved. Under the new Future Naval Capabilities (FNC) process, a FNC for Autonomous Vehicles was established, with funding starting in FY 02. The USMC plans to integrate with the Army and DARPA efforts as much as possible.

Not shown are the extensive robotics research being conducted by the DoE National Laboratories, notably Sandia, addressing some of the critical robotics technology issues. NASA's Jet Propulsion Laboratory also has a significant ground robotics effort. Oak Ridge is doing basic research in cooperative autonomous robotic systems.



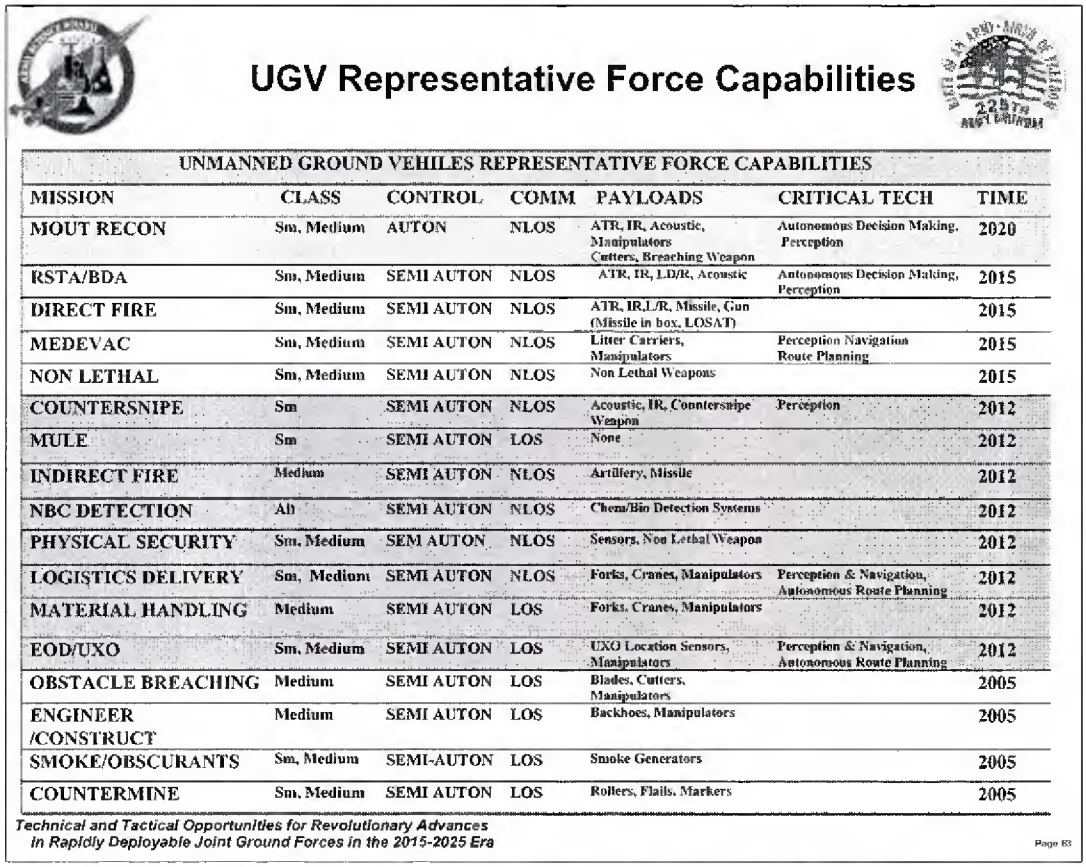
The status of Unmanned Aerial Vehicles (UAV) are more mature than UGVs. Many UAVs are already operational or near operational (Pioneer, Predator, and Hunter).

The USMC Warfighting Lab has recently initiated experiments with UAVs, ranging from mid size RSTA UAVs to large rotor craft logistics vehicles.

The Navy and the Air Force are both conducting ACTDs, with DARPA as a partner. In development are Global Hawk, Tactical UAV, and the Vertical Tactical UAV.

DARPA is conducting programs in Micro Air Vehicles (MAVs), the Hummingbird, and the Canard Rotor Wing.

Army S&T in UAV technologies is very limited at this time. Overall, other than the TUAV (which is wrapping up), the Army is not heavily invested in UAVs S&T.



UGV Representative Force Capabilities

UNMANNED GROUND VEHILES REPRESENTATIVE FORCE CAPABILITIES

MISSION	CLASS	CONTROL	COMM	PAYLOADS	CRITICAL TECH	TIME
MOUT RECON	Sm, Medium	AUTON	NLOS	ATR, IR, Acoustic, Manipulators Cutters, Breaching Weapon	Autonomous Decision Making, Perception	2020
RSTA/BDA	Sm, Medium	SEMI AUTON	NLOS	ATR, IR, LD/R, Acoustic	Autonomous Decision Making, Perception	2015
DIRECT FIRE	Sm, Medium	SEMI AUTON	NLOS	ATR, IR,L/R, Missile, Gun (Missile in box, LOSAT)		2015
MEDEVAC	Sm, Medium	SEMI AUTON	NLOS	Litter Carriers, Manipulators	Perception Navigation Route Planning	2015
NON LETHAL	Sm, Medium	SEMI AUTON	NLOS	Non Lethal Weapons		2015
COUNTERSNIPE	Sm	SEMI AUTON	NLOS	Acoustic, IR, Countersnipe Weapon	Perception	2012
MULE	Sm	SEMI AUTON	LOS	None		2012
INDIRECT FIRE	Medium	SEMI AUTON	NLOS	Artillery, Missile		2012
NBC DETECTION	All	SEMI AUTON	NLOS	Chem/Bio Detection Systems		2012
PHYSICAL SECURITY	Sm, Medium	SEM AUTON	NLOS	Sensors, Non Lethal Weapon		2012
LOGISTICS DELIVERY	Sm, Medium	SEMI AUTON	NLOS	Forks, Cranes, Manipulators	Perception & Navigation, Autonomous Route Planning	2012
MATERIAL HANDLING	Medium	SEMI AUTON	LOS	Forks, Cranes, Manipulators		2012
EOD/UXO	Sm, Medium	SEMI AUTON	LOS	UXO Location Sensors, Manipulators	Perception & Navigation, Autonomous Route Planning	2012
OBSTACLE BREACHING	Medium	SEMI AUTON	LOS	Blades, Cutters, Manipulators		2005
ENGINEER /CONSTRUCT	Medium	SEMI AUTON	LOS	Backhoes, Manipulators		2005
SMOKE/OBSCURANTS	Sm, Medium	SEMI-AUTON	LOS	Smoke Generators		2005
COUNTERMINE	Sm, Medium	SEMI AUTON	LOS	Rollers, Flails, Markers		2005

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The table shows some representative high payoff missions, with size, control, & communications characteristics, and potential payloads. The dates of achieving an effective capability was determined by an analysis of the critical technologies and an assessment of the dates a Technical Readiness Level of 7 could be achieved.

UAV Representative Force Capabilities

UNMANNED AIR VEHILES REPRESENTATIVE FORCE CAPABILITIES						
MISSION	CLASS	CONTROL	COMM	PAYLOADS	CRITICAL TECH	TIME
MOUT RECON	Micro-Min	Autonomous	NLOS	IR, ATR	Autonomous Decision Making	2015
OVER THE HILL RECON	Micro	Semi Auton	NLOS	EO/IR	Communications	2012
BATTLE MANAGEMENT	Med	?	NLOS	EO/IR, SAR/MTI		2012
MINE COUNTERMEASURES	Med	Semi Auton	NLOS	IR, Foliage Penetrator		2012
DIGITAL MAPPING	Med-Heavy	Autonomous	NLOS	?	Autonomous Decision Making Route Planning	2010
ELECTRONIC WARFARE	Min-Med	Autonomous	NLOS	ESM/Jammers	Autonomous Decision Making	2010
COUNTER CAM/CON DECEPT	Min-Med	Autonomous	NLOS	Hyper Spectral Sensors		2010
SIGNALS INTELLIGENCE	Min-Med	Semi Auton	NLOS	SIGINT (COMINT, ELINT)		2005
NBC DETECTION	Micro- Min Med	Semi Auton Teleoperated	NLOS	Chem Bio Sensors		2005
LOGISTICS DELIVERY	Large	Semi Autono		Cargo Module	Perception & Navigation Autonomous Route Planning	2000
OVER THE HILL RECON	Med	Semi Auton Teleopernted	LOS/ Tether	EO/IR		2000
TARGET DESIGNATION	Min-Med	Semi Auton		Laser Tgt Designators		2000
COMMUNICATION/DATA DELAY	Min-Heavy	Semi Auton		Relays		2000

Technical and Tactical Opportunities for Revolutionary Advances in Rapidly Deployable Joint Ground Forces In the 2015-2025 Era

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The above table shows the dates a useful capability for high payoff UAV missions will be attainable. The list of force capabilities was taken from a Joint Staff study.

When Representative UGV Capabilities Will Be Available

2005 Teleoperated	2012 Semi-autonomous	>2015 Autonomous
• Obstacle breaching	• Countersniper	• RSTA/BDA
• Engineer/construct	• Indirect fire	• Direct fire
• Smoke/obscurants	• NBC detection	• MEDEVAC
• Countermine	• Physical security	• Non-lethal
• Follower	• Logistics delivery	•
	• Explosive Ordnance Disposal	
	• MOUT recon	

Unmanned Ground Vehicles
Robotics Technology Status - 1

Technology *"Getting Around"*	Micro < 8 lb	Backpack 8-31lb	Small(D3) 32lb-2ton			Med(FDRU) 2-20 ton		
				TRL '03'	TRL '06'		TRL '03'	TRL '06'
Perception & Navigation								
• terrain characterization	R	R	Y	5	6	G 2010	6 7	
• object recognition/tracking	R	Y	G 2015	6	7	G 2010	6 7	
• obstacle detection/avoidance	Y	Y	G 2015	5 6		G 2010	6 7	
• location awareness (attitude, direction)								
• Open Areas	G 2000	G 2000	G 2000	7	8	G 2000	7	
• Inside Buildings/structures	R	R	G 2015	6	7	G - N/A	8	
Locomotion & Control (WV/Kosovo)	R	R	Y			G	6	7
Power/Energy Sources	R	Y	G 2000	6	7	G 2010		
Internal Autonomous Route Planning	R	G	G 2010			G 2010		

ASSUMPTIONS
- Mission Specific technologies, such as weapon systems not addressed
- The Green, Yellow, and Red ratings refer to overall technical risk of having some practical capability in 2020.

Technical and Tactical Opportunities for Revolutionary Advances In Rapidly Deployable Joint Ground Forces In the 2015-2025 Era

Perception & Navigation: Perception and Navigation covers the ability of an unmanned system to sense and understand its surroundings for the purpose of navigating through that environment.

Terrain Characterization. Terrain characterization places environmental elements (scene components) into broad classes, e.g., soil, green vegetation, rocks, man-made obstacle, that can have an impact upon the mobility or operation of an autonomous system. Barriers include multi-spectral sensors, and the algorithmic infrastructure necessary to perform the analysis in real-time.

Object recognition/tracking Object recognition and tracking includes the ability to recognize or match an object to a template and track the motion of the object within the field of view as a function of time. Challenges include increasing robustness of algorithms, ability to infer the position of the object when it is partially obscured and the ability for the software to make the initial recognition of the target autonomously.

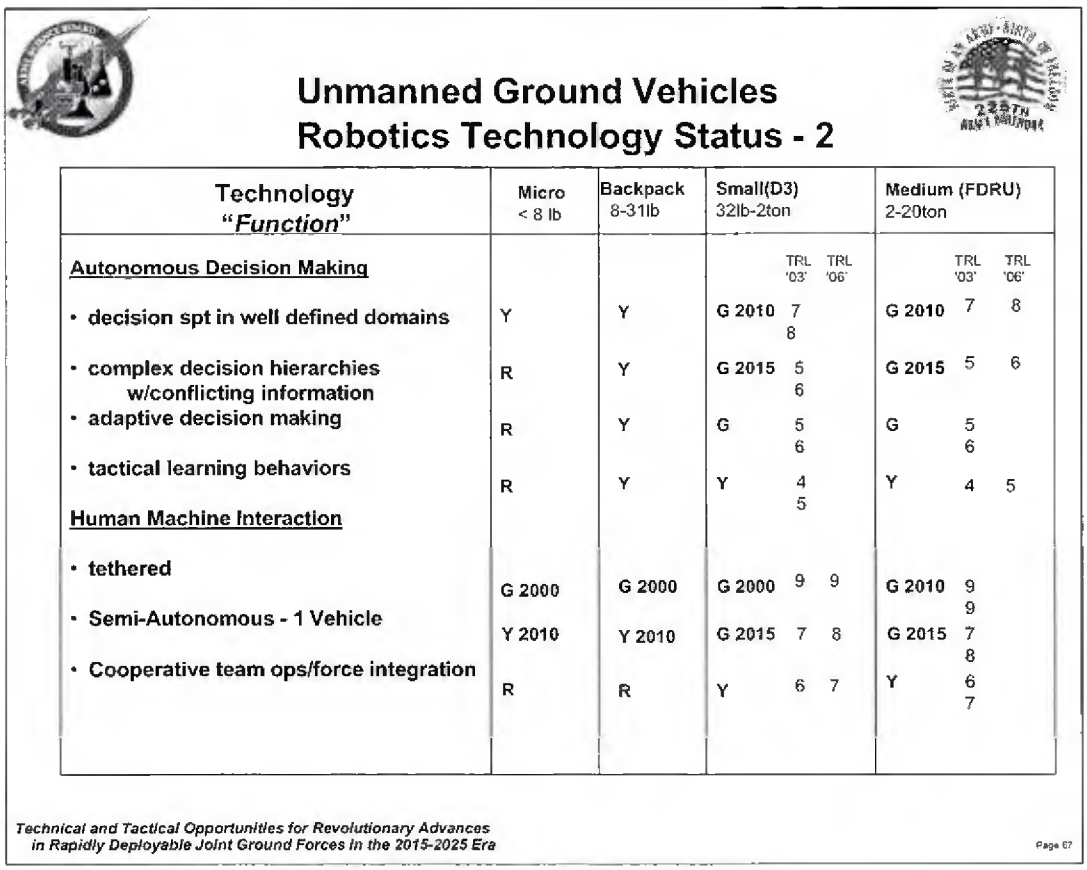
Obstacle detection/avoidance. The detection of obstacles to mobility has been the primary perception technology thrust engaging researchers for past decades. Challenges are: the relative difficulty of detecting negative obstacles; and the treatment of "false alarms."

Location awareness. The ability of a system to understand it's location can be in either an absolute or relative sense. Recent work has concentrated upon placing the robot in an absolute frame of reference, generally utilizing Global Positioning Satellite (GPS) based systems. This may be problematic in urban environments that present obstruction of line-of-sight to the necessary satellite constellations.

Locomotion & Control: In strict terms locomotion is a supporting technology for unmanned vehicle systems. It can be divided into two classes: conventional and unconventional.

Power/Energy Sources The issue of developing efficient power/energy sources permeates all aspects of the military, from vehicle design to the combat load carried by the individual soldier.

Internal autonomous route planning: Internal autonomous route planning refers to the ability of the vehicle system to plan a route (or mission) based upon external constraints and a priori knowledge of the environment without the aid of an operator.



Unmanned Ground Vehicles
Robotics Technology Status - 2

Technology *"Function"*	Micro < 8 lb	Backpack 8-31lb	Small(D3) 32lb-2ton			Medium (FDRU) 2-20ton		
				TRL '03'	TRL '06'		TRL '03'	TRL '06'
Autonomous Decision Making								
• decision spt in well defined domains	Y	Y	G 2010	7 8		G 2010	7	8
• complex decision hierarchies w/conflicting information	R	Y	G 2015	5 6		G 2015	5	6
• adaptive decision making	R	Y	G	5 6		G	5 6	
• tactical learning behaviors	R	Y	Y	4 5		Y	4	5
Human Machine Interaction								
• tethered	G 2000	G 2000	G 2000	9	9	G 2010	9 9	
• Semi-Autonomous - 1 Vehicle	Y 2010	Y 2010	G 2015	7	8	G 2015	7 8	
• Cooperative team ops/force integration	R	R	Y	6	7	Y	6 7	

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Autonomous Decision Making:

Decision support in well defined domains. Decision theory is well developed in areas such as planning, scheduling, and problem solving. The big problems lie in the following four areas: the representation of knowledge about the world as input to decision making algorithms; the ability to simulate what will happen in the future under a variety of possible scenarios; the ability to assign value to entities, events, situations, goals, and priorities; the ability to perform sensory processing, world modeling, and decision making processes in real-time in a changing, real-world environment.

Complex decision hierarchies w/ conflicting information. Hierarchical decomposition of tasks into subtasks enables complex tasks to be broken into strings of simpler tasks.

Adaptive decision making. Adaptive decision making involves changing the parameters of the decision making process based on experience and/or critique by a teacher.

Tactical learning behavior. Ground robotics applied research and advanced development programs have not yet reached the level of maturity to begin to develop tactical learning behaviors.

Human-machine interaction: Human-machine interaction focuses upon the development of control paradigms for one or more unmanned systems. Present programs are focused primarily upon the development of a "semi-autonomous" capabilities that permit an operator to develop a mission plan, perhaps aided by automated tools, initiate autonomous execution by unmanned systems, monitor progress, if desired, be cued to important events by the unmanned systems, and initiate replanning if the situation dictates. The autonomous system can maneuver independently, has limited ability to understand terrain and ability to employ tactical behaviors. Limited computational capabilities restricts the consideration of alternative strategies, behaviors and/or options in real-time, hence there is a reliance upon the human operator as the ultimate backstop

Unmanned Ground Vehicles
Robotics Technology Status - 3

Technology *"Critical Enablers"*	Micro < 8 lb	Backpack 8-31lb	Small(D3) 32lb-2ton	TRL '03	TRL '06	Medium (FDRU) 2-20ton	TRL '03	TRL '06
Task Planning	R	R	Y			G		
Communications (multiple Veh.)								
• Line of Sight (LOS)	G 2005	G 2000	G 2000	9	9	G 2000	9	9
• Non-LOS - Open Terrain	Y	Y	Y	7	8	G 2005	7	9
• NLOS - Complex Terrain	Y	Y	Y	5	7	G 2010	5	7
• NLOS- Inside Bldgs/Subterranean	R	R	Y	3	4	N/A		
Sensor Fusion								
• single platform	G 2015	G 2010	G 2010	6 7		G 2010	7	8
• multi-platform	G	G 2015	G 2015	5	6	G 2010	6	7
Processing Hardware	G 2010	G 2010	G 2005	7	8	G 2005	7	9

Technical and Tactical Opportunities for Revolutionary Advances in Rapidly Deployable Joint Ground Forces in the 2015-2025 Era

Task planning: Task planning encompasses the planning process for the overall mission. In current systems high level planning requires substantial intervention on the part of the operator. suit his purpose. A major challenge in this area will be reduction of the level of operator interaction, through further development of playbook solutions that can be called upon, and more importantly the development of adaptive planning algorithms that can consider dynamically changing situations and infer an appropriate response or modification to the plan .

Communications: The robotics community by and large has not focused upon the development of unique communications systems, Challenges include developing capabilities that will allow large numbers of relatively low-bandwidth transmitters to work together in a coherent, dynamic, mobile network, including the prioritization of information to insure low latency when required, while maintaining low probability of detection and interception. Challenges also include the development of schemes for significantly increasing the range of communication systems to include developing methods for increasing non-line of sight

Sensor fusion While many mobile robots contain multiple sensors, often the sensors are use individually, with each sensor designated for use in one or more mobility modes. Challenges arise in developing schemes for combining data and image registration among multiple sensor systems (located both on single platforms and on two or more platforms) with different fields of view, ranges and resolutions.

Processing hardware:

Mobile robot development programs have greatly benefited from the continuous advances in microelectronics that have given rise to steadily increasing computer speed. Software architecture is a big challenge.

Autonomous Land Navigation (UGV) Technology Maturity

Attributes	Objectives					
	FCS Best Estimated Need	Current	April 2003 Status	Risk	April 2004 Status	Risk
Performance						
Cross-country mobility (day)	40 MPH	10 MPH	30 MPH	M*	40 MPH*	M
Cross-country mobility (night)	25 MPH	5 MPH	20 MPH	M*	25 MPH*	M
Physical						
Mobility module size	10 ft^3	14 ft^3	10 ft^3	L	10 ft^3	L
Mobility module weight	180 lbs	180 lbs	180 lbs	L	180 lbs	L
Environmental						
Temperature Max/Min.	-50°,+125°F	+40°,+105°F	+40°,+105°F	L	+40°,+105°F	L
Programmatic						
Test Environment	Field Test	Limited Field	Field		Field	
Unit Cost (By calculation)		$370K/unit	$370K/unit		$370K/unit	
*Demonstrated/Evaluated on larger platform, e.g., NAC 8X8 Hybrid Electric or new DARPA UGV.						
Overall TRL Level	NA	3-4	5		6	

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This chart illustrates the progression of Technology Maturity Level (TRL) of the key elements during the performance of the program . The risk to equal the mobility of the manned FCS with autonomous land navigation and obstacle avoidance is medium risk for the 2004 time frame. The TRL level of six is achievable by the year 2006.

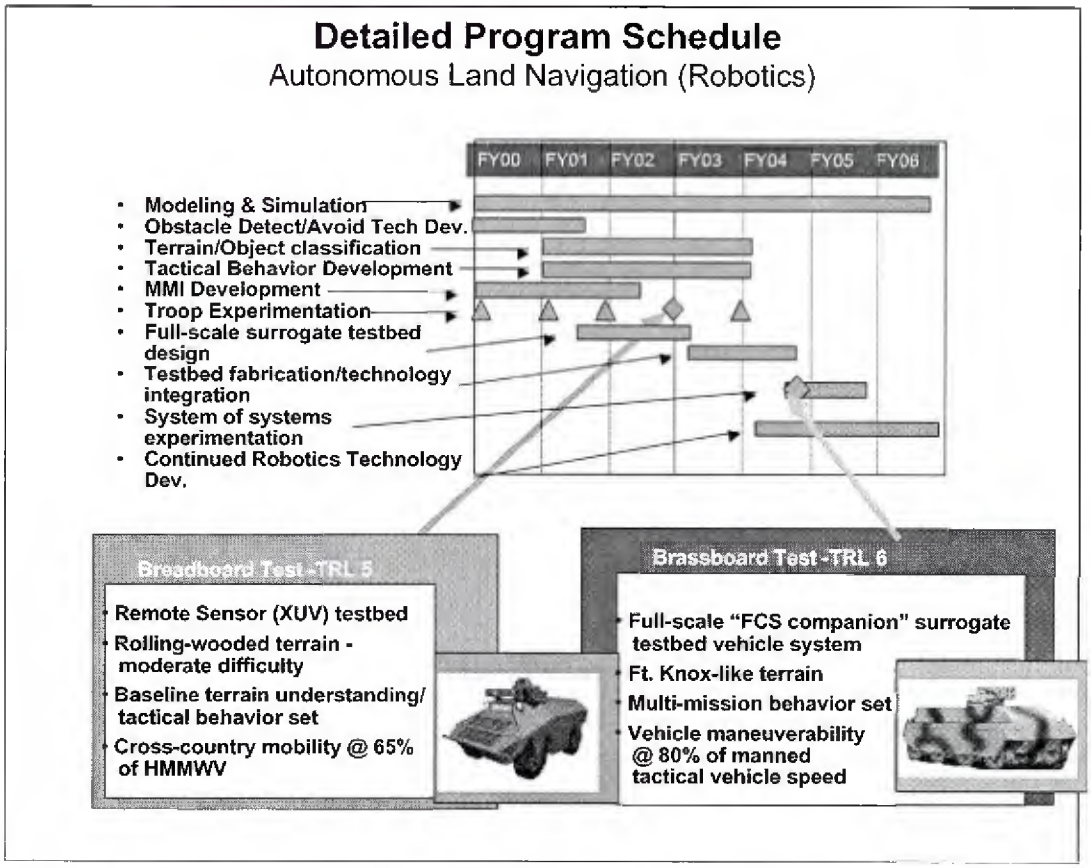
TRL Rationale

Subsystems ◄ ► System

TRL	Description	Perception	Intelligent Control	Man-Machine Interface	Auton Mobility Technology
Current TRL 3-4	Development and testing through simulation & experiments followed by testbed Integration for experiments with troops	Obstacle detection/ classification with multiple sensor modes: stereo, ladar, & radar. testbed integration with troop experiments at Ft. Knox – 10/00	4D/RCS Architecture – Initial implementation on testbed vehicles for troop experiments APG - 9/99	Touch-screen based system developed & integrated for troop testing In virtual & live experiments 8/99 – 9/99	Development of component technology & integration onto testbeds for troop experiments – 10/00
FY02 TRL 5	Extensive experiments including a user appraisal with XUV testbeds	G4 & Pyramid processors provide improved computer capability Development of improved AM sensors	Tactical behavior development – full 4D/RCS implementation	Control of 4 XUV's by single operator Exchange of control by operators	Maturation of component technologies, integration on 4 XUV's, with extensive testing & user appraisal
FY04 TRL 6	Development of testbeds for in-scale tests of system concept	Multi-sensor fusion to provide terrain understanding & enable tactical behaviors in complex terrain	Management/ control of multiple heterogeneous robots by a single soldier	Embedding of MMI into FCS scale system	Integration on & rigorous experiments - FCS scale & heterogeneous systems,

The rationale for achieving the system TRL level depends on the progression and successful integration of the component sub-systems. This vu-graph depicts the projected status of the subsystems, aggregated to achieve the overall TRL.

Continuing software development and validation is inherent for the entire program and will continue through all timelines.



The accompanying diagram depicts the current Army's robotics program elements and schedule. It should be noted that the M$S timeline accompanies the hardware capability development elements throughout the program. Man in the loop simulation is recommended to develop and understand the appropriate soldier-machine interfaces in various operational concepts leading to the ultimate simulation of of a mixed manned & robotic platform scenario. Results of the concurrent simulation activity should guide hardware and software development, and should be used as the basis for tailoring the equipment for selected missions.

Mobility enhancement is of utmost importance; therefore Obstacle Detection/Avoidance & Terrain/Object Classification lead the program schedule.

Tactical Behavior & MMI Development are verified with periodic Troop Experimentation to validate both the hardware and its operability with soldiers in an interactive manned and robotic environment. A breadboard Full Scale Surrogate Testbed will be designed and its component technologies integrated into a total system. After shakedown and evaluation, the design & construction of a brassboard will follow. With tests designed to lead to embedding the system in a System of Systems operational environment. At his point, the goal is semi-autonomous operation with maneuverability and speed approaching manned vehicle performance on the given terrain. The success of this evaluation will verify that the technology readiness level is TRL=7 and the system is ready for engineering development (EMD).

A sustained S&T activity is proposed beyond this phase to continue to add capability and achieve additional autonomy by the year 2020.

Notional Vertical UAV Spectrum
for
Support of Early Entry Forces
(Vehicle Performance)

Characterization				Flyaway Cost		Nom. STO Gross S.L., 103°F (kg)	Nom. VTOL OGE Gross 4 kft, 95°F (kg)	Cargo Space	Nominal Payload (kg)	STO Range S.L., 103°F (nm)	STO Endur. S.L., 103°F (hr)	VTOL Return Radius 4 kft, 95°F (nm)	Max/ Cruise Speed (kts/kts)	Nominal Installed Power	
Surrogate	Vehicle Class	Assumed Config.	Mission Purpose	Base Vehicle ($)	Mission Equipped ($)									Maximum Continuous Propulsion (skW)	Payload & Aux. (kWe)
Vertical C130	Heavy Lifter	Tilt Rotor	Theater Cargo	50M	70M	50,000	40,000	9'x9' x40'	20,000* 20,000**	o 4,500*	o 25	o 1,000* 540**	+ 300/200	o 18,000 S.L. Std turboshaft	200
H-60/ Commanche Follow-on	Intermed. Lifter	Tilt Rotor	Utility Cargo/ Surveil/Attack/ Relay	7.5M	10M	9,000	7,500		2,500* 2,500**	o 3,000*	o 25	o 1,000* 540**	+ 300/200	o 1,500 S.L. Std turboshaft	20
Hummingbird A-160	Light Lifter	Compound Helo	Small Unit Util./Surveil/ Attack/Relay	1M	3M	2,400	2,000		200* 400**	o 3,000*	o 40+	o 1,000* 500**	+ 150/120	o 300 turbo diesel flat to 3 km	10
Vertical Shadow/ Outrider	Heavy Sentinel	Compound Helo	Attached All-Weather Surveillance	300K	1M	300	250	NA	25*	o 2,000*	o 30+	o 500*	+ 120/90	o 40 turbo diesel flat to 3 km	5
Bring Along Equipment	Smart Eagle	Helo	Small Unit Attached Fair-Weather Recce	50K	75K	12	10	NA	1*	o 100*	o 3	o 50*	+ 70/50	o 1.5 H2/Chem	0.15
Vertical Pointer	Smart Pigeon	Helo	Backpack Hand-Launched Recce	2K	5K	1.2	1	NA	0.1*	o 30*	o 1	o 15*	+ 50/30	o 0.15 battery electric	0.015
Insect	Locust	Articulated Wing or Helo	Special Local Purpose	0.1K	0.1K	NA	0.05	NA	0.005	o 0.3*	o 0.1	o 0.1	+ S/S	o 0.01 bio or battery electric	0.001

* Nominal internal payload
** Nominal external payload

	currently off-the-shelf
o	development needed
	very difficult, if at all
NA	not applicable

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The following three slides flesh out the details of notional spectrum of vehicles to reveal just how extreme the performance of these vehicles and their mission equipment can be by 2010-20 and all of the illustrated vertical air robots above the man-portable size may be self-ferried to theater and endure forward for more than a day in the air (much longer in ground loiter) while being based and supported in remote sanctuaries. The same set carry all-weather sensors, SATCOM, local communication relay and psuedolite GPS to support ground forces, and possibly light direct fire weapons. The example listed as Heavy Sentinel (Vertical Shadow/Outrider) (55 lb payload) is considered the smallest that might perform all of these tasks if mission equipment weight reduction advances as expected.

