from nonorganic sources, including current forces and JIM. SDM will perform sensor data format conversions to output the data in FCS standard data formats.

Force Transformation Through the Network

The FCS network is a cohesive and seamless architecture of battle command, communications, computers and ISR connected through the SOSCOE. The network is central to three of the seven transformational KPPs — Joint Interoperability, Networked Battle Command and Networked Lethality — and supports the remaining four — Transportability, Sustainability/Reliability, Training and Survivability. The network enables the Future Force by providing the capabilities to see first, understand first, act first and finish decisively on the future battlefield.

COL JONATHAN A. MADDUX is the Project Manager for FCS Network Systems Integration. He has B.S. degrees in operational research systems analysis and English literature and language from Eastern Michigan University. He holds M.S. degrees in telecommunications, human resource management and strategic studies from the University of Colorado, Central Michigan University and Army War College, respectively. Military education includes the Project Management Course, Defense Systems Management College, Army Command and General Staff College and the Army War College.

DR. GERARDO J. MELENDEZ is the Deputy Project Manager for FCS Network Systems Integration. He has a B.S. in biomedical engineering from Tulane University, an M.S. in electrical engineering from Brown University, a post-master's in electrical engineering from Princeton University and a Ph.D. in electrical engineering (digital signal processing and neural networks) from Drexel University. He also received an M.S. in strategic studies from the Army War College.

System-of-Systems Integration: The Most Ambitious Army Program Ever

Scott Davis and Tom Bagwell

System-of-Systems

Future Combat Systems integration as a system-of-systems (SoS) through a network environment will provide total operational capabilities not achievable by individual platforms. This SoS includes integration of 19 systems that make up the FCS Family-of-Systems (FoS); integration across the distributed system functions that include command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR); logistics and training; and integration with complementary programs such as Commanche, Warfighter Information Network-Tactical and High-Mobility Artillery Rocket System. FCS-equipped battalions will make up the unit of action (UA). Integration of these combat, combat support, sustainment and C4ISR systems into a networked SoS enables the UA to operate as a fully integrated combined arms force and will facilitate interoperability with the unit of employment (UE) and Joint, Interagency and Multinational (JIM) forces.

Unprecedented FCS network integration will allow the UA to:

- Share superior situational awareness.
- Engage the enemy at tactically significant standoff ranges.
- Mass effects at the time and place the UA commander chooses.
- Move to the most advantageous points in time and space to engage the enemy — offensively and defensively.
- Employ area force protection and avenge-kill capabilities to enhance force survivability.
- Synchronize pulsed resupply with combat operations to maintain high operational tempo.
- Conduct embedded, distributed mission training and mission rehearsal to enhance proficiency.

These capabilities can only be achieved through highly networked operations that leverage the ability of individual elements to achieve synergistic effects. While the FCS is designed to function in a highly collaborative manner as a tightly integrated SoS, it will still maintain the capability of independent action by individual units and platforms.

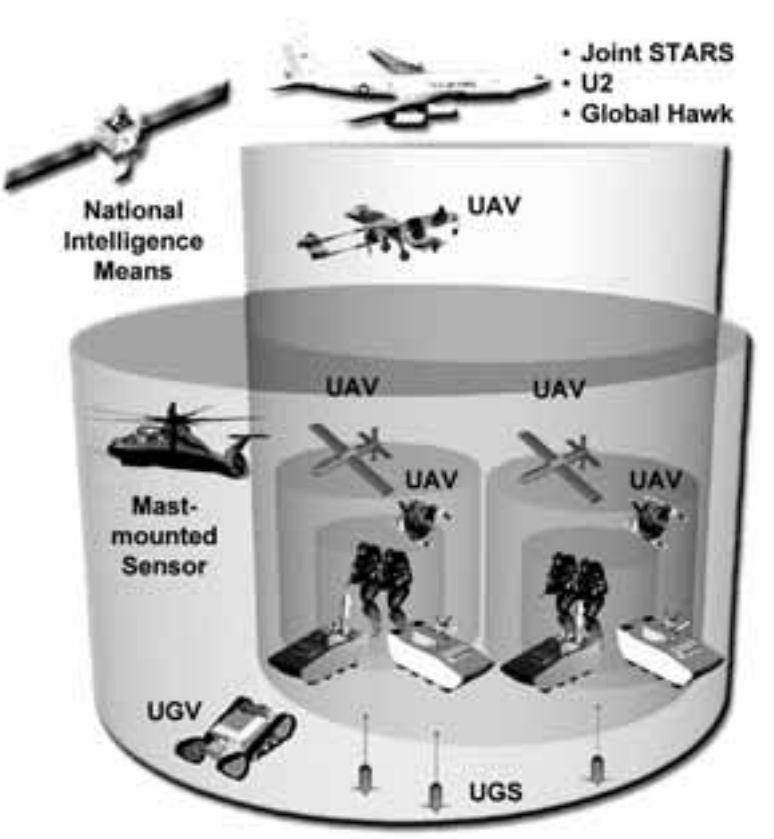
While individual systems and force elements are capable of independent action, SoS operational effectiveness is significantly enhanced by shared information, shared assets and a highly collaborative battle command environment that enables continuous collaborative planning and synchronized execution.

