Six Sigma Approach Adds Discipline to Excalibur Program Work Practices

Improving Process Control for Development Test Hardware

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The Army's Excalibur Program Office teamed with the system developer Raytheon Missile Systems to develop an improved process that has significantly increased control over the build of development hardware. The Army's Excalibur Program is a family of cannon delivered, precision engagement, extended range artillery projectiles that use the Global Positioning System (GPS) to self-guide to a programmed location. The first of the family to be developed is a versatile unitary munition with a high explosive fragmenting warhead. It consists of an aerodynamically streamlined, fin stabilized projectile in three sections: guidance navigation and control (GN&C), payload, and base (Figure 1).

While there will be only one tactical configuration of the unitary munition, Excalibur's extensive development testing program requires eight basic projectile test configurations. However, counting variations within each configuration, the development build program comprises a total of 39 different hardware test configurations. As initial hardware builds began, both the government and contractor program offices viewed as a critical challenge the configuration management and build process control of this wide variety of test hardware.

Six Sigma Build Process Team

Since the government and contractor offices had used the Six Sigma approach on a number of other applications with good results, a Six Sigma team of contractor and government PM personnel was formed for Excalibur's hardware build process. Six Sigma is a quality technique incorporating a rigorous methodology to define, measure, analyze, improve, and control selected processes in order to reduce errors and scrap. Key to the approach is the formation of a multi-functional team directed by team leaders trained in the Six Sigma methodology.

The Excalibur Six Sigma team identified the initial tasks as reviewing and documenting the current development build process and identifying any issues that impede that process. The team first did an extensive series of interviews with program personnel running the gamut from senior management to the hands-on production workers. There were two primary purposes for these interviews: first, to gather information to document the ongoing production build process; and second, to obtain comments, issues, problems, and recommendations to improve the existing process.

The sessions were highly productive, providing the team with not only the information necessary to process map the existing build process, but also a

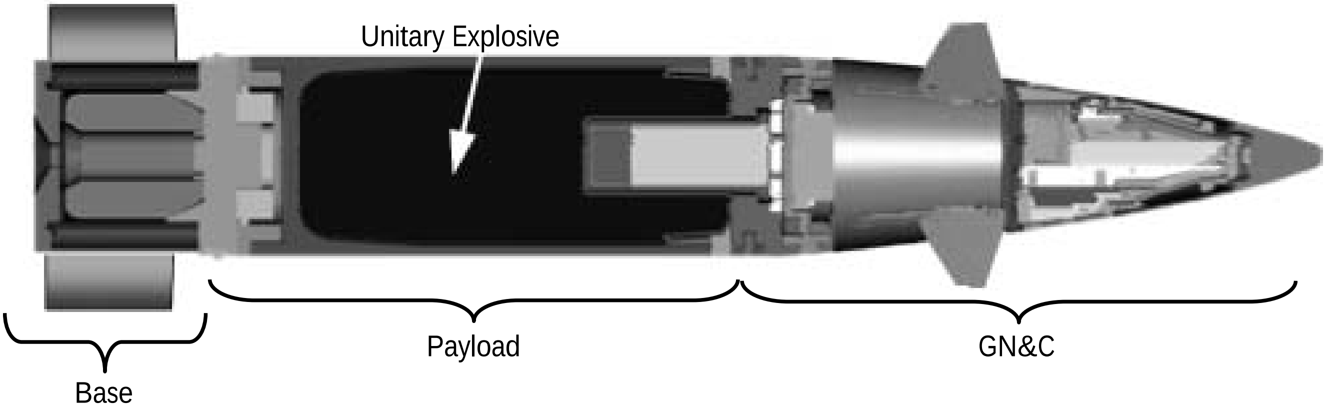

FIGURE 1. First Extended Range, Self-Guided Artillery Projectile Developed under Army's Excalibur Program

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wealth of feedback on the system. The team identified over 100 issues or problems associated with previous builds of test hardware and, using Pareto analysis, prioritized them for use in corrective action sessions.

Mapping (Defining) the Current Process

The process mapping stage of Six Sigma consists of putting together a flow diagram showing how the various steps of the process sequence and interrelate. Figure 2 shows a portion of the Excalibur development build process. Note that the development build process consists not only of fabricating the hardware, but also of a series of steps prior to and subsequent to the build. Many of these steps are multi-disciplinary meetings acting as “gates” before the process proceeds. They extend from initiating the build process by generating the planning through the actual shipment of the test hardware.

The process map for the Excalibur development build allowed the team to clarify what the current process was and examine it from the viewpoint of improvement. This step became an iterative effort to ensure that all involved personnel had a chance to give their input and to comment as this phase of the project progressed.

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Measuring and Analyzing

Analysis of the existing process revealed redundant steps that could be combined, out-of-phase elements, poorly defined steps, and other process shortcomings. In addition, problems and failures with previous hardware builds were identified and analyzed to see if they would be corrected with process changes. The team also collected data to measure the current baseline against proposed improvements (for example average process times for each step, completeness of documentation, and performance of the hardware).

In concurrent brainstorming sessions, the previously prioritized issue areas were analyzed, and cause and effect diagrams were prepared. During this phase, a fault tree analysis and a complete set of Failure Mode and Effects Analyses (FMEA) were prepared. They were followed by a series of information exchange sessions to keep everyone updated on progress, to present the completed map of the current process, and to obtain additional comments and inputs.

The Improved Process

A multitude of suggestions for improvement came out of the detailed mapping of the current process. Before these improvements were incorporated, they were often experimented with offline to assess their merit. This process led to further changes to make the recommended process even more robust. Checklist sheets were also prepared to assist team leaders in following each step of the improved process to ensure its consistency. But perhaps the biggest change to the build process was to formalize it by putting it under configuration control so that in addition to the configuration management control of the hardware itself, the process too was now controlled.