Notional Vertical UAV Spectrum
for
Support of Early Entry Forces
(Mission Equipment Characteristics)

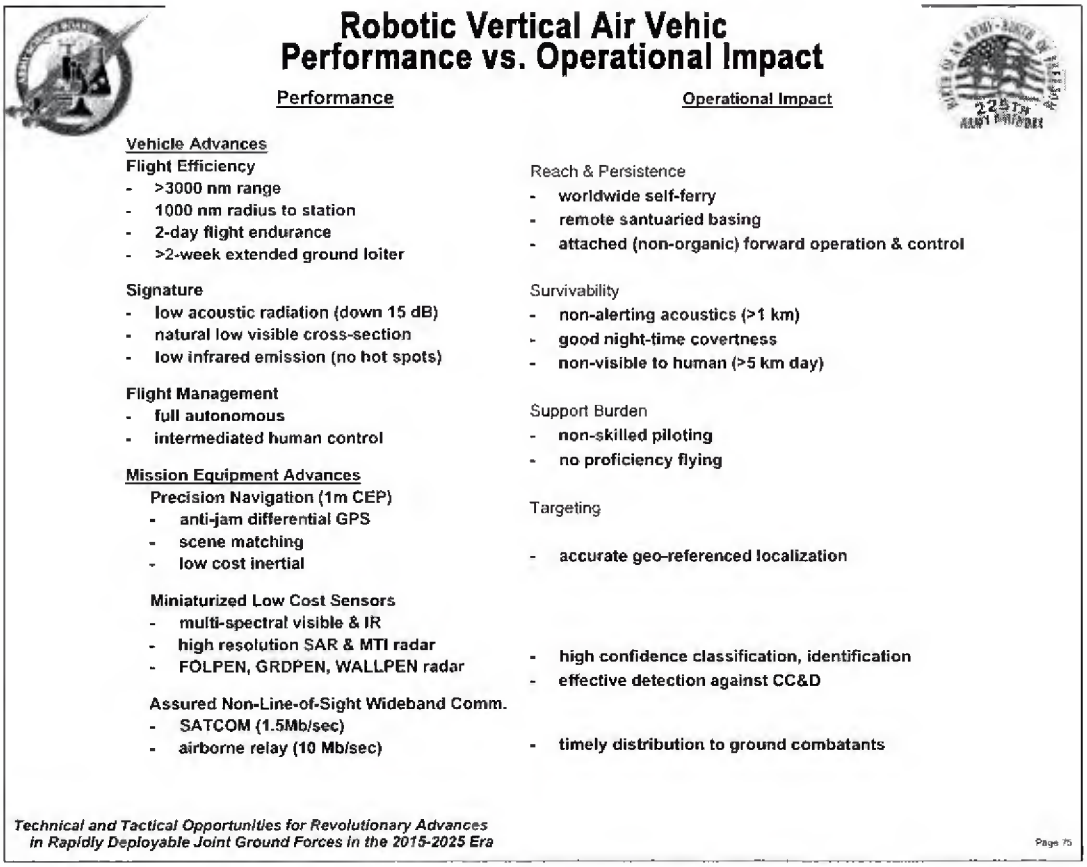
Characterization				Sensors						Readout (Return Link) Communications			Control				
				RF				Optical									
Surrogate	Vehicle Class	Assumed Configuration	Mission Purpose	MTI/ SAR	FOL-PEN	GRD-PEN	Wall PEN	Uncooled Vis/IR	Multi-Spec	SATCOM	Line-of-sight	Thru-Wall and Foliage	Precision NAV	Precision Hover in Turbulence	Vibration at Payload	Autonomous Flight Mgmt.	Accident Rate
Vertical C130	Heavy Lifter	Tilt Rotor	Theater Cargo	+	+	NA	NA	5"	NA	10 Mb/sec	100 Mb/sec 100 kb/sec covert	NA	+ Anti-jam	+	+	o	o 1/100 khr
H-60/ Commanche Follow-on	Intermed. Lifter	Tilt Rotor	Utility Cargo/ Surveil/Attack/ Relay	+	+	o	o	5"	+	10 Mb/sec	100 Mb/sec 100 kb/sec covert	NA	+ Anti-jam	o	+	o	o 1/100 khr
Hummingbird A-160	Light Lifter	Compound Helo	Small Unit Util./Surveil/ Attack/Relay	+	+	o	o	4"	o	1.5 Mb/sec	100 Mb/sec 100 kb/sec covert	NA	+ Anti-jam	o	o	o	o 1/30 khr
Vertical Shadow/ Outrider	Heavy Sentinel	Compound Helo	Attached All-Weather Surveillance	o	o	NA	NA	2"	o	10 kb/sec	10 Mb/sec	100 kb/sec	+	o	o	o	o 1/10 khr
Bring Along Equipment	Smart Eagle	Helo	Small Unit Attached Fair-Weather Recce	NA	NA	NA	NA	1"	o	1 kb/sec	1.5 Mb/sec	10 kb/sec	o		o	o	o 1/1 khr
Vertical Pointer	Smart Pigeon	Helo	Backpack Hand-Launched Recce	NA	NA	NA	NA	.25"	NA	NA	100 kb/sec	1 kb/sec	o		o	o	o 1/100 hr
Insect	Locust	Articulated Wing or Helo	Special Local Purpose	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	o	NA

+	currently off-the-shelf
o	development needed
	very difficult, if at all
NA	not applicable

Notional Vertical UAV Spectrum
for
Support of Early Entry Forces
(Mission Equipment Characteristics - Continued)

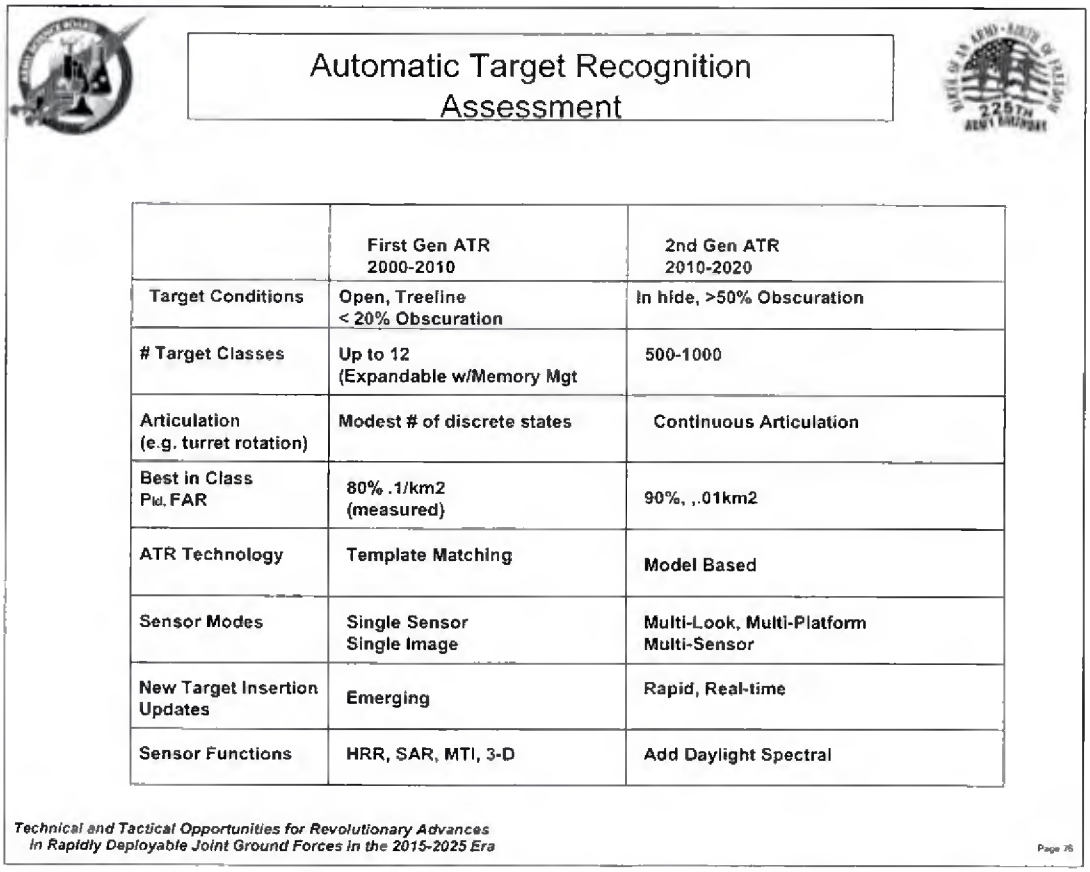
Characterization				Signature				Countermeasures				Armor	Weapons			Materials Handling	
								RF		Optical							
Surrogate	Vehicle Class	Assumed Config-uration	Mission Purpose	Acous-tic	Vis/ IR	RF Short λ	RF Long λ	On-board	Towed	On-board	Releas-able		AAM	AGM/ Guns	DEW	Onload	Offload
ertical C130	Heavy Lifter	Tilt Rotor	Theater Cargo	-	-	o	-	+	+	+	+	Cockpit, Floor, Ramps, Gearboxes, Props, fuel, 50 cal. Hit	+	+	+	drive-on slide-on & sling	drive-off slide-off & sling releas
-60/ ommanche ollow-on	Intermed. Lifter	Tilt Rotor	Utility Cargo/ Surveil/Attack/ Relay	o	-	o	-	Threat Warn only	+	+	+	Cockpit, Floor, Gear-boxes, Props, fuel, 50 cal. hit	NA	+	o	interior slide-on & sling	slide-out & sling releas
lummingbird -160	Light Lifter	Compound Helo	Small Unit Util./Surveil/ Attack/Relay	+	o	o	-	Threat Warn only	o	o	o	FMS, engine, prop, fuel, 30 cal. hit	NA	o	o	grappling arm & sling	grapple placement
ertical hadow/ utrider	Heavy Sentinel	Compound Helo	Attached All-Weather Surveillance	+	o	o	-	NA	NA	NA	NA	FMS, engine, prop, fuel, 30 cal. hit	NA	NA	NA	small package grappling arm	external release fro grapple
ring Along quipment	Smart Eagle	Helo	Small Unit Attached Fair-Weather Recce	+	+	o	+	NA	NA	NA	NA	NA	NA	NA	NA	external hook	external deposit an perch
ertical oinier	Smart Pigeon	Helo	Backpack Hand-Launched Recce	+	+	+	+	NA	NA	NA	NA	NA	NA	NA	NA	NA	external deposit an perch
nsect	Locust	Articulated Wing or Helo	Special Local Purpose	+	+	+	+	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

+	currently off-the-shelf
o	development needed
-	very difficult, if at all
NA	not applicable



The above figure shows just how profound the specific operational impact of these new extreme performance vertical air robots can be. The >5-fold improvement in flight endurance over existing light helicopters enables true robust, attached, but non-organic, overhead support to the notional FCS medium weight ground force. Low signature (particularly acoustic) is essential for non-alerting reconnaissance and counter-CC&D. True autonomous flight control with intermediated human override can eliminate the need for piloting skill and proficiency flying.

Fortunately, mission equipment evolutions are proceeding in parallel, possibly even leading the vehicle advances. So, accurate (1m), unjamable navigation and targeting will be available. Relatively, lightweight SAR & MTI radar is here. Foliage, ground, and wall penetrating radar is lagging, but essential to the necessary substantial improvement against the vexing CC&D. Good wideband SATCOM and line-of-sight relay communication for the ground elements are big additions for dispersed, urban, or rough terrain operations.



Automatic Target Recognition (ATR) has benefited from the phenomenal advances in computer technology. This growth is expected to continue and possibly accelerate. Sensor technology is also exploding; computers deal with larger & larger image files. Sensors are also becoming more affordable, allowing a proliferation of tactical sensors, and making it desirable to handle larger volumes of data from more sources.

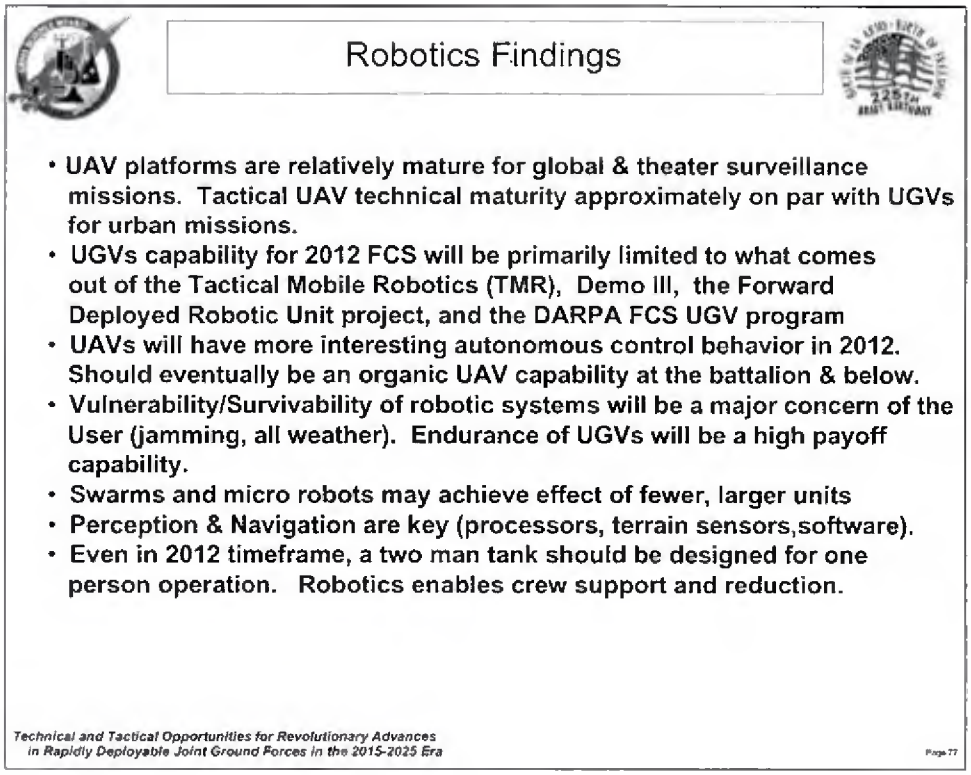
ATR developers have declared victory on targets in the open. Systems such as ISTARS, Commanche, JSF, and IMINT. This should be the first generation of modern imaging ATR. This first generation has limitations which stem from engineering tradeoffs and not from fundamental barriers. Indeed, the ATR community has identified the barriers and approaches to deal with them.

The Table summarizes the current SOA and the expected progress over the next two decades. The Table blurs a large no. of technology parameters in order to give a snapshot of what to expect. The keys to achieving 2nd Generation are:

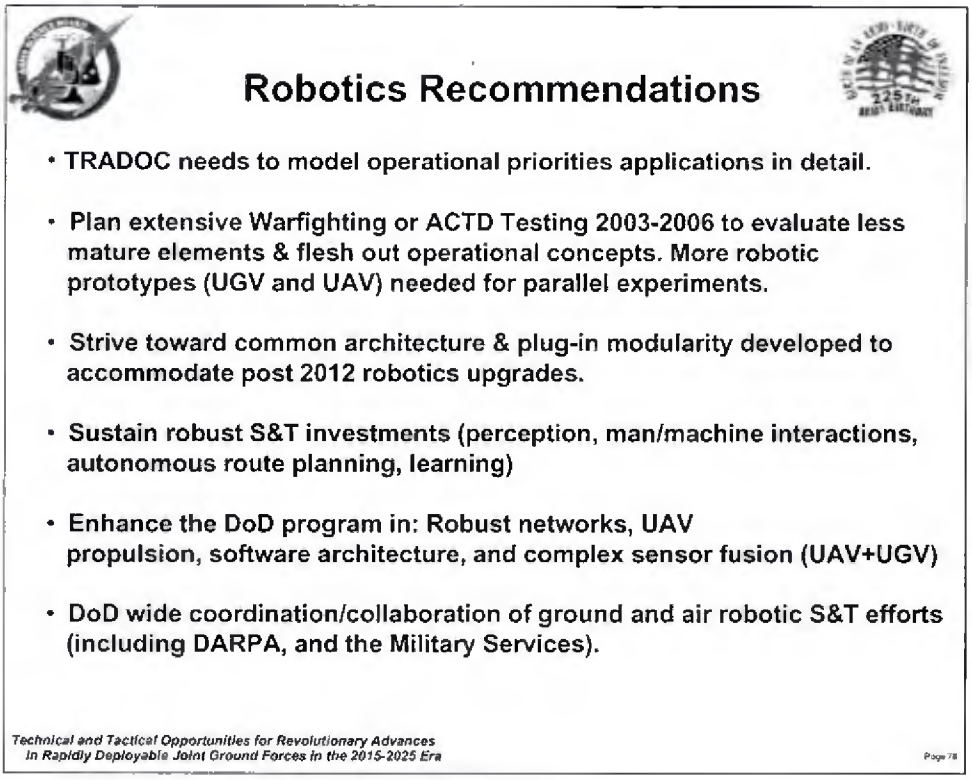
a. Model based vision

b. Computer memory

c. New & combined sensor domains



- UAVs are very mature for global & theater surveillance missions. Tactical UAV technical maturity are approximately on par with UGVs for urban missions. Issues are:
  - line of sight
  - civilian, ground force interactions
  - intelligence? (how smart must they be)
  - route planning
- UGVs capability for FCS will be primarily limited to what comes out of the Tactical Mobile Robotics (TMR), ARL Demo III, and the related Forward Deployed Robotic Unit projects. The scope of the DARPA programs are still unknown, but focus will still be the DEMO III and FDRU demonstrators. 2005/06 is the effective cutoff point for technology insertion into the FCS system.
- UAVs will have more interesting autonomous behavior. The technology is more mature, and there are more fielded systems. There should be an organic UAV capability at the battalion & below. At company and platoon level, these initially could be Micro or Minature class, with fiberoptic tethers.
- The fragility, (and endurance) of these systems, as compared to manned systems, will be a major concern and be a major test issue.
- Recent experiments indicate that small robotic units using swarming behavior could have significant operational utility (i.e. area denial)
- Robotics is a critical enabler for crew reduction.



Recommendations

- TRADOC needs to model operational priorities applications in detail.
  - -- TRADOC ICT study is a good start
- Plan extensive Warfighting or ACTD Testing 2003-2006 to evaluate less mature elements & flush out operational concepts. Plan for sufficient robotic prototypes (UGV and UAV) for parallel experiments. Some potential concepts:
  - o Area Denial
  - o Robotic Resupply of Forward Units
  - o Reconnaissance
  - o Robotic Direct & Indirect Fire
- Strive toward common architecture & plug-in modularity developed to accommodate post 2012 robotics upgrades.
- Sustained S&T programs (perception, man/machine interactions, autonomous route planning, learning).
- Enhance the DoD program in: Robust networks, UAV propulsion, software architecture, and complex sensor fusion (UGV+UGV).
- DoD wide coordination of ground robotic S&T efforts (including DARPA, Army, and the USMC).
  - o USMC initiating sizeable ground robotics effort in FY 02

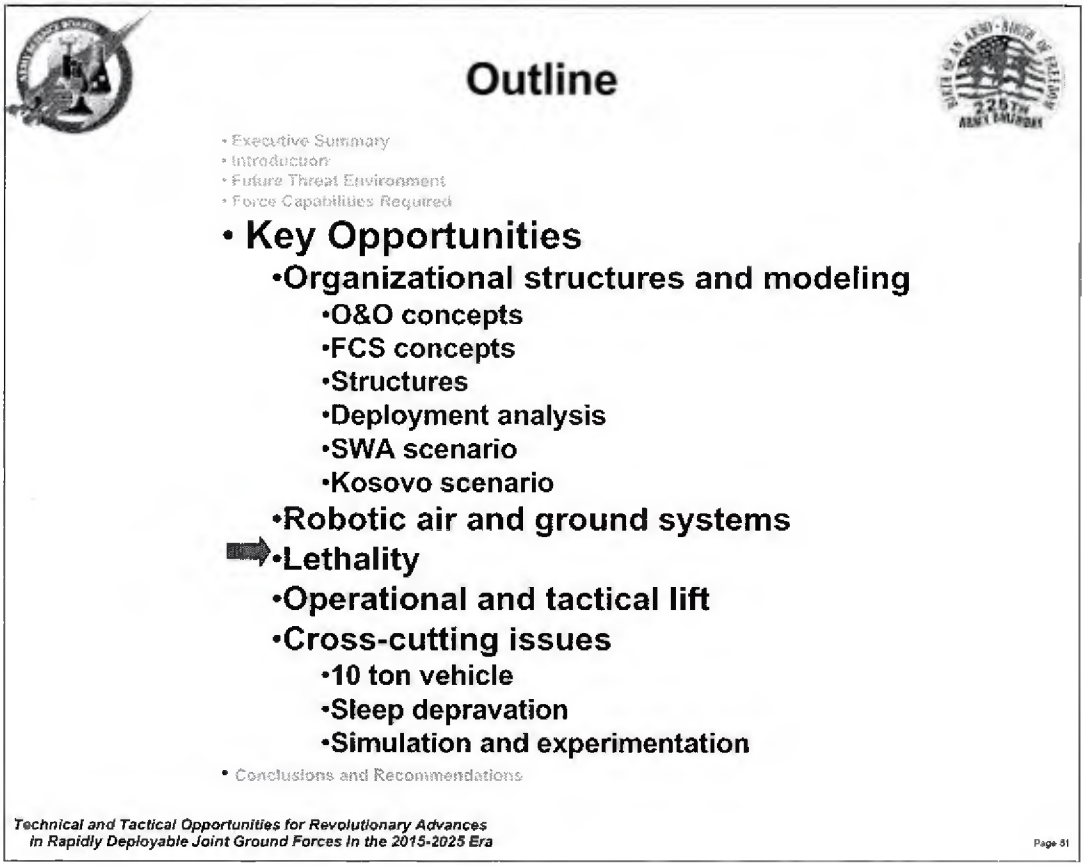
DoD UGV Robotics Funding

UGV Programs	Focus	Funding Adequate	Funding Delta
ARL Robotics Research Consortium	Machine Perception Intelligent Control		$ 5M/Yr *
Forward Deployed Robotic Unit ATD	Integration Fire Control		~ $6M Add 4 units
DEMO III	Mobility		~ $9M Add 6 units
Crew integration & Automation Testbed	Driving Aids 2-man crew Adv Networks	✓	
USMC AUV	In Formulation	✓	
DARPA Robotics	Mobility Networks	Pending	
Autonomous Mortar	Weapon Integration	Pending	

* Depends on final DARPA investments

Technology Readiness Levels

		Description
TRL 1	Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
TRL 2	Technology concept and/or application invented.	Invention begins. Once basic principles are observed, practical applications can be formulated. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.
TRL 3	Active research and development is initiated.	This includes analytical studies and/or characteristic proof of concept. Analytical and experimental critical function laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
TRL 4	Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.
TRL 5	Component and/or breadboard validation in basic technological relevant environment.	Fidelity of breadboard technology increases significantly. The components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
TRL 6	System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.
TRL 7	System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle or space. Examples include testing the prototype in a test bed aircraft.
TRL 8	Actual system completed and "flight qualified" through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
TRL 9	Actual system "flight proven" through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using the system under operational mission conditions.



This section discusses lethality issues.

Lethality

- **Objective:**
  - **Evaluate the Potential for overmatching lethality for ground platforms in the 2015 to 2025 Era**
- **Focus of Evaluation**
  - **Weapons Systems for FCS and other mobile ground platforms employed as part of the objective force**
- **Technologies of Interest**
  - **Conventional Cannon and Associated Projectiles**
  - **Electromagnetic and Electrothermal Chemical Launch Systems**
  - **Missile Systems**
  - **Directed Energy Weapons**
  - **Non Lethal Weapons**

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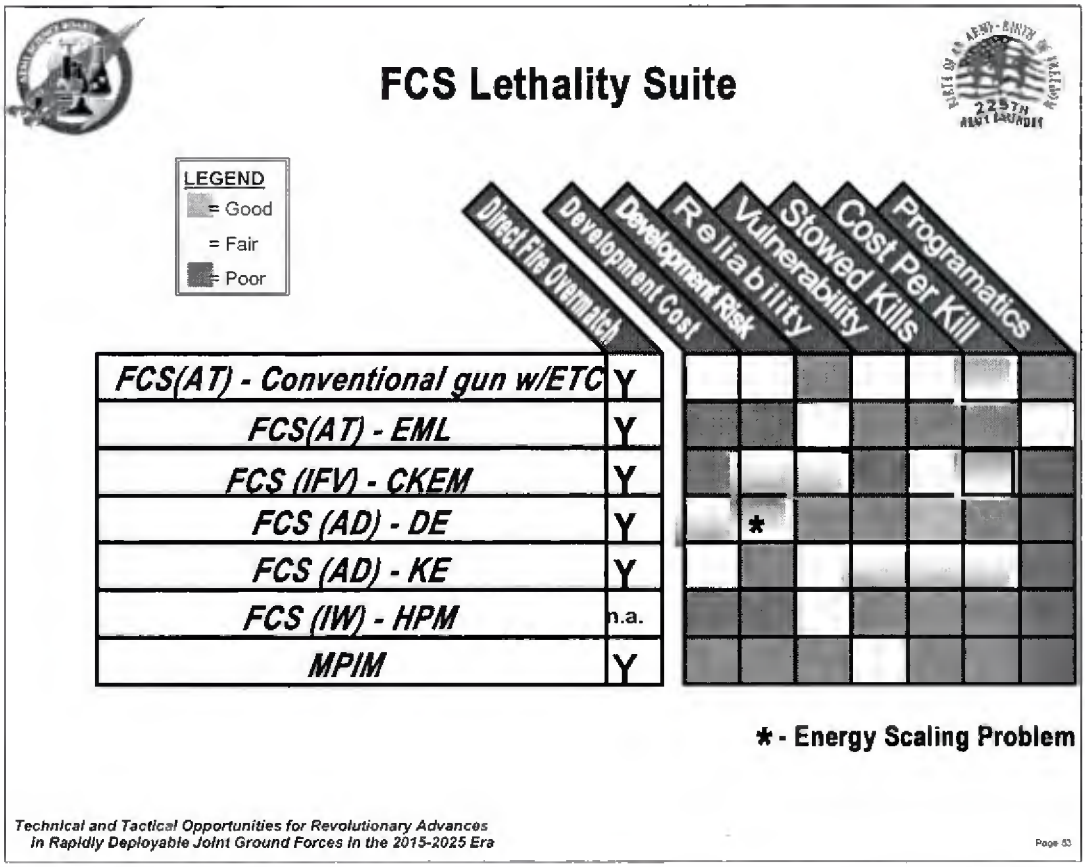
It is a virtual certainty that future conflicts in the 2025-era will find U.S. forces opposing traditional massed heavy armor. There will be occasions where the 20-ton FCS being considered in this study will encounter such enemy forces and direct fire engagements will be unavoidable. Under such circumstances, Overmatching Direct Fire Lethality (ODFL) will be essential to FCS survivability. For a vehicle as light as 20 tons, however, ODFL as protection reflects a last-ditch defensive measure of desperation to be called upon only after the vehicle has gotten itself into a situation that should have been avoided in the first place. If the FCS is used in a manner that optimizes its capabilities and minimizes its operational weaknesses, the overall contribution of its ODFL capabilities to survivability will be relatively small.

Overmatching Indirect Fire Lethality (OIFL), on the other hand, may well represent an even more important consideration with respect to FCV survivability. The superior capabilities of U.S. indirect-fire precision munitions can be exploited on a variety of platforms. They must be considered for the FCS. It seems noteworthy that the ability of U.S. tank forces to out-range opposing forces during Desert Storm is considered to be a more important factor contributing to operations success than the higher level of survivability provided by its superior armor. By 2025, increased engagement ranges for direct fire weapons will make OIFL capabilities even more decisive.



In exploring various options for achieving overmatching lethality for a 20-ton FCS, seven different evaluation parameters were considered for five different classes of weapons:

Conventional guns incorporating ETC technology: Hard Kill

Electromagnetic Launch Kinetic Energy Kill (KE): Hard Kill

KE missiles: Hard Kill

Agile Target Effect weapons: Soft Kill

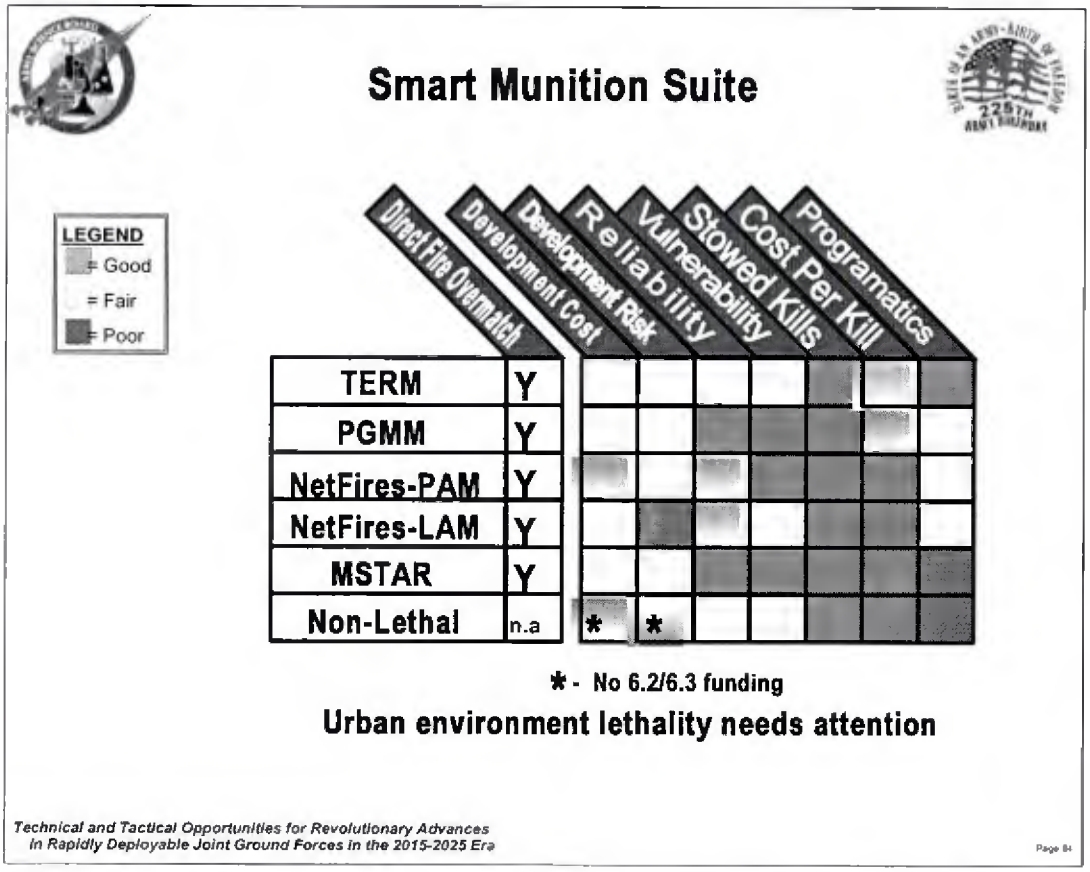
Directed Energy (DE) weapons: Soft Kill

The first three classes of the weapons considered offer significant potential for providing over-matching lethality for both direct and indirect fires. Risks associated with the needed development work for each of these weapon types were also assessed. Risks associated with advances involving conventional guns w/ETC were considered to be moderate. Electromagnetic launch technology is not sufficiently mature to warrant commitment as a primary weapon system on a 10-20-ton FCS in the time period under consideration. KE missile Technology has significant potential for direct/indirect fire lethality, but there are questions concerning reaching propellant performance goals and crew safety.

Required advances in the DE systems were judged to be high risk developments until scaling validation has been executed. An Army STO is underway addressing scaling validation as being the major engineering issue as well as determination of synergistic individual weapons enhanced effectiveness. MOUT and Less than Lethal technologies should be integrated into this program for these reasons.

Current KE and DE efforts will provide the Tech Base to permit the development and deployment of KE/DE systems by FY10. Empirical lethality/effectiveness data continues to be derived and used wherever possible in the assessment of missile and Laser weapon performance against key threat Artillery and 122mm & 240 mm rockets. There is a dearth of empirical missile or laser weapon lethality/effectiveness data for various foreseen threats. However, empirical lethality/effectiveness data derived to date can be extrapolated, and theoretical lethality analysis/projections continue to form the basis for substantive performance assessments against future FCS threats. A series of sensors are projected to exist at that time frame that will enhance the effectiveness of both Direct Fire and Active Defense.

Additional information about the individual programs can be found on CD in the Lethality Subpanel report.



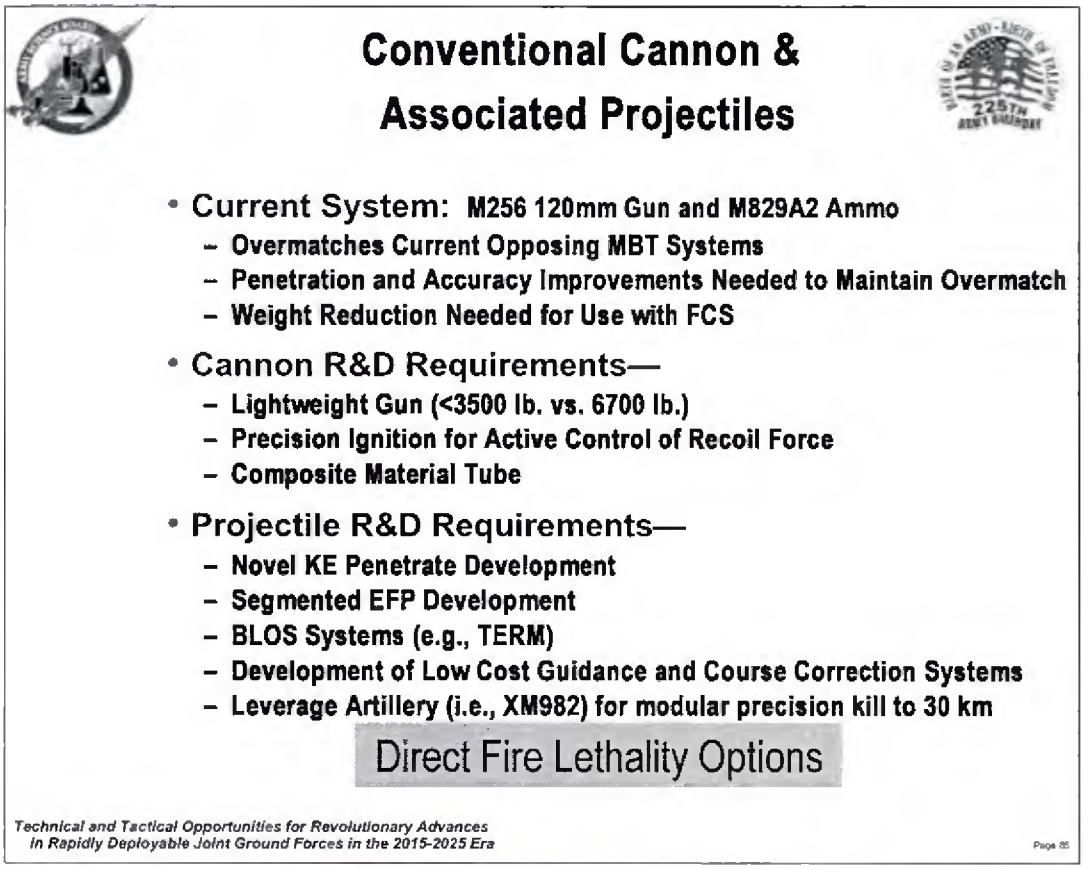
Smart munitions are essential to the success of the Objective Force (OF) as presently conceived. Collectively, these weapons are the implementing element enabling both effective offensive action and successful defense for combat vehicles that have given up heavy armor in exchange for greater strategic and tactical mobility.