Systems Engineering

Traditional systems engineering (SE) is a disciplined and iterative approach using tools and processes to translate user requirements for a single weapon system into performance specifications, architectures and configurations. SE consists of three major steps — requirements analysis, functional analysis and allocation and design synthesis. It is important that the performance and functional requirements can be traced back to the users' requirements and that verification of the functions against the system design occurs as part of the iterative SE process.

SE uses a series of reviews to measure the design progress and maturity along key points in the milestone schedule. Specific entrance and exit criteria are established for each review. Some key reviews during the system development and demonstration (SDD) include the system requirements review (SRR), system functional review, preliminary design review and critical design review.

FCS uses SE to manage the program and ensure that the process discipline provides the control and traceability required to develop systems that meet users' requirements. However, FCS uses the flexibility of the DoD 5000 series to tailor the SE process to better conform to the FCS SoS approach. The SE process is being performed at the SoS level, resulting in an SoS-level specification that articulates SoS requirements and provides a top-level allocation of requirements down to the 18 individual systems that make up the FoS, which include mounted combat systems, non-line-of-sight cannons and distributed systems such as C4ISR, logistics and training.



Distributed and networked sensors will allow FCS unequaled situational awareness and enhanced survivability by avoiding enemy fires. It will also enable precision engagement and maintain contact and engagement for U.S. Forces.

The initial SRR will be conducted at the SoS level followed by individual-platform SRRs. Subsequent SE reviews will be conducted at the individual platform level and then rolled up at the SoS level. The SoS approach allows subsystem requirements and functions that cannot be performed by one system to be reallocated to another system without impacting the performance at the UA level.

FCS SoS Integration

A basic FCS program challenge is introducing a whole new way of acquiring warfighting capabilities for our soldiers. Traditionally, the Army procures a new weapon or weapon system, introduces it into the active force and lets the operational unit determine how to integrate it into its operational concepts. Then through exercises or tests and in some cases actual combat, the operational unit determines what it does for overall unit performance. With the FCS SoS approach, the Army is procuring operational capabilities designed from the start to deliver specific integrated unit performance. That is, specific integrated UA performance is being designed into the various FCS vehicles, sensors, C4ISR and training/sustainment software.

With FCS, the Army is acquiring an integrated UA with specific operational

capabilities. Thus, the FCS SoS SE activities must have an SoS focus that enables design decisions and engineering trades at the SoS level, perhaps trading individual system performance for the good of overall UA performance. The Army is most interested in how the various systems perform together at the UA level to achieve the program's key performance parameters (KPPs) articulated in the operational requirements document (ORD). The FCS KPPs are joint interoperability, networked battle command, networked lethality, transportability, sustainment and reliability, training and survivability.

> While the FCS is designed to function in a highly collaborative manner as a tightly integrated SoS, it will still maintain the capability of independent action by individual units and platforms.