The point was emphasized by the inclusion on the process flow map of a signature block for the approval authority. This measure was taken to indicate that there could be no deviation from the baseline process without formal approval. Another major change was to develop a system ensuring consistency and discipline within the individual blocks. Many of the blocks were meetings, and the team felt it was critical to document each of them. This was accomplished by clearly identifying the group with lead authority, the organizations needing to have representation, the entrance criteria, and the meeting inputs and outputs. This information was formalized into block descriptors for each of the process steps (Figure 3).

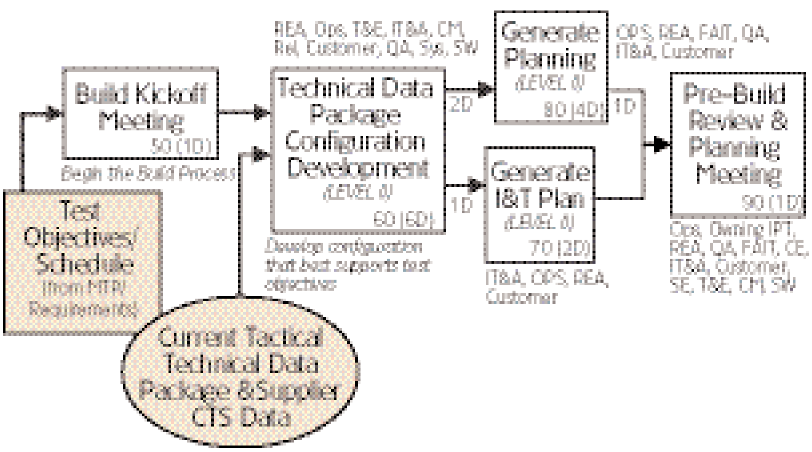

FIGURE 2. Representative Portion of the Excalibur Development Build Process

FIGURE 3. Example of a Process Step Block Descriptor Developed to Ensure Consistency and Discipline

Build Kickoff Meeting (50)

Description: Develop a build schedule and assign action items to begin the build process.
Authority: IPT Lead
Members: IT&A, OPS, T&E, Software, Customer, Systems, CM, REAs, QA, FAIT, and Reliability
Entrance Criteria:
Test Objectives (Sys, T&E, IPT), Quantity (IPT Lead)

Inputs:	Outputs:
•Estimated Schedule Dates (IPT Lead)	•Proposed Build Schedule (IPT Lead)
•Approved Test Objectives (Sys, T&E)	•Key Component Configuration (IPT Lead)
•Hardware Status Review, Key Components (IPT Lead)	•Assign Action Items (IPT Lead)
	•Identify Key Personnel (All)
•Supplier CTS Delivery Dates (REA)	•Risk Identified (All)
•TPR, FRB Lessons Learned (QA, Rel)	•Supplier/Subsystems Build Req (IPT Lead)

The team then presented the improved process to all the involved personnel in a series of briefings intended to familiarize them with the new process and to solicit any further comments or suggestions.

Implementation and Control

The next phase was to run the process through several hardware builds to iron out the bugs and make any further changes, after which the next version of the improved process was put under configuration management control. This step was highlighted by a formal signing of the overall process map.

The team, recognizing the likelihood that the benefits of the improvements would be short-lived if not monitored, established a set of metrics to monitor the system, measure benefits, and provide the basis for changes or corrective actions (Figure 4).

Even though it is still early in the hardware build cycle, a number of benefits have already been realized. All project personnel have a much better understanding of the build process, and many areas of confusion have been eliminated with the formalization of the process. Numerous steps were streamlined or combined, and feedback from the initial interview sessions prompted corrective actions to remove bottlenecks and other impediments to production. A further benefit was that the process times could be predicted more accurately and compared to historical times. Using the Six Sigma process for the build process has also added discipline to the overall work practices of all Excalibur personnel.

Although the major benefits are yet to be realized since the program is just entering a more intensive build phase, the improvements to date—shorter process times, less confusion over the build cycle and better documentation—are justifying the investment in the Six Sigma process. As the builds continue, the established metrics will allow the program to monitor closely the improvements and—most important—the impact on the quality of the test hardware.

Editor's Note: The authors welcome questions or comments on this article. Contact them at charles.giufurta@us.army.mil and kldunham@raytheon.com.

FIGURE 4. Example of Metrics to Monitor System, Measure Benefits, and Provide Basis for Changes/Corrective Actions

METRICS FOR THE EXCALIBUR BUILD PROCESS

Metric	Description	How Measured
Complete Cycle Time	The amount of time to complete the build process.	Compare to previous hardware builds; time in days from Block 60 to Block 320.
Individual Cycle Time	The amount of time to complete the build process. Looking to improve the times.	Compare to previous hardware builds; time in days from each Block to Block.
Adequate Review Times	Was the adequate amount of review time provided for at the various steps?	Review documentation as to when meetings notices were sent out, read-aheads, etc.
Adherence to Process	Is the build process being followed?	Audit conformance. Meeting attendance review documentation.
Documentation	Is required documentation of individual builds being accomplished, i.e., meeting notices, minutes, attendees, checklists, etc?	Review documentation trail for missing elements, i.e. no meeting minutes, notices, checklist, etc.
Performance	How successful were the builds?	Problem documentation: Build Problems, Test Failures, Non-Conformance Material Reports, Test Problem Reports, Failure Review Board Action Items.
User Satisfaction	How satisfied are the users that the system is an improvement and is working?	Questionnaire/Follow-up Interviews Meeting Critique.