Army Science Board
2003 Summer Study

Challenges and Opportunities for Increments II and III Future Combat Systems (FCS)

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KPP to TOR Crosswalk

Terms of Reference	Joint Inter.	Net B.C.	Netwk Leth.	Transport	Sustain/Rel.	Training	Surviv.
Suggest insertion priorities…	X	X	X	X	X	X	X
Assure expansion of C4ISR capabilities…	X	X	X				
Address automating fusion, transform data into knowledge…	X	X	X				
Address embedded training, mission planning and rehearsal…		X	X			X	
Assess technologies to enable manned-unmanned collaboration		X	X			X	
Address achieving and assuring software integrity…	X	X	X	X	X	X	X
Identify robust countermeasures (life cycle red teaming)…	X	X	X				X
Address reliability and industrial base matters	X	X	X		X		

Highest Priority Risks

- **Networked battle command (OF central nervous system)**
  - **Bandwidth**
  - **Software/Middleware**
  - **Network degraded mode operation**
- **Networked survivability**
  - **Trades to meet weight goals**
  - **Off-ramp readiness to fight**
  - **Dependence upon deep targeting and precision engagement**
- **Transportability: Power projection**
  - **Current vehicle weight projections and historical weight growth**
  - **C-130 limitations**

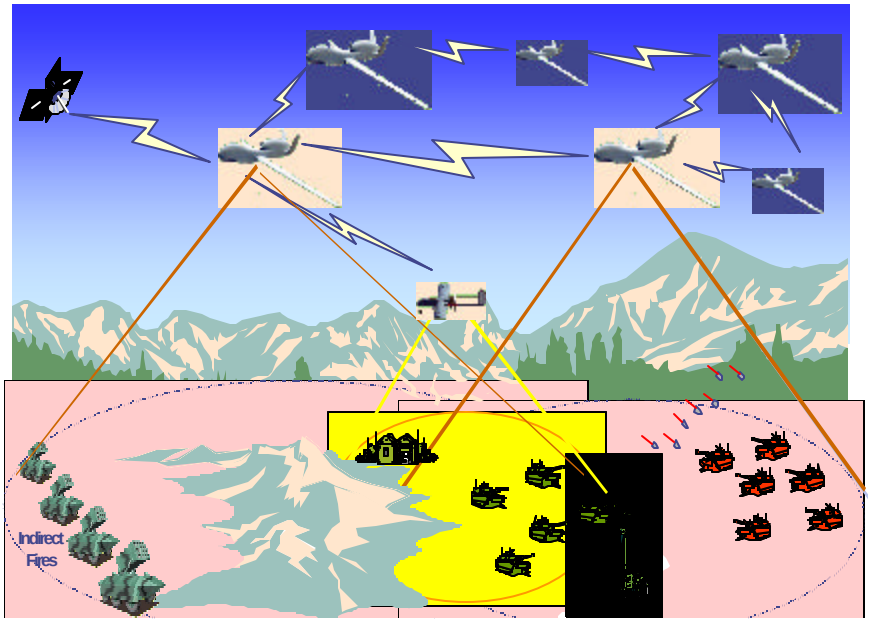
Increment I Spirals

• **Joint Interoperability for Network Centric Survivability and Lethality**	• **KPP 1,2,3,7**
• **Networked Survivability**	• **KPP 3,7**
• **Bandwidth Campaign**	• **KPP 1,2,3,7**
• **Smart Antennas**	• **KPP 1,2,3,7**
• **Middleware/Software**	• **KPP 1,2,3,4,5,6,7**
• **Transparent Battle Space**	• **KPP 2,3,7**
• **Systems of Systems Reliability**	• **KPP 5**

Joint Interoperability for Network Centric Survivability and Lethality

- Global Information Grid (GIG) connectivity to the edge
  - Assured and ubiquitous communications from the most forward edges of the battlefield to the global information grid, connecting dispersed forces into a cohesive joint force
- Networked lethality
  - Assured reach-back for timely joint precision fires
  - Lethality/collateral damage
- Networked survivability
  - Leverage of joint ISR assets
  - Benefit from killing first

GIG Connectivity to the Edge



Findings

- Multi-tiered, layered communications is essential
- Adaptive Joint C4ISR Node (AJCN) and Terahertz Operational Reachback (THOR) are developing enabling technology
- No transition program identified

Recommendations

- PEO C3T deploy AJCN payloads on UAVs and aircraft e.g., KC-135 (Increment I)
- CECOM and PEO C3T leverage THOR (Spiral 1)

Payoff

- Joint Interoperability
- JTRS and WIN-T range extension
- Dedicated complement to SATCOM

Networked Lethality

Musts

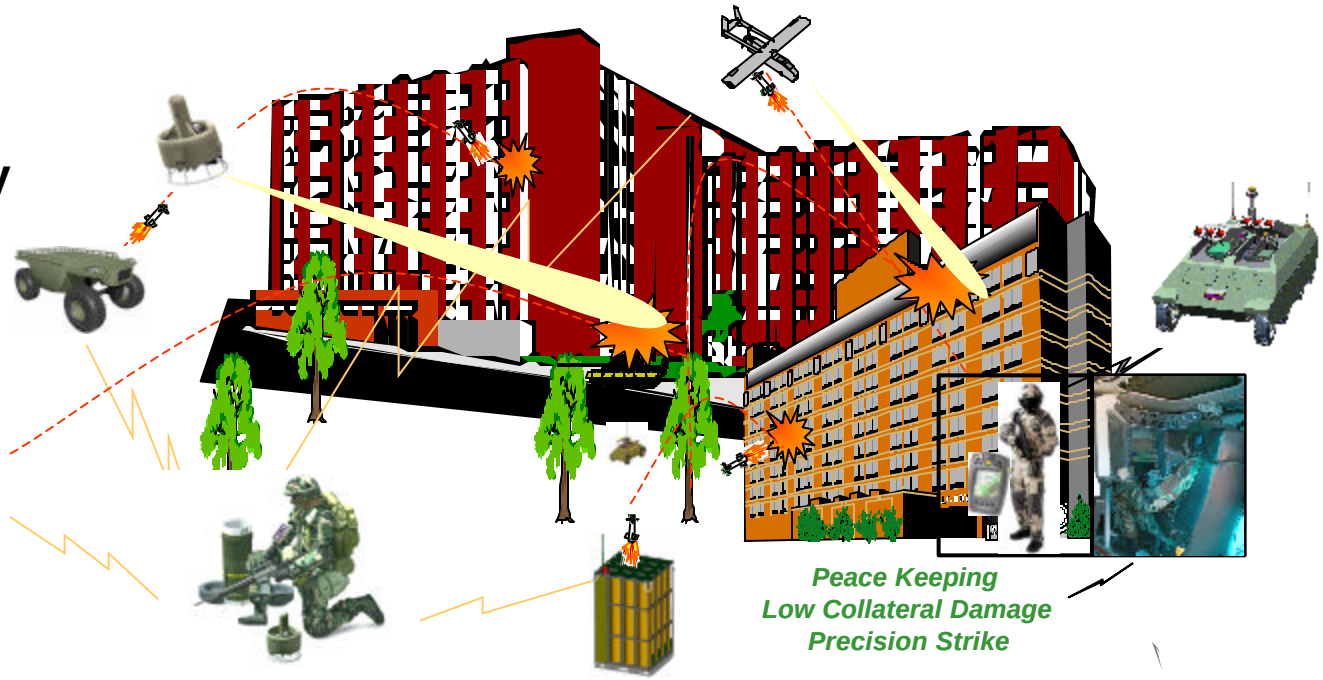
- Be highly responsive (goal ~ seconds)
- Leverage joint fires (e.g., air delivered)
- Tailorable to target set. Variety of munitions available:
  - Small warheads for low collateral damage (e.g., AF small diameter bomb)
  - Loitering overhead for short time of flight (e.g., AF LOCAAS; USN AWS)
  - Highly maneuverable for urban canyons
- Precise

Findings

- AF and Navy ahead of Army in loitering munitions
- Loitering Attack Munition (LAM) is currently deferred; Mid-range munition underfunded
- Army missiles oriented on anti-armor. Improvements needed:
  - Agility for urban canyons
  - Advanced warheads (e.g., thermobaric, novel explosively formed penetrators)

Dismounted Networked Lethality

- **Key elements of FCS that are highly useful to dismounted infantry were deferred**
- **Wide array of networked distributed lethality options for urban and complex terrain engagements needed**



Clear need for a formal development effort for Distributed Dismounted Lethality comparable to the mounted FCS including the ability for robust urban operations while avoiding direct fire engagements where possible and winning these engagements when avoidance is not possible.

