The FCS Requirements Development Process Sets New Standards of Excellence

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The Future Combat Systems (FCS) Unit of Action's (UA's) complexity mandated modification of the classical system engineering processes to provide high-quality requirements and to minimize future rework on the program. The System-of-Systems (SoS) Engineering Integration (SSEI) Integrated Product Team (IPT) management understood that given the program's intricacy, a traditional model for requirements development was inadequate and had to be enhanced. The processes used on the program have been tailored and are continually improved as a result of the increased understanding of handling such a complex program. Today, the FCS requirements development process is a new way of doing business, and the FCS program is setting new standards for the industry to follow.

The new requirements development process will minimize future rework on FCS programs such as the Stryker. Here, a 120mm mortar round is fired from a Stryker MCV-B mortar tube at Yakima Training Center, WA. (U.S. Army photo by Jason Kaye.)

First and foremost, emphasis is placed on identification and involvement of all key stakeholders. This means that requirements development process participants include the Lead Systems Integrator (LSI) — Boeing and Science Applications International Corp. — the U.S. Army Program Manager UA, Army combat developers, the U.S. Army Training and Doctrine Command, the Army user community and the UA Maneuver Battle Laboratory. Additionally, the FCS One Team Partners encompass those companies that are directly involved in developing SoS requirements as they impact their specific prime and configuration items. This engagement of all critical stakeholders ensures continuous focus on the FCS SoS requirements and, in turn, will have a major impact on successful program execution by balancing cost, schedule and risk effectively at the system level.

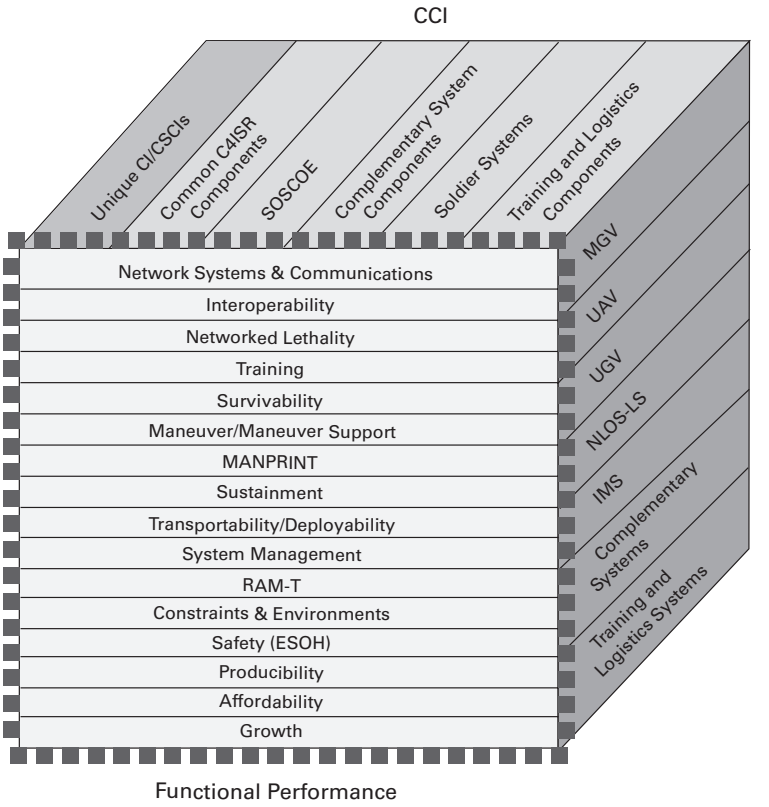


Figure 1. The FCS Cube provides multidimensional relationship visibility between functional performance, CCIs and systems/platforms.

The FCS SoS's complexity and the addition of four integrated FCS technology spin outs to the Current Force identified the need for an incremental engineering, integration and assessment/verification approach. This incremental approach enables the program to prioritize requirements and design development activities within each phase to reduce overall risk. This approach also allows the FCS SoS concepts, requirements, architecture and designs to mature as performance trades and analyses are conducted and the results of experiments and development tests are assessed.

CPL Chris Chladny (right) and SSG Joshua Rygiel, 2nd Battalion, 7th Infantry Regiment, 3rd Infantry Division, maneuver a Raven unmanned aerial vehicle near Tikrit, Iraq, March 29, 2005. (U.S. Army photo by SGT Matthew Acosta.)