TERM with an advanced EFP warhead offers the prospect of an advanced cannon round, useable with both current and future primary combat vehicles, that provides overmatching lethality for both direct and indirect fire modes, from 500 meters to 10 kilometers.

PGMM provides precision close-in fire support. MSTAR provides precision fire support from mid to long range.

Given the solution of the communications problems inherent in the OF concept, Netfires will provide a synergistic companion to robotic combat vehicles that will enormously augment their effectiveness and survivability.

Additional information about the individual programs can be found on CD in the Lethality Sub panel report.

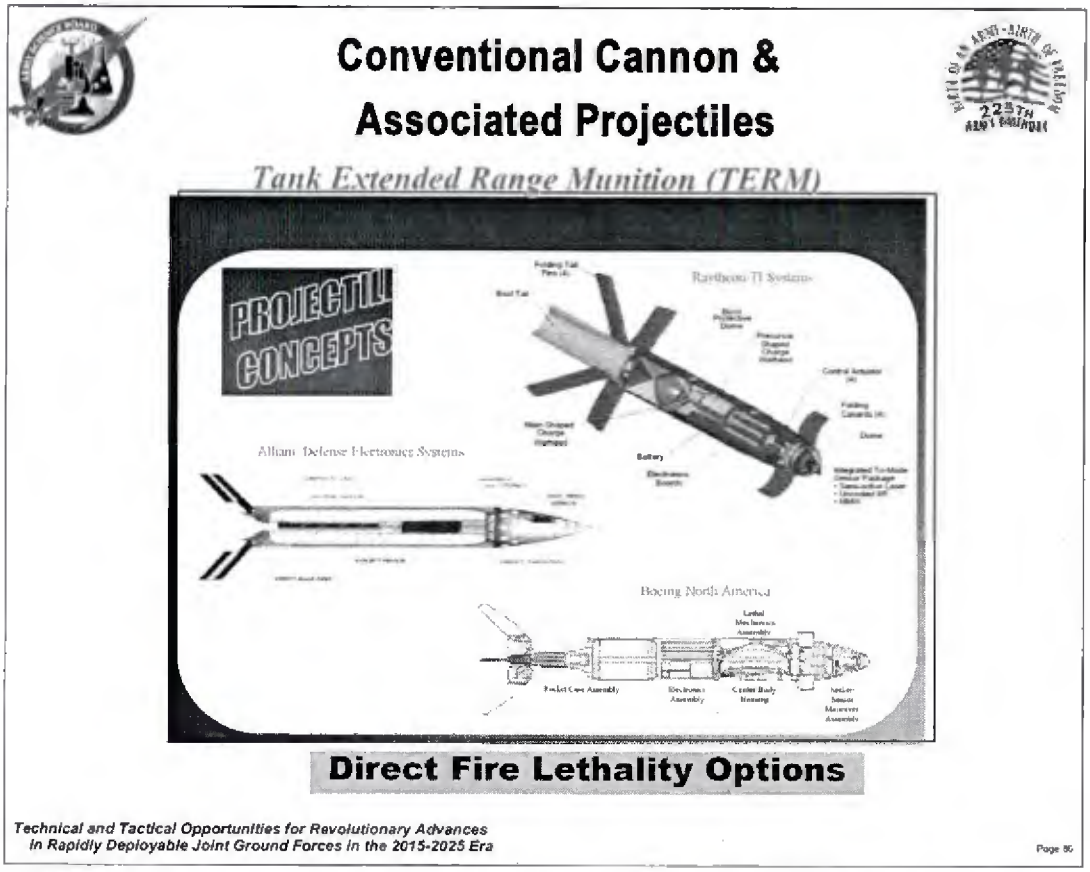


Remarkable advances continue to be made in the development of high-performance explosively formed projectiles (EFPs), strongly aided by ever-improving, physics- based modeling capabilities and an enhanced fundamental understanding of the dynamic behavior of materials at high strain rates in complex geometries. EFP formation and penetration behavior have become highly controllable and reproducible. Warhead designs capable of forming-- in near real time-- a broad spectrum of application-specific projectiles on a selectable basis are being devised.

Experimental work conducted as part of the EFP warhead Technology program also has addressed the performance potential of highly segmented (~10 segments), self-forming KE rods. Results to date suggest that dramatic increases in lethality might be achieved in the near term using this approach. Segmented KE penetrators thus appear to offer a very promising means for achieving overmatching direct fire lethality in the FCV.

Work on composite barrels and ETC precision ignition to support recoil control and mitigation promise to provide significant weight reduction for the FCS.

Additional information about this work can be found on CD in the Lethality Sub panel report.



Despite having an overmatching direct fire capability, the survivability of a 20-ton FCS will be severely threatened by close-in encounters with enemy main battle tanks. FCS survival will depend on vehicle capability to engage and defeat enemy targets at extended ranges outside the reach of enemy guns. The TERM program is directed toward providing that capability while retaining an overmatching direct fire capability as well. A variety of projectile concepts are being pursued. Contractor teams are being led by Alliant, Boeing, and Raytheon.

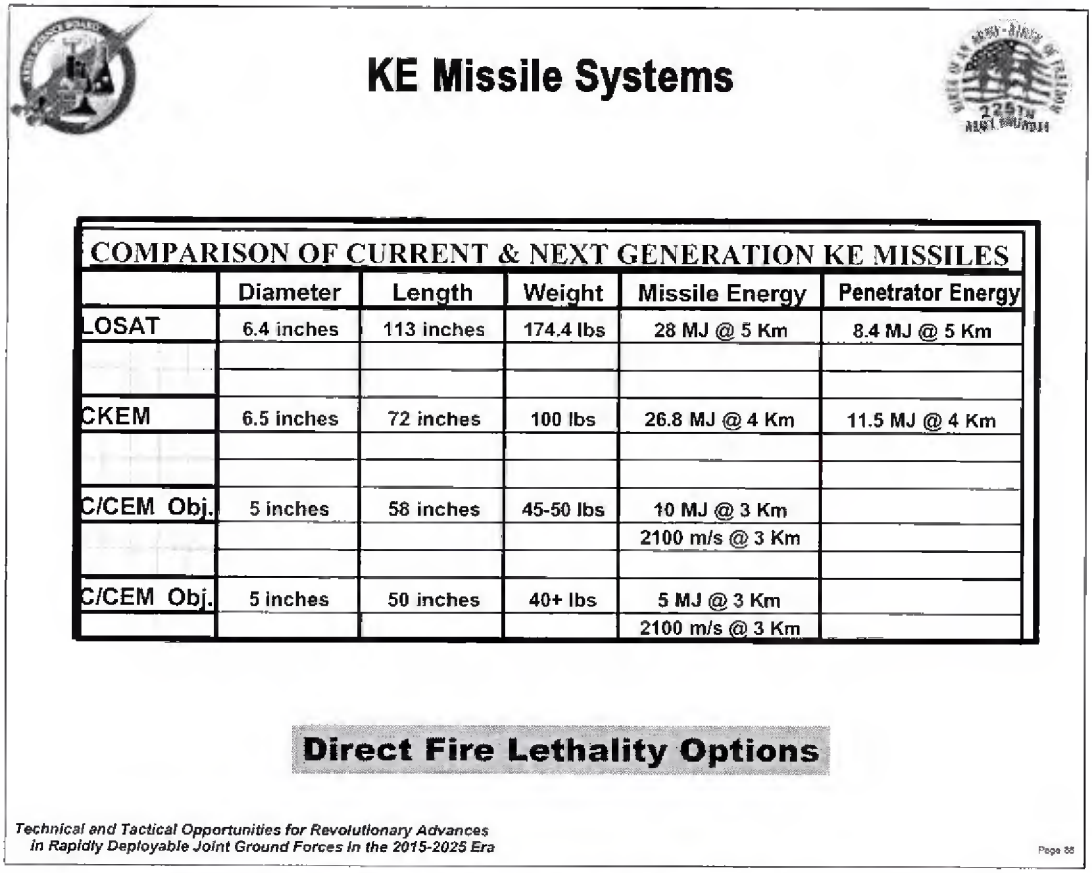
The TERM program is structured to meet a First-Unit Equipped (FUE) goal of 2010. This date is compatible with the planned development cycle for FCS, set to begin in 2005.

Additional information about TERM can be found on CD in the Lethality Sub panel report.

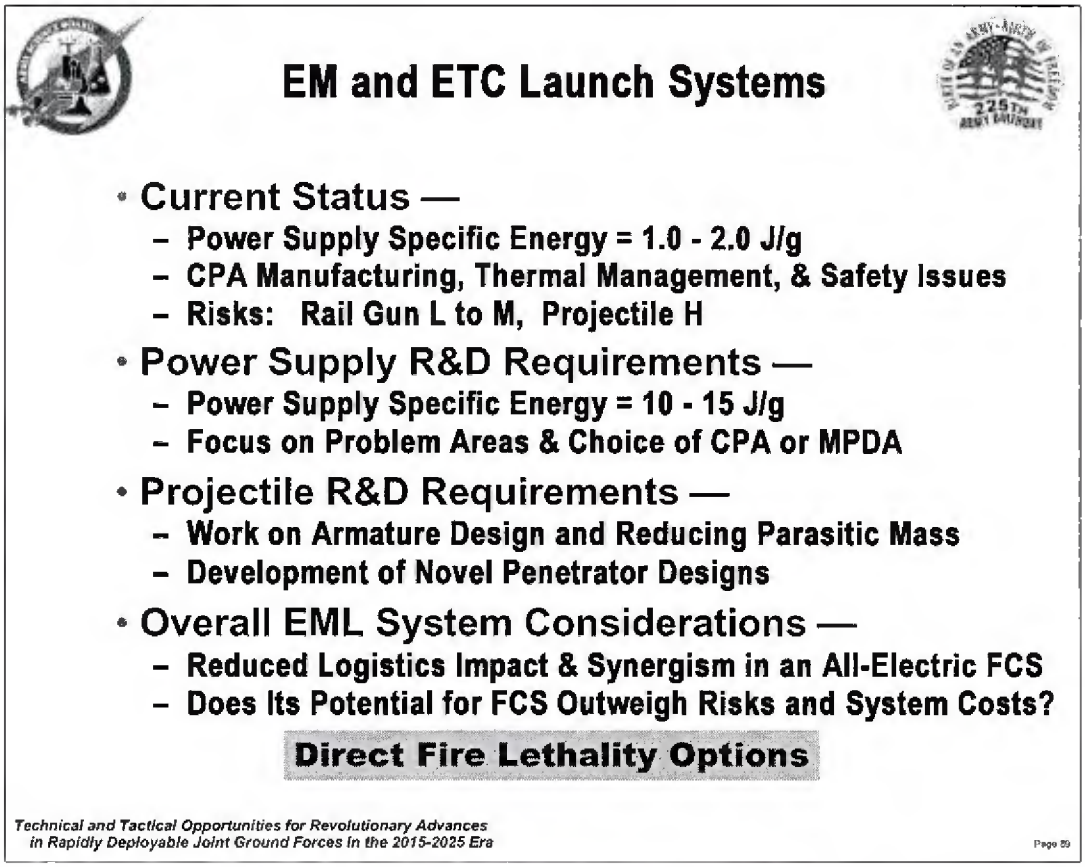
In reviewing the potential utility of missiles as a means for achieving overmatching direct or indirect fire lethality for the proposed 20-ton FCV, the lethality panel received briefings from Army experts from the Missile Research, Development and Engineering Center (MRDEC) at Redstone Arsenal and also examined the March 1999 report prepared by an Independent Review Team on the subject. The principal focus was on the Compact Kinetic Energy Missile (CKEM), a planned follow-on to the larger Line-Of-Sight Anti-Tank (LOSAT) missile. CKEM is designed to achieve the same level of lethality as LOSAT but at a smaller size and weight. It also will feature a shorter minimum range than that for LOSAT. Providing an indirect fire capability to augment the planned direct fire capability of CKEM may require a different guidance scheme than currently planned.

Overall the CKEM program appears to be well planned and comparatively low risk. However, questions remain concerning the development of the propellants needed to achieve the desired performance and crew safety.

Additional information about this program can be found on CD in the Lethality Sub panel report.



Two conceptual KE missiles that might serve as follow-ons to CKEM are being considered. Both of these conceptual missiles are smaller and lighter than CKEM. Other details regarding their design, potential platforms, and expected performance are not yet available.



Electro-thermo-chemical (ETC) technology development efforts have been directed toward gun propulsion. In the near term, however, the demonstrated ability of the technology to provide precisely timed ignition of a conventional charge may be more useful. There are established approaches (e.g. firing out of battery) that can greatly reduce gun recoil forces, a matter of critical importance in designing reliable lightweight cannon. Reliable and precisely timed ignition is required to make such approaches work. It appears that ETC technology can meet this need. In the future, ETC technology also may enable higher muzzle energies and velocities with a truly insensitive propellant, thereby contributing to increased vehicle survivability.

Novel penetrator concepts, including projectiles able to extend in flight and segmented rods, may be particularly well suited for hypervelocity delivery systems. Work at LLNL has indicated that certain extender projectiles fired in the hypervelocity regime exhibit a 20% performance advantage compared to similar projectiles fired at normal ordnance velocities. Experimental results with segmented penetrators obtained at the University of Texas, Institute of Advanced Technology, have shown that dramatic increases in penetration are possible.

However, electromagnetic launch technology is not sufficiently mature to warrant commitment as a primary weapon system on a 10-20-ton FCS in the time period under consideration.

Overwhelming Lethality Can Be Achieved

Problem:

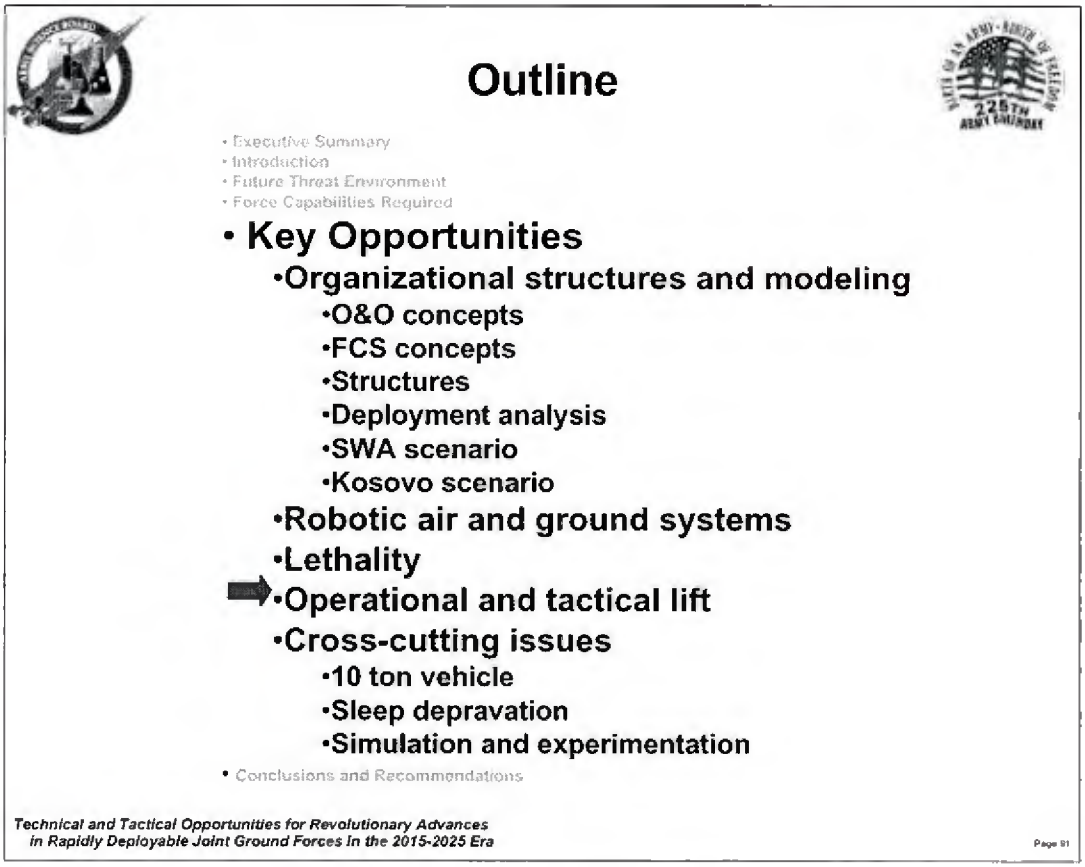
To achieve precise, overwhelming, direct/indirect lethality for the future force

Discussion:

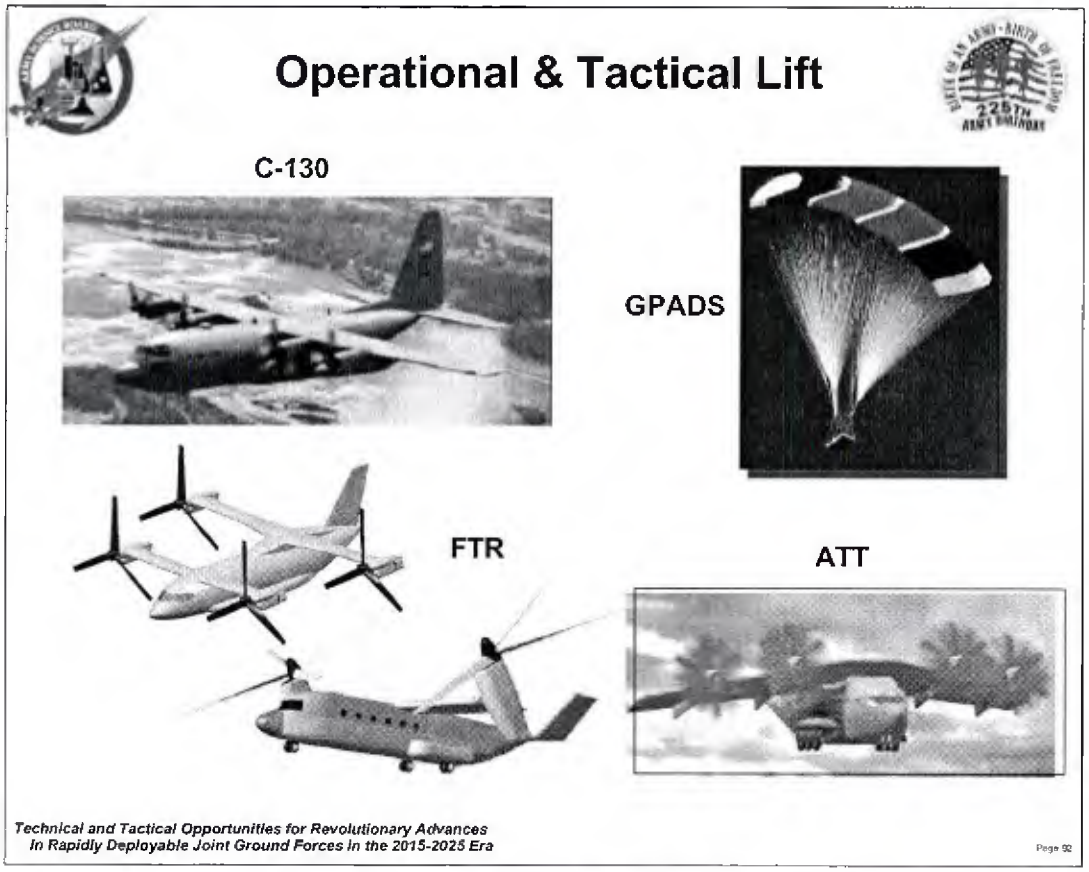
- A lethality suite has been identified:
  - ETC Cannon w/advanced penetrators; TERM; Net Fires (PAM & LAM); CKEM; Air Defense (DE & KE); PGMM; MSTAR; and MIPM.
- This suite provides both direct and indirect fire overmatch, kills beyond line of sight, multiple kill mechanisms and utility in complex/urban terrain
- The technology is well understood, however demonstrations should be planned. Achievement of CKEM performance goals is an issue.
- Electromagnetic launch technology is not sufficiently mature to warrant commitment as a primary weapon system on a 10-20-ton FCS
- Several high payoff programs are not being aggressively pursued: MSTAR, Air defense (DE & KE), PGMM, and MIPM. These programs are important for force protection and urban combat

Recommendations:

- Field test ETC system including novel penetrators
- Conduct a review of precision guided munitions for payoff and technical maturity, taking into consideration FCS O&O. Pursue and adequately fund high payoff programs
- Reconsider programs not currently being aggressively pursued



Operational and tactical life are covered in this section.



C-130 Hercules is the current tactical airlift aircraft capable of lifting a 20 ton FCS.

Guided Precision Air Delivery System (GPADS) is a GPS guided parafoil capable of delivering up to 20 tons, from high altitude and stand-off distances.

Future Transport Rotorcraft (FTR). is a transport rotorcraft designed to lift a 20 ton FCS. Many different rotorcraft configurations are possible in the FY 2015 timeframe including: helicopter, tilt rotor, quad tilt rotor and compound helicopter.

Advanced Tactical Transport (ATT) is a proposed Super Short Take-Off and Landing (SSTOL) aircraft capable of lifting 30 tons in SSTOL mode for combat or 40 tons (two 20 ton FCS) from a runway for deployment.

Army Will Continue to Require Forcible Entry and Vertical Envelopment

Pros	Cons
• Bypass of very high risk areas during debarkation (seaports and airfields)	• Cost, cost, cost
• High rate of buildup	• Survivability of aircraft enroute
• Surprise	
• Operations in underdeveloped areas (deep water ports, high capacity airfields, transportation grid)	
• Bypass barriers, mines, complex terrain	

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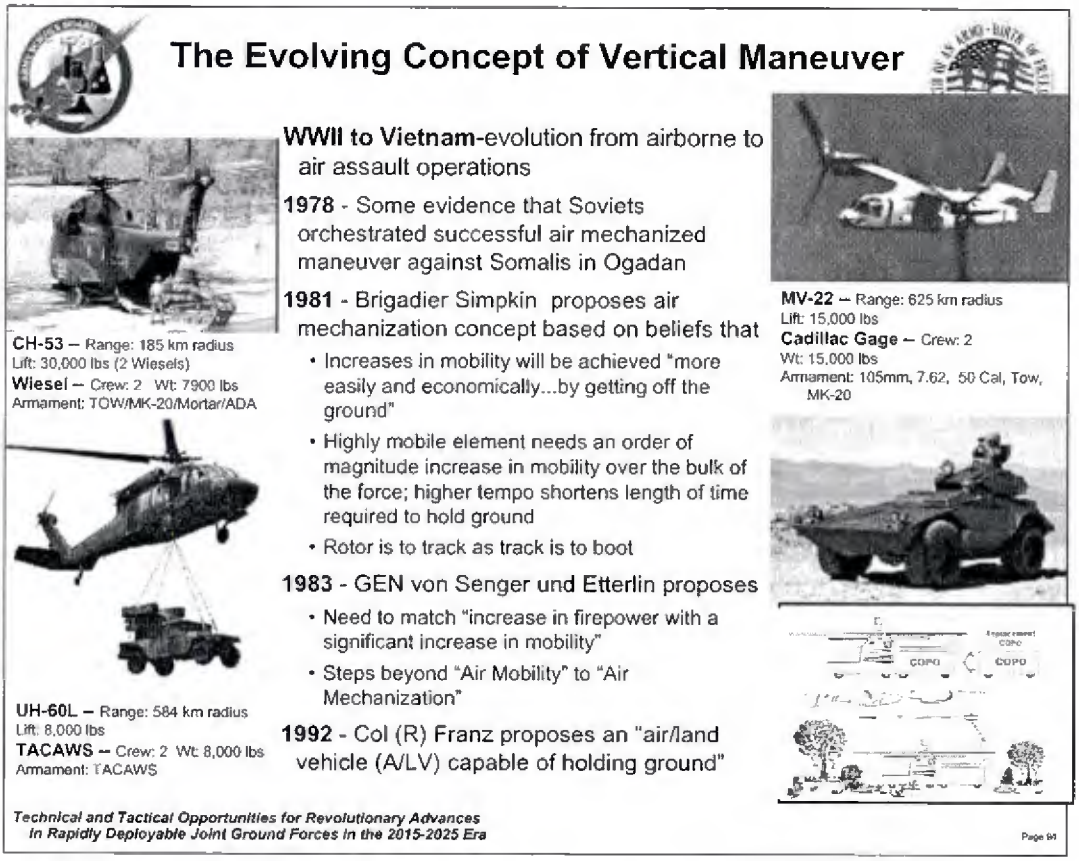
The utility of these capabilities to gain entry, expand the battlespace, diffuse enemy focus, disperse enemy assets and enable initiation of ground operations from positional advantage will continue into the future.

Coupling of FCS and FTR will increase this utility - linking the listed payoffs (Pros) with a highly mobile, lethal and survivable ground maneuver force will provide revolutionary capabilities.

The challenges to achieving this revolution include both cost and survivability. Acquisition cost is a major challenge for FTR and an even greater challenge for FCS and FTR together. FTR survivability will require an integrated solution combining: dominant battlespace situational awareness and joint suppression of enemy air defense with active and passive protection systems. Active protection should include the ability to defeat MANPADS by attacking both the missile and the launcher.



Since the inter-war years between World War I and II, armies have been seeking to exploit the potential of air movement of ground forces. In World War II, airborne divisions provided depth to the battlefield, fixed and interdicted enemy ground forces and enabled the employment of decisive ground forces in both theaters of war for invasions and follow on operations. Likewise, Korea saw the employment of airborne forces as an enabling capability. Korea also saw the first significant employment of the helicopter, but not so as to have an operationally significant impact.

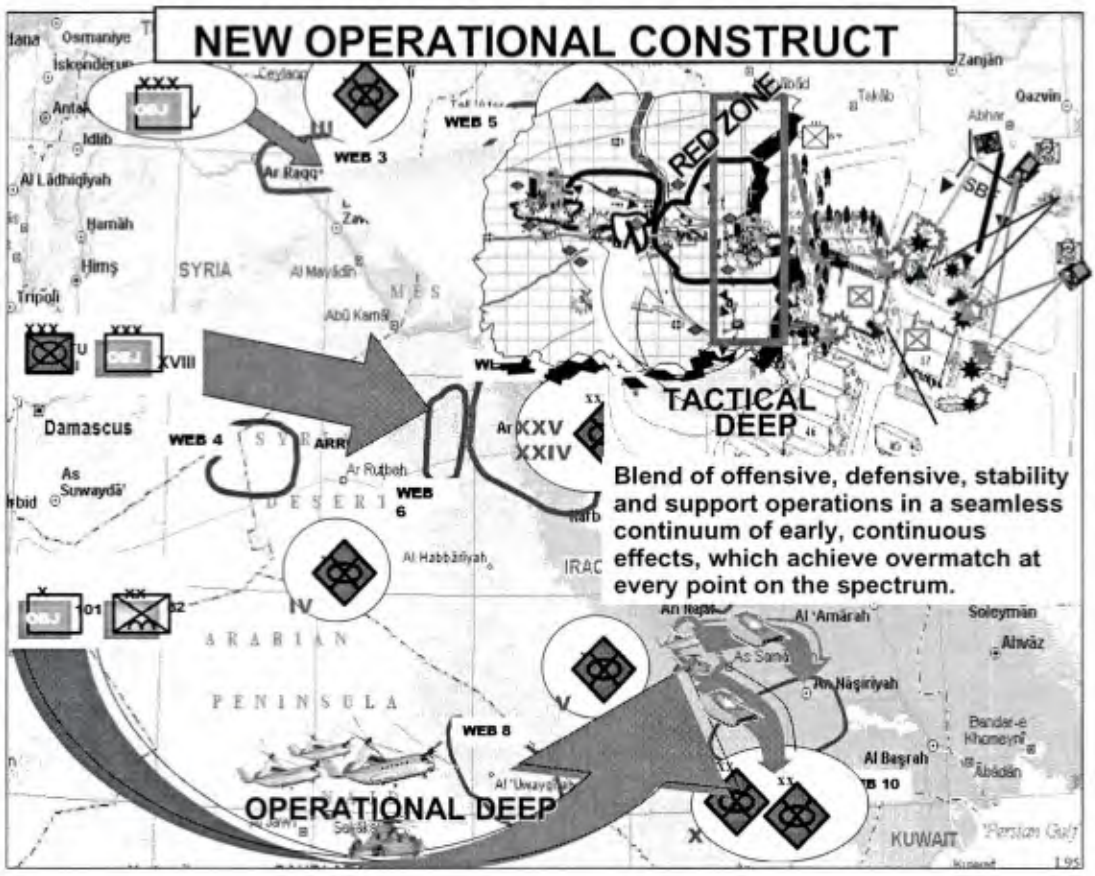
Post Korea, the Army began experimentation with the helicopter, culminating in the Howze Commission and creation of the 1st Cavalry Division. From that foundation, the Army established a dramatic new capability that was optimized for the distributed operations it faced in Vietnam.

Force design examinations during this period included experimentation with the TRICAP division that included mechanized, air mobile and combat aviation brigades. This test documented the value of a separate air cavalry brigade and continued the validation of the air assault concept. The formation of the 6th Cavalry Brigade (Air Combat) and the reorganization of the 101st Airborne Division into an air assault configuration were the results of the TRICAP test. However, limited ground mobility, anti-tank lethality and survivability precluded greater proliferation of the air mobile brigade concept beyond the 101st.

Moving forward to Desert Storm, the 101st Airborne Division's (Air Assault) aerial agility allowed the CINC to close the door on Iraqi reinforcement. This capability brought home the power of being able to focus on the enemy and not the terrain.

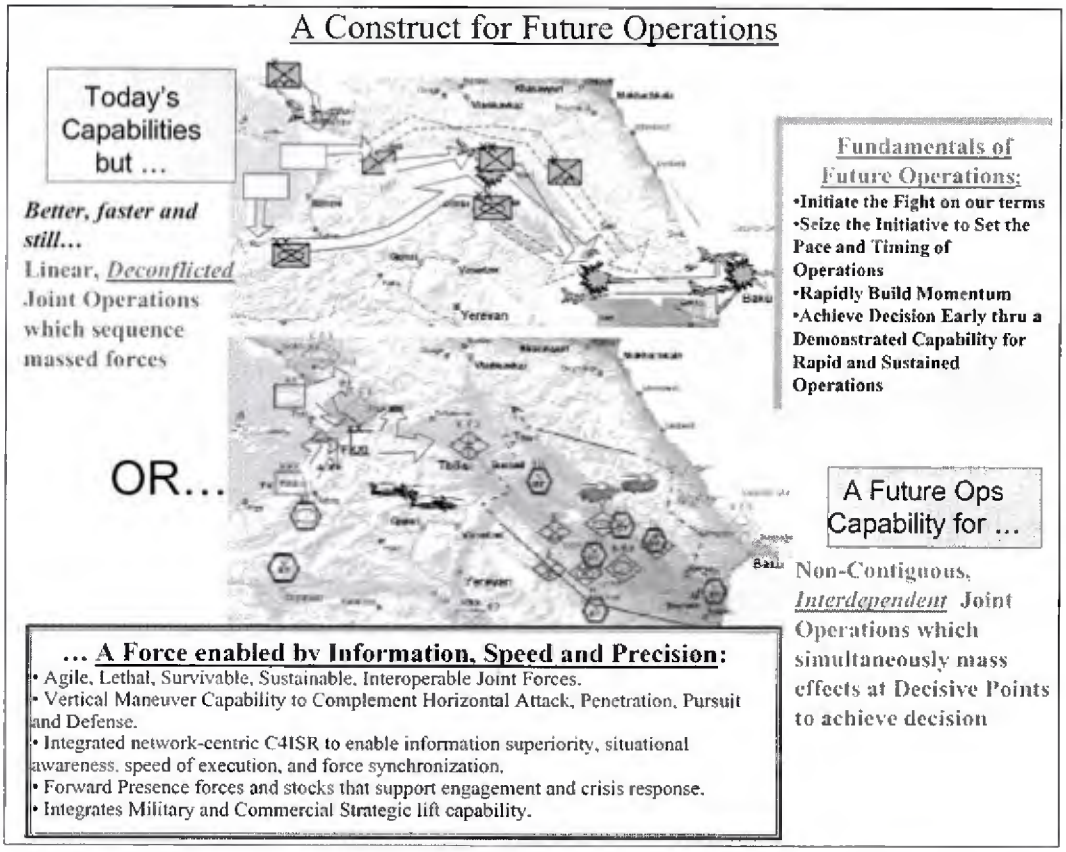
Over time, observers of these capabilities built upon the US Army's and their own experiences. The Soviets embraced air mobile forces to further operationalize their deep operations concept--Desant. Similarly, several European allies have developed air mobile capabilities that verge on air mechanization with light armored forces, including the German anti-armor brigade based around the Weasel and CH-53. As recently as NATO operations in Kosovo, these capabilities have been used by the UK and Germany to agilely deploy and employ light armored forces.

With the advent of new capabilities, including the Future Combat System holds the promise of exploiting the agility of light forces with the mobility, lethality and survivability of heavy forces. Such a capability portends substantial payoffs for the joint and operational commander on the distributed and asymmetric battlefields of the future.