Recommendations: Networked Lethality

- Work with AF and Navy regarding joint fire doctrine. Fold this into evolving FCS O&O (TRADOC/LSI; Now)
- Continue to develop and field LAM. Leverage insofar as possible AF and Navy investments (Army S&T; Spiral 1)
- Begin exploratory program on advanced lethality (propellants, warheads, maneuverability, etc.) (Army S&T; Spiral 1)
- Accelerate Mid-range Munition (MRM); field with Full Operational Capability (FOC) UA (Army S&T; with first UA)
- Establish a non-lethal weapon thrust with USMC-led Joint Non-Lethal Weapons Program (Army S&T; Spiral 1)
- Establish a dismounted networked lethality thrust (Army S&T; with first UA)
- Fund PEO Soldier now – Target Geolocation & Designation for loitering munitions; standoff breaching munitions; smart rounds

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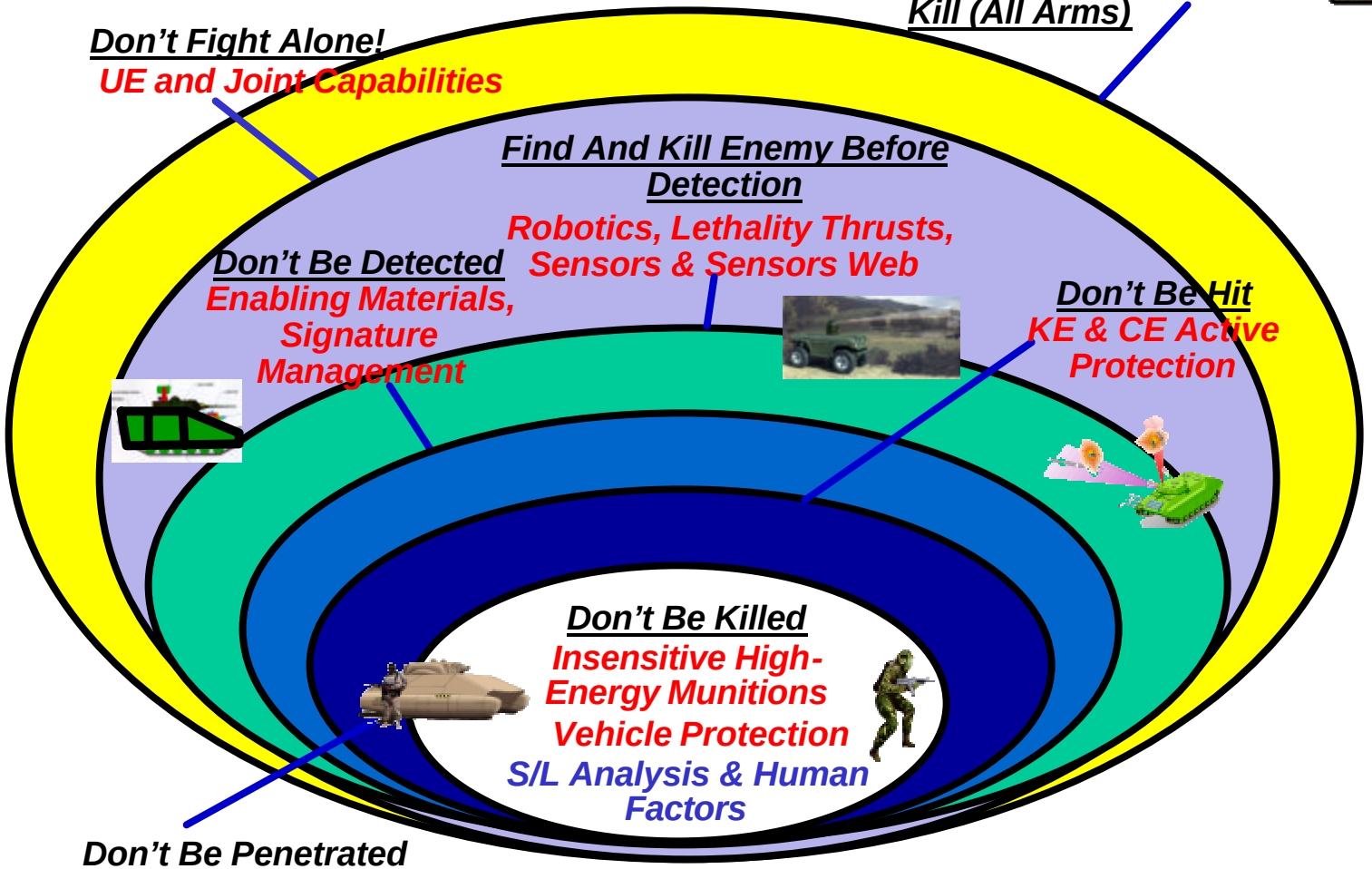
Networked Survivability



Networked Survivability Enablers

Joint Force

- **Full spectrum low latency Army and joint lethality**
- **Networked battle command and lethality (Army fires, JDAM, LGB, arc light and joint loitering munitions LOCAAS, AWS, etc.)**

Unit

- **Sensor nets provides synoptic situation awareness, (take advantage of change detection and tracking); use robots to take risks and hits; Loitering missile available to prosecute in seconds**

Platforms

- **Multimode, multifaceted survivability suite**

Revenge Kill

- **Integrate sensor web for localization, specialized "warfighting rules" and rapid fires application**

Recommendations: Networked Survivability

- **Kinetic energy active protection and electromagnetic armors**
  - **Army S&T complete technology development (PM FCS transition and field; Spiral 1)**
- **Unit, section, platform survivability campaign**
  - **Establish campaign concept and initial local warfighting rules and use of layered capability (including revenge kill) (UAMBL and LSI; Now)**
  - **Expand sensor web concept to provide focus on survivability; Experiment with possible solutions (UAMBL, C3OTM); Transition into FCS program (PM FCS and LSI; Spiral 1)**
  - **Revenge kill should be explicit part of networked battle command (PEO GCS; Now)**

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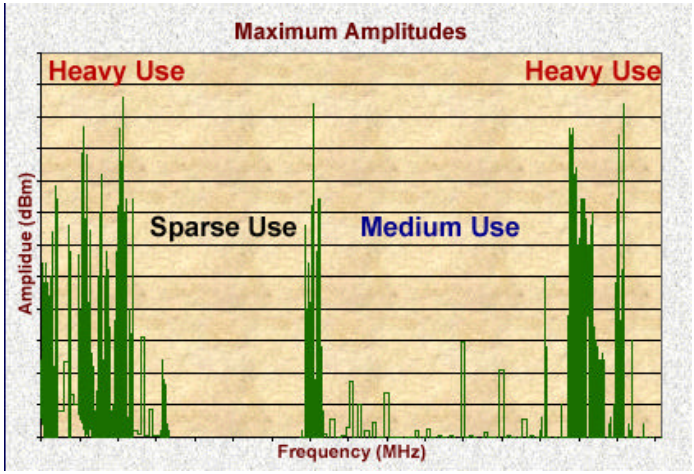
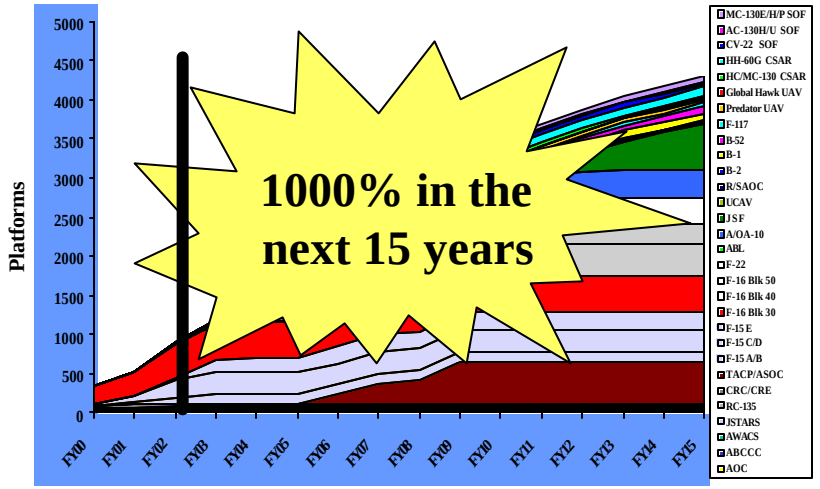
Bandwidth Challenge