The FCS SoS acquisition is not about procuring individual parts. The integrated UA is an SoS made up of many individual systems, some of which are specific to the FCS program and some that are complementary. The FCS program is procuring manned ground vehicles, unmanned air vehicles, unmanned ground vehicles and C4ISR-related equipment. This includes integrated training and supportability capabilities that address individual system or vehicle training and supportability needs and the UA's training and supportability needs as a whole. The FCS program is procuring integrated interfaces with the Army's Soldier systems, current Army forces and other existing or developing complementary programs within the Army, Joint services, interagencies and international coalition forces. It is all of these systems working together as an integrated whole that make up the UA SoS.

The complex integration task is multidimensional and must simultaneously address multiple requirements. Specific FCS systems will be procured only after four dimensions of integration are demonstrated — vertical, horizontal, performance and interoperable. The Army will actually procure individual vehicles that possess advanced *vertically* integrated lethality, sensors, C4ISR, survivability and supportability functionality. However, before the Army decides to buy any vehicles, they must demonstrate that they can work together and are *horizontally* integrated to enhance force effectiveness through networked collaboration of individual systems. Most importantly, unit-level operational testing must show that the vehicles are *performance* integrated and that they can work together to accomplish the 24 designated operational integrated processes to achieve the desired KPP thresholds and objectives. Finally, the UA must demonstrate that it is *interoperably* integrated with current Army elements as well as JIM forces.

> The Army is procuring operational capabilities designed from the start to deliver specific integrated unit performance. That is, specific integrated UA performance is being designed into the various FCS system's vehicles, sensors, C4ISR and training/sustainment software.

SE and Integration

To acquire the FCS SoS, the Army has partnered with a strong industrial team consisting of the Boeing Co. and Science Applications International Corp. (SAIC) to form the Lead Systems Integrator (LSI). Over the past 6 months, the Army and LSI team, through a series of competitive proposal actions, brought together the best of industry to help design, develop, integrate, test and deliver the various parts of the FCS SoS.

There are currently more than 20 supplier partners who will produce the integrated FCS SoS building blocks. The principle challenge today is to ensure that the specifications given to the numerous supplier partners correctly reflect the performance and integration requirements so that when the pieces come together in 2007, they can be successfully integrated against the multiple objectives discussed above. This can only be done with a focused organization, dedicated people, proven processes and robust tools that are all focused on the integrated UA SoS performance objectives.

Organization

The LSI has established an FCS-tailored organization that is designed to facilitate the FCS component acquisition. The organization's key aspect is that it operates as a true integrated product team (IPT) at every level from the program manager down to the various product acquisition teams. At each organizational level, there is a co-leader relationship consisting of an Army and LSI contractor representative from either Boeing or SAIC. IPTs are staffed with both contractor and Army personnel to help do the work and deliver the products. In IPTs where FCS products are acquired and integrated, there are representatives from the appropriate supplier partners. This IPT concept helps ensure that all stakeholders have continuous input to the design, development and integration process. In some cases, additional

specialized working groups or teams have been formed to focus on specific program aspects. The most important groups include the following:

- Senior integration management team.
- Requirements working group.
- Trade study working groups.
- Interface control working group.
- System integration working group.
- Nonadvocate review groups.

People

Both the Army and LSI contractor team have reached out broadly to get the best and brightest to support the FCS program, so the team is geographically dispersed. The staffing focus has been on centers of excellence within the two contractors, their supplier partners and within Army and DOD agencies. The LSI team is principally focused in several key centers. The program is headquartered in St. Louis, MO; and other key locations are Huntington Beach and Anaheim, CA; Seattle, WA; Houston, TX; Huntsville, AL; Orlando, FL; and Washington, DC.

Process

Key to a large program like FCS is the use of proven processes and procedures. The "best-of-breed" practices from Boeing and SAIC have been gathered to produce common best processes and procedures tailored for FCS and designed for Level 5 Capability Maturity Model (CMM) Integration. These best practices are available to the whole LSI team and to all supplier partners. However, care is being taken in the application of these processes by suppliers so that their current CMM-level certifications are not disrupted. Key processes include a:

- Risk Management Review Board.
- Configuration Control Board (CCB).
- Program CCB.
- Earned Value Management System applied at all IPTs.

The Army and LSI team, through a series of competitive proposal actions, brought together the best of industry to help design, develop, integrate, test and deliver the various parts of the FCS SoS.

