

# Case Study: United Space Alliance Wins Bronze Award at International Team Excellence Competition

Headquartered in Houston, TX, United Space Alliance, LLC (USA) is one of the world's leading space operations companies. Established in 1996, USA is equally owned by The Boeing Company and Lockheed Martin Corporation and employs people in Texas, Florida, and Alabama.

USA manages and conducts work involving the operation and maintenance of multipurpose space systems, including systems associated with NASA's human space flight program and other reusable launch and orbital systems beyond the space shuttle and space station.

As the prime contractor for NASA's space shuttle program, USA is responsible for the day-to-day operation and management of the U.S. space shuttle fleet and brings a broad range of expertise to the job, including mission design and planning; flight operations; software development and integration; payload integration; integrated logistics; astronaut and flight controller training; and vehicle processing, launch, and recovery.

## USA's Continuous Improvement Journey

Continuous improvement is a key element of USA's contracts with NASA. Since the start of the space flight operations contract in 1996, USA has maintained safety and reliability as top priorities while successfully reducing the overall costs of operating the space shuttle fleet.



**Members of United Space Alliance's Bronze Award winning team are pictured (front row, l to r): Adam Richards, Chuck Kubricht, and Shawn Holcomb. (second row) Erin Ethington, Ginger Biehl (Black Belt), Matt Lee, Ray Moreno, Bobby Jarvis, and Cindy Sweitzer.**

In 2002, building on USA's successful first six years, employees were challenged to achieve world-class quality in processes across the company saying, "Achieving world-class quality is important to our customers and to shuttle and International Space Station safety—and it is the right thing to do for our business."

Lean Six Sigma was chosen as the methodology that USA would use to achieve this quality challenge. Lean Six Sigma is a system for process improvement that

builds on USA's continuous improvement culture, adding more rigorous tools and techniques and providing a strong project management approach. It provides a structure and methodology for company-level process and product quality improvements tied directly to company goals. It is the combination of two highly successful process improvement methods—"Six Sigma" which focuses on eliminating variation and defects in processes and "Lean" production methods, which improve process speed and efficiency. The benefits of combining these methodologies are well documented and demonstrate that significant improvements in quality are possible without sacrificing process cycle time and efficiency.

In 2002, USA selected deployment champions at its Texas and Florida locations, and Mary Burgess was named Lean Six Sigma senior deployment champion. In 2003, USA selected, trained, and certified two waves of Lean Six Sigma Black Belts (approximately 40 people). Since 2003, USA has trained and certified Lean Six Sigma Master Black Belts,

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several waves of Green Belts, and additional waves of Black Belts. USA also has developed a Lean Six Sigma manager's course and is in the process of providing formal Lean Six Sigma training to its entire management team.

Since its introduction at USA, Lean Six Sigma projects have yielded excellent results throughout the company.

### Participation in the International Team Excellence Competition

USA's Shuttle Payload Integration and Cargo Evaluation (SPICE) team was selected as a finalist, then as Bronze winner, in the International Team Excellence Competition at ASQ's World Conference on Quality and Improvement in Seattle, WA, in May 2005. The SPICE team entered the competition after significant recognition for its outstanding accomplishments. At USA's annual Team Showcase/Competition in August 2004, the SPICE team was selected "USA Team of the Year" and also received the "Customer Impact Award." The SPICE team also won USA's "Quest for Excellence" award (an award that recognizes outstanding individual and team accomplishments). The SPICE team's accomplishments also have been commended in award fee evaluations from NASA.

In the qualifying round of the ASQ competition, the team submitted the required 25-minute video for judging. Competing teams were scored against 36 specific evaluation criteria associated with the major areas addressed in this article. The 26 qualifying finalists then competed in a live competition scored by another panel of judges. The three highest scoring teams received the Gold, Silver, and Bronze Awards. USA's SPICE team received the Bronze Award. The team's toughest challenges were to present the project clearly to a nonaerospace audience, adequately address the 36 individual competition criteria, and adhere to the 25-minute time constraint.