- Army/FCS bandwidth requirements growing (e.g., >>20Mbps for UA)
- OF needs voice, data, imagery and video distribution in near real time
- Joint, interagency and multi-national competition for spectrum (e.g., AF)

- Spectrum crowded and oversubscribed - Fixed allocations inefficient
- Conventional spectrum planning overly complex
- Dynamic tools lacking

Air Force Projected Tactical Data Link Growth



Adopt Bandwidth Efficient Strategy

- Control bandwidth demand
  - Optimize packets/update rate, on-board processing, data compression
- Spectrum management
  - Adopt dynamic assignment and policy management strategies
  - Introduce DARPA's "XG" dynamic spectrum usage into FCS Network Management in 2010 spiral
- Time and space utilization
  - Introduce bandwidth enhancements from DARPA's FCS Communications and Army's MARCON-i STO during 2010 spiral
  - Extend JTRS frequency range above 2 GHz for Wideband Network Waveform
  - Establish program for asymmetric transmission with small up- links and robust down-links (e.g., DIRECT/TV/PC)
  - Employ adaptive and directional antennas

Recommendation: Bandwidth Campaign

- Assign “Bandwidth Campaign” mission to Army CIO now
- Roles and responsibility
  - Ensure electromagnetic spectrum is managed as precious and limited resource
  - Ensure Army acquisition is consistent with campaign plan
  - Influence DoD initiatives to support Army needs (e.g., transformational communications)
  - Plan for the continual growth in bandwidth requirements
  - Ensure information distribution and access efficiency

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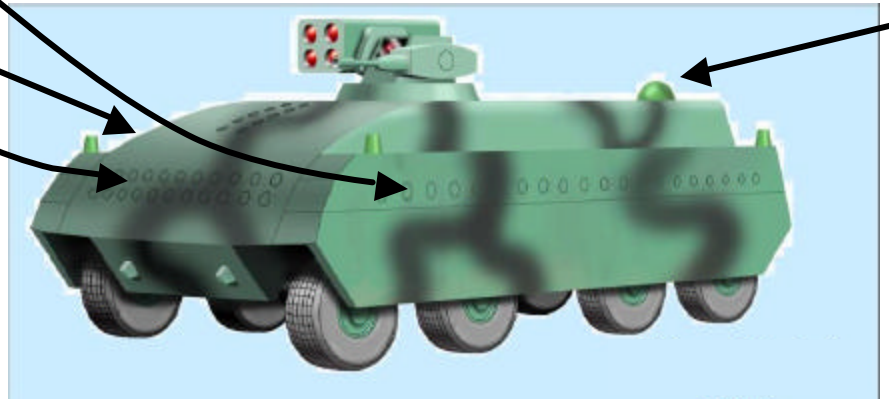
Smart Antennas to Provide Breakthrough Capabilities

- Opportunity to move aggressively to objective capabilities
- Enables distributed, multi-functional operations
  - Each platform contributes to communications, active protection, EW, SIGINT, deception, radars
  - Multiple combat platforms acting as a "team;" networked operations eliminate dedicated single function platforms
- Leap ahead - bandwidth, range, anti-jam, reliability, multi-function

Complementary Multifunctional Architectures

Low Band VHF to GHz Distributed Adaptive Array Antenna

- Solid tech base
- Commercial investment
- Extends JTRS/WIN-T performance envelope



High Band - Microwave Steered Multi-Beam Antenna

- Limited tech base
- Expensive boutique applications
- Cost is an issue

(ASB Ad Hoc Antenna Study)

Antenna Recommendations for Implementation in Baseline

- Develop protocols and open standards for JTRS and WIN-T to accommodate “smart antennas” (ASAALT; Now)
- Extend JTRS and WIN-T software architecture to manage distributed antennas (ASAALT; Now)
- Accelerate investment in network control, integrated waveform/ protocol development (ASAALT/DARPA; 04)
  - CERDEC MARCON-i , MOSAIC, DARPA FCS Comms and MIMO BAA
- Invest in RF components to reduce ESA cost (ASAALT; Now)
- Aggressive SiGe program: “Antennas on a chip” (ASAALT or DARPA; Now)
- Evaluate and verify progress through trials, experiments and test (ASAALT/LSI; Now)
  - Restructure the C3OTM test-bed to support technology maturation, development of TTPs for training insights