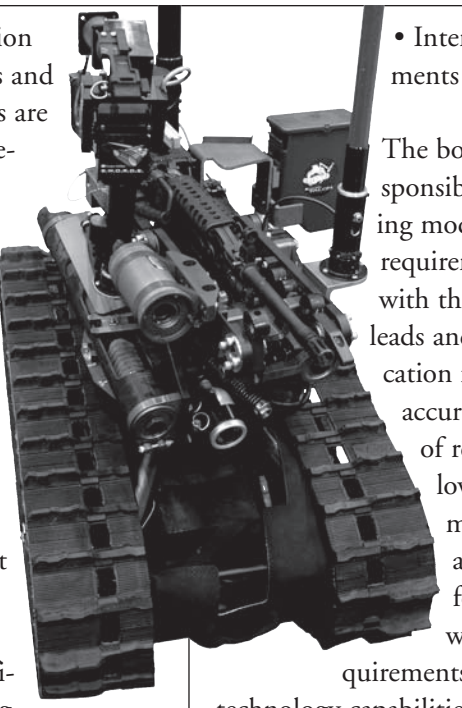
The processes used to develop the FCS UA requirements comprise critical elements such as architecture, requirements analysis, requirements management and leadership, which must be seamlessly interconnected to produce a high-quality product. Those processes must be effectively executed to ensure that the program meets an aggressive schedule to support iterative and evolutionary development concepts consisting of four integration phases.

Requirements Leadership Execution

One of the program's most challenging aspects is associated with the definition of the framework for FCS technical requirements development and allocation. With SoS requirements reaching more than 11,000, it is important to ensure that the program's seven key performance parameters (KPPs) are provided robust coverage. To do that, a unique process using "requirements leaders or owners" and "book leads"

has been developed based on the FCS "cube" that provides visibility of the multidimensional relationships between functional performance, common critical items (CCIs) and systems/platforms as depicted in Figure 1.

Requirements leaders are responsible for "womb-to-tomb" (development through verification to SoS "sell-off") ownership of their assigned FCS capability, function or requirements sets. The requirements owners are acknowledged subject matter experts within the LSI team. They have powerful coordination and integration abilities and have been delegated responsibility, authority and accountability for their functional areas. Each requirements owner is supported by a multifunctionally staffed team with dedicated leaders and members drawn from various FCS IPTs, including verification, architecture and modeling and simulation. These "owners" are responsible for requirements definition tasks at the SoS and Prime Item Development Specification (PIDS) levels. The IPTs and their associated suppliers are responsible for subtier requirements definition below the PIDS level with the responsible requirements leader's concurrence to ensure the continued development of appropriate requirements and design concepts.



The book leads represent the product IPT's interests and their assigned section of the SoS specification and corresponding lower-tier requirements documents:

- PIDS
- System requirements review
- Hardware configuration item
- Computer software configuration item
- Interface requirements document
- Interface control drawing
- Interface requirements specification

The book leads are responsible for coordinating modifications to the requirements database with the requirements leads and assigned verification focals to ensure accurate "flow down" of requirements to lower-level documents. They are also responsible for identifying whether the requirements are beyond technology capabilities or adversely impact the prime item design, while keeping program affordability and schedule in mind. The book leads also ensure consistency across the requirements leads and prevent duplication or conflict of requirements.

The assignment of requirements and book leads establishes a natural "tension" within the FCS organization. The requirements leads/teams look horizontally across the systems to fulfill the SoS concepts and achieve the KPPs. The book leads look vertically within their system and are responsible for balancing the technical, cost and schedule risks associated with their system as part of the overall FCS SoS.

Requirements development encompasses requirements analysis, operational and system architecture development and functional analysis, functional decomposition and allocation as depicted in Figure 2. Feedback on the risks, achievability and FCS SoS maturity and system requirements are provided through the use of performance measures and through feedback from experimentation, assessment and verification activities.