The power of this combination is inherent, in part, in emerging Army operational concepts illustrated here.

These operational concepts seek to aim is to isolate and mitigate tactical and operational elements of the enemy force to deny mutual support by fires, effects or maneuver to disintegrate enemy forces and formations so that friendly forces can deal those enemy forces in a "piecemeal" fashion.



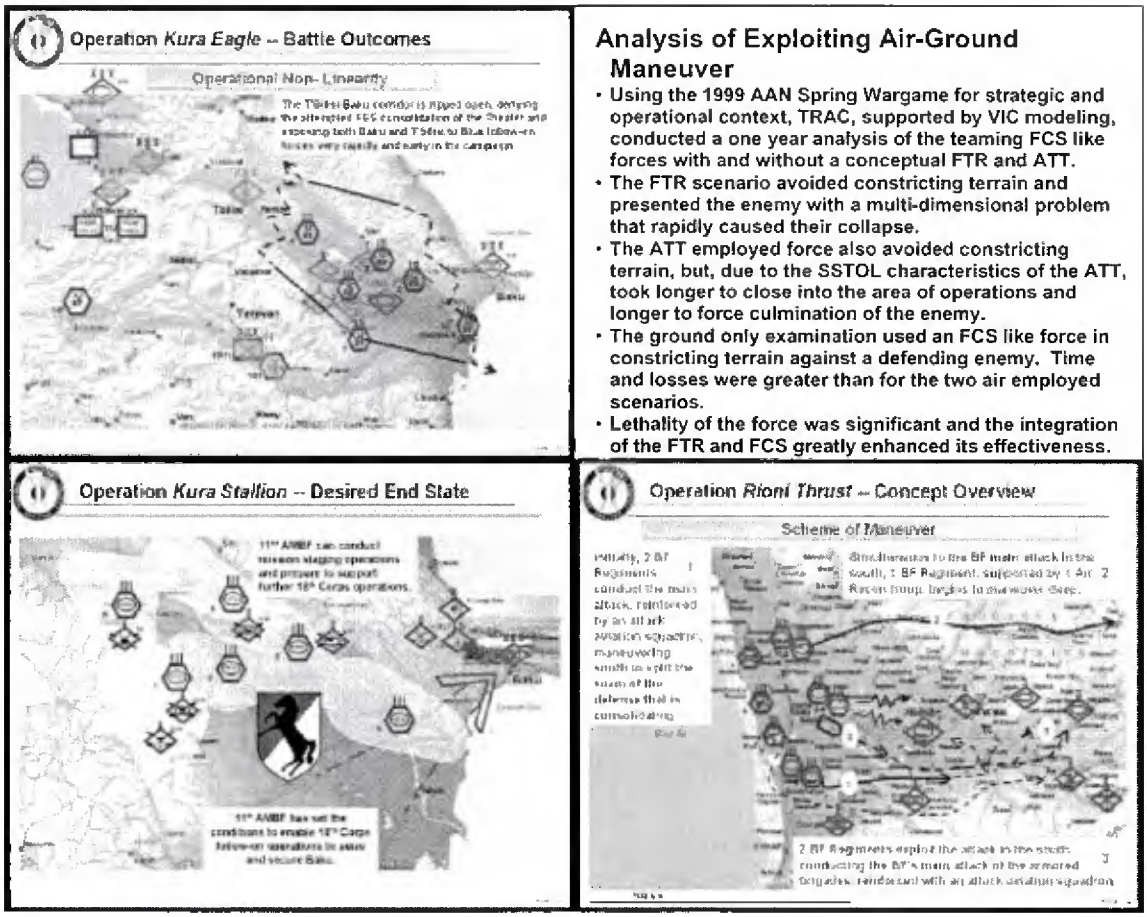
The Army has investigated the implications of such capabilities, centered around the teaming of the FCS and FTR. Given the future operational environment and adaptive approaches exhibited by recent opponents, retention of linear and sequential approaches will provide the enemy with a number of options that can be denied through the application of agile and lethal forces in a non-contiguous, non-linear, distributed operation.

Shown here is an illustration of a military problem from the 1999 Army After Next Spring Wargame.

The enemy had invaded both Georgia and Azerbaijan with the intent of rapidly consolidating the theater and preparing a defense in depth with both surveillance and recon strike complexes.

Dealing with this problem in a linear and sequential manner given the very restrictive terrain of the Caucuses presents a number of challenges while providing the enemy with numerous advantages, not the least of which is the ability to focus his efforts in a single direction--facing the attacking blue force with the full effects of the Red capability

Conversely, enabled with both a non-linear, non-contiguous and distributed operational concept as well as the means of executing that concept in a simultaneous and rapid fashion, denied the enemy the ability to focus his resources, exploit the terrain and set the conditions for stalemate. Additionally, this approach dislocated the enemy from the onset and disintegrated the coherence of the enemy's force and operational plan--tactically, operationally and to a degree strategically.



Analysis of Exploiting Air-Ground Maneuver

- Using the 1999 AAN Spring Wargame for strategic and operational context, TRAC, supported by VIC modeling, conducted a one year analysis of the teaming FCS like forces with and without a conceptual FTR and ATT.
- The FTR scenario avoided constricting terrain and presented the enemy with a multi-dimensional problem that rapidly caused their collapse.
- The ATT employed force also avoided constricting terrain, but, due to the SSTOL characteristics of the ATT, took longer to close into the area of operations and longer to force culmination of the enemy.
- The ground only examination used an FCS like force in constricting terrain against a defending enemy. Time and losses were greater than for the two air employed scenarios.
- Lethality of the force was significant and the integration of the FTR and FCS greatly enhanced its effectiveness.

Analytical Foundations for employment of FTR-FCS teaming

The Army has conducted several studies into the implications of teaming the FTR and FCS. Both TRAC and RAND have sponsored analysis. The most recent analysis was conducted by TRAC in 1999-2000 (TRAC-TR-0999, April 2000)

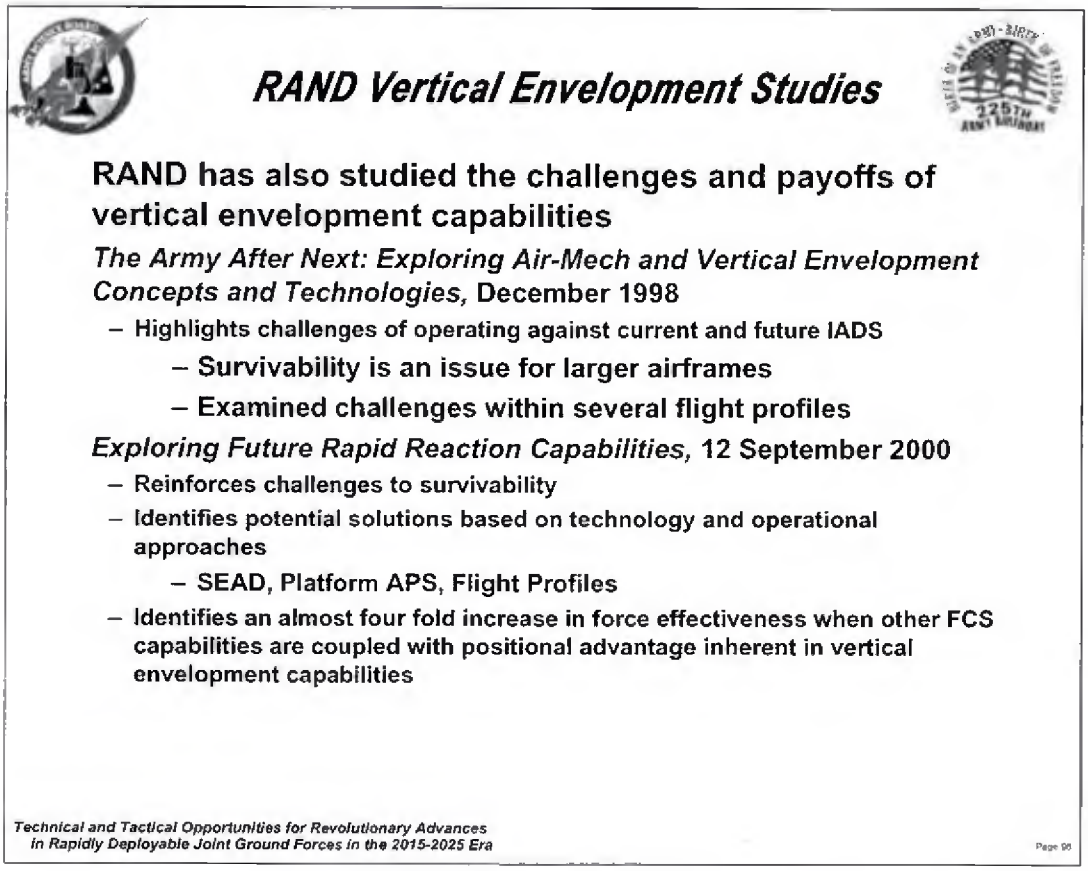
Using the 1999 AAN Spring Wargame for strategic and operational context, TRAC, supported by VIC modeling, conducted a one year analysis of the teaming FCS like forces with and without a conceptual FTR and ATT.

The tactical excursions described in this report examined potential future army force organizations and concepts. The excursions looked in detail at how this notional forces could execute the Army's emerging operational concept--Advanced Full Dimensional Operations (AFDO)--in tactical operations against an adaptive and challenging enemy force.

The study revealed a variety of potential operational and tactical concepts and revealed the importance of several themes:

- Criticality of condition setting to employ the force
- Exploitation potential of vertical envelopment to unhinge the enemy
- Establishment of reconnaissance-strike complexes to exploit superior force level ISR and air and ground stand off fires capabilities
- Execution of standoff tactics that exploit organic ISR and NLOS and BLOS fires to neutralize the enemy and enhance survivability of the force
- Holistic approach to force protection

Outcomes shoed that a lightly armored force with positional advantage, high agility, weapons range and lethality overmatch, coupled with information superiority at the point of attack and stand-off tactics can successful engage and win against a challenging enemy threat.



RAND has conducted two studies of future vertical envelopment capabilities

- *The Army After Next: Exploring Air-Mech and Vertical Envelopment Concepts and Technologies*, December 1998
- *Exploring Future Rapid Reaction Capabilities*, 12 September 2000

– These studies highlight the challenges of operating against current and future IADS

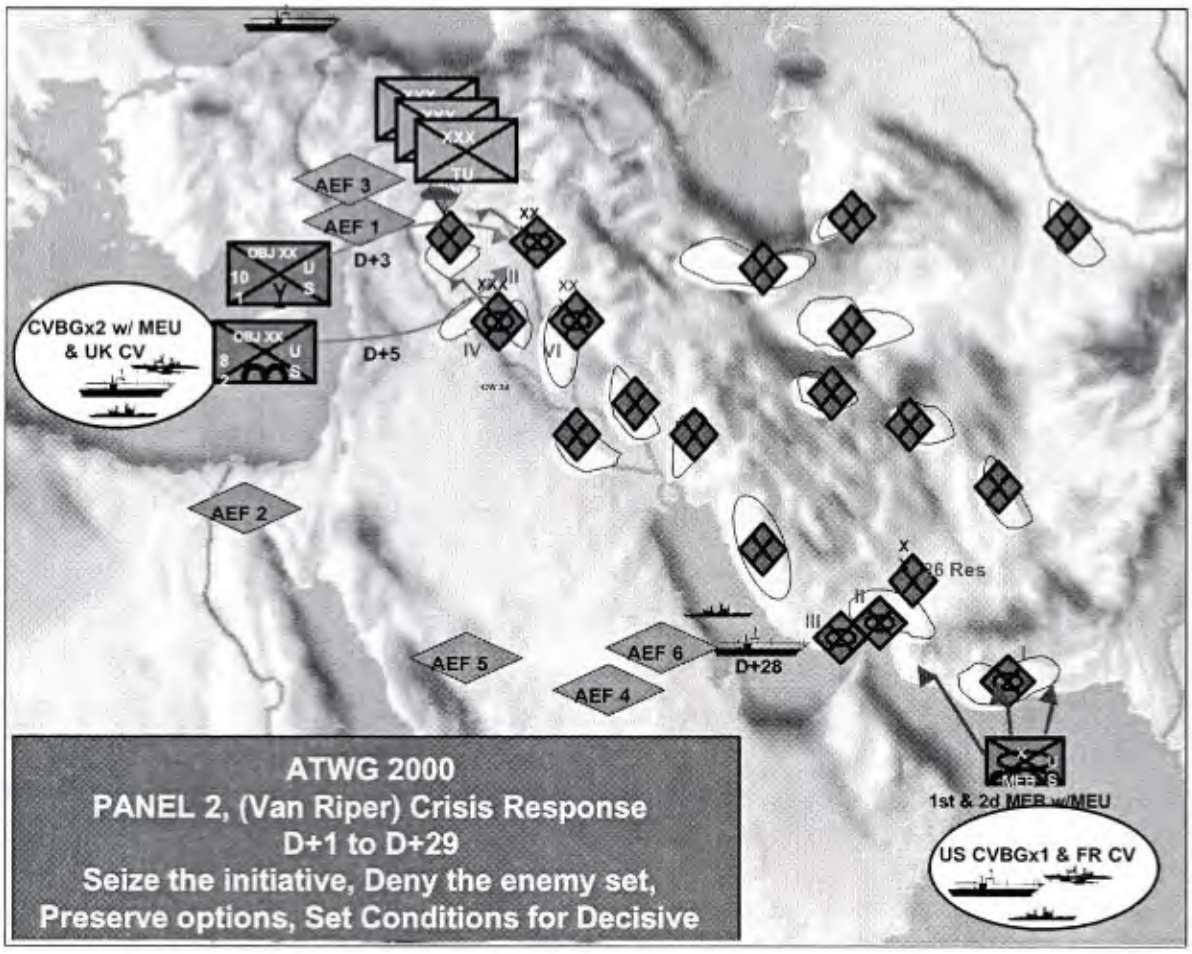
Survivability is an issue for larger airframes

Examined challenges within several flight profiles

– Identifies potential solutions based on technology and operational approaches

SEAD, Platform APS, Flight Profiles

– Assuming success in achieving survivability, the SEP 2000 report identifies an almost four fold increase in force effectiveness when other FCS capabilities are coupled with positional advantage inherent in vertical envelopment capabilities



Use of the FTR-FCS team in ATWG 00

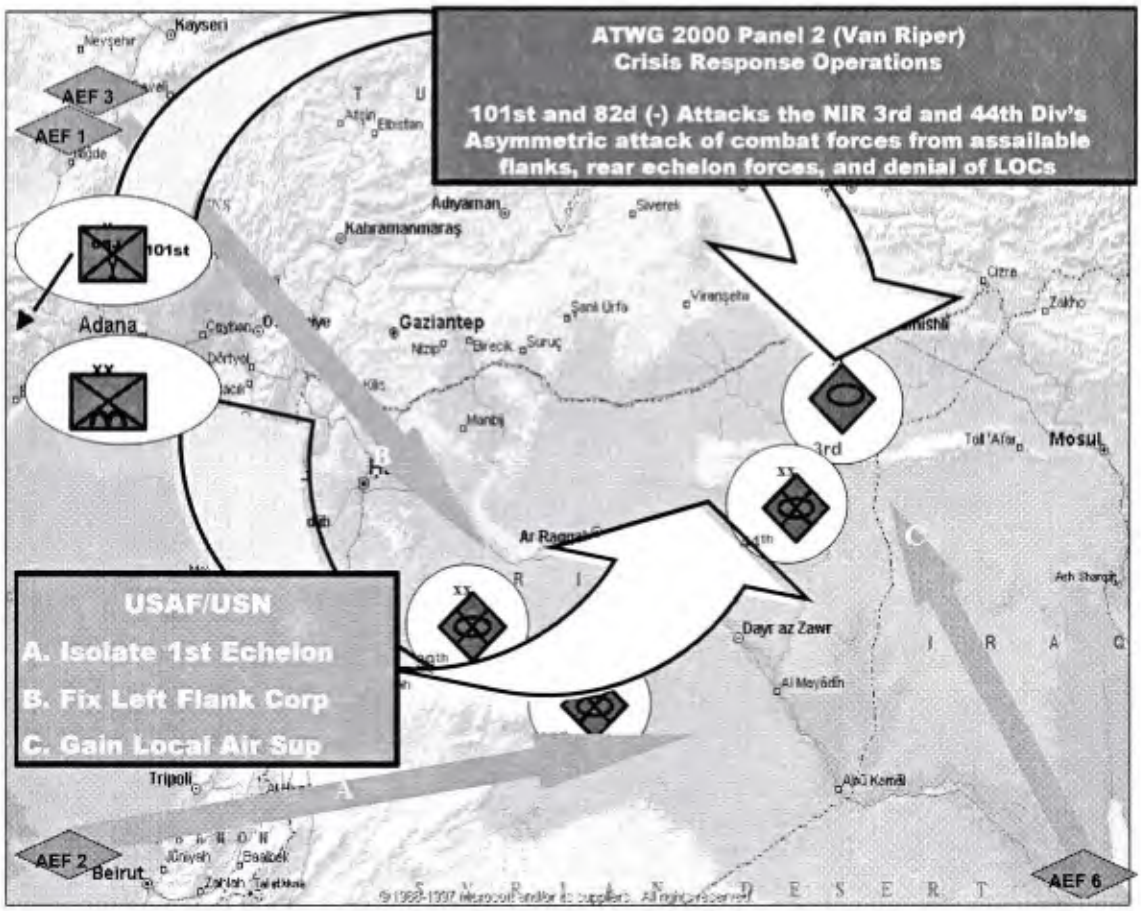
Building off of the insights of the previous year's TRAC study and the Army Transformation vision, the Army investigated the implications of teaming FCS and FTR as part of an emerging Objective Force in the first Army Transformation Wargame. While only a small part of the total Army force package, the agility of this force proved to be very useful as part of several operational vignettes.

Strategically responsive Army and joint forces prevented Red forces from achieving their desired operational objectives and forced them into undesirable COA's.

While these early arriving forces did not preclude Red action, they were also critical to setting the conditions for follow on operations.

In this example, the Blue force sent two Objective Force divisions from staging bases in Cyprus and western Turkey to southeast Turkey and eastern Syria to repel Red forces there. According to LTG (R) Van Riper, the Blue forces had originally not planned to take offensive action for several more days, but were able to respond because of the Objective Force divisions' rapid deployability capabilities.

As recounted in a Defense News article: "That deployability is directly derived from the forces' FCS and FTRs. The 20-ton FCS is intended to replace the Army's current fleet of General Dynamics [GD] M1 tanks, United Defense, L.P., M2 and M3 Bradley Fighting Vehicles, and other armored vehicles, but at the same be transported by a Lockheed Martin [LMT] C-130 aircraft. The FTR, meanwhile, is intended to carry 20 tons like a C-130, but takeoff and and vertically like a helicopter. Equipped with FCS and the FTRs to transport them, the Objective Forces were able to combine the firepower of heavy mechanized forces with the speed of light air assault forces. 'They were the only forces we could get engaged within 48 hours,' Van Riper said. 'We wouldn't have been there' without those forces, he added."



Use of the FTR-FCS team in ATWG 00 (continued)

That early entry operation comprised both the 101st and the 82d (-) exploiting organic FTR capability in the 101st and support from the parent corps aviation brigade to conduct asymmetric attacks against the rear of the Red corps attacking into Turkey.

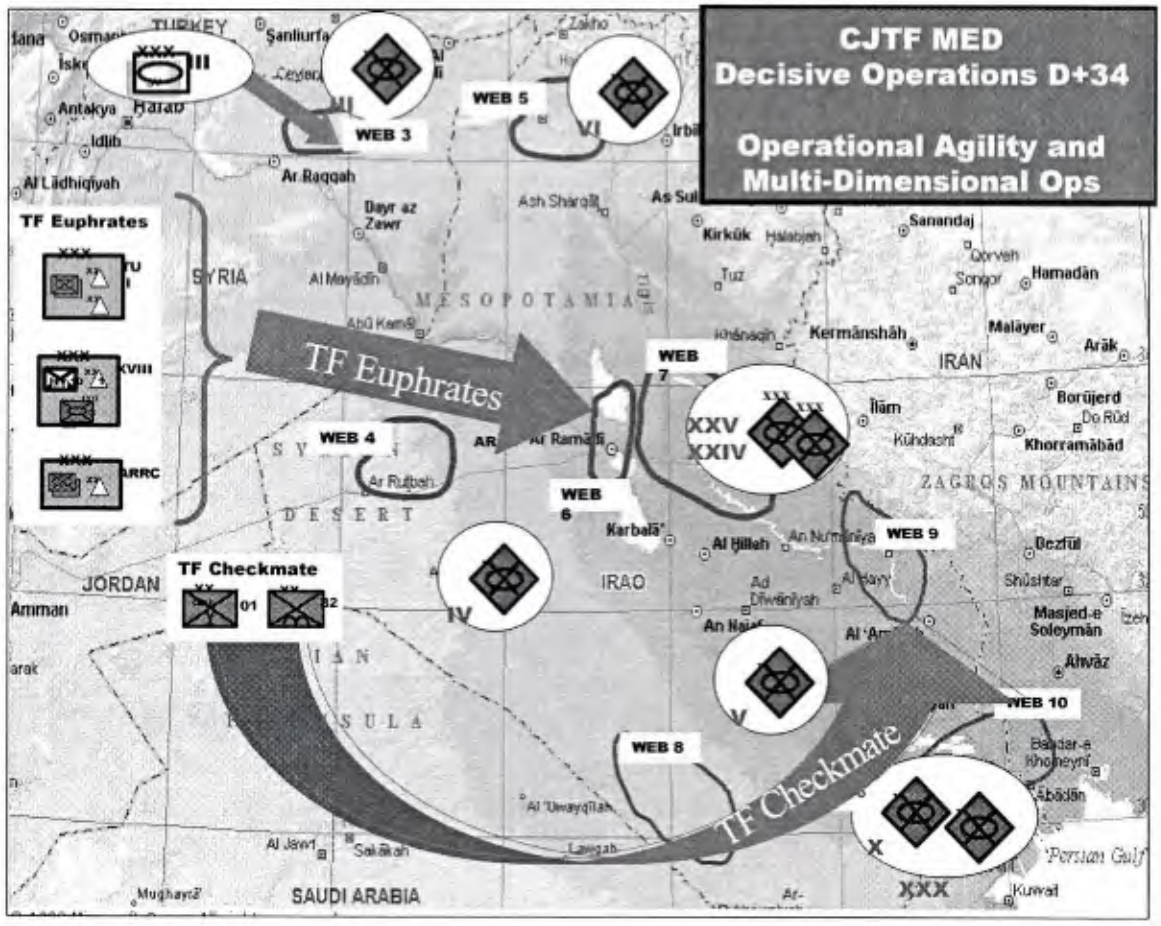
Exploiting the linear and conventional defensive operations of the Turks, these air maneuver operations placed mobile, lethal and survivable combined arms forces into the rear of that corps to attack, ICW joint strike and other effects lines of communication, rear echelon forces and launch attacks into the rear of engaged combat formations already fighting the Turks.

These operations cause the Red corps to culminate and begin withdrawal from Turkey and initiated the setting the conditions for decisive operations.

The agility of these forces enabled their immediate employment against enemy units either unprepared for or incapable of dealing with combined arms maneuver forces attacking from unexpected directions and locations.

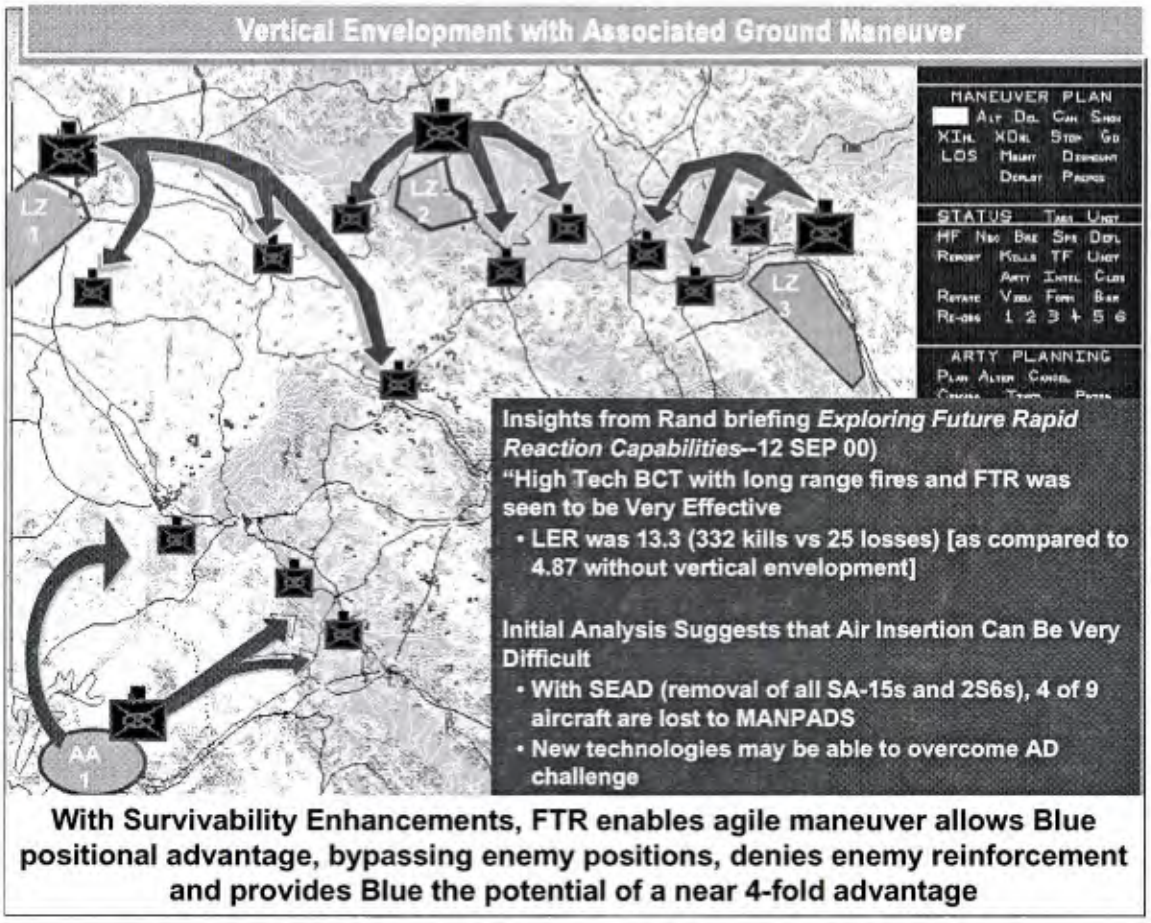
These operations created a multi-dimensional problem for the enemy and forced their early culmination.

Early employment of US forces also cemented the coalition for the duration of the war, denying the enemy any opportunity to attack the cohesion of the coalition.



Use of the FTR-FCS team in ATWG 00 (continued)

- Later in the same campaign, the agility and robustness of these same air maneuver forces was exploited to add permanent depth and simultaneity to the battlespace.
- A multi-national C/JTF of Turkish, US and NATO forces conducted a linear advance from the west towards Baghdad while simultaneously, the 101st and 82d were maneuvered to cut off fleeing Red units and prevent their escape into Iran.
- This action ensured that the force could in fact destroy or deny the Red federation the capability to launch future offensive actions against their neighbors and set the conditions for the employment of forces from the Persian Gulf region against the underbelly of the Red defense.
- The combination of linear and non-linear, operations conducted by highly agile, mobile and lethal Army and joint forces prevented Red from focusing its efforts in any one direction, created conditions for a rapid collapse of the enemy.



Based on the RAND Medium Weight Force study in Kosovo, RAND conducted analysis within the same scenario using the Notional FCS force capabilities. Potential payoff of using FTR capabilities was one area addressed.

Insights from RAND briefing, 12 SEP 00, "*Exploring Future Rapid Reaction Capabilities*"
"High Tech BCT with long range fires and FTR was seen to be Very Effective"

LER was 13.3 (332 kills vs 25 losses) [as compared to 4.87 without vertical envelopment]

Initial Analysis Suggests that Air Insertion Can Be Very Difficult

With SEAD (removal of all SA-15s and 2S6s), 4 of 9 aircraft are lost to MANPADS

New technologies may be able to overcome AD challenge

- **The ability to bypass the enemy and achieve positional advantage dislocated enemy forces defending the river crossing and allowed blue forces to achieve defensible positions before the enemy follow on forces were able to enter Kosovo.**

Future Transport Rotorcraft

Notional System Capabilities

Operational Mobility

Sizing Mission Payload **(Army Hot Day, 4000 ft / 95 °F) - 20 tons**

Vertical Take-Off Mission Radius **(Initial VTOL) - 500 km**

Rolling Take-Off Mission Radius **(Mid-Point VTOL) - 1000 km**

C-130 Internal Cargo Box **(Width x Height x Length, ft) - 10 x 9 x 40**

Operational Flexibility

Vertical Take-Off and Landing **(VTOL)** from Unprepared Surfaces

Rapid Ground Vehicle Load / Unload Times **- Automatic Vehicle Control**

Joint Service **(Shipboard Compatible)**

Strategic Mobility

Global Self-Deployment **(Longest Over-water Leg)**

Pacific Ocean - 2,100 nm (Asia via Hawaii, unfavorable winds)

Overload Gross Weight **(Rolling Take-Off)**, Best Altitude Cruise

Sling Load 22.4 ton MILVAN from Container Ship in Austere Port

Hover Out of Ground Effect (HOGE), Sea Level / Hot Day (SL / 103 °F)

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Operational Mobility. FTR is sized to provide assured vertical envelopment capability for a 20 ton FCS. Assured means Army hot day (4,000 ft / 95 degrees F) Vertical Take-Off and Landing (VTOL) capability to provide over 90% probability of operation, world-wide. FTR sizing mission radius is 500 km with a VTOL initial take-off. The fuel tank is sized to allow a 1,000 km mission radius with a rolling initial take-off and VTOL capability at mission mid-point.

Operational Flexibility. The ability to operate from unprepared surfaces is critical. This places a limit on maximum downwash velocity, which results in the use of rotors or props for lift instead of jets. Rapid (10 to 20 seconds) combat vehicle unload and load times are important to minimize FTR exposure time. This is accomplished by FCS, in robotic mode, operating in a controlled environment inside the aircraft. FTR is designed to be shipboard compatible. It can take-off from and land on current USMC aircraft carriers (LHD). However, it is not designed to fold into a package that fits on the elevator or in the hanger of a LHD.

Strategic Mobility. The longest over-water leg for global deployment is from Travis AFB, CA to Hickham AFB, HI (2,100 nm or 3,900 km). Prevailing winds are unfavorable. It is necessary to fly about 2,400 air nm to cover 2,100 ground nm. FTR can perform a rolling take-off from Travis AFB at a 125% overload gross weight. Additional fuel is carried in auxiliary fuel tanks. FTR can sling load a 22.4 ton MILVAN from a ship at sea level on a hot day (103 degrees F). FTR can lift substantially more at sea level than at 4,000 ft / 95 degrees F.