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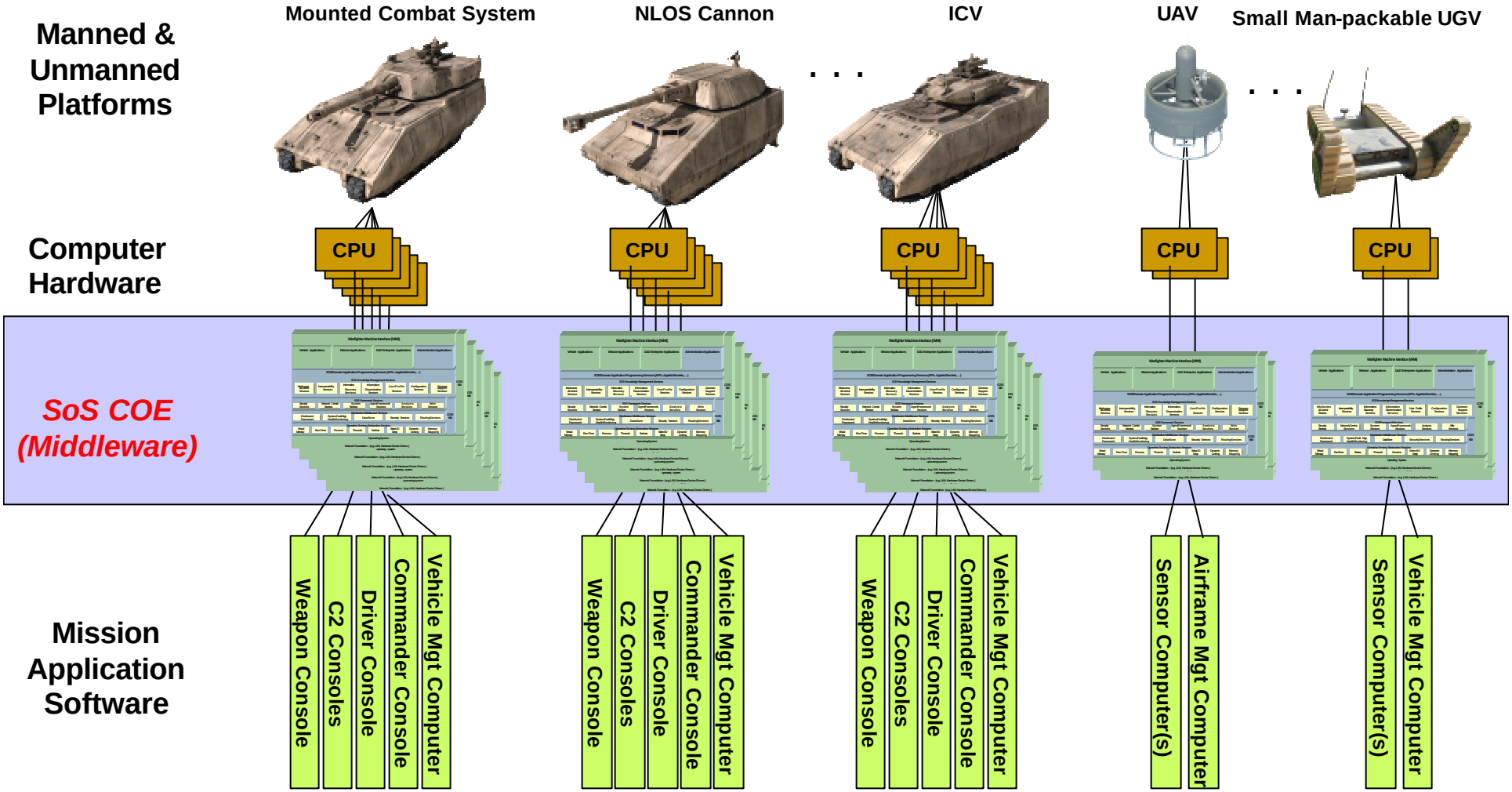
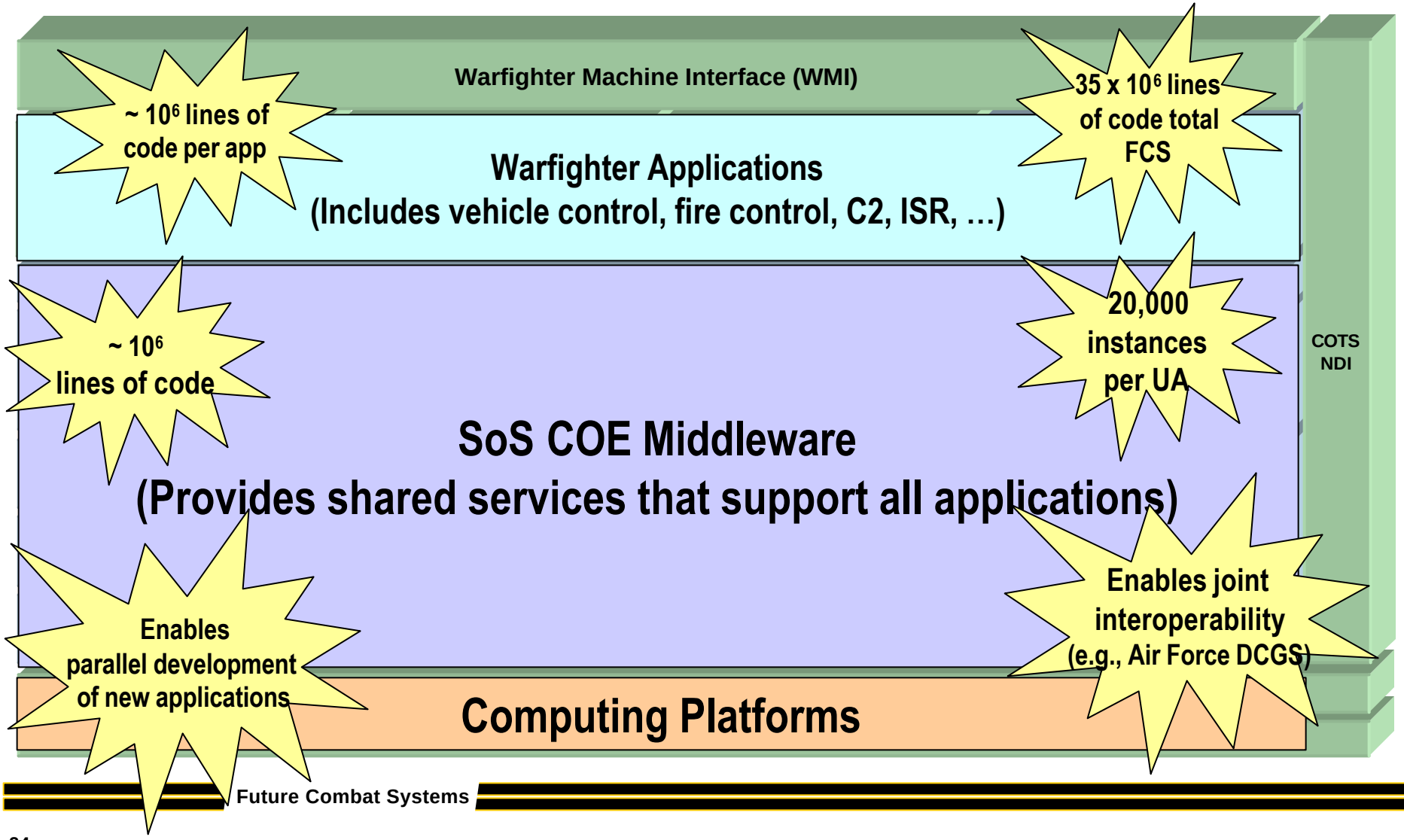
Risk: Unprecedented Scale and Complexity