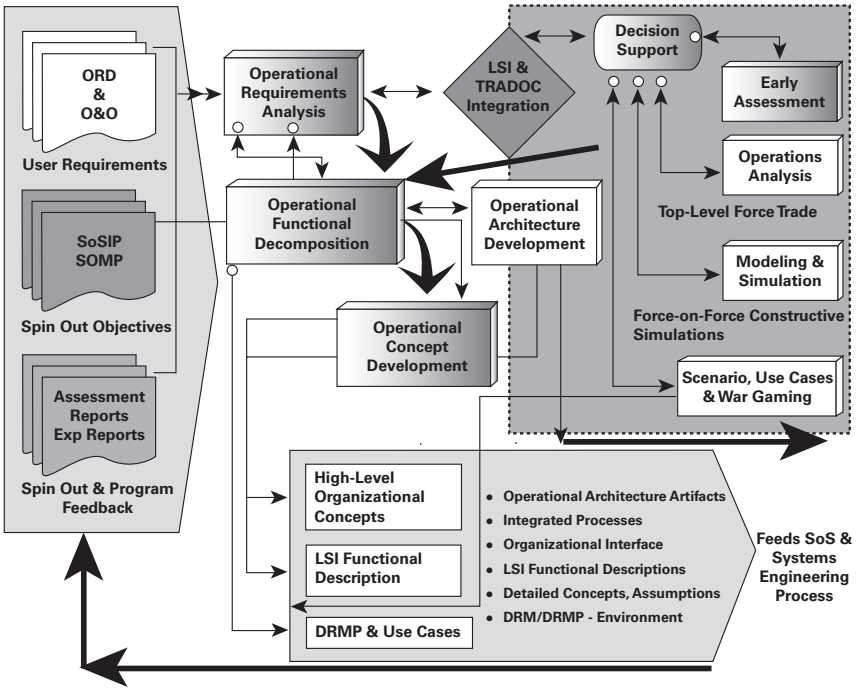


Figure 2. The Requirements Development and Management Process

Requirements Analysis

Requirements analysis is being conducted on FCS to identify and capture the overall SoS and system-required capabilities and intended usage environments. Requirements analysis produces the SoS, prime item and configuration item specifications. Requirements analysis also documents assumptions, rationale and guidelines for use in SoS. Likewise, it also documents system requirements and design analysis and definition. Traceability of specification requirements, assumptions and guidelines will be maintained and validated as part of these tasks. Initial requirements analysis was accomplished using integrated working groups comprised of the joint Army customer and the LSI's Systems Engineering and Integration, Integrated Simulation and Test and platform IPTs.

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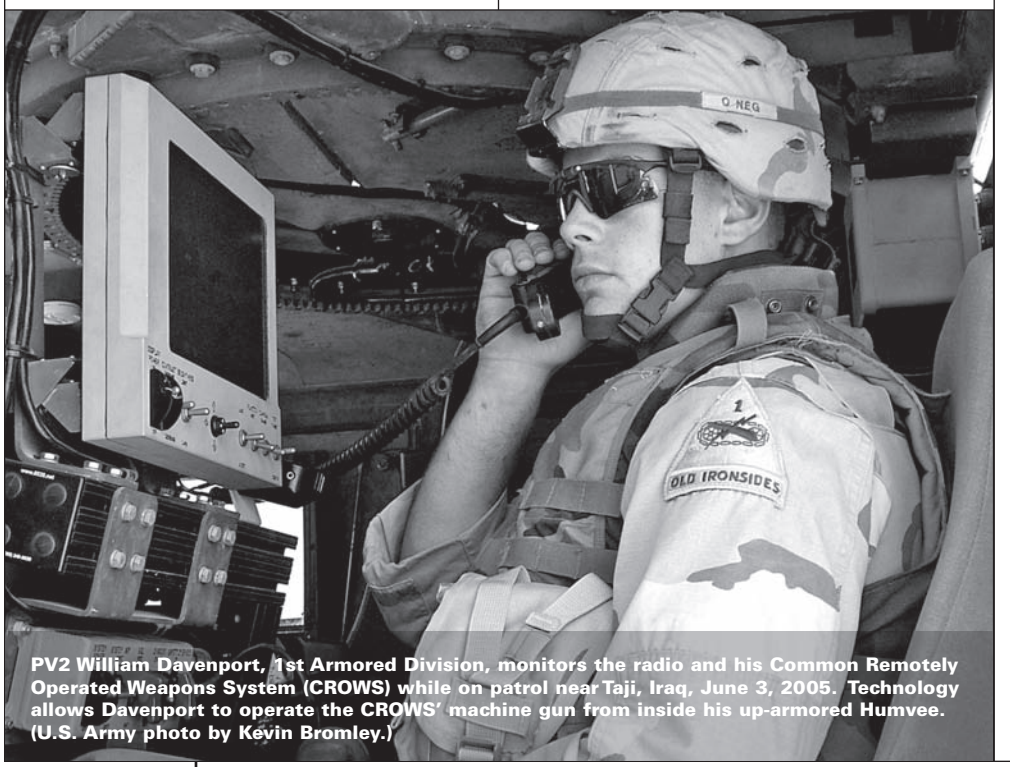
Requirements analysis started with an assessment of the FCS Operations and Organization (O&O) and Operational Requirements Document (ORD), including the seven FCS KPPs. These documents were used along with Army Universal Task List, Universal Joint Task List and Mission Training Plans to capture the operational concepts across the various Army command levels. These concepts are documented within 24 approved integrated processes.