FTR Payload vs Range

Self-Deployment with Fallout Payload

Design for Tactical / Operational Mobility Mission

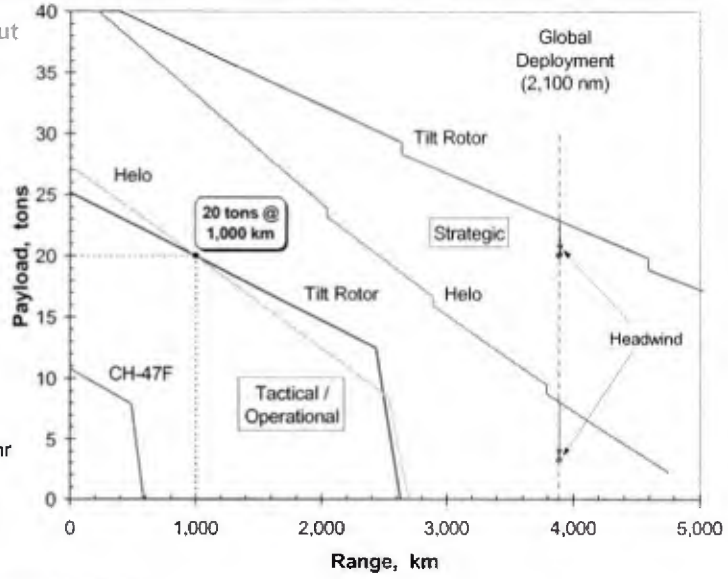
- **VTOL, 20 ton Load, 500 km Radius** (1,000 km Range), **Army Hot Day**
- **Sizes: Design Gross Weight, Rotor, Wing, Engines, Drive System, ...**

Let Strategic Mobility Fallout
- Deploy to Asia via Hawaii
- Longest Over-water Leg
- 2,100 nm (3,900 km)
- 85th Percentile Headwinds
- Fallout Payload

Ground Rules
- Rolling Take-Off
- Overload Gross Weight
- 125% of Design Gross Wt
- Best Cruise Altitude
- Auxiliary Fuel Tanks

Tilt Rotor Capability
- 21 tons to 3,900 km in 8.5 hr

Helicopter Capability
- 7 tons to 3,900 km in 16 hr



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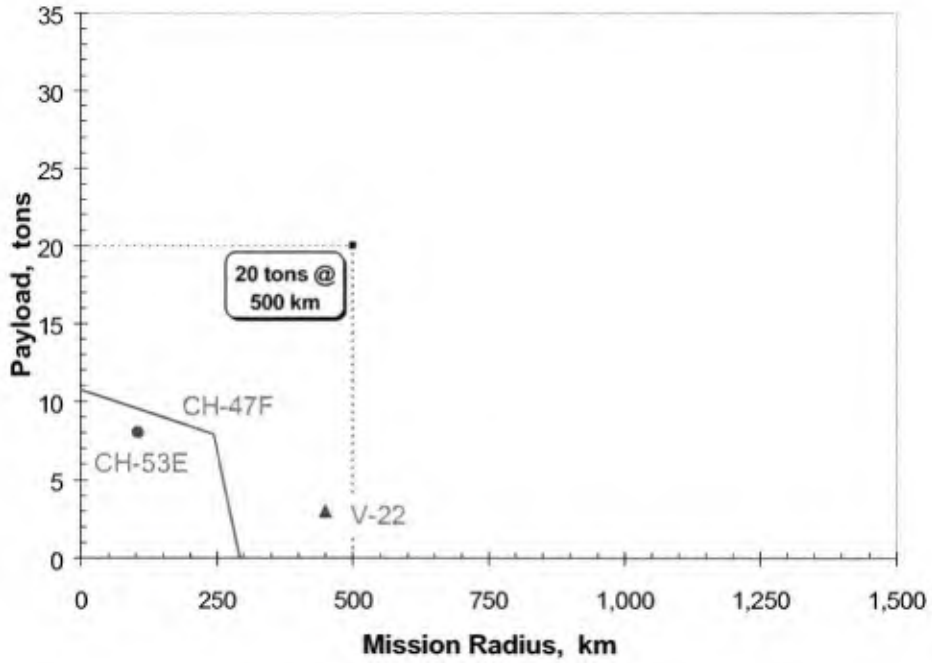
Design for Operational Mobility Mission. The VTOL operational mobility mission sizes most aspects of FTR (design gross weight, rotor, wing, engine, drive system, etc). This graph plots payload vs range (not mission radius). Thus the 20 tons at 500 km VTOL sizing mission radius is equivalent to 20 tons at 1,000 km range.

Let Strategic Mobility Fallout. The longest over-water leg for global deployment is from Travis AFB, CA to Hickham AFB, HI (2,100 nm or 3,900 km). This is the first leg of a deployment to Asia via Hawaii, Mid-way and Guam. Prevailing winds (e.g., 85th percentile, winter quarter) are unfavorable. They are shown as payload reducing arrows on the plot at 3,900 km range. The payload carried is a fallout. Both helicopter and tilt rotor FTR designs can reach Hawaii. The helicopter takes almost twice as long to reach Hawaii and carries 1/3 as much payload.

FTR can perform a rolling take-off from Travis AFB at an overload gross weight that is 125% of the VTOL design gross weight. This extra lift allows FTR to carry the additional fuel required, which is carried in auxiliary fuel tanks. FTR also cruises at best altitude instead of the low altitude used on tactical missions. This best altitude is 12,000 ft for the helicopter design and 24,000 ft for the tilt rotor design. The tilt rotor design is pressurized for high altitude operations, while the helicopter only has NBC overpressure.

Payload vs Mission Radius

Tactical / Operational - VTOL at 4000 ft / 95 °F



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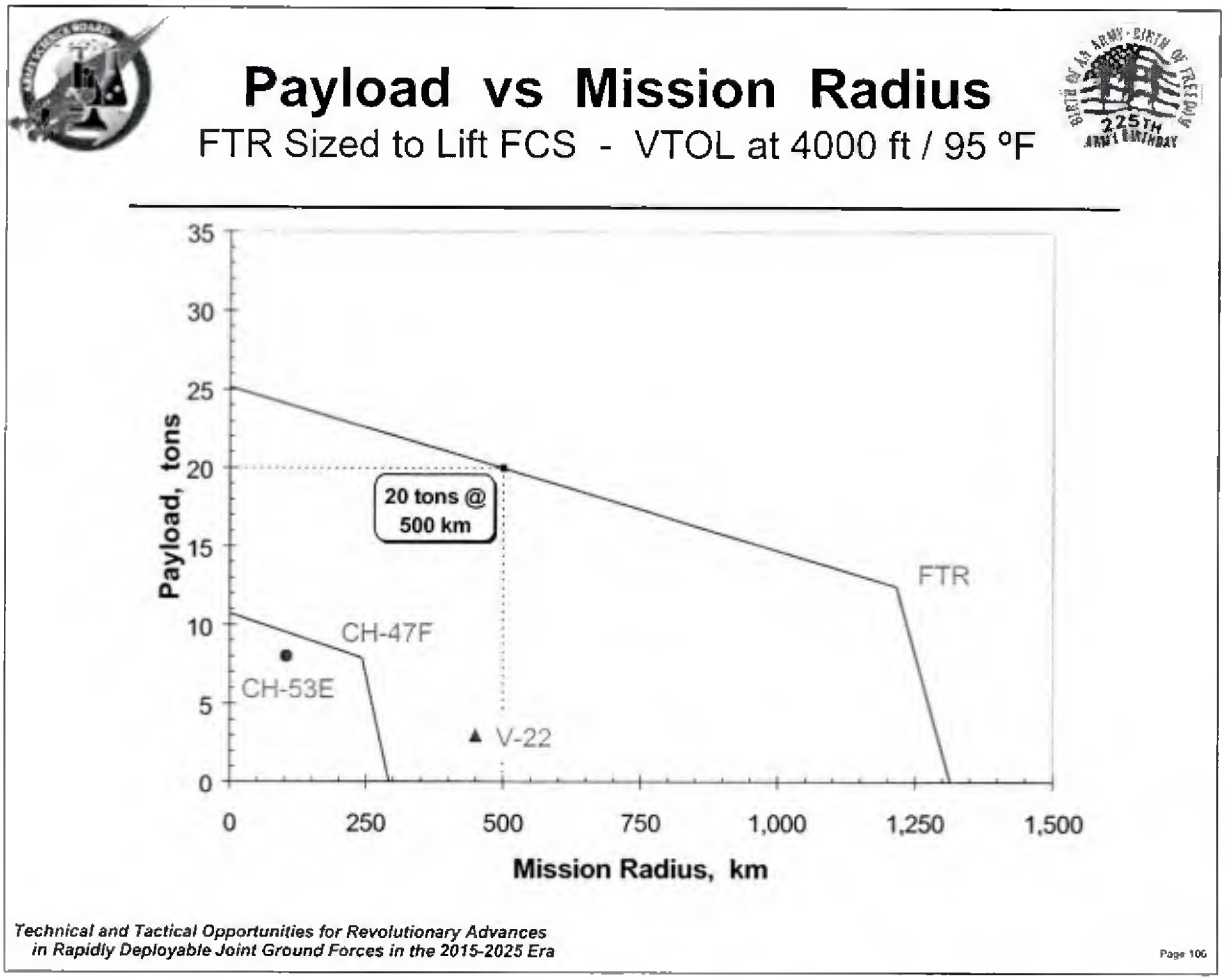
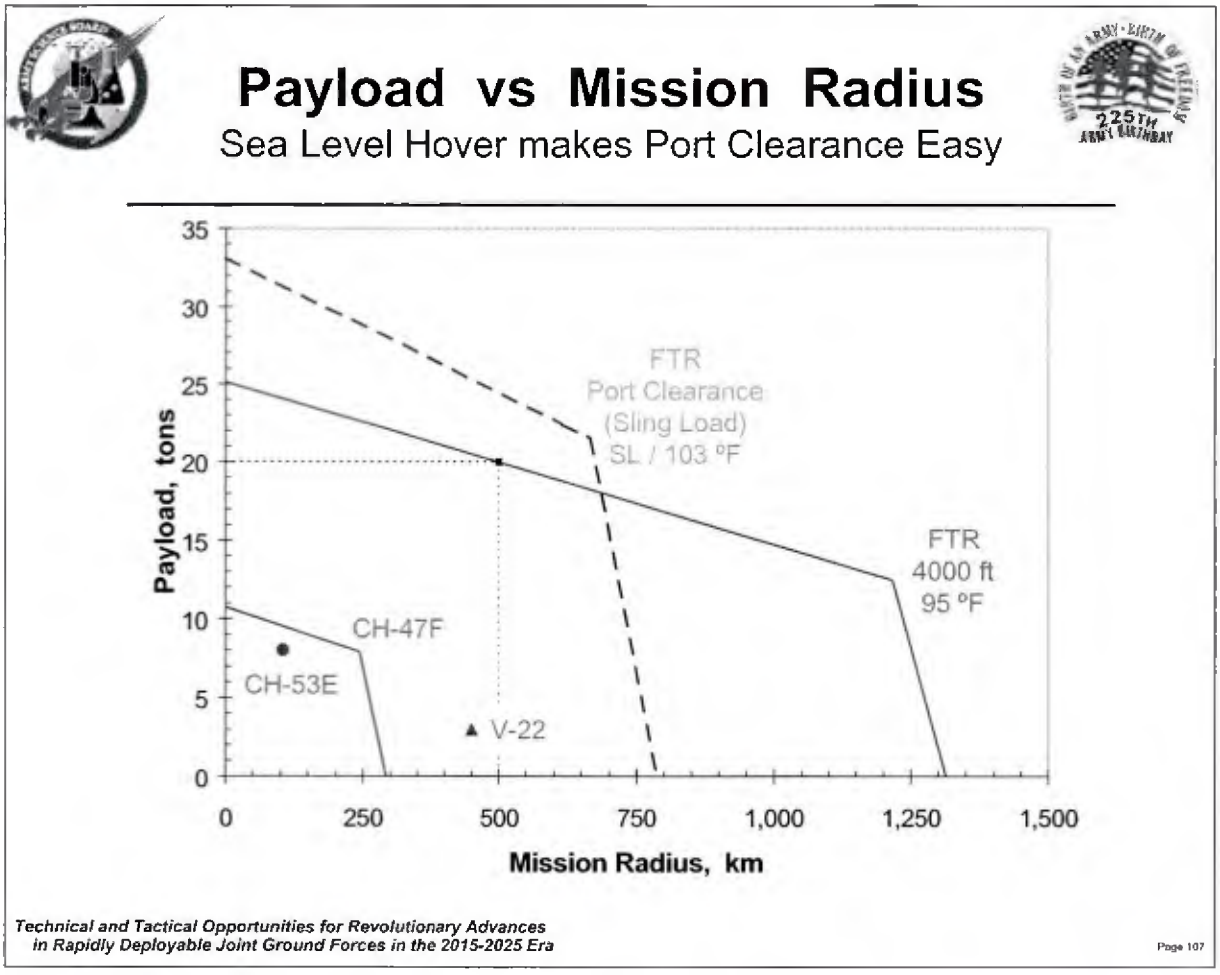
Payload vs Mission Radius. This graph plots payload vs mission radius. A mission radius of 250 km means the aircraft can fly 250 km to a mission mid-point and then return to base, without refueling. The difference in payload between zero mission radius and 250 km is the fuel burned to fly 500 km (250 km out and 250 km back).

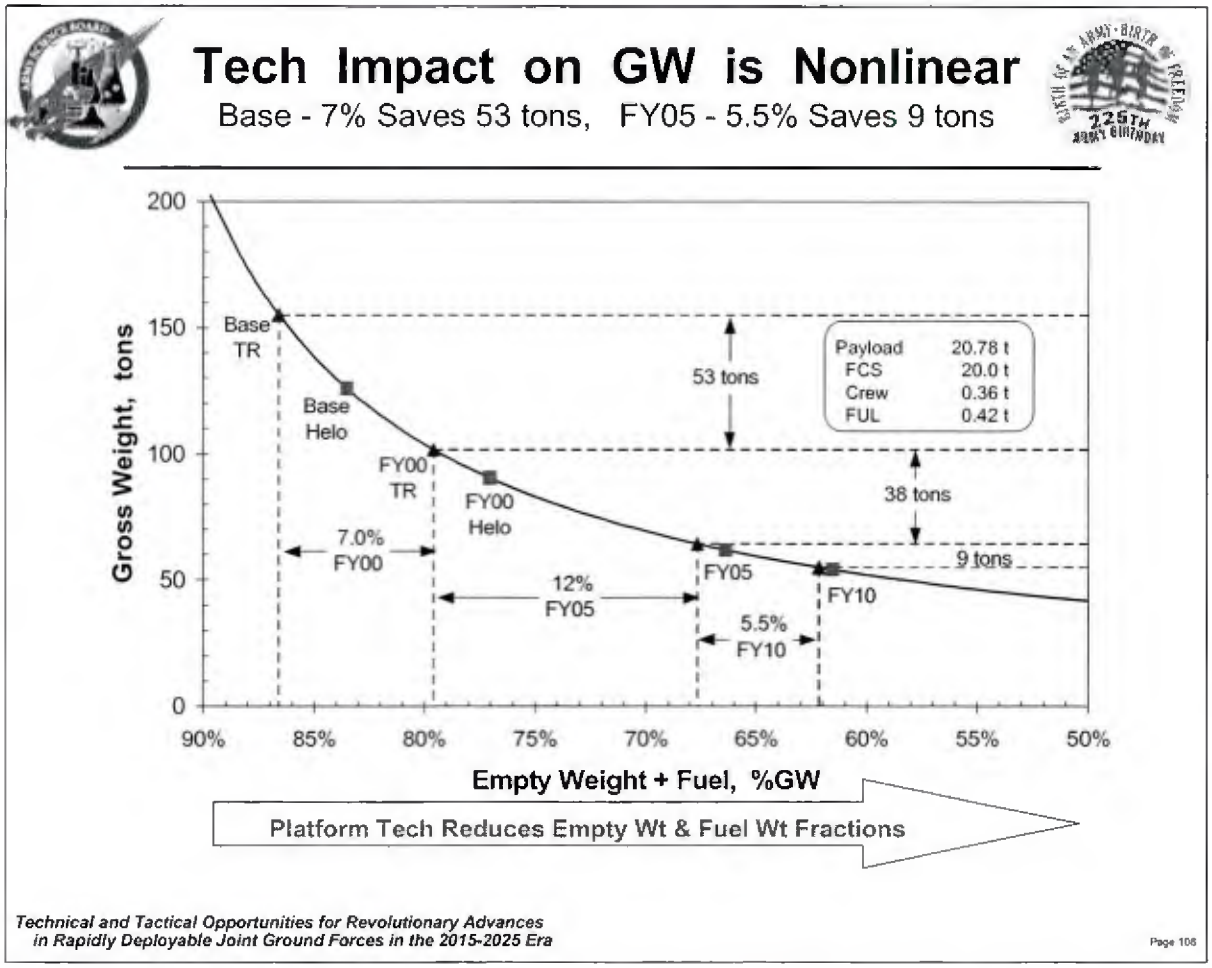
Tactical / Operational. Army hot day (4,000 ft / 95 degrees F) Vertical Take-Off and Landing (VTOL) capability provides over 90% probability of operation, world-wide. This 4k / 95 VTOL capability is essential tactical / operational missions. The notional FTR design point of 20 tons at 500 km mission radius is identified. The payload capability of existing rotorcraft (CH-47F, CH-53E and V-22) is much less than the 20 tons required to lift FCS. A Quad Tilt Rotor (QTR) based on V-22 engines, rotors and drive would lift about twice as much as V-22. This is still much less than 20 tons.



FTR Sized to Lift FCS. The tactical / operational (4k / 95) payload vs mission radius capability of a typical FTR designed to lift a 20 ton FCS 500 km is added to this graph. The FTR fuel tank is large enough allow a mission radius of some 1,200 km with a reduced payload.



Port Clearance. The port clearance mission payload vs mission radius capability of a typical FTR is added to this graph. The reduction in altitude from 4,000 ft to Sea Level (SL) has a greater impact on VTOL lift capability than the increase in ambient temperature from 95 degrees F to 103 degrees F. Thus the VTOL lift capability at SL / 103 is much greater than at 4k / 95. This extra lift allows carriage of enough fuel to overcome the extra drag of sling loading a MILVAN. The result is an ability to sling load a 22.4 ton MILVAN to a 650 km mission radius.

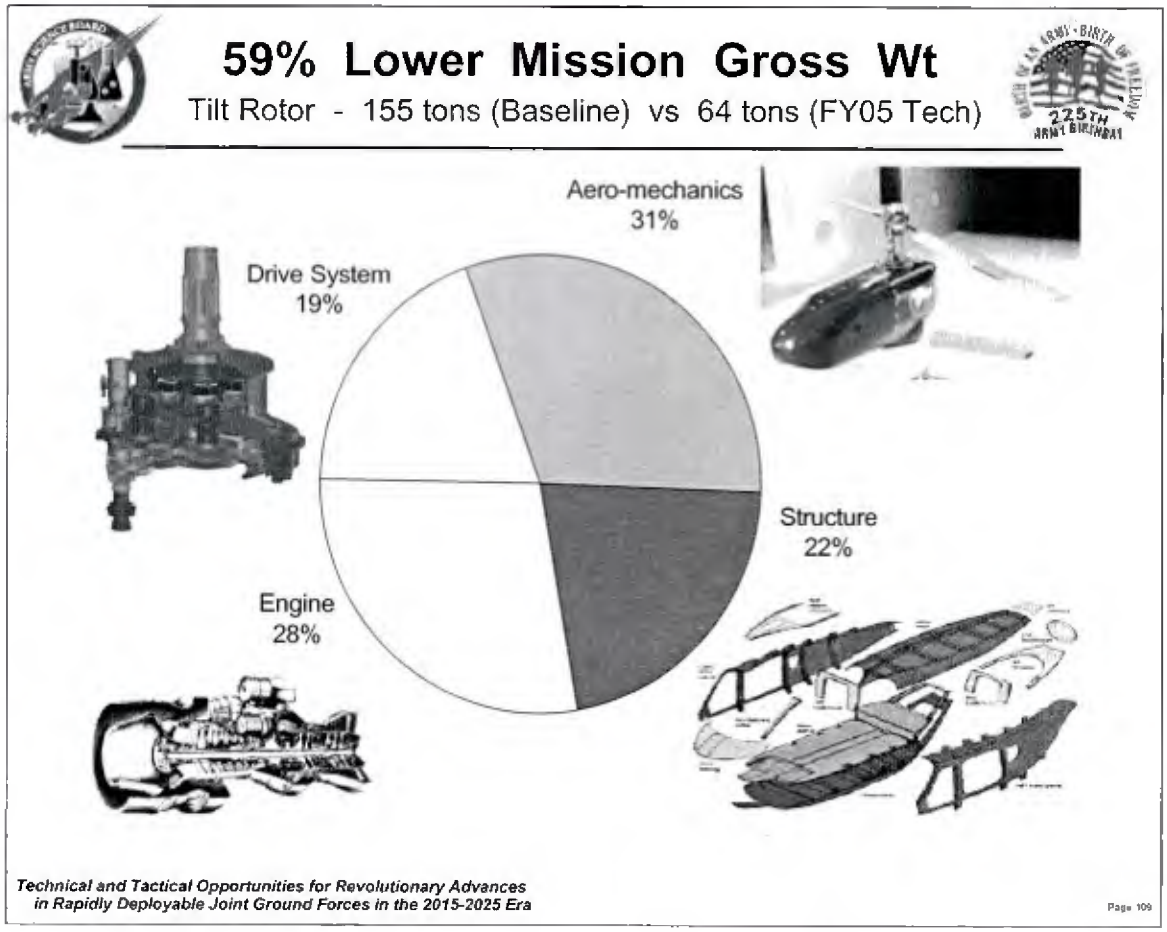


This graph demonstrates the substantial impact of improvements in rotorcraft (helicopter and tilt rotor) technology on the gross weight of the aircraft. These improvements are derived from rotorcraft drive systems, aero-mechanics, engines and structures.

The vertical axis on the graph represents the Gross Weight (GW) of rotorcraft designed to airlift 20.78 tons of payload out to a radius of 500 km. This payload weight includes the 20 ton Future Combat System (FCS), a crew weight of 0.36 tons and a Fixed Useful Load (FUL) of 0.42 tons. The FY94 baseline technology design results in a 155 ton tilt-rotor or a 128 ton helicopter. The horizontal axis represents rotorcraft empty weight plus fuel as a percentage of GW. Technology improvements can substantially decrease both empty weight and fuel weight as a percentage of GW. Since GW is Empty Weight + Fuel + Payload, this results in increased payload as a percentage of GW.

The graph shows a reduction in tilt-rotor GW of 53 tons from the FY94 baseline design due to technology improvements between FY94 and FY00. This is the result of payload increasing 7% from 13.5 % (100%-86.5%) to 20.5% of GW. By FY05, technology improvements will further reduce GW 38 tons by increasing payload 12% to 32.5% of GW. By FY10, technology improvements will decrease GW a further 9 tons by increasing payload 5.5% to 38% of GW.

Technological advances in the areas of rotorcraft drive systems, aero-mechanics, engines and structures can decrease FTR GW by 38 tons from 102 tons to 64 tons over the 5 year period from FY00 to FY05. This dramatic reduction provides a powerful argument to resource the technology programs that can yield the FY05 improvements in time to support a FTR development program. Beyond FY05, GW decrease due to advanced technology is much smaller. The technology improvement is about half as much (5.5% GW vs 12% GW). However, the reduction in GW is less than a quarter as much (9 tons vs 38 tons) because of the nonlinear impact of technology on GW.



What technologies investments are required to produce the FTR Gross Weight (GW) reductions displayed in the previous graph? As shown here, Aero-mechanics and engine technology advancements will produce the greatest payoff in GW reduction, followed by structure and drive system improvements.

Aero-mechanics advancements that provide the 31% of the total gross weight reduction include:

- Blade Loading
- Rotor Figure of Merit
- Rotor Cruise Efficiency
- Smart Actuators
- Parasite Drag Reduction
- Download Reduction
- Vibratory Load Reduction
- Active Controls
- Tail Volume Reduction
- Ice Protection Weight Reduction

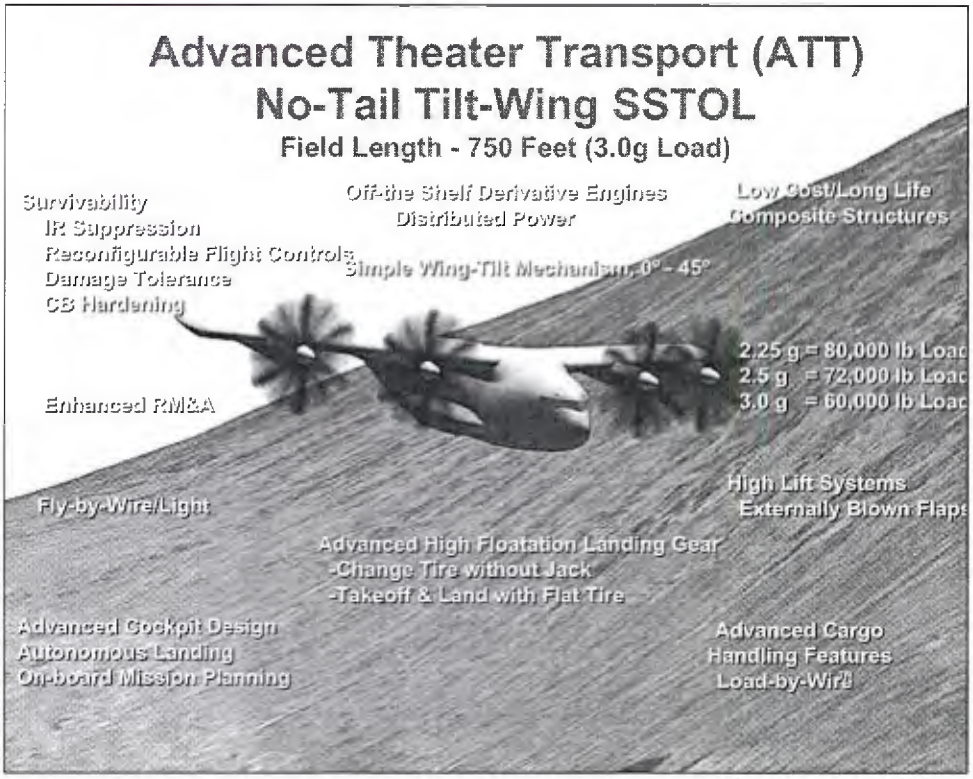
Gross weight reduction due to engine technology is 28% of the total GW reduction and results from decreases in specific fuel consumption and engine weight. Long range FTR missions cause fuel weight to be more important than engine weight. Both higher compressor pressure ratio (overall and per stage) and higher turbine inlet temperature (due to materials and cooling) contribute to increased fuel efficiency.

The structural contributions to gross weight reductions include:

- Structural Efficiency
- Manufacturing Efficiency
- Threat Protection Systems Weight
- Variable Area Nozzle

Nineteen percent of the gross weight reduction is due to drive system improvements. Enhanced materials and decreased drive system noise permit reduced weight not only in the drive systems themselves but also in the noise attenuation material used to limit the cabin noise to acceptable levels.

Technology improvement programs in these four areas must continue through FY05 in order to realize the FTR gross weight savings presented on the "Tech Impact on GW is Nonlinear" slide.



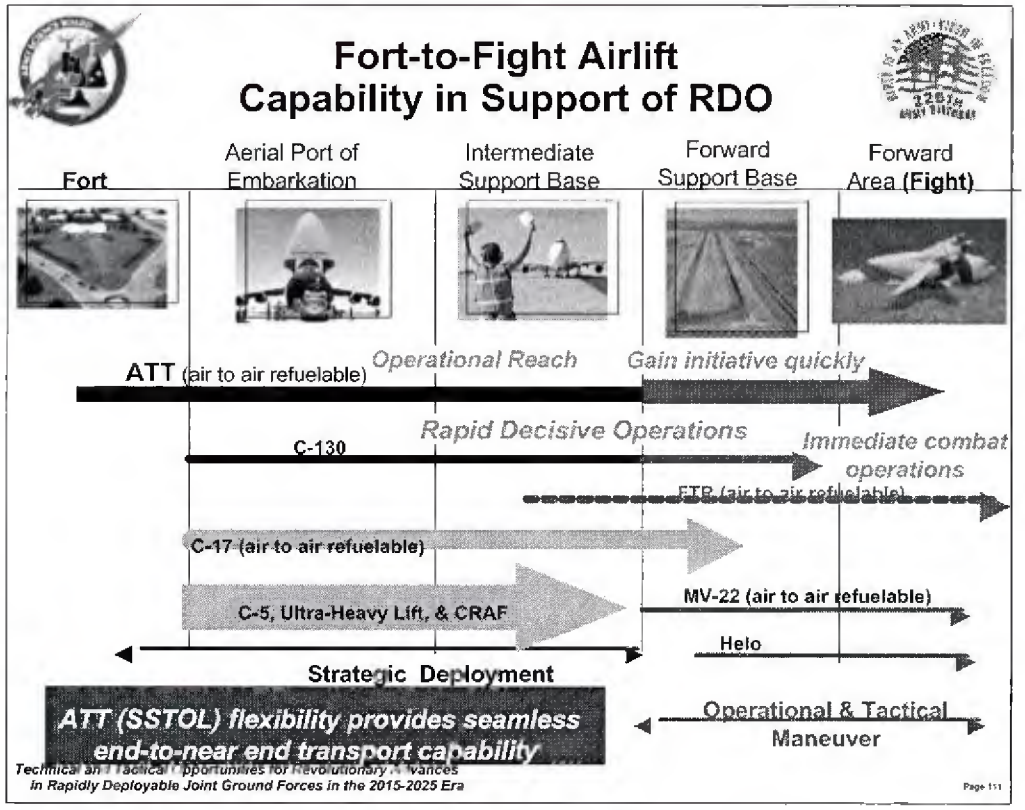
This is one of several possible concepts for Advanced Theater Transport (ATT). It is a Super Short Take-Off and Landing (SSTOL) aircraft capable of lifting 30 tons in SSTOL mode or 40 tons (two 20 ton FCS) from a runway at reduced load factor.

ATT would replace C-130 for intra-theater and tactical airlift with a significant increase in capabilities. This ATT concept doubles the strategic airlift payload to 40 tons (war emergency). It also doubles the cargo box width and increases the height. SSTOL tactical delivery of 30 ton loads would be possible into prepared airfields with 66% to 80% reduction in length compared to that required for current airlift aircraft.

An ATT with high floatation landing gear would increase the number of usable landing sites beyond prepared airfields, providing at least 750 feet of suitable land (1,250 feet of clear zone) is available.

An advanced aircraft cargo handling system will substantially decrease off-load and on-load times.

The USAF has not yet established a MNS for ATT.



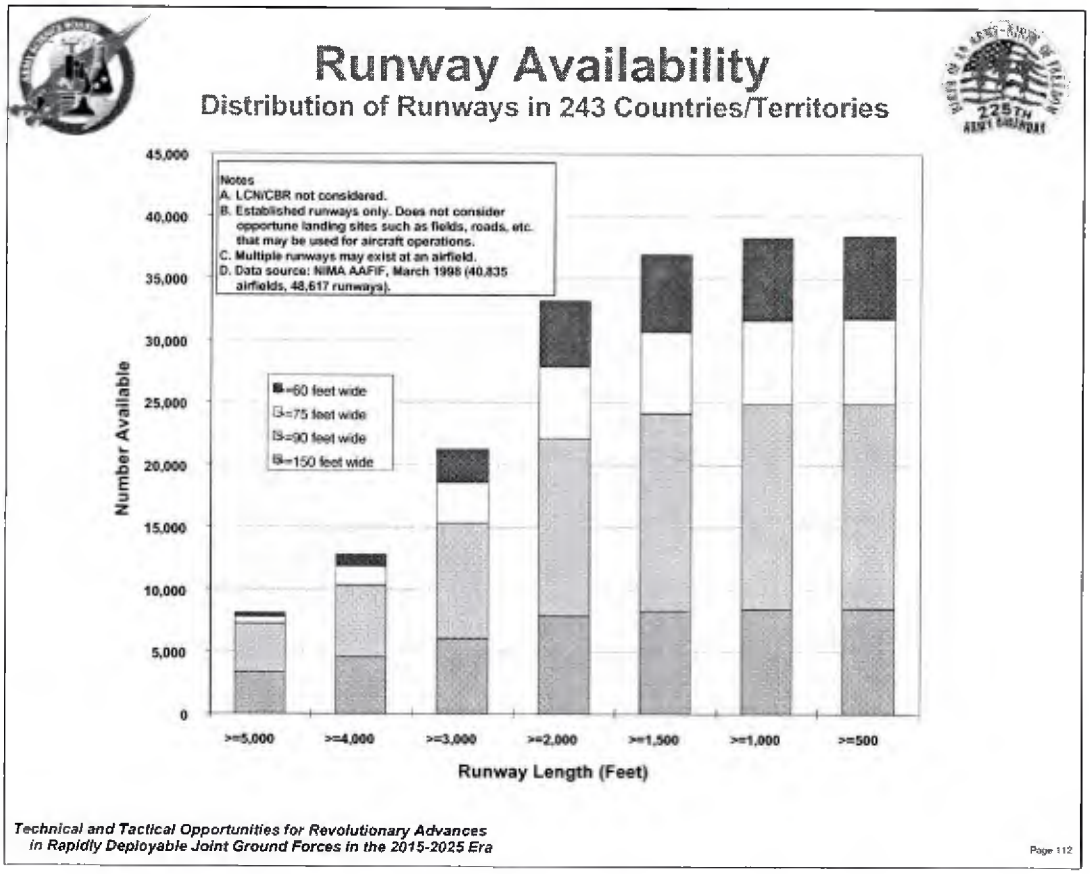
There are many different airlift aircraft with complementary capabilities. Together they transport soldiers and equipment from fort to fight.

Heavy strategic airlift aircraft are efficient at carrying large, heavy loads over long distances. However, they must operate from long runways in a low threat environment.

ATT could operate from fort to fight providing at least 750 feet of suitable land (1,250 feet of clear space) is available. FTR is the only aircraft capable of lifting large (20 ton) loads into and out-of areas without landing sites.

All of the proposed delivery systems (i.e., ATT, FTR and GPADS) may be necessary to provide the large capacity needed to handle the fast deployment pulse that strategic air and sea lift will deliver to forward support bases or ports.