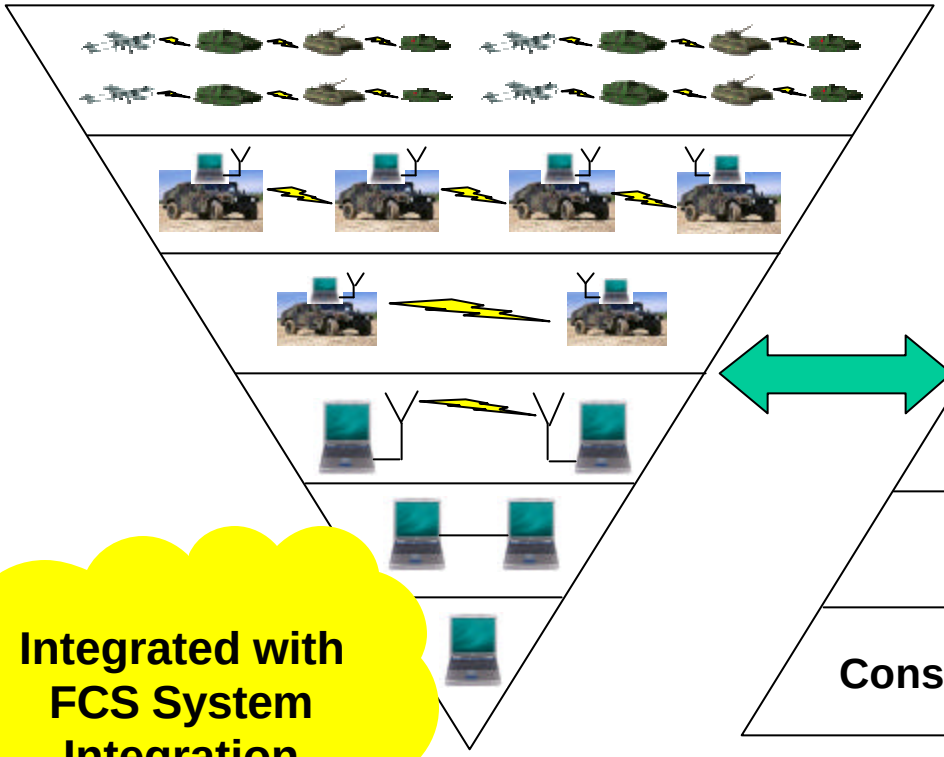


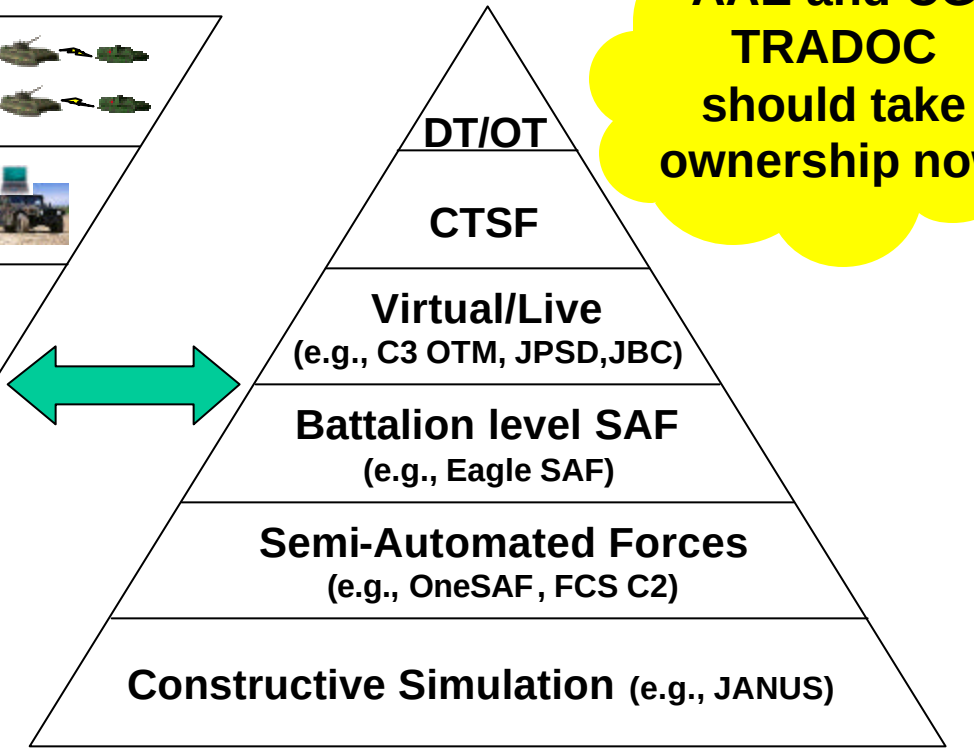
System of Systems Common Operating Environment (SoS COE)



SoS Validation through Continuous Experimentation and Testing

By: Conducting scaled systems level experimentation and testing





AAE and CG TRADOC should take ownership now

Integrated with FCS System Integration Laboratory

And by: Enhancing and leveraging Army's simulated test and experimentation environments

FCS Software: Recommendations

- Within the FCS community, adopt open source SW development for SoS COE, including development of supporting tools e.g., CM tools, security (LSI; Now)
- Establish FFRDC "SoS COE Blue Team" for controlled intellectual competition, leveraging existing models, e.g., Intel Community's S&T Expert Partnership (AAE; Now)
- Establish Army S&T Program to leverage middleware advances in DARPA and NSF programs (e.g., DARPA MoBIES, PCES) (AAE-FY04)
- Continuous "non-attribution" experimentation to gauge progress and optimize warfighting effectiveness of FCS SW
  - Utilize existing constructive/virtual/live environments integrated with the FCS SIL

The Army's "Bolder Stroke"

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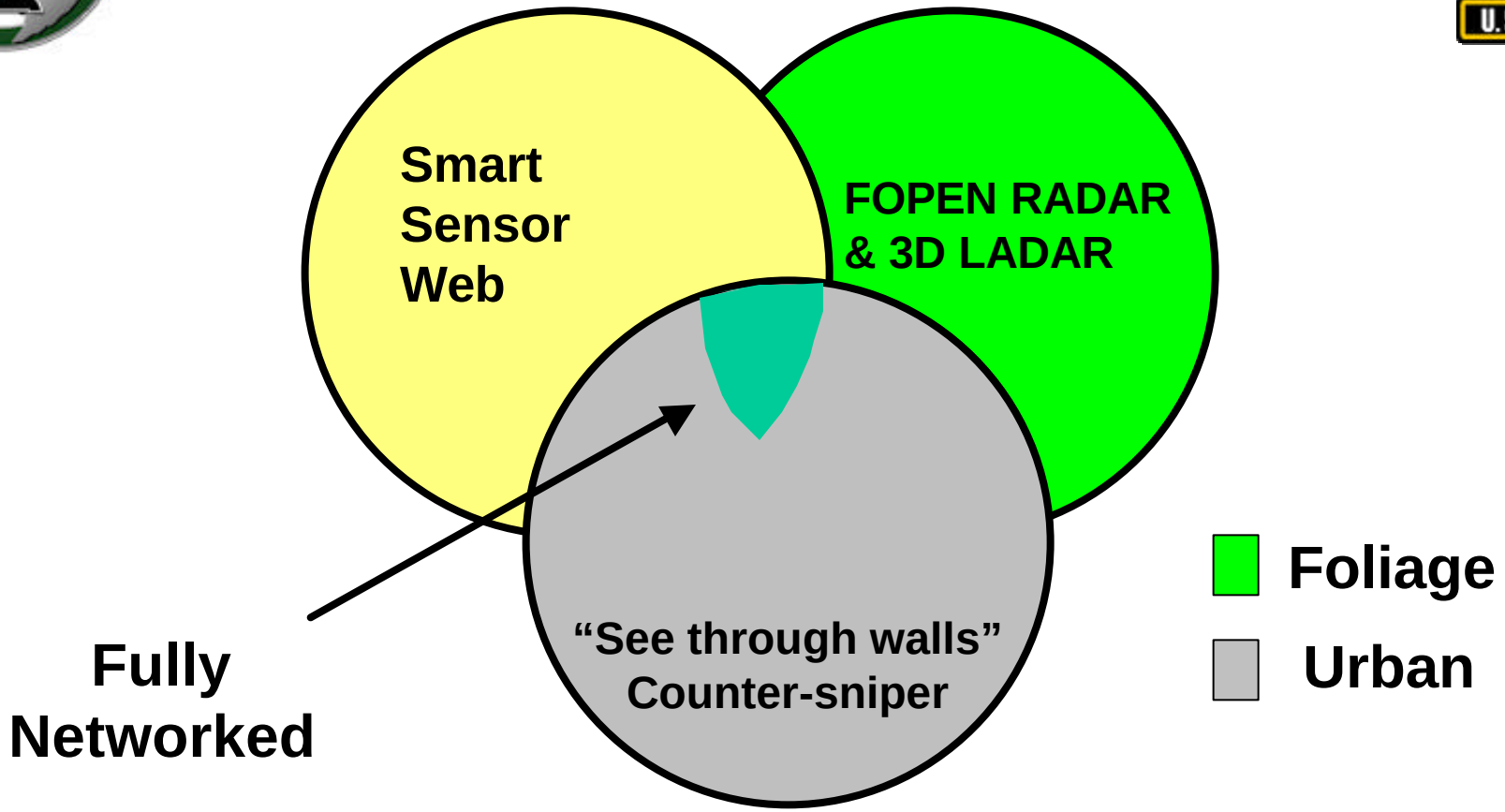
Sensor Panel KPP Summary

KPP	Threshold	Spirals	Objective
#1 - Joint Interoperability	100% Top IER	Information Exchange Requirements	100% IER
#2 - Networked Battle Command	Situational Awareness	Smart Sensor Webs FOCAM Urban Combat Sensors	Fused COP
#3 - Networked Lethality	Chap 4 LOS, BLOS & NLOS	Sniper detection/engagement	Autonomous B/N/LOS
#4 - Trans	ECC C5/RORO Intra 500 NM	Essential Combat Configuration, High Speed Sealift, Roll-on Roll-off	ECC HSS Intra 1000 NM
#5 - Support & Reliability	95% OA -30% Stryker	Operational Availability	99% OA -85% Stryker
#6 - Training	TESS IAW CTIA	Tact Engagement Simulation System Common Training Instruction Architecture	TESS IAW CTIA & JIS
#7 - Survive	HEAT @ xxM 30mm Sabot	Urban Combat Sensors Advanced countermine (imaging technology) FOCAM	KE @ xxM 45mm Sabot