In parallel with FCS integrated processes development, the SoS boundaries and interfaces to external, non-FCS programs were defined. Here again, the integrated FCS UA's complexity becomes apparent. The FCS SoS boundaries include the UA/Unit of Employment (UE) boundary; interfaces to complementary programs within the UA and across the UE boundary to other current Army, U.S. and international forces; and commercial systems and services.



PV2 William Davenport, 1st Armored Division, monitors the radio and his Common Remotely Operated Weapons System (CROWS) while on patrol near Taji, Iraq, June 3, 2005. Technology allows Davenport to operate the CROWS' machine gun from inside his up-armored Humvee. (U.S. Army photo by Kevin Bromley.)

The integrated processes and SoS boundaries described above established the foundation for performing the FCS team's functional analysis and allocation, and SoS and system performance analyses as described below. The SoS human factors, design standards and constraints were identified by assessing the existing and projected technology base, applicable laws and standards and strategic programwide management plans and decisions.

Functional Analysis and Allocation

The functional analysis at the FCS SoS level transforms operational capabilities into functional, performance and interface attributes at the system level. These attributes are then used to guide the design synthesis activity that follows. Additionally, functional analysis products flow into the integration and test phases to clarify what verification method will be used to ensure that each system meets its individual functionality and combined interoperability capacity. Functional analysis is performed to transform the top-level user operational requirements (capabilities) and concept of operations into a set of SoS, prime item and common subsystem functional and performance requirements to achieve FCS capabilities.

The functional analysis process's key results are identified and more detailed functional and related performance requirements are determined. Functional requirements define details of how the needed capabilities must be provided over the span of expected usage scenarios and environments. The performance requirements — derived from analysis of mission activities — provide measurable parameters for the functions in terms of quantity, quality, coverage, timeliness and effectiveness. Critical performance measurements are being tracked at the

A Soldier with Company B, 1st Battalion, 55th Parachute Infantry Regiment, communicates via tactical radio with his command cell after responding to a "shots fired" scenario in Fallujah, Iraq. FCS will ensure the SoS provides precise information when and where Soldiers need it most. (U.S. Army photo by SSG Charles B. Johnson.)

program level in the form of KPPs and technical performance measures (TPMs). These KPPs and TPMs provide summary indicators of the development effort's health.

Integrated Architecture

During the requirements derivation process, direct linkages of the defined functional operations and the associated performance and interface requirements in the integrated requirements database are maintained with the FCS-equipped UA architecture model data elements. This process supports the full traceability of all the requirements to the ORD and the associated context documents related to it.

The integrated architecture describes the FCS architecture, beginning with the FCS SoS, through the individual system, to hardware subsystems and software components. This integrated architecture will be captured in a single integrated representation called "The Integrated Model." The Integrated Model will incorporate numerous views to represent the information required by stakeholders, including operational, system and use-case views. Links and traceability will be maintained within the integrated architecture as well as between the SoS, system, subsystem and component architecture levels and requirements. The integrated architecture and specification form the essential requirements baseline for the FCS UA.

The FCS program is setting new standards of excellence and pushing the envelope for requirements management. The goal is to deliver quality products and systems on time and within cost. This is a challenging task given SoS complexity, interactions and interdependencies between different KPPs, TPMs and system constraints. Uniform execution of the requirements management processes and commitment to continual improvement to accommodate growing understanding of the system's complexity are the key. The FCS program has modified best practice systems engineering techniques to perform requirements development in light of the special challenges an SoS requirements set poses. The program has adopted an iterative engineering and integration approach, acknowledging the integrated FCS SoS's complexity. This process enables experimentation and assessment results to be fed back into the requirements base and initial design.

This process starts with the O&O and ORD and leads to functional analysis, the initial operational architecture and, ultimately, helps define the initial requirements set for the system IPTs. The initial architecture is then used to integrate the SoS requirements and perform the SoS detailed design configuration. This process leads to further recommended changes to the base requirements and design. Additional assessments are made and continuous trade studies are reviewed and analyzed for possible implementation into the design structure. These essential steps will be repeated, to some extent, in each of the program's four integration phases.

When asked to name the most significant elements of the successful requirements management process, Brad Cohen, SSEI IPT Director, answers without any hesitation — "It is people, leadership and organizational execution of the systems engineering processes."

The Army SSEI IPT Co-Director, Cliff Boyd, agrees and, together, they strive to provide innovative leadership for the FCS SoS engineering activities. Their goal is to deliver a quality product to the user, and with the implementation of the requirement lead and book lead process for requirements management, the framework is established for ensuring the necessary balance is achieved between optimizing the FCS SoS and providing affordable and technically feasible systems. Indeed, the FCS requirements development process is a new way of doing business.

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