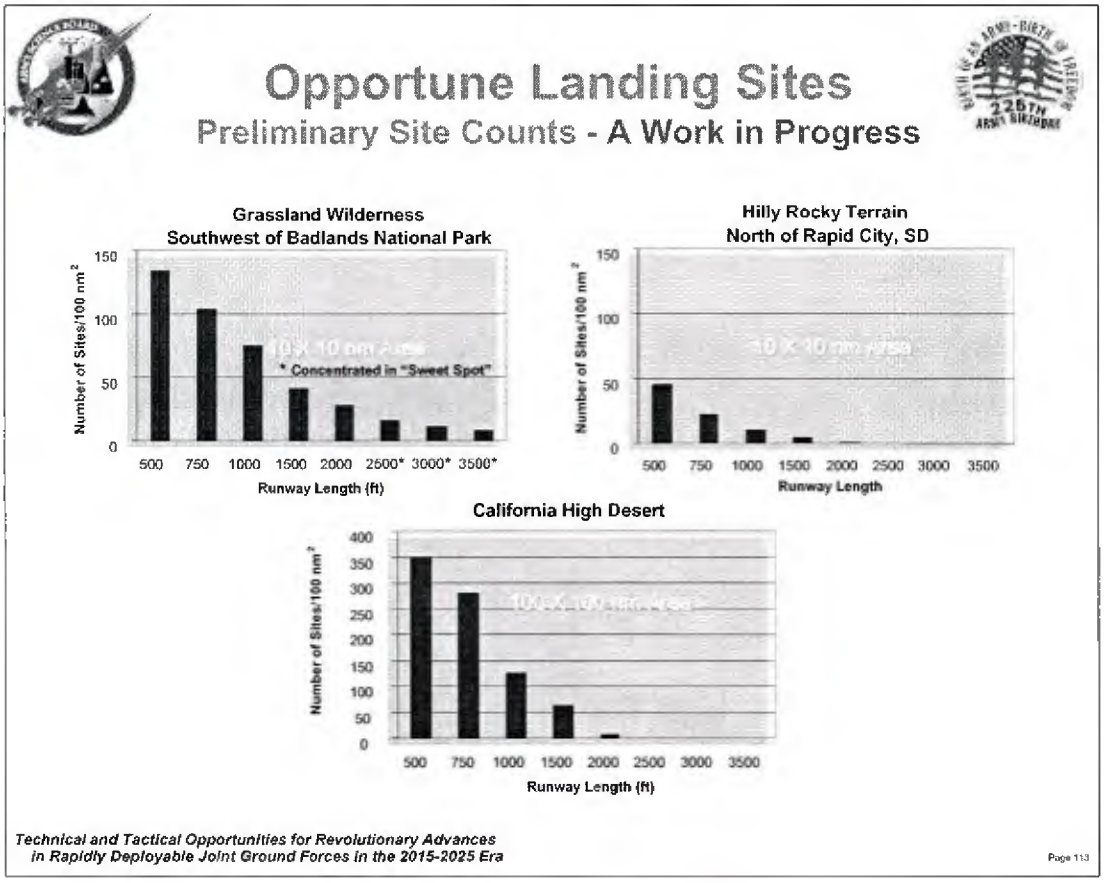
Speed of deployment would be increased with C-17, ATT or FTR by using air-to-air refueling when deployment time is critical and tankers are available.



Advanced Tactical Transport (ATT) significantly increases the number of usable existing runways, world-wide compared to C-5, C-17 and C-130.

In addition to operations from existing airfields, ATT could include the ability to operate from opportune landing sites such as roads and open fields. This would substantially increase the number of usable airfields.

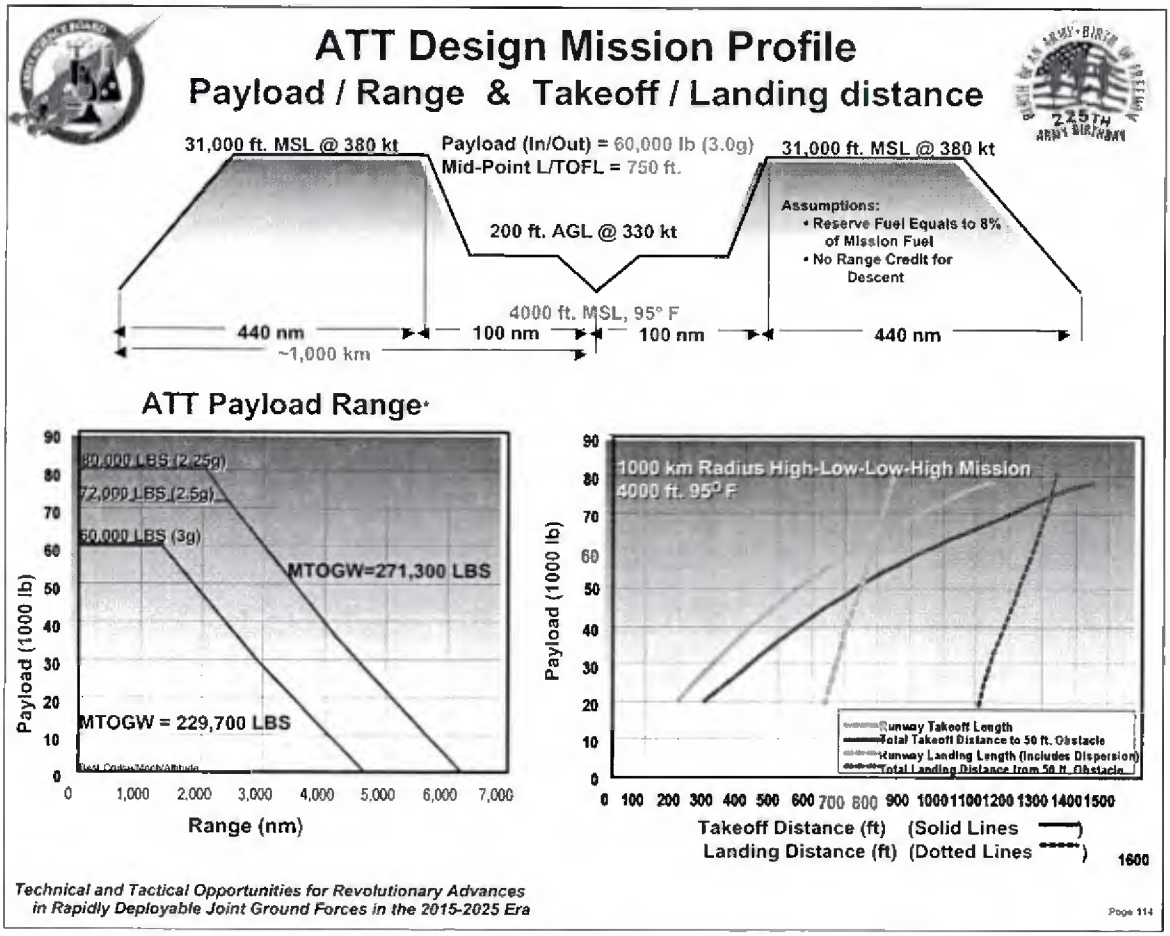
Operational use of landing sites must also consider Maximum On Ground (MOG) capabilities which could be the limiting factor in tactical deployment.



These are examples of the number of potential landing sites available in addition to prepared airfields. Actual operational use of these opportune sites would need careful consideration of soil weight bearing capability and potential obstacles near the site. Only FTR could provide maximum flexibility to deploy to the fight without the use of prepared runways or careful, pre-planned analysis of opportune landing areas.

The number of potential opportune landing sites shown here is based on analysis of commercial satellite imagery with only limited ground truth validation. Hence, this is a work in progress.

High floatation landing gear is critical to exploit opportune landing sites. High floatation implies both low ground pressure and high strength to support operations from rough landing sites.



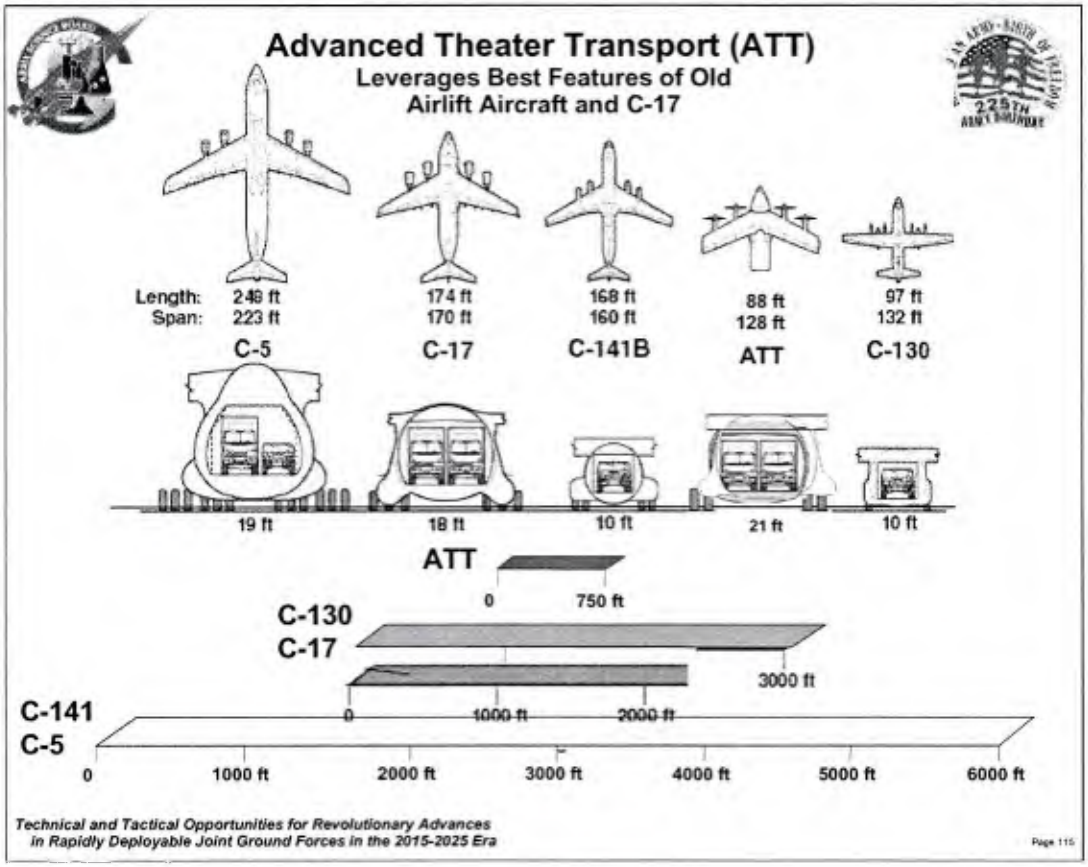
The ATT tactical mission is a 1,000 km radius, Hi-Low-Low-High profile with SSTOL landing and takeoff at mid-point. The mid-point and the 100 nm on either side of mid-point are at 4,000 ft MSL (above mean sea level) on a 95 °F day. The rest of the mission is flown at optimum altitude on a standard day. A 30 ton payload is carried both out and back. The ATT has full 3.0g combat maneuverability and low altitude dash speed capability under these conditions. The initial takeoff is from a long runway and is not a limiting factor.

The mid-point takeoff and landing performance plot is based on the ATT tactical mission profile. The mid-point gross weight includes enough fuel to fly a 1,000 km return leg plus a fuel reserve. The runway length (ground roll) required to carry a 30 ton payload is just over 750 ft for landing and just under 750 ft for takeoff. The total landing zone length (including runway) for landing over a 50 ft obstacle is just over 1,250 ft for a 30 ton payload. These numbers are based on wartime "assault rules" which allow the ATT to roll beyond the end of the runway after an engine failure.

The payload range plot is based on a deployment mission profile. The entire mission is flown at optimum altitude on a standard day, without a mid-point landing. This is more fuel efficient than the tactical mission profile. Hence the range for a 30 ton payload (1,300 nm or 2,400 km), is greater than the 2,000 km needed to fly a 1,000 km radius tactical mission.

ATT can deploy with a 40 ton payload (e.g., two 20 ton FCS) at a 2.25g load factor. Operation at the high Maximum TakeOff Gross Weight (MTOGW) allowed by a 2.25g load factor is restricted to emergency wartime situations due to structural limitations on turbulence penetration and maneuverability. This is a caution area in the flight manual.

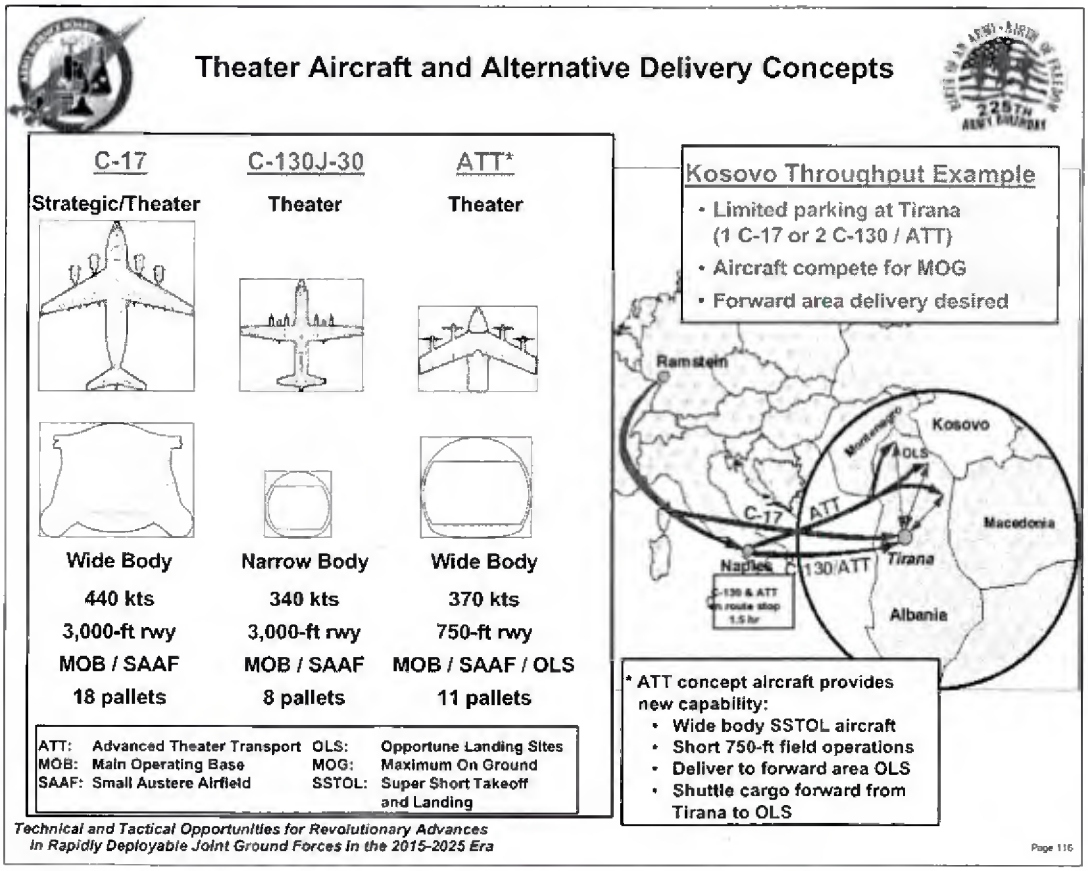
ATT can carry a 36 ton payload at its normal 2.5 g load factor. Normal operation has limitations on maneuverability and low altitude dash speed compared to combat operation.



Advanced Tactical Transport (ATT) - this illustrative design concept would replace C-130 for intra-theater airlift with a significant increase in capabilities. It doubles the strategic airlift payload to 40 tons. It also doubles cargo box width and increases the height. Tactical delivery of 30 ton loads would be possible into prepared airfields with 66% to 80% reduction in length compared to that required for current airlift aircraft.

ATT is a key part of an integrated airlift system from fort to fight. ATT provides the connecting link between strategic airlift from CONUS to theater and the tactical / operational vertical lift provided by FTR. The ATT:

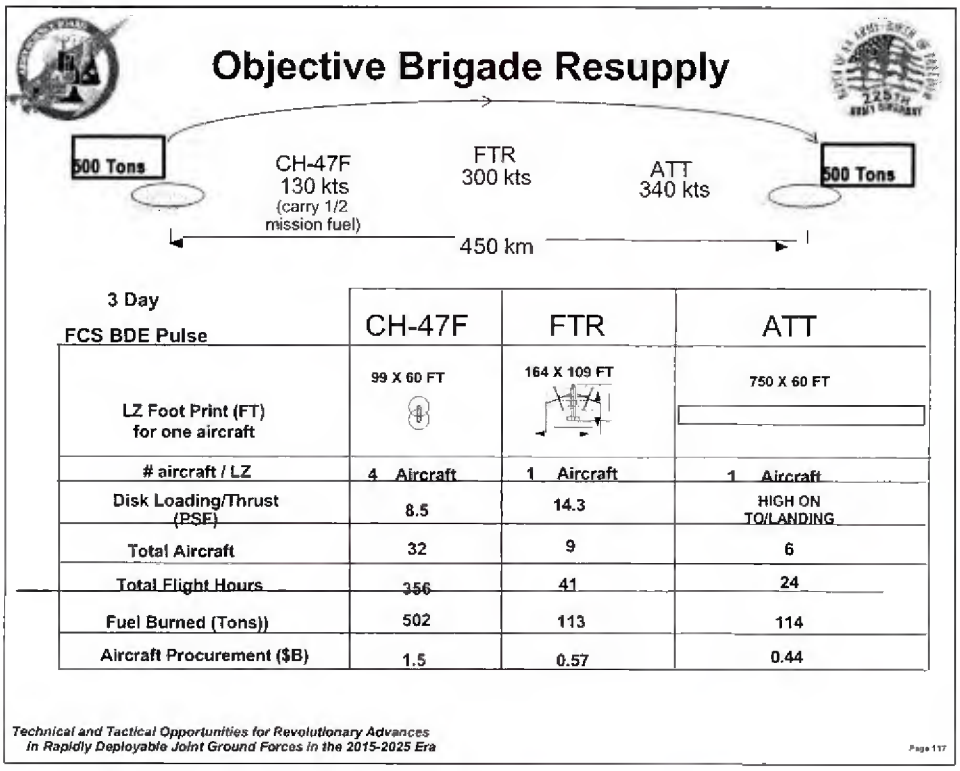
- Could be a Super Short Take-Off and Landing (SSTOL) aircraft (750 feet ground roll, with a 30 ton payload).
- Would include an advanced cargo handling system for much faster ground load and off-load times with no greater ramp foot print than C-130.
- Could supplement C-5 and C-17 strategic airlift capabilities in deployment, redeployment and resupply phases.
- Could include the ability to operate from opportune landing sites such as roads and open fields. This would substantially increase the number of usable airfields.



ATT could bypass Small Austere AirFields (SAAF) or staging MOBs (i.e., Rumstead / Naples) and go direct to opportune landing sites.

Once aircraft leave MOBs the limiting factor for forward area delivery will normally be Maximum On Ground (MOG). This will include limitations on ramp space at SAAFs and parking space at opportune landing sites.

ATT could have the same MOG as C-130 with 1.5 to 2 times the payload.

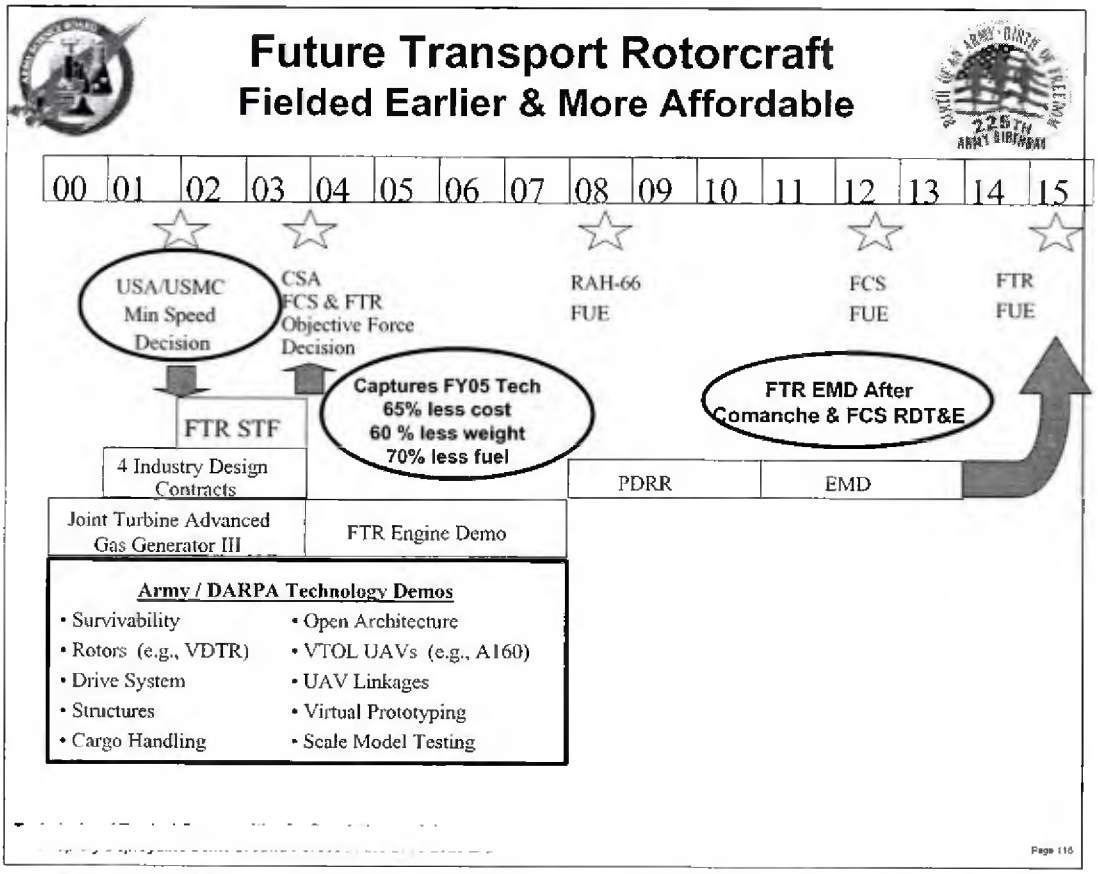


The Fort Knox designed Objective Force Brigade requires a 500 ton pulse of resupply every three days. This analysis assumes the Brigade will be located 450 km from its supply source and re-supplied exclusively by air using either CH-47F, Future Transport Rotorcraft (FTR) or Advanced Tactical Transport (ATT). Each aircraft is assumed to fly 12 flight hours per day. FTR lifts 20 tons and cruises at 300 knots, while ATT carries 30 tons at 340 knots. Both of these aircraft can complete a resupply sortie without refueling. CH-47F flies at 130 knots and must carry 2.64 tons of extra fuel for the flight back from the brigade, thereby reducing its payload to 5.26 tons.

With these payloads, FTR requires 25 sorties, ATT 17 sorties and CH-47F 95 sorties to complete the mission. This implies that the logistics footprint for one landing zone or runway to support the brigade must accommodate almost four times the number of CH-47F's versus FTR's. ATT will require a runway of 750 feet by 60 feet. The rotor/propeller disk loading determines the velocity of the downwash on the unprepared surface of the landing zone. CH-47F has a moderate disk loading of 8.5 psf (pounds per square foot), while FTR will have a disk loading of 10 to 14 psf and thus produce more dust and create a less comfortable working area under a hovering aircraft to manage sling loads. ATT propwash will be higher velocity than that for FTR with the wing at a 45 degree angle as the ATT lands and takes off, although the volume will be less.

In comparing the productivity of the three aircraft, the analysis illustrates that 32 CH-47F's are required for the mission versus 9 FTR's and 6 ATT's. The CH-47F's will fly 356 flight hours and burn 502 tons of fuel, while the FTR consumes 113 tons of fuel flying 41 hours. The ATT will consume 114 tons of fuel in the 24 flight hours it takes to complete the mission. The higher cruise speeds and greater payloads of the FTR and ATT enormously increase their productivity in comparison to the CH-47F and substantially reduce their aircraft fleet costs to complete the mission. At a unit fly-away-cost of $25 million, the CH-47F fleet required for the resupply mission will cost $1.5 billion. The FTR fleet will cost $570 million for 9 aircraft at $84 million each and the ATT fleet of eight aircraft will cost $437 million at $110 million each.

The primary insight from this simple analysis is that the productivity of an aircraft to perform a certain mission is much more important then just unit flyaway cost. The FTR is a substantially more effective vehicle for resupply at this distance than the CH-47F in terms of both fleet cost and the fuel used to accomplish the mission. The ATT is even more efficient than the FTR, but the ATT cannot land and takeoff vertically.



The Army will not have the intra-theater lift and mobility for FCS to fully realize its revolutionary forced entry, deep operations, vertical envelopment and reduced logistical footprint since the current Army plan does not field FTR until 2020. This is primarily due to affordability concerns and a lengthy requirement development plan.

So far, the USMC is not an active participant in the Army requirement and concept development processes. Due to the cost of the FTR program, it is widely believed that it must be at least a joint USA/USMC program to be affordable. The USMC, with support from DDR&E and DARPA, is exploring a Quad Tilt Rotor (QTR) concept consisting of a fuselage in the C-130 class and V-22 components. Although the QTR configuration has merits, developing it with V-22 components results in an aircraft that: (1) can not carry a 20 ton FCS in a VTOL mode; (2) does not support vertical envelopment with FCS; and (3) fails to capture the significant cost, weight and fuel savings that would be derived from the ongoing DoD rotorcraft technology demonstrations maturing in FY2005. The recommended FTR acquisition strategy (above) would field FTR 5 years sooner than currently planned while greatly improving its affordability, capabilities and chances of being at least a joint USA/USMC program.

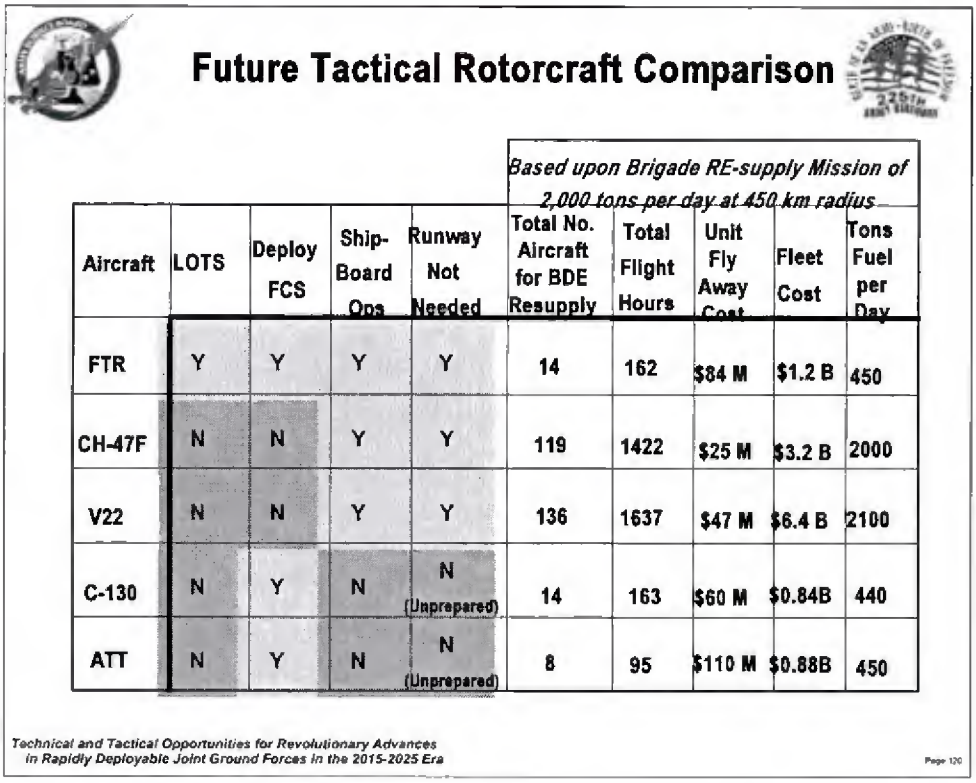
Greater program affordability is achieved by: (1) funding Engineering and Manufacturing Development (EMD) for FTR after RAH-66 Comanche and FCS development, (2) making FTR a joint USA/USMC program, (3) selecting the minimum speed early and (4) funding critical technology demonstrations to be ready for development.

Because the USMC will require FTR to be at least as fast as V-22 and because FTR must be at least a joint USA/USMC program to be affordable, the Army should decide the FTR minimum cruise speed by 2001. Selecting the minimum speed by 2001, will allow the Army to avoid multiple tech demos for multiple configurations, e.g. helicopter and tilt rotor. With the exception of recommended, but unfunded, industry and Government design study support ($5M/year for 24 months), the current Army technology demonstration program funding should be sufficient to achieve the required FY2005 Integrated High Performance Turbine Engine Technology (IHPTET),

rotor system, transmission, structures, survivability and cargo handling technology demos and virtual prototyping. The proposed strategy also leverages the currently funded DDR&E/DARPA variable diameter tilt rotor (VDTR), QTR design feasibility studies, A-160 UAV rigid rotor and DDR&E/University of Maryland QTR aerodynamic analysis.

Capturing these technologies in FY2005 is essential to making FTR affordable and survivable with acceptable risk for a FY2008 Program Definition/Risk Reduction (PDRR) start for critical components and FY 2011 EMD start. Compared to V-22 era technology, this will reduce fuel consumption by 70%, unit cost by 65% and weight by 60%.

This strategy selects the speed in 2001, awards multiple design study contracts, establishes a USA/USMC special task force (STF) to conduct requirement and concept development, conducts a Joint Warfighting Capability Analysis (JWCA) and focuses the technology demonstrations. Doing so will make the essential FTR information available in time for the FY 2003 Chief of Staff's FCS decision.



Future Tactical Rotorcraft Comparison

Aircraft	LOTS	Deploy FCS	Ship-Board Ops	Runway Not Needed	Based upon Brigade RE-supply Mission of 2,000 tons per day at 450 km radius: Total No. Aircraft for BDE Resupply	Total Flight Hours	Unit Fly Away Cost	Fleet Cost	Tons Fuel per Day
FTR	Y	Y	Y	Y	14	162	$84 M	$1.2 B	450
CH-47F	N	N	Y	Y	119	1422	$25 M	$3.2 B	2000
V22	N	N	Y	Y	136	1637	$47 M	$6.4 B	2100
C-130	N	Y	N	N (Unprepared)	14	163	$60 M	$0.84B	440
ATT	N	Y	N	N (Unprepared)	8	95	$110 M	$0.88B	450

This table compares the capabilities of Future Tactical Rotorcraft (FTR) with CH-47F (Chinook), V-22 (Osprey), C-130, and a concept for a C-130 replacement called the Advanced Tactical Transport (ATT). The first column indicates the capability for Logistics Over the Shore (LOTS). Only the FTR has the vertical lift capacity to off-load the standard 22.4-ton container from surface ships.

In the second column only CH-47F and V-22 cannot deploy the projected 20 ton Future Combat System (FCS). All three Vertical Takeoff and Landing (VTOL) aircraft: FTR, CH-47F and V-22, can conduct Ship-Board Operations from Navy helicopter carriers. The fourth column shows the C-130 and ATT require at least unprepared runways for takeoff and landing.

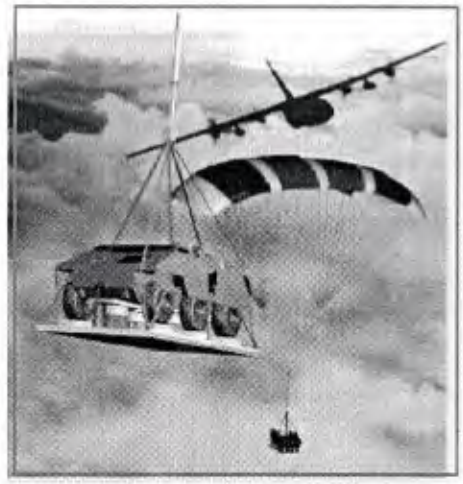
The last five columns in the table refer to the same scenario covered in the "Objective Brigade Resupply" slide, except for 2,000 tons of resupply per day. The analysis assumes the Brigade will be located 450 km from its supply source and re-supplied exclusively by air using either the FTR, the CH-47F, the V-22, the C-130, or the ATT. Each aircraft is assumed to fly a total of twelve flight hours per day. The FTR lifts 20 tons of payload and cruises at 300 knots, V-22 carries 2.7 tons at 220 knots, the C-130 carries 21 tons at 285 knots, while the ATT carries 30 tons at 340 knots. These four aircraft can complete a resupply sortie without refueling. The CH-47F flies at 130 knots and must carry 2.64 tons of extra fuel for the flight back from the brigade, thereby reducing its payload from 7.9 to 5.26 tons.

In comparing productivity, the analysis illustrates that the FTR is comparable with the C-130 and the ATT due to a similar cruise speed and payload. The CH-47 is hampered by a significantly slower cruise speed and less than half the FTR payload, while the V-22 suffers from a drastically smaller payload. The FTR fleet required for the resupply mission will cost $1.2 billion for 14 aircraft and is only 50% higher in cost than the C-130 and ATT resupply fleets at $0.84 and $0.88 billion respectively. The last column displays the fuel consumed to accomplish the mission, and gives an indication the operating costs associated with each aircraft. Both the CH-47 and the V-22 are significantly more costly in terms of fuel than the other three.