Transparent Battle Space



Fully Networked

All with persistence

Nowhere to hide

Smart Sensor Webs

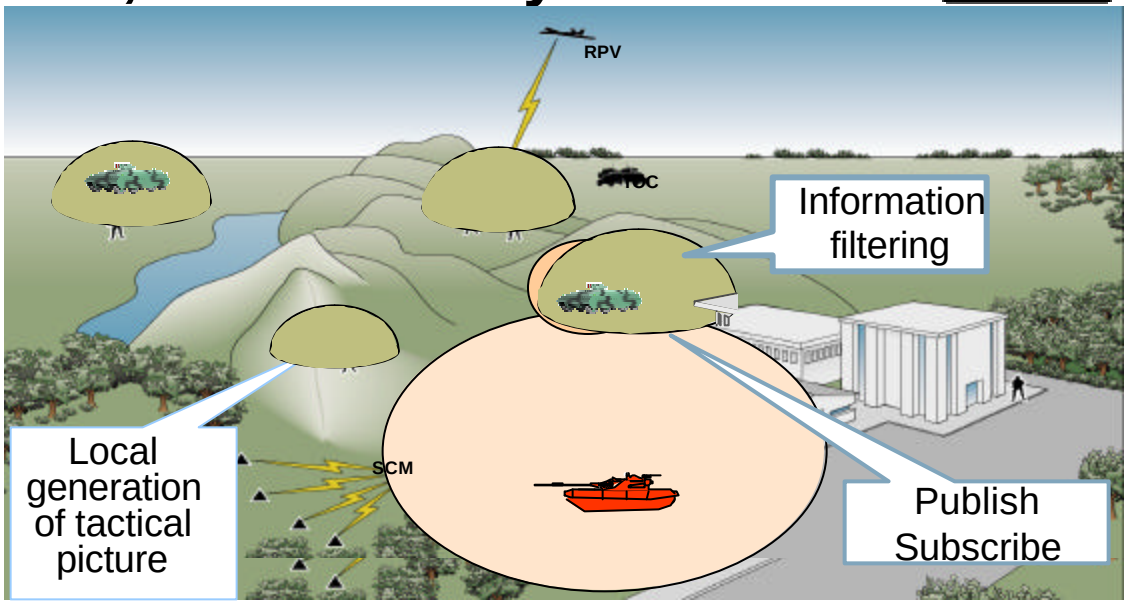
Situational Awareness Through Netted, Processed, Sensor Arrays

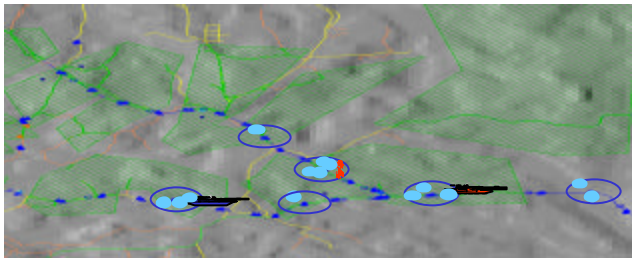
Applications

- Urban canyons
- Subways & sewers
- Rural terrain and roads
- Heavily foliage
- Real time target tracking

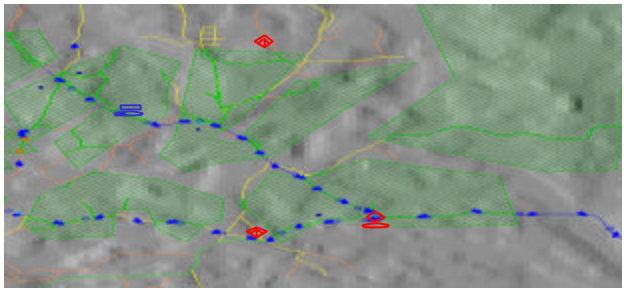
Functionality

- Self organizing, Info filtering
- Comms and Geo-location
- Publish / Subscribe concept