### Overview of the SPICE Project

The SPICE Lean Six Sigma team was chartered to improve the overall accuracy and quality of its product, an analysis used to assess mission payload mass properties, and overall shuttle mission capability. The key output of the SPICE analysis is the mission-specific Ascent Performance Margin (APM) prediction. APM is the amount of additional weight

that the space shuttle can successfully carry to orbit. The SPICE APM prediction is used by the space shuttle and space station planning communities to determine whether payloads can be added to a shuttle mission and to determine the overall configuration of each shuttle mission. The SPICE APM prediction is released 13 months prior to each scheduled space shuttle launch. At this point, many mission requirements are preliminary; therefore, assumptions and estimations must be made in the SPICE process.

Approximately three months after the SPICE analysis is released, many mission requirements are finalized and a high-fidelity simulation is conducted to calculate APM. The accuracy of the SPICE analysis is reflected by the difference between the SPICE APM prediction and the high-fidelity simulation APM calculation. Large differences between the two can result in significant rework across the space shuttle and space station communities. The SPICE team's goal was to improve the accuracy of the SPICE APM prediction.

The project was managed following the Lean Six Sigma "Define-Measure-Analyze-Improve-Control" (DMAIC) methodology shown in Figure 1. This project-management approach is based on data-driven decision making. The specific phases provide a step-by-step approach to the project. At the conclusion of each phase, the team had a formal "gate review" with all stakeholders to obtain concurrence on the completion of that phase and approval to proceed to the next phase.

### Evaluation Criteria One: Project Selection and Purpose

The "project selection and purpose" step of the Team Excellence Award criteria aligns with the "define" phase of the Lean Six Sigma project management methodology.

USA's SPICE process owner submitted the project as a Lean Six Sigma candidate primarily because SPICE APM predictions were not meeting customer expectations and because internal attempts at improving the process had not yielded the desired results. Analysis of historical data supported the need to improve the accuracy of this contractual deliverable. A Lean Six Sigma Black Belt project manager worked with the process owner and project sponsor to evaluate the project. This group decided if the project met the criteria for acceptance using an initiative assessment tool/database based on criteria including projected savings/benefits, internal and