The primary insight gained from this straightforward analysis is that an aircraft fleet's productivity associated with a particular mission is a substantially more important factor than unit flyaway cost. The FTR is a markedly more effective vehicle for resupply at this distance than either the CH-47F or the V-22 in terms of both fleet cost and the fuel consumed. The FTR is comparable in efficiency to both the C-130 and the ATT, while also possessing the ability to takeoff and land vertically.

Precision Air Insertion

- **Full Scale Concept for Guided, Autonomous Precision Heavy (42,000 Lbs) Air Insertion of A Future Combat Vehicle Payload**
- **20 Km Offset and 100 Meters Circular Error Probable (CEP) High Altitude Accuracy**
- **Synergistic Vehicle / Airdrop System Integration**
- **Strategic Deployability To Tactical Level**
  - Immediate Tactical Deployability
  - Reduced LZ / DZ Detectability
  - Reduced Ground Threat Vulnerability
  - Rapid Repositioning of the Force, DZ Clearing



High Altitude, Offset GPS-Based Guidance Drive-On / Drive-Off

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One of the major impediments to deploying a force is the availability of real estate at the receiving end. Airports (improved or unimproved) typically cannot service more than 1 to 3 airplanes at a time. Seaports are typically not available, and over the shore capability is limited to Sea State 3 or less.

In order to deliver a Brigade size force within 96 hours, and a pulse of 6 hours, avoiding airports and seaports is almost mandatory. One method for doing this is to develop and utilize the Future Transport Rotorcraft (FTR) which provides a Vertical Precision Air Insertion capability and has been detailed elsewhere.

However, there does exist technology which can use current air lift capability such as the C-17 and C-130 as shown above and insert payloads with precision. The technology is developed by the Army's Natick Center and NASA. For example, NASA is developing a man-rated guided parafoil for the X-38 crew return vehicle. Natick is developing Precision Air Insertion capability which would initiate the insertion as far as 20 KM from the final ground location. A proposed FCS version could carry 42,000 lb, equivalent to a C-130 payload. In addition, the insertion error can be made very small down to possibly 10 meters but always within 100 meters using GPS. Current Natick work on Precision Heavy Air Insertion is not man-rated. Hence it is substantially less expensive than the man-rated NASA parafoil.

Programmatically however, the Army Natick program is severely under funded. In order for this capability to be available, an infusion of resource and priority is required.

Findings

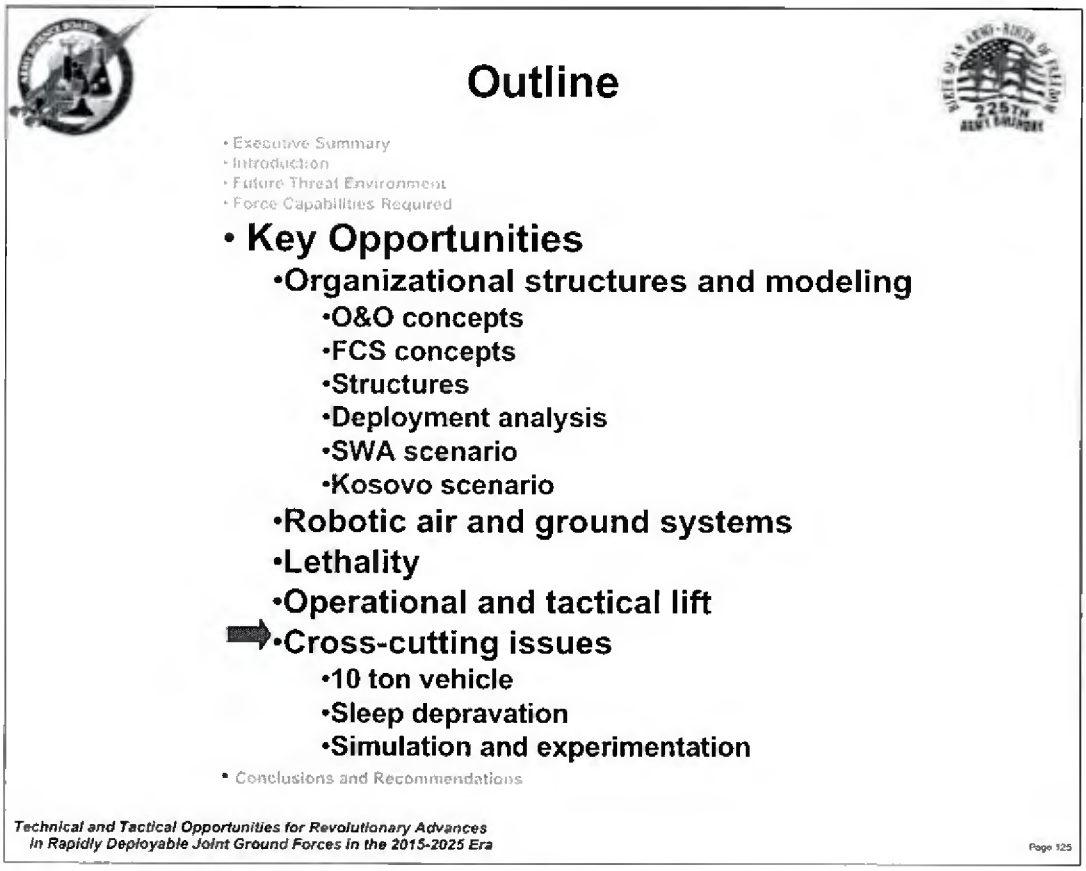
- FTR in 2015 adds revolutionary operational & logistic advantages to FCS
  - Deep vertical envelopment with heavy force capability
  - Agile intra-theater positioning
  - Prevent enemy set
  - Forced entry
  - Synchronized attack on multiple centers of gravity
  - Global self-deployment
  - By-pass air & sea ports
  - Logistics Over The Shore (LOTS)
  - Vertical lift extension for C-130 payloads
- FTR development program
  - Tech demos by 2005 reduce: cost 65%, weight 60% & fuel 70%
  - Survivability and affordability are critical
  - FTR only affordable as USA/USMC program. USA/USMC should decide min cruise speed by 2001 to save S&T & achieve 2015 FUE
  - FTR RDT&E funding 'bow wave' follows Comanche & FCS development
  - FTR requirements & concept studies should be in time for 2003 FCS objective force decision whether to proceed with FTR

Findings (continued)

- **ATT would be part of an integrated airlift system with FTR**
  - **Replaces C-130 for intra-theater / tactical airlift**
  - **Complements C-5 and C-17 strategic airlift**
  - **Substantially increases cargo weight and volume capacity**
  - **Significant increase in operational landing and takeoff sites world-wide**

Recommendations

- Army, USMC & USAF coordinate FTR & C-130 replacement (ATT)
- By 2001 award multiple contracts to explore concepts (2 yrs, $2M each)
- Initiate in 2001, FTR Task Force with CSA/USMC Commandant or Joint charter in time to support FCS objective force decision in 2003
- Select FTR min. speed by 2001 to focus S&T investment, capture FY 2005 technology & achieve 2015 FUE
- Implement S&T investment for FUE 2015 FTR strategy
  - Integrated survivability (active, passive and information dominance)
  - Rotorcraft & IHPTET Tech Development Approach Plan
  - Variable Diameter Tilt Rotor (VDTR)
  - QTR configuration design studies & analysis
  - Scale flight demos
  - Scale up of A-160 component technologies
- Invest in precision air insertion capability to complement FTR & USAF capabilities
- Army, USMC & USAF need to synch FTR, ATT & C-130 replacement requirements & concept formulation



- This section examines cross-cutting issues.

Why Have a 10-Ton Vehicle?

- Having a subset of the force at 10 tons or less enables
  - Vertical envelopment CONOPS with existing rotary lift
  - Potential for reduce overall lift and logistics support
- 10-ton vehicles also have potential shortfalls
  - Limited weight and space for armor protection, weapons and mission payload
  - Additional support requirements (spares, training, etc.) class of vehicles

10-ton vehicle could offer benefits if employed properly-- at present, they seem best suited for unmanned and noncombatant roles

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We looked at 10-ton vehicles as an enable of vertical envelopment and with an eye to reducing the amount of heavy lift needed. In particular, until such time as an FTR is fielded, the only way to reposition the force rapidly on the battlefield is by keeping system weight below 10 tons.

Having explored 10-ton concepts, we find that they are severely limited in terms of protection, armament capacity, and useful munition payload. They may also impose a logistics penalty by having a second unique class of vehicles.

All things considered, 10-ton vehicles can be an asset if sued properly; for example, as unmanned vehicles or in rear echelon and noncombatant roles.

The charts that follow provide additional information on our analysis, findings and recommendations.

10 Ton Study and 20 ton Variants

Implications [1]		
Cases	**10 Ton Platform**	**20 Ton Platform**
Case 1: Armed with Main Gun or Missiles	•Armor: Small arms (all around) •Other Protection: None, no wt. Available •Main gun not possible (missiles only)	•Armor: Med. Cannon/RPG (crew frontal), Hvy Mach Gun (180 deg) •Other Protection: KE APS (12) CE APS (8), Warning Receivers, Radar, Smoke •Gun and/or missiles possible
Case 2: Armed with only Limited Self Protection	•Armor: Small arms (all around), Heavy machine gun nose only •Other Protection: CE APS (4), Warning Receivers, Radar, Smoke [2] •Mission payload is limited (<500 lbs)	•Armor: Med. Cannon/RPG (crew frontal), Hvy Mach Gun (180 deg) •Other Protection: KE APS (12) CE APS (8), Warning Receivers, Radar, Smoke •5 ton weight margin available[4]
Case 3: Case 2 with Drastically Reduced Profile and Volume	•Armor[3]: Small arms (all around), Heavy Machine Gun/enhanced artillery (crew) •Other Protection: None, no volume available •1 person crew, electric drive but not hybrid	•Armor: Med. Cannon/RPG (180 deg. crew) •Hvy Mach Gun (180 deg) •Other Protection:KE APS (12), CE APS (8), Warning Receivers, Radar, Smoke •1 person crew

1-Armor levels assume the use of advanced armor/structure materials
2-Full heavy machine gun protection for crew is possible at the expense of CE APS
3-Vehicle length shortened by 30 inches resulting in 4x4 configuration and reduced mobility with the Heavy Machine Gun Protection
4-Weight margin can be used for additional payload, applique armor (C130 width restriction requires armor to be removed for transport)

This chart illustrates some parametric variations based around the 10-ton concept variant and the 20-ton FY99 ASB concept.

- In Case 1, the C2 mission equipment and self protection weapon from the 10-ton concept variant were replaced with a CKEM missile system. Because of the relatively heavier weight of the missile, system in comparison to the C2 mission equipment, the vehicle could not accommodate an APS system or armor beyond the small arms level.
- In Case 2, the 20-system weight is reduced to 15 tons due to reduction in weight of the armament. This weight savings could be retained or used for additional payload, or for additional armor if it is bolt-on/bolt-off (width restrictions for C-130 preclude thicker integral armor).
- In Case3, the internal volume for the 10-ton vehicle was reduced by removing a crew person, making the vehicle a 4x4, reducing fuel, and removing the hybrid capability (i.e., batteries) from the electric drive. This saves two tons, but the weight savings cannot be used to enhance the armor protection, because it would degrade the mobility of the 4x4 chassis.
- In Case 3, the internal volume for the 20-ton vehicle was reduced primarily by removing one of the crew persons. Additional armor was "wrapped" around the remaining crew person which extends the arc of armor coverage around the crew.
- The bottom line finding for 10-ton vehicles is that you can only get one of the following: lethal armament, or a reasonable amount of internal payload, or machine gun-level armor protection. At 20 tons, you can have all three and in greater amounts.

10 Ton Study and 20 ton Variants Assumptions (Backup)

General
- Study based on projections from the 10 ton concept developed for ASB 2000 Summer Study and for the 20 ton concept developed for the ASB 1999 Summer Study.
- Results are for specific described configurations
- Detailed concept studies required

Case 1:
- 10 tons
- 6X6 vehicle, 2 crew, w/missiles (10), OCSW w/272 rds., no medium cannon
- 12.75 lbs/sq.ft. all around (depending on technology, protection ranges from 7.62 ball to 7.62 AP)
- 120 gallons fuel

10 Ton

Case 2:
- 10 tons
- 6X6 vehicle, 2 crew, w/o missiles, OCSW w/272 rds., no medium cannon, 7.3 ton GVW
- 12.75 lbs/sq.ft. all around (depending on technology, protection ranges from 7.62 ball to 7.62 AP)
- 25 lbs/sq.ft. crew (composite ceramic) (nose only, no skirts or top enhanced)
- Weight savings is 1400 lbs. over concept 1a (provides volume + wt. For CE APS + warning receivers, radar, smoke).
- 150 gallons fuel

Case 3:
- 7.7 tons
- 4X4 vehicle (HMMWV tires), 1 crew, w/missiles (10), OCSW w/272 rds., no batteries (except 1 starting battery)
- 12.75 lbs./sq. ft. all around (depending on technology, protection ranges from 7.62 ball to 7.62 AP)
- Heavy Machine Gun protection for crew at 8.7 tons, but severe mobility limitations
- 30 inches shorter
- 100 gallons fuel
- No volume remaining for CE APS or hit avoidance, or NBC?

Case 1:
- 8X8 vehicle, 2 crew, w/missiles (12), OCSW w/200 rds., 35mm cannon (80 rds)
- 25 lbs/sq.ft. (CAV or Tech Base)
- 65 lbs/sq.ft. 60 deg frontal armor (upper glacis), 160 lbs/sq. ft. hull front
- 160 lbs/sq.ft. (hull front)

20 Ton

Case 2:
- Same as 2a, 2 crew except w/o missiles, 35mm cannon
- 14.5 tons GVW, cannot increase protection - width constraint for C130
- Medium cannon protection could be added for 2 tons but vehicle would exceed width restriction for C130 transport
- 2 person crew station + structure & mobility components - 100 inches

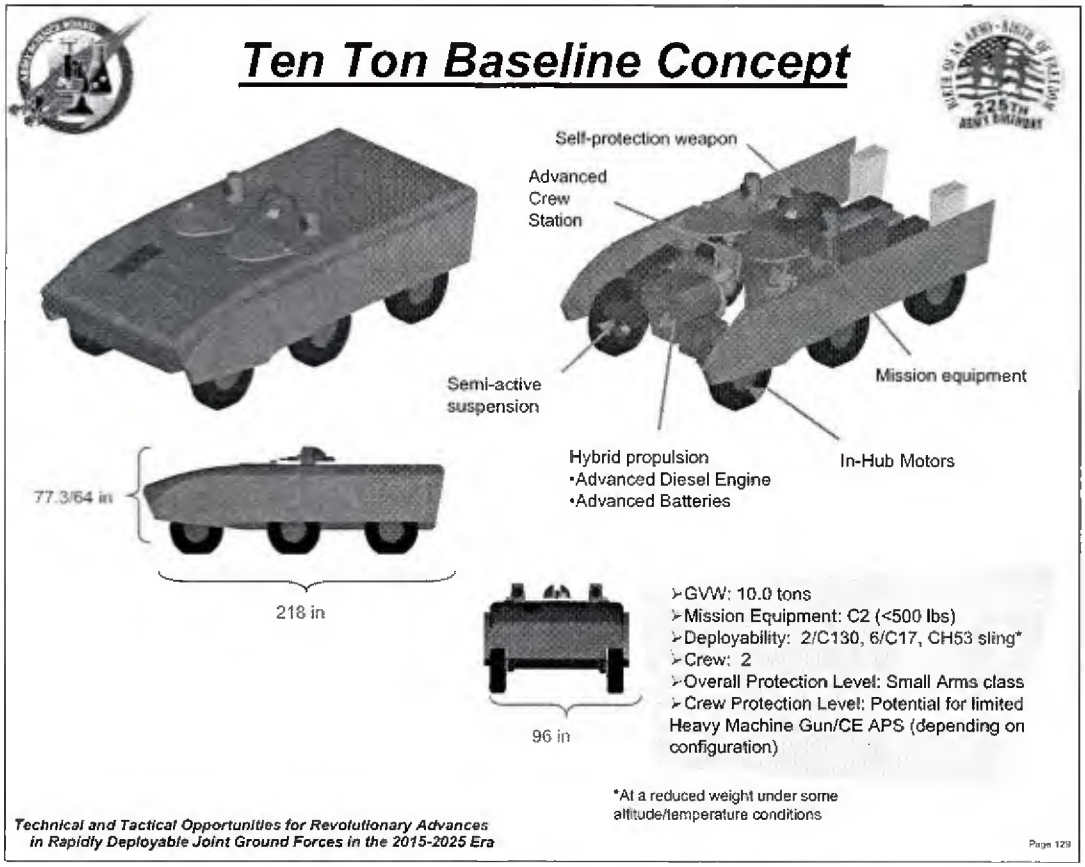
Case 3:
- Same as 2a, except 1 crew + 25 inches increase in armor around crew
- 160 lbs/sq.ft. (180 deg) to back of crew compartment only

This slide shows the assumptions behind the three cases for the 10-ton and 20-ton concepts.

Case 1 for 20 tons and Case 2 for 10 tons were evaluated in detail. The other 5 variations were examined as excursions.

At 10 tons, eliminating the main armament (going from Case 1 to Case 2) allows more weight to be assigned to armor protection. But making the vehicle smaller (going from Case 2 to Case 3) does not allow additional armor to be added, because the smaller vehicle is severely limited in terms of carrying capacity and mobility.

At 20 tons, there is adequate design margin so that a choice among lethality, protection and payload is not necessary. Tactically useful levels are all three are possible.

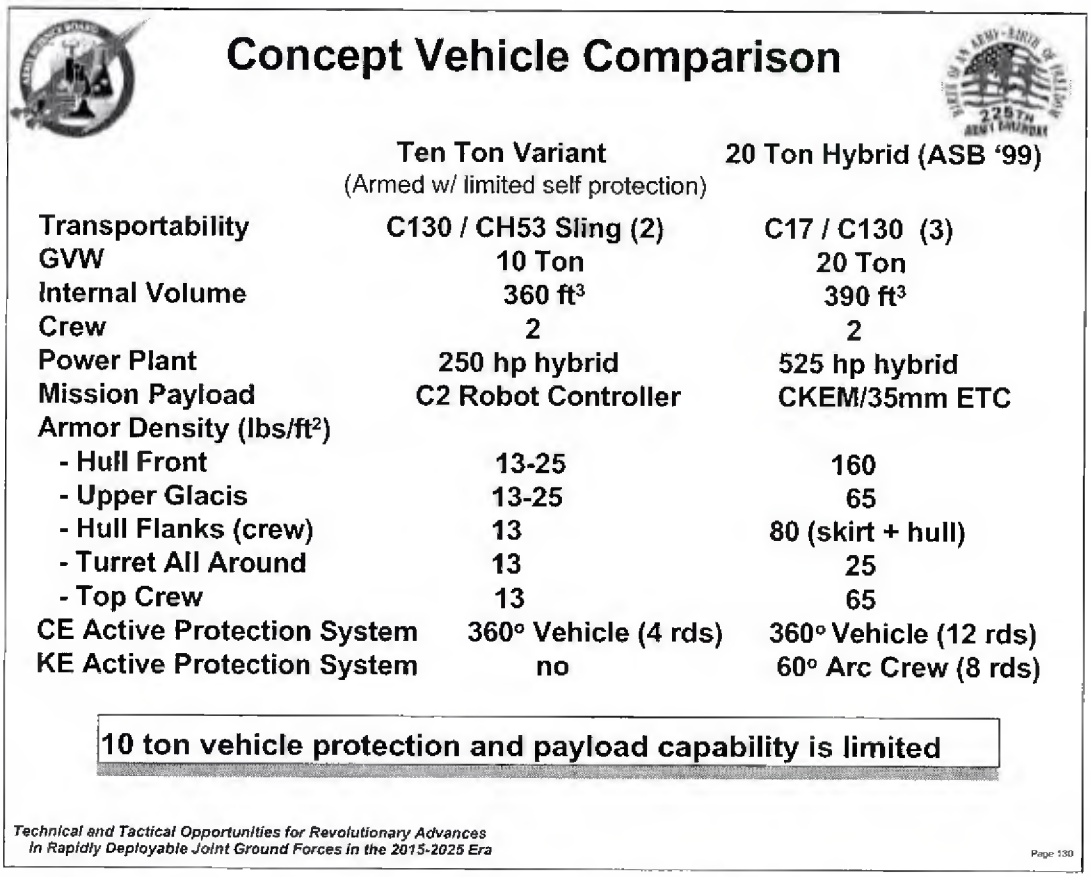


A ten ton vehicle concept was developed to understand the capabilities and limitations of a 10 ton chassis.

This is a 6x6 wheeled, hybrid electric vehicle with a 2 person crew station, self protection weapon, and a limited mission payload of electronics to supervise robotic vehicles.

This low profile chassis was designed to fit two in a C130 and 6 in a C17. It is also capable of being sling loaded to a CH53 and CH47 under certain altitude and temperature conditions.

The armor protection is only good against small arms (7.62 mm). It may be possible to add a Chemical Energy Active Protection System and some heavy machine gun (14.5mm) protection in limited areas.



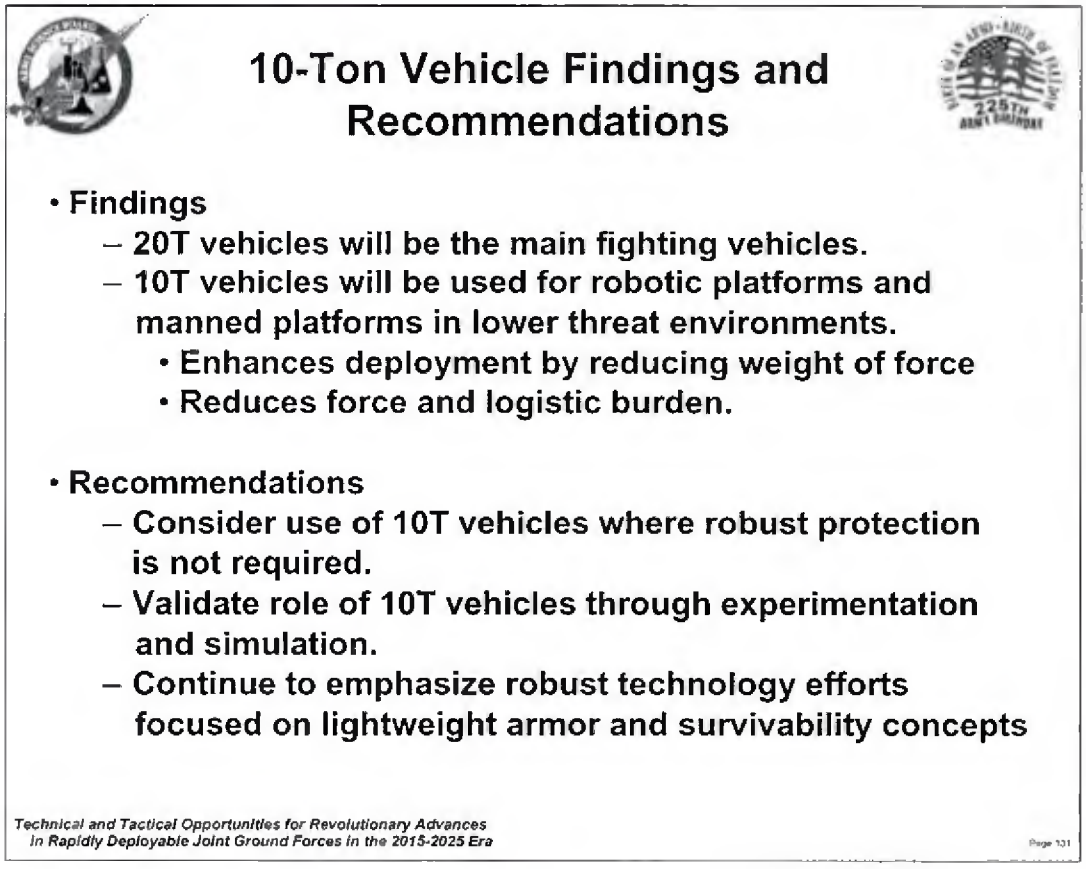
Although a 20 ton vehicle will be the main "fighting" vehicle of the FCS, a 10 ton vehicle is near the optimum weight for deployment. It is then envisioned that the FCS force may be a mix of 10 and 20 ton platforms, appropriately tailored to their specific missions.

This chart compares a10-ton vehicle with limited self protection and a small mission payload to supervise robotic systems, to the 20 ton Hybrid ETC gun/missile concept developed for the ASB 1999 Summer Study.

The primary difference in capability between the concepts is the reduction in protection level and payload capability available in the 10 ton system compared to the 20 ton system.

The protection level differences are especially evident when the areal density available for structure/armor in the 20-ton concept is compared to the 10-ton concept. The 20-ton vehicle has over 5 times as much armor in critical locations. Essentially, the 10 ton platform offers a small arms class of protection, while the 20 ton concept offers medium caliber/hand held HEAT armor combined with a full spectrum active protection system.

Another important difference is the ability to equip the 20 ton concept with a KE APS system because of the thicker structure available to stop KE debris, and a more robust CE APS system.



Findings:

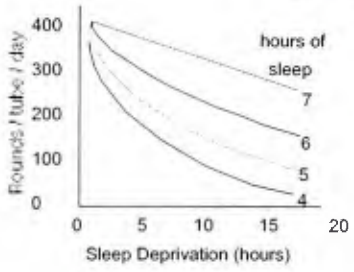
• It will be extremely difficult to achieve a family of vehicles that will weigh only 20 tons and has the lethality and survivability equivalent to the current heavy armored vehicular fleet. This goal will only be achieved by a combination of enhanced situational awareness, assured communications within a network centric force, and new technologies in the lethality and protection regimes. The 20 ton limit is set by the desire to make the vehicles transportable by C-130 aircraft. The challenge is great at the limit of 20 tons. It is even more daunting at lower weight limits for manned vehicles that live in the most dangerous zones of the battlespace. However, there are opportunities to apply a lighter and less survivable variant to robotic vehicles and to vehicles which operate outside the zone of maximum danger most of the time. Therefore,

- 20T vehicles will be the main fighting vehicles.
- 10T vehicles will be used for robotic platforms and manned platforms in lower threat environments.

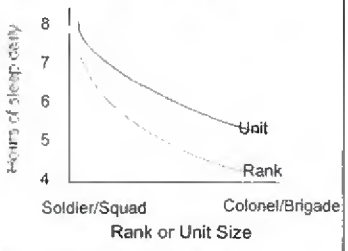
The **Recommendations** speak for themselves.

Impact of Sleep Deprivation

A Combat Example- 48 hrs into Desert Storm
- Loss of grasp of tactical situation
- Impaired ability to lay weapons accurately
- Some effects appeared after only 24 hours



Sleep deprivation varies across the echelon of command
- The higher the echelon, the greater the sleep loss
- The sleep loss is greatest during force-on-force ops
- The higher the rank, the greater the sleep loss



Sleep loss degrades the human's ability to work with information more than the ability to perform motor skills. 'Dual tasking' of key positions may enhance the performance of complex tasks

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Studies have shown that sleep deprivation has a profound effect when performing continuous operations. As the amount of sleep decreases, the efficiency of each soldier decreases as well.

The chart above shows a drastic decline in the efficiency of the soldier in combat with only 4 hours of sleep. In addition to the problems stated above, after an extended period of time with limited sleep, the efficiency of the soldiers became nearly nonexistent.

Another problem with sleep deprivation is that it varies across the echelon of command. As seen in the second graph, soldiers in the smallest units and at the lowest ranks are getting the most sleep and those at the highest ranks in the largest units are getting the least amount of sleep. This is a concern because the higher ranking individuals are the ones making the important decisions. Their decision making skills become increasingly more impaired the longer the operation.

Finally, sleep deprivation occurs more during force-on-force operations than during any other type of military operation. This is due to the high level of stress put on individuals during these types of operations.

Maintaining 7/24 Operations

Issue:

There is a severe reduction in performance associated with long periods of sleep deprivation

Possible Solutions:

Organizational

- **Develop two separate teams (Black and Gold) to utilize at different times throughout the operation to ensure sleep deprivation does not occur**

Operational

- **Control the tempo of the battlefield in order to keep as many units in reserve as possible.**

Technological

- **Explore the use of robotics and "auto-pilot" systems as a means to reduce sleep deprivation on the battlefield.**

Medical

- **Explore the use of drug therapy as a replacement for sleep during continuous operations.**

The key issue with maintaining operations 24 hours a day, 7 days a week is the severe reduction in performance that is associated with sleep deprivation. As seen from the charts on the previous page, there is a large problem with decreased performance as operations get longer. We must look for alternate solutions to maintain soldier efficiency.

There are four areas that contain possible solutions. These areas are organizational, operational, technological, and medical. There are many possible solutions that we have described that will possibly reduce the effects of sleep deprivation. We found that the organizational and operational solutions are not as promising as the technological and medical solutions because of the vast improvements the latter two areas made over the past few years.

Although more research needs to be done, we believe that the best solutions lie within the areas technology and medicine.

Simulation and Experimentation

Problem: Traditional approaches to requirements, O&O, and concept development/models are overwhelmed by FCS complexity and timelines

Discussion:

- Current constructive simulations model P(k) and P(h) well, but not contributions of flexibility, agility, knowledge, and speed
- Army/DARPA pioneered exploration of distributed interactive simulation (DIS) to assess/develop advanced operational and systems concepts
- Warfighting experiments supported by DIS are needed allow the warfighter, acquirer, and technologist to develop robust requirements and O&O for new systems

Recommendations: Enhance modeling and simulation process to address FCS complexity. Exploit DIS and warfighting experimentation in time to support the 2003 Objective Force decision

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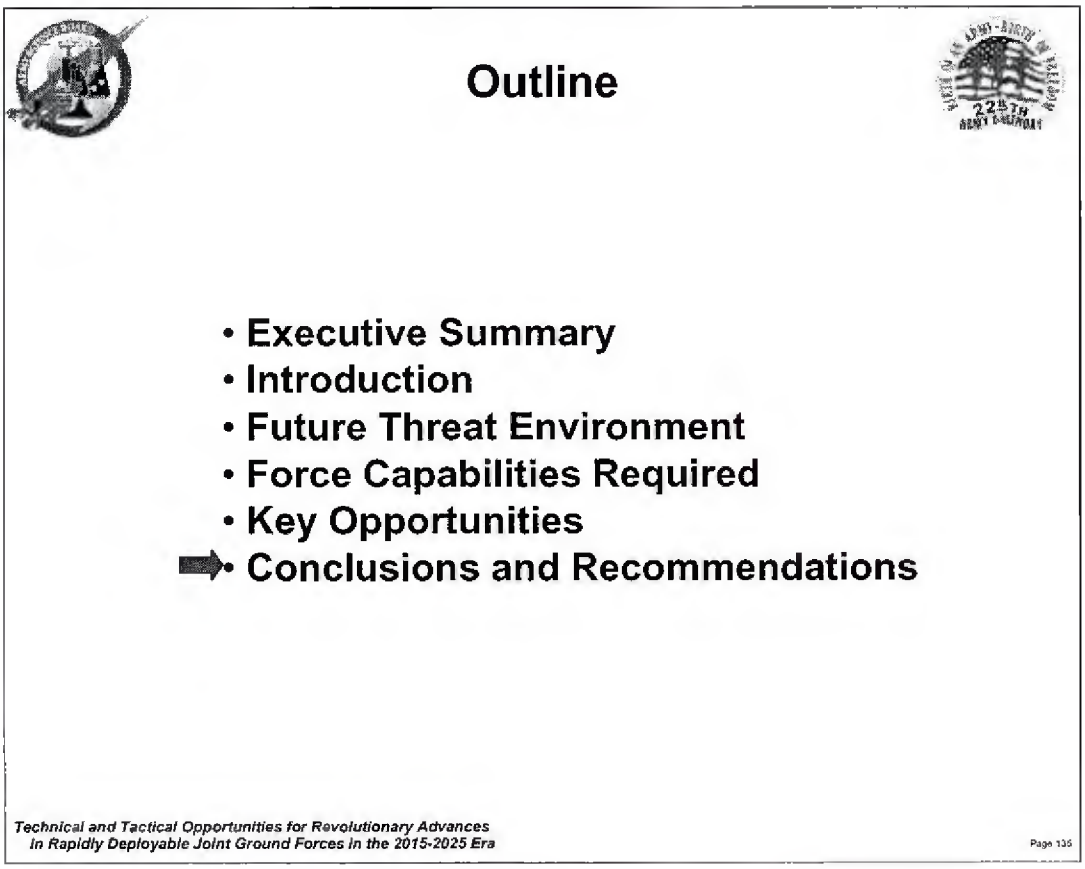
- The FCS objective force is one of the most complex transformation efforts undertaken by a military service. Traditional serial requirements and acquisition processes are overwhelmed by the FCS objective force complexity and timelines supporting constructive models are inadequate.
- Current constructive simulations model the lethality of Cold War systems well, e.g., probability of hit (Ph) and probability of kill (Pk). Modeling and simulation tools are needed to support analysis of survivability, lethality, agility and versatility of the FCS objective force,which relies on situational awareness, systems of systems and is collaborative.
- The Army and DARPA pioneered the development and application of distributed interactive simulations employing a combination of manned, constructive and virtual simulation to develop and assess advanced operational and systems concepts. Examples are SIMNET, Synthetic Theater of War and Joint Precision Strike Demonstration.
- Past successful transformations have relied on experimentation to allow the warfighter, technologist and industry to uncover unforeseen problems, determine operational practicality, explore interfaces with legacy systems and "how to fight" the new concepts and technologies. Examples include 11th Air Assault and digitization.
- FCS objective force warfighting experiments supported by DIS will allow the warfighter, acquirer and technologist to spirally develop robust concepts, requirements and operation and organizational (O&O) in a timely manner.