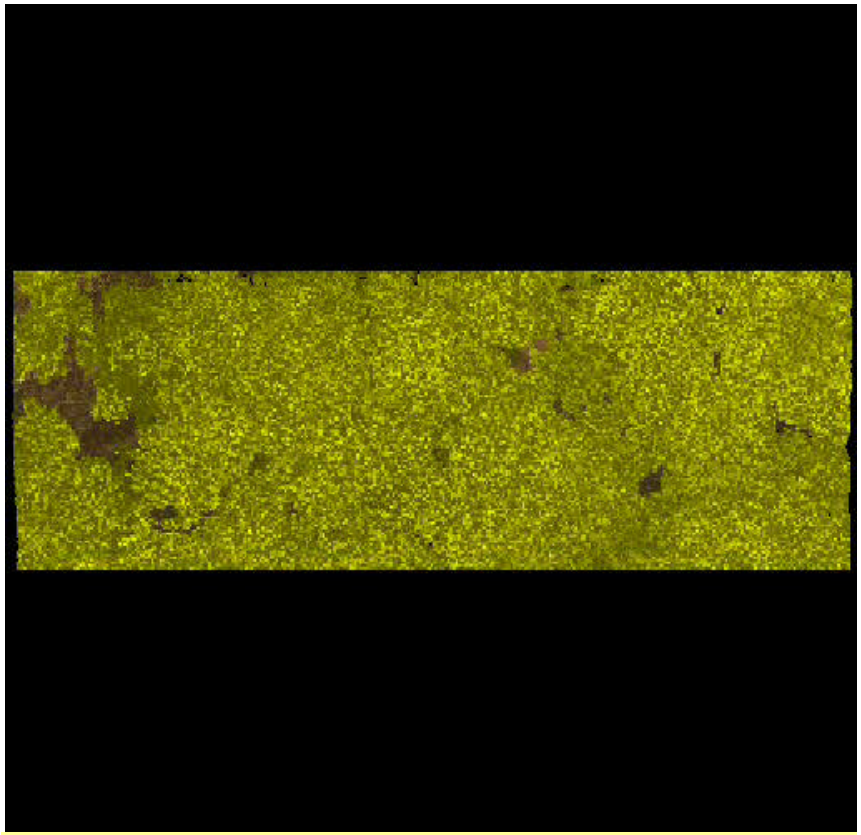


- Organic & external reports
- Blue force position
- SALUTE reports



Performs fusion locally to generate a tactical picture

Foliage Penetration SAR & 3D LADAR

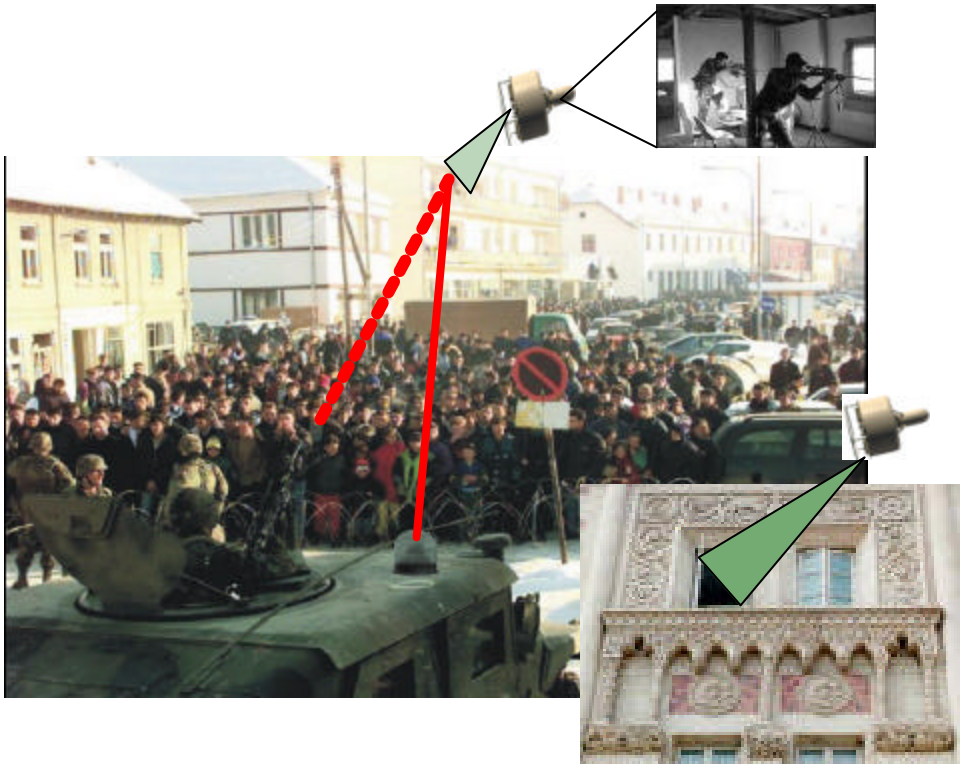


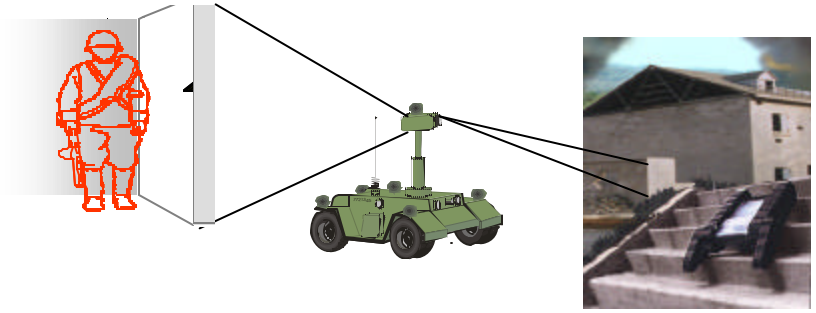
Foliage Penetration

Data combined from multiple viewpoints

Urban Combat
“See Everywhere - All the Time”

- Virtual presence
  - Early seamless integration of intelligence
  - Persistent, ubiquitous, dynamic, volumetric imaging and video
  - Viewpoints from any angle
- See behind walls, detect mines & tunnels
  - “Through-the-walls/windows” standoff sensors
  - Counter-sniper system
  - Imaging ground penetrating radar
  - Seismic and acoustic imaging





“Nowhere to hide”

Sensor Recommendations

- **Smart sensor web**
  - **Integrate available sensors with embedded processing (PEO FCS & LSI; Spiral 1)**
- **Foliage penetration, counter camouflage RADAR and 3D LADAR,**
  - **Complete DARPA, ARL and CERDEC FOPEN and 3D LADAR S&T program (Director, DARPA and CERDEC; Spiral 1)**
- **See-through-wall RADAR adapted to UAV/OAV**
  - **Complete efforts at DARPA and in Army S&T [Director, DARPA & DASA (R&T)]**
  - **Transition to FCS (PEOs GCS, IEW&S, Aviation, and LSI; Increment II)**
- **Counter-sniper system**
  - **Integrate available technology including prototypes (i.e., SMDC Overwatch, CERDEC) (PEOs GCS and Soldier and LSI; Increment II)**
- **Counter-mine system**
  - **Integrate available technology to provide rapid and sure detection (air/ground) of mines and booby traps (PEOs Ammo and IEW&S; Spiral 1)**

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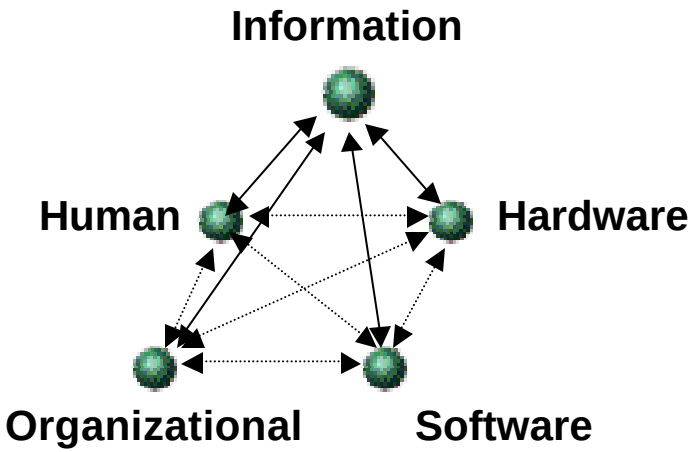
SoS Reliability

Issue

- SoS must
  - be reliable
  - possess redundancy
  - degrade gracefully
  - have a fail safe mode
  - be able to recover quickly
  - be low latency



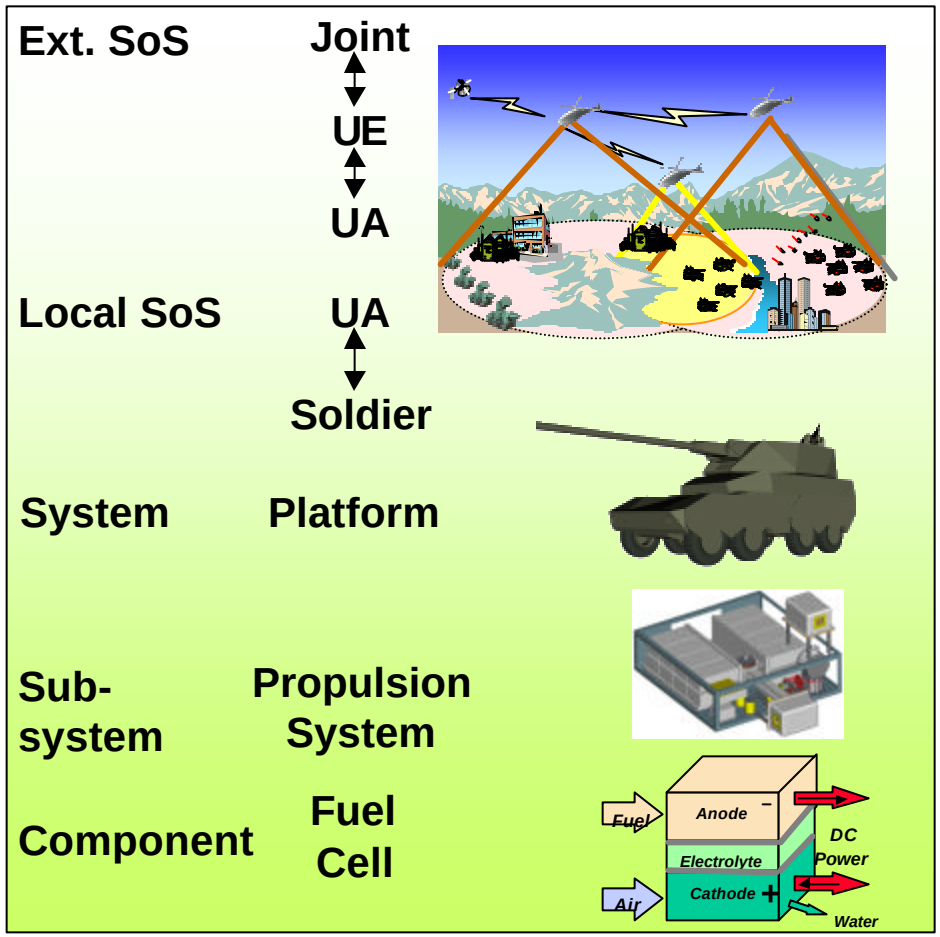
Findings

- Traditional platform way of thinking not applicable – must be viewed from a SoS operational effectiveness perspective
- Information, human, hardware, software and organizational performance in combination will all dictate SoS reliability and readiness

SoS Reliability

Recommendations

- Relationship between reliability and SoS readiness must be modeled and understood now
- PM FCS and LSI should
  - develop candidate metrics for SoS reliability and readiness
  - consider contractor incentive for reliability
  - model the role of information quality, assurance, and service on reliability and readiness
  - provide FCS UA and UE reliability and readiness definitions - now



Vision for Increment II: a New "Top Four"

Top Four	Enables ~
1. Air deployment and maneuver	• Forced entry • Over the shore logistics • Eases weight constraint
2. Unprecedented protection – DE Wpns	• Bottomless magazine • Engaging unengagable targets • Dial-a-lethality
3. Pervasive robotics	• Find and hold threats at risk • All class of dirty, dangerous, dull tasks • Autonomous
4. 10x training	• Be all you can be!