Tools

A critical aspect of the integrated FCS SoS approach is a robust SoS architecture that is developed from the Army's operational requirements, the operational and organizational plan and the 24 integrated processes. A single integrated FCS SoS architecture is being developed that consists of operational, system and technical views that are modeled in Unified Modeling Language. The "FCS One-Team, One Architecture — One Single Integrated Model" slogan implies that the architecture addresses the SoS-level functionality, includes the FoS-level functionality and addresses both the physical hardware systems as well as the software systems. Single integrated FCS SoS architecture development is an iterative process designed to support all LSI and supporting supplier/partner needs.

The tools also include a full suite of government models and simulations to help analyze and assess UA performance as well as help in the integration labs. A very important tool is the LSI's Advanced Collaborative Environment (ACE), which is designed to bring all the geographically dispersed locations into a single collaborative work structure that allows everyone to work from common (configuration-controlled) databases using common tools. Key ACE tools include:

- Architectures in Rational Suite.
- Requirements in the Dynamic Object-Oriented Requirements System, a tool from Telelogic Corp.

- Government models and simulations.
- Integration labs — component development labs, C4ISR System Integration Lab (SIL), platform SILs at partner sites, SOS Integration Lab, and field tests.

The Path Forward

The challenge of implementing an SoS integration approach for FCS has been successfully met through the Army and LSI partnership. The Army and LSI senior leadership's focus on SoS engineering and integration activities in SDD's early phases ensures that the FCS program is successfully integrated with the UA, UE and JIM forces. The near-term focus is to baseline the FCS program to get the whole "One-Team" aligned to a common objective and associated roadmap. Upcoming actions include completing the Integrated Baseline Review Phase I, which will ensure that schedules are integrated horizontally and vertically. The SoS Requirements Review was scheduled for completion in December 2003 followed by the individual IPT SRRs. The One-Team will continue to leverage partner expertise in developing the SoS integration approach.

SCOTT DAVIS was the Director of Engineering in the FCS Program Management Office when he co-authored this article. He is now the Deputy Program Manager FCS. Davis holds a B.S. in mechanical engineering and an M.S. in industrial engineering and has completed the Defense Systems Management College's Advanced Program Managers Course. He is also a Command and General Staff College graduate.

TOM BAGWELL is the Deputy Director for Engineering in the FCS PMO. He holds a B.S. and an M.S. in civil engineering from Virginia Polytechnic and State University and an M.S. in national resources strategy from the Industrial College of the Armed Forces. He has also completed the Defense Acquisition University's Senior Acquisition Course and the Defense Systems Management College's Program Managers Course.

Future Combat Systems and the New DoD 5000 Acquisition Guidance

COL Donald P. Kotchman

May 14, 2003, was a significant day for Army transformation: the Defense Acquisition Executive authorized the Future Combat Systems (FCS) program, the largest and most comprehensive development effort for the acquisition of combat capability in U.S. history. Program magnitude and challenges were daunting and the program's complexity surpassed any previous Army developmental effort. Along with tackling the program's scope, Army program managers (PMs) had to address three aspects simultaneously — keeping up with the ongoing requirements definition process revisions, an ongoing update to defense acquisition processes and implementation of a system-of-systems (SoS) management philosophy — as they prepared for a milestone decision run against unprecedented schedule goals.

Combatant commanders encounter near-term strategic capability gaps that may affect the range of land power options needed to operate in today's dynamic security environment to exercise National Command Authority. In his October 1999 presentation on Current and Future Force Capability, then Army Chief of Staff (CSA) GEN Eric K. Shinseki set the course for Army transformation when he described the capabilities that would be required of FCS as the centerpiece of the Future Force materiel and doctrinal solution. The Secretary of the Army and the CSA articulated their vision of how the Army would transform to meet 21st century demands in a white paper.

The Director of the Defense Advanced Research Projects Agency (DARPA) and the Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASAALT) executed a Memorandum of Agreement (MOA) on Feb. 28, 2000, to establish a collaborative program to develop and define an FCS design concept. Simultaneously, the U.S. Army Training and Doctrine Command (TRADOC) worked with the Army staff to construct Future Force