The conclusions and recommendations of the study panel are re-examined in the final section.

Summary & Recommendations

Findings:

- FCS concept is solid. It addresses critical mobility, insertion, and survivability issues
- FCS 20-ton vehicle is not a stand-alone program. To ensure its effectiveness, must consider:
  - Robotic companions
  - Appropriate munitions suites
  - Lift: operational, theater and strategic
  - Simulation tools

Recommendations:

- Press forward vigorously with FCS. In the short term:
  - Develop CONOPS
  - Develop man-in-the-loop simulations
  - Restructure munitions priorities
  - Expand robotic programs
- Over the long term:
  - Work with DoD to develop in-theater and strategic lift for FCS
  - Develop access to commercial lift

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First and foremost, from the Operations panel perspective, the FCS concept is solid. Critical concerns raised about the deployability and intratheater mobility of the legacy force and the survivability issues raised about a light force have been addressed. The brigade which we analyzed can fight and win in challenging environments.

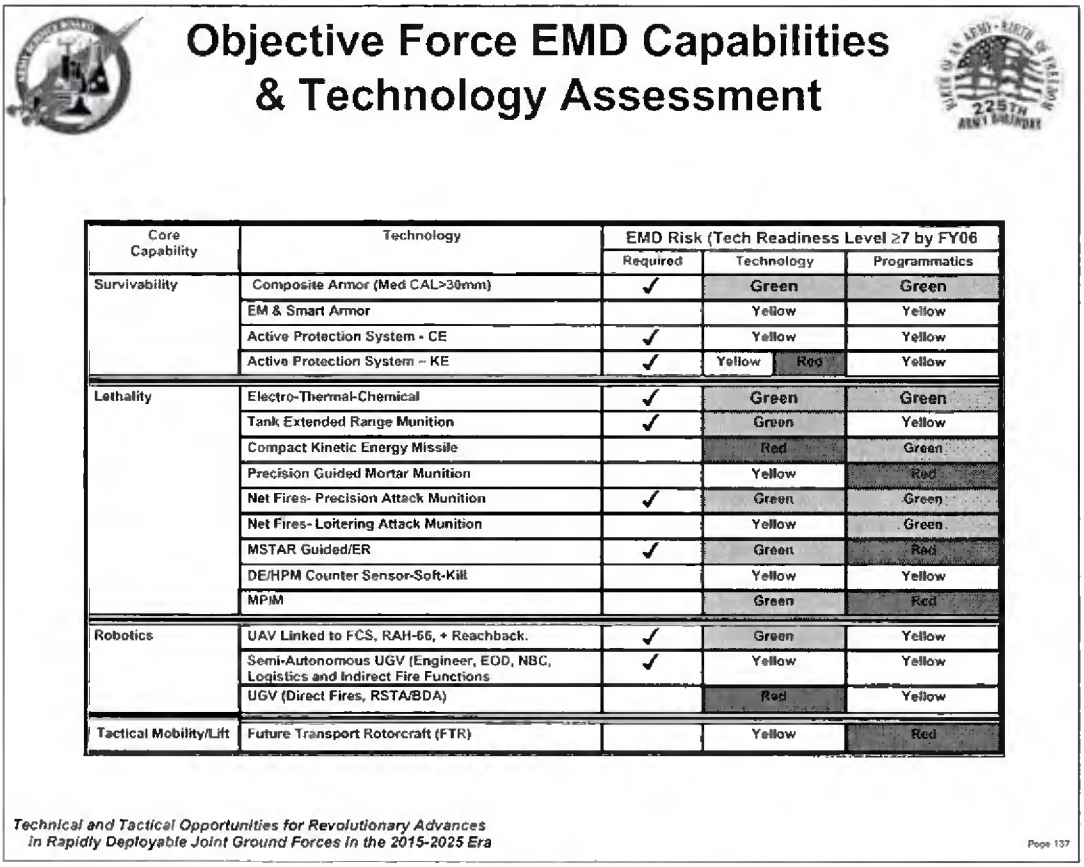
Several important findings are:

- First, the Future Combat System (FCS) is not a stand alone new combat vehicle. Rather, it is a system-of-systems which includes robotic companions, smart munitions and access to the tactical infosphere;
- Next, for timely application of the force, lift capabilities are a key consideration;
- Finally, robust simulation tools are needed to investigate among complex issues such as man-robotic interactions.

The primary recommendation is to press forward with FCS. Near term actions should include:

- Developing a CONOPS;
- Upgrading and/or developing man-in-the-loop simulations in order to be able to accurately portray the FSC CONOPS and work issues such as control of robotic companions;
- Restructuring munitions priorities keeping in mind that smart munitions are a key enabler to effectiveity, deployability and sustainability of the FCS force;
- And expanding robotic programs with a view toward getting robotic ground vehicles in the hands of troops and early assigning of limited complexity tasks such as a logistic follower.

Over the longer term the lift issue for the FCS force needs to be studied and technologies funded that will ultimately enhance/enable vertical envelopment.



Core Capability	Technology	EMD Risk (Tech Readiness Level ≥7 by FY06		
		Required	Technology	Programmatics
Survivability	Composite Armor (Med CAL>30mm)	✓	Green	Green
	EM & Smart Armor		Yellow	Yellow
	Active Protection System - CE	✓	Yellow	Yellow
	Active Protection System – KE	✓	Yellow / Red	Yellow
Lethality	Electro-Thermal-Chemical	✓	Green	Green
	Tank Extended Range Munition	✓	Green	Yellow
	Compact Kinetic Energy Missile		Red	Green
	Precision Guided Mortar Munition		Yellow	Red
	Net Fires- Precision Attack Munition	✓	Green	Green
	Net Fires- Loitering Attack Munition		Yellow	Green
	MSTAR Guided/ER	✓	Green	Red
	DE/HPM Counter Sensor-Soft-Kill		Yellow	Yellow
	MPIM		Green	Red
Robotics	UAV Linked to FCS, RAH-66, + Reachback.	✓	Green	Yellow
	Semi-Autonomous UGV (Engineer, EOD, NBC, Logistics and Indirect Fire Functions	✓	Yellow	Yellow
	UGV (Direct Fires, RSTA/BDA)		Red	Yellow
Tactical Mobility/Lift	Future Transport Rotorcraft (FTR)		Yellow	Red

Objective Force EMD Capabilities and Technology Assessment

Building on the 1999 ASB Summer Study, several high priority technologies were identified as significantly contributing to Objective Force Capabilities. The required core capabilities for the initial FCS force, i.e. building blocks that should be fielded and upgraded in an evolutionary manner as the other identified technologies become available, are marked by a check. Thus we identified technologies which must be demonstrated to at least a technology readiness level of 7, in time to support a successful FY2006 EMD decision in order to provide the Army a sufficiently capable, survivable and affordable FCS fielded in FY 2012. The other technologies listed mature later than the start of FCS EMD and still deserve support because they: (1) could be available for a 2012 FUE even though they are not ready for EMD in FY2006; or (2) will so greatly increase objective force responsiveness, deployability, agility, versatility, lethality, survivability and/or sustainability, that they should be developed and fielded as soon after FY2012 as feasible and affordable. Examples include FTR, autonomous unmanned ground vehicles, etc.

The 'Technology' column contains an assessment of the technical risk for the technology. The 'Programmatics' column identifies the program (current schedule and funding) risk assuming an EMD start of 2006. Technology risk categories are: Green - Low, Yellow - Moderate and Red - High.

Composite armor is required for lightweight passive protection against light arms up to 30 mm. Its requirements are established and its technology and program are on track for the FCS evaluation. The issue is maintaining that schedule.

Active protection is essential for an effective FCS. Its requirements are defined roughly. Its technology has been demonstrated in separate pieces. The program is fragmented and lacks focus. Any further drift would delay the FCS decision.

Electro-thermal chemical rounds use a combination of electrical initiation and chemical energy release to obtain greater energy from a given amount of charge, which allows them to maintain lethality overmatch from FCV without additional weight.

TERM permits either direct or indirect fire from current guns, which could effectively complement sensor developments to enhance overall effectiveness.

Net fires delivered by rockets in a box have the potential to provide the indirect fire support required for full FCS effectiveness if the communication and lethality need can be provided efficiently

Robotic links to UAVs are needed to provide the high resolution, prompt local sensors and comm needed for situational awareness and integration of forces in contact.

Secure and mobile C4I is required for situational awareness and integration of FCS. The DARPA mobile network is a good testbed and possible prototype for the network required, if it can be developed in time.

Sensor and Target Acquisition Overmatch is required to assure friendly detection and acquisition of enemy systems and target acquisition capabilities and optics in order to enable stand-off engagement and see first-shoot first capabilities.

Robust brigade & below is the integration of such networks at all echelons.

20 Ton vehicle is the baseline chassis for the FCS.

Hybrid electric engines have significant potential for improving the FCS performance envelope while reducing logistics requirements.

Reliability, availability, and maintainability are essential attributes of an effective FCS. Their requirements and understood and the technology required is in development, but the current program is inadequate to support the FCS decision timeline.

The following are considered high technical risks:

Compact kinetic energy missile (CKEM) – unproven high specific impulse with low vulnerability propellant

Directed energy/high power microwave counter sensor-soft kill – engineering scaling

Autonomous UGV – Sensor fusion, signal processing and software for autonomy

Programmatic risk assessments refer to the funding and schedule risk of the current funded army program: Green - Funding and schedule are adequate to achieve TRL of 7 by FY2006 EMD start; Yellow – Moderate risk due to inadequate funding and/or schedule; Red – unacceptable schedule &/or funding to get to TRL7 by FY2006 EMD start.

The following are considered high program risk:

Multi-purpose individual munitions (MPIM) - Procurement unfunded

Precision guided mortar munitions (PGMM) - No funded transition and ATD stretched

MSTAR guided , extended range 270mm missile – MSTAR killed

Ten ton (10T) vehicle – no funded program

Reliability, availability & maintainability – Needs to be required now. No threshold metrics.

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

February 28, 2000

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

Dear Mr. Bayer:

I request that you conduct an Army Science Board (ASB) Summer Study on "Technical and Tactical Opportunities for Revolutionary Advances in Rapidly Deployable Joint Ground Forces in the 2015-2025 Era." The ASB members appointed should consider these Terms of Reference (TOR) as guidelines and may include in their discussions related issues deemed important or suggested by the sponsors. Modifications to the TOR must be coordinated with the ASB office.

I envisage that this work by the Army Science Board will also yield practical near term insights and opportunities that will assist the Army Leadership in focusing priorities for our limited research, development and acquisition accounts to create the most combat effective and cost efficient rapidly deployable joint ground forces for the 2015-2025 period.

The study should be composed of four parallel investigations leading to an integrated set of recommendations. This work is to be guided by, but not limited to, the following lines of inquiry:

Team 1 - Operations. To the goal of achieving rapidly deployable forces with dominant maneuver supported by precision fires, look at those opportunities which offer the greatest pay off for quickly deploying forces which feature a highly flexible array of full spectrum force capabilities. Focus on combat operations, accounting for capabilities required to achieve systems overmatch as a critical component of overall force effectiveness both for initial entry into a theater of operations and to enable operational maneuver within the theater once operations begin. The array of systems and force capabilities should assure future commanders retain battlefield freedom of maneuver and are not denied tactical options for offensive or defensive schemes of maneuver. While combat operations are the focus, the relevance of the capabilities to stability and support operations, such as peace operations, should be assessed. Consider, but do not limit your investigation to the following opportunities:

a. Look at the feasibility of synchronizing the requirements for the Future Combat System, the Joint Transport Rotorcraft (JTR), and Comanche to provide revolutionary tactical and theater mobility and increased strategic mobility. If feasible, what are the assumed tactical benefits of this union?

b. Assess the capabilities gained by exploiting robotic air and ground systems as reconnaissance/surveillance, attack systems, and other functions. Which force capabilities or platforms appear to benefit most from this relationship?

c. Propose a suite of smart munitions/sensor combinations in our direct fire and indirect fire forces that offer the most cost effective investment and the most decisive outcome in expected scenarios.

d. Determine those areas of the force that demand robust 24 hours a day, 7 days a week manning, and portray the benefits of various manning arrangements.

e. Identify the optimal organizational structures that best exploit future information technology.

f. Determine the need for or utility of an Advanced Theater Transport (ATT) to replace the C-130 to support the operational capability and systems described above.

Team 2 – Sustainment and Support. To the goal of providing this force a support/sustainment capability with significantly reduced logistic burden, look at the opportunities in providing forces with significantly greater systems reliability (including mechanical, electronic, photonic reliability, etc.) along with graceful degradation and ultrareliability leading to simplified battlefield maintenance, repair and diagnostics/prognostics (including disposable/expendable components/systems), significantly smaller fuel and ammunition tonnage requirements, improved battlefield medical support, transport means (manned and unmanned), and remote services. Consider, but do not limit your investigation to the following opportunities:

a. Assess the opportunities to leave outside the theater significant logistic, intelligence, and administrative support, thereby reducing the force requiring in-theater support.

b. Assess the opportunities for advanced power plants that reduce the specific fuel consumption at least 25% per HP delivered.

c. Assess the logistic implications of the alternative families of smart munitions (as generated by Team 1).

d. Exploit the opportunity for remote surgery (telemedicine) to reduce the number of in-country specialty surgeons.

e. Assess the capability of the JTR to contribute to rapid medical treatment and evacuation along with other joint force options.

f. Assess the opportunities to improve the Army's capability to conduct Near Shore/Logistics-Over-the-Shore operations.

Team 3 - Information Dominance. To the goal of providing this force Information Dominance through the provisioning of an advanced "central nervous system" to meet the needs of our forces and to deny the threat force basic information needs consider at least two perspectives. First is the broad, relatively global C4ISR focus that flows vertically from the Joint Task Force down through corps and divisions (as units of employment) all the way to units of action executing their tactical operations and tasks. The second perspective includes the time sensitive information at the local level that is dependent on rapidly changing battle command and control, "around the next hill/corner" situational awareness, and the needs at the tactical maneuver/support units and teams level - platforms and organic sensors centric. This assessment should consider both of these complementary perspectives. The objective of providing maneuver units a fundamental capability to expand their engagement envelopes to include short timeline, beyond line of sight and fleeting targets may provide a catalyst for this information dominance challenge. Look at capabilities which provide digital map location and terrain elevation data to support the needs of ground maneuver commanders and precision fires employment, yield superior situational awareness of friendly and threat forces, instantaneous critical logistic asset status and location, theater missile threat detection, location and ongoing tracking of any threat weapons of mass destruction, and deny the threat forces this basic capability using both lethal and non-lethal means. Provide forces with timely, reliable information updates (unit and platform level updates) to facilitate tactical and support mission planning and rehearsal during deployment and on the move. As technology opportunities are assessed, it is essential that future forces operating in urban and complex terrain environments have robust, high confidence situation awareness, across the full spectrum of military operations. Consider, but do not limit your investigation to the following opportunities.

a. Assess the suite of National and Theater sensors: overhead, air breathing, manned and robotic necessary to provide the desired data and information.

b. Assess the technological opportunity to provide necessary bandwidth for data, voice, and video requirements for the force.

c. Ascertain the requirements to deny the threat the necessary voice and data information he requires to effectively employ his forces.

d. Assess the ability to link all systems through an inter-netted system of non-line-of-sight communications.

Team 4 - Training. To the goal of ensuring that these deployed forces have an organic capability to train to peak effectiveness within the theater of operations, look at opportunities for providing embedded training devices for crew, team and small unit training; the ability to deliver training into the theater using "distance learning " opportunities; the ability to provide "mission rehearsal" capabilities as required; and the ability to permit staff and command training with sensitive intelligence products. These investigations should be grounded in a vision of a future training strategy for both collective and individual training which leverages a proper mix of live, virtual and constructive training and which is supported by an information based system of systems architecture. Consider, but do not limit your investigation to the following:

a. Assess the command and control systems' ability to provide necessary alternative mission analyses and threat scenario generation using all source intelligence.

b. Assess the opportunities for embedding necessary training system requirements in the Future Army Land and Aviation Vehicles, to include mission rehearsal capabilities. This assessment should include embedded joint training and real time cooperative training with units and systems both in and out of theater from alert through deployment and employment.

c. Assess the training requirements necessary to train the sensor to shooter precision fires employment.

d. Look at the need for and feasibility of using distance learning techniques to train portions of the force with out-of-Theater resources.

e. Investigate approaches which can link training and operational system capabilities to facilitate the creation of realistic conditions and which can store, fuse, filter and disseminate relevant information to a variety of training system components.

Study Support. Sponsors of this study are GEN John M. Keane, Vice Chief of Staff; GEN John N. Abrams, Commanding General, US Army Training and Doctrine Command; GEN John G. Coburn, Commanding General, Army Materiel Command, and LTG John J. Costello, Commanding General, Space and Missile Defense

Command. LTG Paul J. Kern is the ASA(ALT) cognizant deputy and LTG Randall L. Rigby, Jr., is the TRADOC cognizant deputy.

Schedule. The study panel will initiate the study immediately and conclude its effort at the report writing session to be conducted July 17-27, 2000, at the Beckman Center on the campus of the University of California, Irvine. As a first step, the study co-chairs will submit a study plan to the sponsors and the Executive Secretary outlining the study approach and schedule. A final report will be issued to the sponsors in September 2000.

Sincerely,

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

APPENDIX B

PARTICIPANTS LIST

PARTICIPANTS LIST

ARMY SCIENCE BOARD
2000 SUMMER STUDY

TECHNICAL AND TACTICAL OPPORTUNITIES FOR REVOLUTIONARY ADVANCES IN RAPIDLY DEPLOYABLE JOINT GROUND FORCES IN THE 2015-2025 ERA

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APPENDIX C

ACRONYMS

Acronyms

A2C2	Army Airspace Command and Control
AAC	Army Acquisition Corps
AAE	Army Acquisition Executive
AAFIF	Automated Air Facilities Information File
AARs	After Action Reviews
ABCS	Army Battle Command Systems
ABN	Airborne
ACAT	Acquisition Category
ACOM	Atlantic Command
ACR	Armored Cavalry Regiment
ACTD	Advanced Concept Technology Demonstration
ADO	Army Digitization Office
AEF	Air Expeditionary Force
AF	Air Force
AFSAB	Air Force Scientific Advisory Board
AFSS	Advanced Fire Support System
AJ	Anti Jamming
AGCCS	Army Global Command and Control System
AGS	Armored Gun System
AI	Artificial Intelligence
ALP	Advanced Logistics Project
AMC	Army Materiel Command
AMCOM	Aviation and Missile Command
AMSAA	Army Materiel Systems Analysis Activity
AOR	Area of Responsibility
APFSDS	Armor-Piercing, Fin-stabilized, Discarding Sabot
APC	Armored Personnel Carrier
APOD	Aerial Port of Debarkation
APOE	Aerial Port of Embarkation
APS	Active Protection Systems; Army Prepositioned Stocks
ARDEC	Army Research, Development, and Engineering Center
ARL	Army Research Laboratory
ATT	Advanced Tactical Transport
ARTY	Artillery
ASA(ALT)	Assistant Secretary of the Army for Acquisition Logistics and Technology
ASB	Army Science Board
ASD C3I or ASD(C3I)	Assistant Secretary of Defense (Command, Control, Communications, and Intelligence)
ASTMP	Army Science and Technology Master Plan
ASTWG	Army Science and Technology Working Group
AT	Anti Tank
ATD	Advanced Technology Demonstration
ATG	Anti-Tank Gun

ATGM	Anti-Tank Guided Missile
ATR	Automated Target Recognition
AWE	Advanced Warfighting Experiment
B2C2	Battalion and Below Command and Control
BAT	Brilliant Anti-Tank
BCIS	Battlefield Combat Identification System
BDA	Battle Damage Assessment
BDE	Brigade
BITS	Battlefield Information Transmission System
BLOS	Beyond Line of Sight
BN	Battalion
C2	Command and Control
C2E	Command Center Element
C2OTM	Command and Control On-The-Move
C2SID	Command and Control System Integration Directorate
C2T2	Commercial Communications Technology Testbed
C2V	Command and Control Vehicle
C2W	Command and Control Warfare
C3	Command, Control and Communications
C3I	Command, Control, Communications and Intelligence
C3IEW	Command, Control, Communications Intelligence and Electronic Warfare
C4	Command, Control, Communications and Computers
C4I	Command, Control, Communications, Computers and Intelligence
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CASCOM	Combined Arms Support Command
CASTFOREM	Combined Arms and Support Task Force Evaluation Model
CBW	Chemical and Biological Warfare
CC&D	Concealment Camouflage and Deception
CDR	Critical Design Review
CDT	Commercially Driven Technologies
CE	Chemical Energy
CECOM	Army Communication-Electronics Command
CHP	Controlled Humidity Preservation
CINC	Commander-in-Chief
CINCTRANS	Commander-in-Chief, Transportation Command
CKEM	Compact Kinetic Energy Missile
CM	Countermeasures
CONOPS	Concept of Operations
CONUS	Continental United States
COA	Course of Action
COTS	Commercial Off-The-Shelf
CPX	Command Post Exercise

CRAF	Civil Reserve Air Fleet
CSA	Chief of Staff, Army
CSSCS	Combat Service Support Computer System
CTC	Combat Training Center
DARPA	Defense Advanced Research Projects Agency
DAS	Director of Army Staff
DAS(R&T)	Deputy Assistant Secretary for Research and Technology
DBBL	Dismounted Battlespace Battle Lab
DCS(RDA)	Deputy Chief of Staff Research Development and Acquisition
DCSD	Deputy Chief of Staff Combat Development
DCSDOC	Deputy Chief of Staff Doctrine
DCSINT	Deputy Chief of Staff Intelligence
DCSLOG	Deputy Chief of Staff Logistics
DCSOPS	Deputy Chief of Staff Operations
DDR&E	Director, Defense Research and Engineering
DE	Directed Energy
DEW	Directed Energy Weapons
DISA	Defense Information Systems Agency
DISC4	Director, Information Systems, Command, Control, Communications and Computers
DL	Distance Learning
DLA	Defense Logistics Agency
DMSO	Defense Modeling and Simulation Office
DoT	Department of Transportation
DPG	Defense Planning Guide
DPICM	Dual Purpose Improved Conventional Munitions
DS	Direct Support
DSB	Defense Science Board
DSWA	Defense Special Weapons Agency
DSP	Digital Signal Processing
DTAP	Defense Technology Area Plan
DTLOMS	Doctrine, Training, Leader Development, Organization, Materiel, and Soldiers
DTO	Defense Technology Objective
DU	Depleted Uranium
DUSA-OR	Deputy Undersecretary of the Army - Operations Research
EAD	Echelons Above Division
EFOGM	Enhanced Fiber-Optic Guided Missile
EFP	Explosively Formed Penetrator
ELINT	Electronic Intelligence
EM	Electro-Mechanical, Electro-Magnetic
EMD	Engineering and Manufacturing Development
EML	Electro-Magnetic Launch
EMPRS	En Route Mission Planning and Rehearsal System

EO/IR	Electro-Optical/Infrared
ERA	Extended Range Artillery, Explosively Reactive Armor
ETC	Electro-Thermal Chemical
EW	Electronic Warfare
F&M	Firepower and Mobility
FBCB2	Force XXI Battle Command Brigade and Below
FC	Fire Control
FCS	Fire Control Systems; Future Combat System
FCV	Future Combat Vehicle
FCVT	FCV Team
FLIR	Forward Looking Infra-Red
FOB	Forward Operating Base
FOG-M	Fiber-Optic Guided Missile
FORSCOM	Forces Command
FTR	Future Transport Rotorcraft
FSCS	Future Scout and Cavalry System
FSV	Future Scout Vehicle
FTX	Field Training Exercise
GCCS	Global Command and Control System
GCSS	Global Combat Support System
GCSS-A	Global Combat Support System – Army
GIG	Global Information Grid
GIS	Global Information System
GOSC	General Officer Steering Committee
GPS	Global Positioning System
GVW	Gross Vehicle Weight
HE	High Explosive
HEAT	High Explosive Anti-Tank
HHH	Hand-Held Heat
HIMARS	High Mobility Artillery Rocket System
HMMWV	High Mobility Multi-purpose Wheeled Vehicle
HNS	Host Nation Support
HPM	High Power Microwave
HQAMC	Headquarters of the Army Materiel Command
HSS	High-Speed Shipping
HVAP	High Velocity Armor Penetrating
I2R	Imaging Infrared
IA/IW	Information Assurance/Information Warfare
ICM	Improved Capabilities Missile, Improved Capabilities Munitions
IFSAR	Interferometric Synthetic Aperture Radar
III	Integrated Information Infrastructure(s)
IO	Information Operations

IPT	Integrated Product Team
IR	Infra Red
IR&D	Independent Research and Development
ISC/R	Individual Soldier's Computer/Radio
ISR	Intelligence Surveillance Reconnaissance
IT	Information Technology
IW	Information Warfare
IWS	Individual Warfighter System
J3	Operations Directorate, Joint Staff
J4	Logistics Directorate, Joint Staff
JCF	Joint Contingency Force
JCS	Joint Chiefs of Staff
JIT	Just-in-Time
JOPES	Joint Operation Planning and Execution System
JROC	Joint Requirements Oversight Council
JS	Joint Support, Joint Staff
JSTARS	Joint Surveillance Target Attack Radar System
JTA	Joint Technology Architecture(s)
JWCA	Joint Warfighting Capability Assessment
KE	Kinetic Energy
KE/CE	Kinetic Energy / Chemical Energy
KEM	Kinetic Energy Missile
LAM	Land Attack Missile
LADAR	Laser Radar
LAV	Light Armored Vehicle
LAW	Light Anti-tank Weapon
LCLO	Low Cost Low Observable
LCMS	Laser Counter Measures System
LCPK	Low Cost Precision Kill
LIDAR	Light Detection and Ranging
LIWA	Land Information Warfare Activity
LLNL	Lawrence Livermore National Laboratory
LMSR	Large Medium Speed Roll-on/roll-off
LO	Low Observables
LOS	Line of Sight
LOSAT	Line-of-Sight Anti-Tank
LOTS	Logistics Over-the-Shore
LPD	Low Probability of Detection
LPI	Low Probability of Intercept
LRIP	Low Rate Initial Production
LTL	Less-than-Lethal
LW	Land Warrior

M&S	Modeling and Simulation
MAGTF	Marine Air-Ground Task Force
MANPADS	Man-portable Air Defense System
MANPRINT	Manpower and Personnel Integration
MAVs	Micro-Autonomous Vehicles, Micro Air Vehicles
MEM	Micro-Electro-Mechanics
MEMS	Micro Electric Mechanical System
MEP	Mobile Electric Power; Mission Equipment Package
METT-T	Mission, Enemy, Troops, Terrain, Time
MEU	Marine Epeditionary Unit
MHE	Materiel Handling Equipment
MILDEP	Military Deputy
MLRS	Multiple Launch Rocket System
MMCS	Multi-Mission Combat System
MMUAV	Multi-Mission Unmanned Air Vehicle
MNS	Mission Needs Statement
MOUT	Military Operations in Urban Terrain
MPIM	Multipurpose Infantry Munition
MPS	Maritime Prepositioning Ship
MRDEC	Missile Research, Development and Engineering Center
MSTAR	Moving and Stationary Target Acquisition and Recognition
MTI	Moving Target Indicator
MTI-SAR	Moving Target Indicator – Synthetic Aperture Radar
MTMC	Military Transportation Management Command
MTMC-TEA	Military Transportation Management Command – Transportation Engineering Agency
MVMT	Movement
MW	Mounted Warrior
NBC	Nuclear, Biological and Chemical
NDF	National Defense Features
NG APS	National Guard - Army Prepositioned Stocks
NGB	National Guard Bureau
NGIC	National Ground Intelligence Center
NL	Non-Lethal
NLT	No Later Than
NLW	Non-Lethal Weapons
NMD	National Missile Defense
NRAC	Naval Research Advisory Committee
NRDEC	Natick Research, Development and Engineering Center
NSA	National Security Agency
NTC	National Training Center
NVESD	Night-Vision/Electronic Sensors Directorate
O&O	Operational and Organizational
OCAR	Office of the Chief, Army Reserve

OCONUS	Outside Continental United States
ODCSOPS	Office of the Deputy Chief of Staff for Operations
OOTW	Operations Other Than War
OPM	Other People's Money
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
P3I	Preplanned Product Improvement
PAM	Precision Attack Munitions
PDR	Preliminary Design Review
PDRR	Program Definition/Risk Reduction
PEO	Program Executive Office (Officer)
PEO/3C	Program Executive Officer for Command, Control and Communications
PGM	Precision Guided Munitions
PGMM	Precision Guided Mortar Munitions
POD	Point of Debarkation
POL	Petroleum, Oil and Lubricants
POM	Proparation for Overseas Movement
POS/NAV	Position/Navigation
PREPO	pre-positioned stocks
RHA	Rolled Homogenous Armor
RHAE	Rolled Homogenous Armor Equivalent
R/S	Reconnaissance/Surveillance
RC	Reserve Component
RDA	Research Development and Acquisition
RDT&E	Research Development Testing and Evaluation
RFPI	Rapid Force Projection Initiative
RHA	Rolled Homogenous Armor
RORO	Roll-on Roll-off
RPG	Rocket Propelled Grenade
RRF	Rapid Reaction Forces
RSTA	Reconnaissance Surveillance, Target Acquisition
S&T	Science and Technology
SA	Situation Awareness
SAALT	Secretary of the Army for Acquisition, Logistics and Technology
SACLOS	Semi-Automated Line of Sight
SADARM	Sense and Destroy Armor
SAR	Synthetic Aperture Radar
SARDA	Secretary of the Army for Research Development and Acquisition – outdated, now SAALT – Secretary of the Army for Acquisition, Logistics and Technology
SAS	Situation Awareness System
SBIR	Small Business Innovation Research

SES	Surface Effect Ships
SIGINT	Signal Intelligence
SIMNET	Simulation Network
SINCGARS	Single Channel Ground and Airborne Radio System
SIPE	Soldier Integrated Protective Ensemble
SLAD	Survivability and Lethality Directorate
SLID	Simple Low-cost Interception Device
SM	Signature Management
SRO	Strategic Research Objective
SSCOM	Soldier Systems Command
SSTOL	Super Short Take-Off & Landing
STARC	State Area Command
STI	Stationary Target Indicator
STO	Science and Technology Objective
STOW-E	Synthetic Theater of War-Europe
SUO	Small Unit Operations
SUOSAS	Small Unit Operations Situation Awareness System
SUSOPS	Sustained Operations
SWA	South West Asia
T&E	Test and Evaluation
TAA	Tactical Assembly Area
TAAD	Theater Area Air Defense
TACOM	Tank Automotive and Armaments Command
TAP	Technology Area Plan
TARA	Technology Area Review and Assessment
TARDEC	Tank Automotive Research Development and Engineering Center
TDA	Table of Distribution and Allowances
TENCAP	Tactical Exploitation of National Capabilities (program)
TERM	Tank Extended Range Munitions
TES	Tactical Engagement System; Tactical Engagement Simulation
TEU	20-foot-equivalent unit
TF	Task Force
THAAD	Theater High Altitude Defense System
TOC	Tactical Operations Center
TOR	Terms of Reference
TOW	Tube-Launched, Optically Tracked, Wire Command-Linked Guided
TPFDD	time-phased forces deployment data
TRADOC	Training and Doctrine Command
TRANSCOM	Transportation Command
TTP	Tactics, Techniques, and Procedures
TWG	Technology Working Group
TWS	Thermal Weapon Sight
UAV	Unmanned Aerial Vehicles
UGS	Unattended Ground Sensors

UGV	Unmanned Ground Vehicles
UHF	Ultra-High Frequency
USMA	United States Military Academy
USMC	United States Marine Corps
UV	Ultra-Violet
UWB	Ultra-Wide Band
UXO	Unexploded Ordinance
V/STOL	Vertical or Short Take-off and Landing
VCSA	Vice Chief of Staff of the Army
VISA	Voluntary Intermodal Shipping Agreement
VSAT	Very Small Aperture Terminal
VTOL	Vertical Take-off and Landing
VTOL JTR	Vertical Take-off and Landing – Joint Tilt Rotor
WARSIM	Warfighter Simulation
WIN	Warfighter Information Network
WMD	Weapons of Mass Destruction
WRAP	Warfighting Rapid Acquisition Program

For Acronyms not found here, consult:

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