"Delivering step function increase in capabilities"

Management Initiatives

- **Unit managed readiness**
- **Experimentation/modeling and simulation (survivability of small units)**
- **Life-cycle Red Teaming**

The DARPA Role in Spirals - Major!

Spiral	DARPA Contribution	New Ideas?
Joint interoperability for network centric survivability and lethality	AJCN THOR UCAR	Non lethal weapons Highly maneuverable weapons
Integrated survivability	Urban combat (tbd)	Soldier survivability
Bandwidth campaign	FCS comms MIMO	
Smart antennas	SiGe antenna	
Middleware/Software	Middleware research	
Transparent battle space	Sensor webs See-thru-walls MANTIS	Mine detection
System of systems reliability		Understand problem

FCS Spiral Development Challenge

- **Unprecedented opportunity for transition of technology, subsystems and prototypes in an integrated spiral development process**
- **We need DARPA to maintain commitment to develop innovative, high risk, high payoff technologies for transition to FCS**
- **Spiral development processes must be developed in parallel with experimentation technology and prototype development**

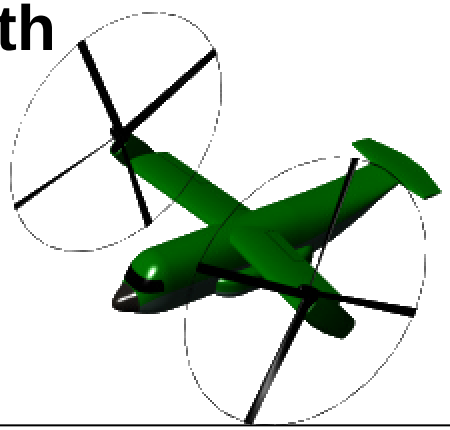
Successful spiral development requires stakeholders to bridge the gap between S&T and SDD to provide needed objective capability

Takeaways

- **Manage highest priority risks**
  - **Networked battle command**
  - **Networked survivability**
  - **Transportability: Power projection**
- **Apply technology spirals across the total force**
- **Expand experimentation to define and develop DOTLMPF spirals**
- **Refocus transformation management**

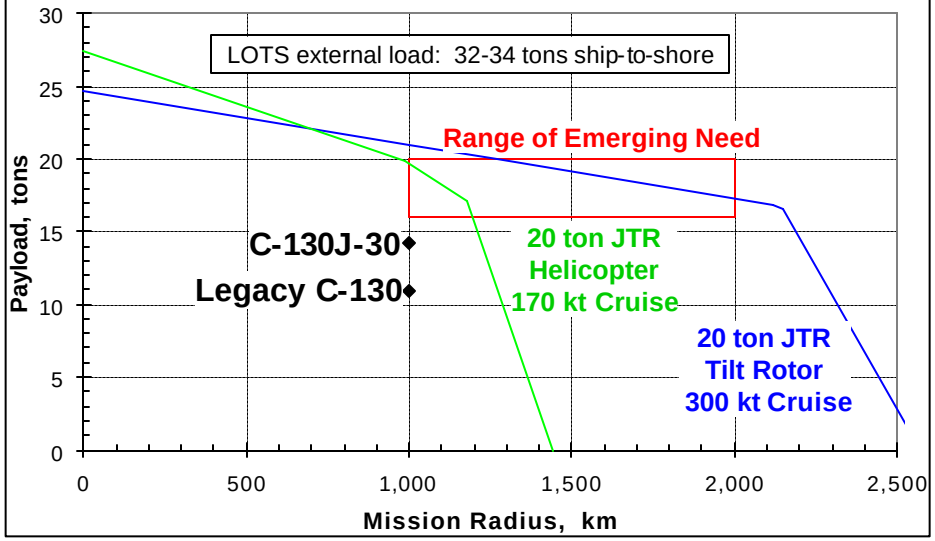
Backup

Joint Transport Rotorcraft (JTR) Provides FCS Mounted Vertical Maneuver to Operational Depth



Joint Tactical Rotorcraft

Range/Payload Tradeoff - Sea Level Base to High Hot LZ



JTR is Required for the Army, Marines, & SOF

- **Fixed Wings**:
  - Must use APODs
  - Cannot unload ships
- **Rotary Wing**:
  - Evolutionary designs do not meet needs

Only the JTR can provide the FCS the capability for vertical mounted maneuver to operational depth

(ASB Ad Hoc Aerial Support Study)

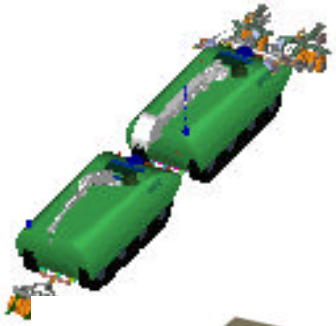
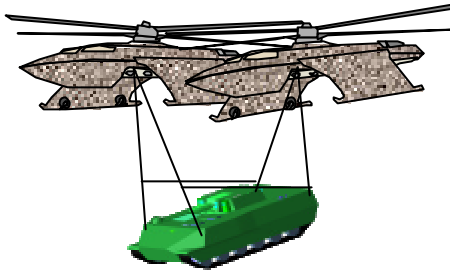
Directed Energy Weapons

- **Supports a variety of functions**
  - **Air defense (e.g., rockets)**
  - **Counter RSTA**
  - **Disable booby traps**
  - **Aircraft protection**
- **Bottomless magazine**
- **Instantaneous effect**
- **Dial-a-lethality**
- **Element of information warfare**

Pervasive Robotics

RSTA	Attack	Maneuver Support	Maneuver Sustainment





Army begins campaign to incorporate unmanned systems multi-role for RSTA, weaponization, maneuver support and sustainment functions

10X Training: Tying it all Together

Embedded training

+

Multi-player wars (scenarios) over the net

+

Individual performance monitoring

+

Cognitive learning processes designed to specific tasks

+

Individualized unit and soldier training packages

Across the total force

Recommendations: 10X Training

Findings

- Does not include all components of UE SoS, e.g., CS and CSS
- Collective training requires high overhead and is not persistent
- Automated performance assessment not embedded

Recommendations

- Include all elements of UE SoS in embedded training architecture (G8/LSI; Now)
- Leverage online gaming technology for collective training environment (Army S&T; Spiral 1)
- Embed automated performance assessment in C4ISR and training architecture (Army S&T; Spiral 1)
- Research cognitive learning processes based on complex FCS tasks and prepare individualized training for units/soldiers (Army S&T; Increment II)

Unit Managed Readiness (ASB SS 2002)

Issues

- UA will
  - Be technologically sophisticated and highly complex
  - Face diverse, adaptive threats
- UA will require
  - Cohesive teams of leaders and led
  - High-aptitude, cross-trained, well-rehearsed soldiers
  - Continuous learning to evolve joint interoperability

Finding

- Neither present leader development program or current individual replacement system are well suited to address above issues

Recommendation

- Adopt from the onset unit managed readiness for FCS UA (G1; Now)

Land Warfare & Joint Experimentation

Recommendations

- **Develop a transformation experimentation plan**
- **Establish a permanent organization to experiment and work in DOTLMPF (TRADOC/LSI/Dir OF, now? Spirals…). Key functions:**
  - **Develop and validate the joint tactical operational rules**
  - **Establish and maintain an experimentation "core cadre"**
  - **Program funding for experimentation**
  - **Provide mechanism to equip soldiers with mature technologies**
- **Use C3OTM and JPSD as basis for building experimental organization**
- **One or two company size unit(s) with hooks to battalion elements**
- **Composition/focus changes over time**

Life Cycle Red Team

Functions

- Conduct analytical OPFOR-like missions against the FCS SoS
- Conduct technical assessments
- Design longitudinal scoreboard based on objective capabilities

Benefits

- Ensure long term survivability of system of systems
- Provide life cycle feedback on capabilities

Recommendations

- Establish independently funded FCS Red Team reporting directly to the Secretary of the Army (VCSA; Now)
- Actively integrate (intel, testing, training, ops, signal, joint, etc.) red-teaming into FCS development process in accordance with draft OSD “Best Practice Guide” (Red team; ASAP)