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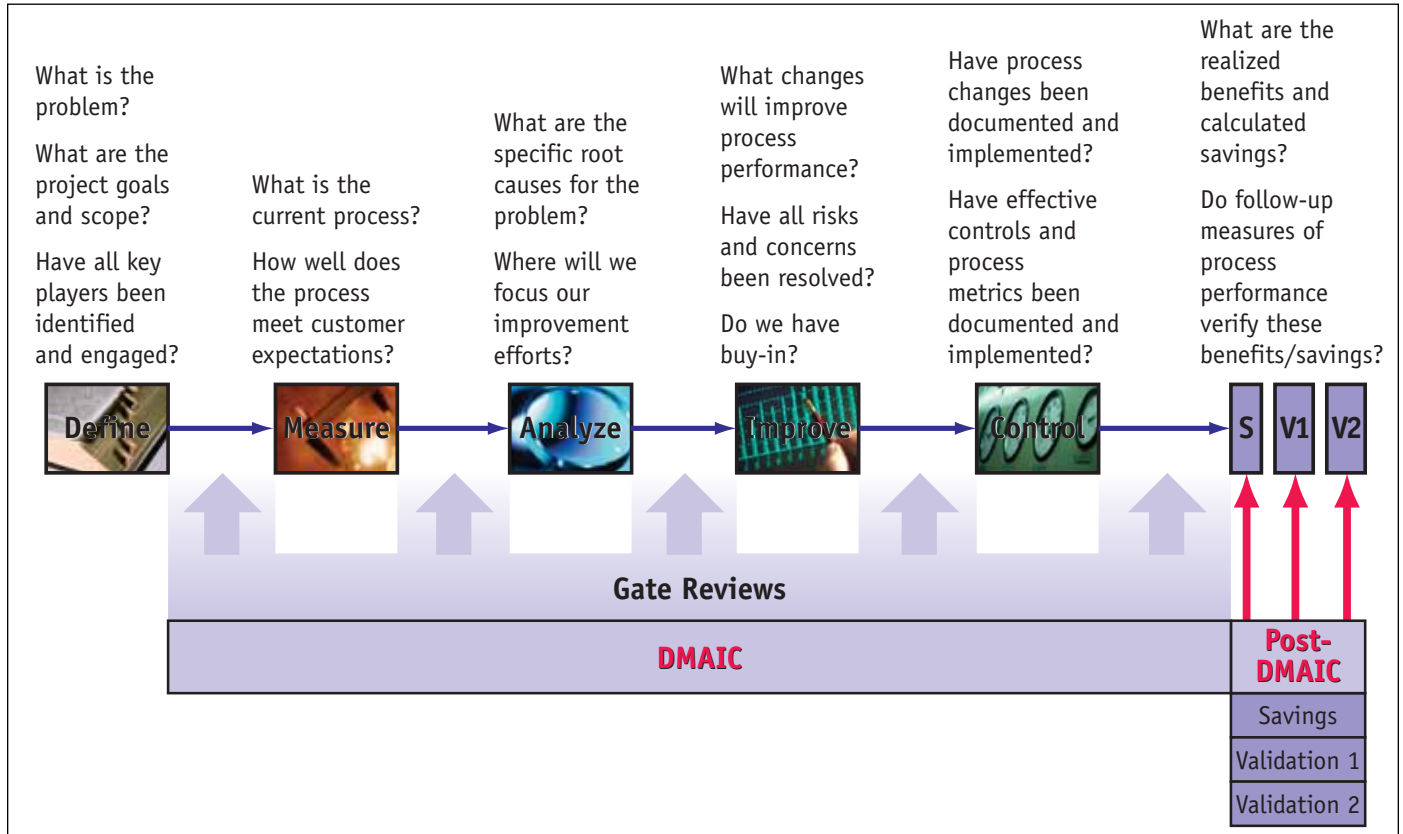


Figure 1

external customer impact, risk, sponsor commitment, and data availability. The SPICE project successfully met these criteria and was chartered as a Lean Six Sigma project.

USA has a vision-support plan that establishes high-level company goals that flow down to the specific organizations and departments within the company, as shown in Figure 2. The SPICE project directly supported USA's "quality" and "customer" goals. The project was expected to have a high positive impact on "achieving outstanding quality in all aspects of our business" by improving the accuracy of the SPICE analysis. A high positive impact also was expected on "achieving excellent customer satisfaction and program performance" by reducing rework in space shuttle planning and manifesting.

Stakeholders identified were those directly or indirectly affected by the quality of the SPICE product. The stakeholders included internal and external organizations that would be positively impacted by process improvements. Table 1 provides a summary of the evaluation.

## Evaluation Criteria Two: Current Situation Analysis

The "current situation analysis" step of the Team Excellence Award criteria aligns with the "measure" and "analyze" phases of the Lean Six Sigma project management methodology. Extensive data collection efforts began at this point in the project.

In accordance with the "measure" phase, the team needed to create a baseline of the current state, which means determining

USA VSP Company Goals		
<b>Safety</b> Provide Safe Operation for All Aspects of Our Business	<b>Customer</b> Achieve Excellent Customer Satisfaction and Program Performance	<b>Quality</b> Achieve Outstanding Quality in All Aspects of Our Business
<b>People</b> Be the Company of Choice for Our Employees	<b>Community</b> Contribute Positively to the Enrichment of Our Communities	<b>Financial</b> Provide Excellent Financial Returns to Our Stakeholders

Figure 2

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INTERNAL STAKEHOLDERS	
Stakeholder	Degree/Type of Impact
USA space shuttle program manager	<b>High:</b> SPICE product affects contract performance evaluation and award fee.
SPICE process owner	<b>High:</b> Directly accountable to NASA customer for SPICE process and products.
SPICE engineers	<b>High:</b> Responsible for generating SPICE products and accountable for product quality.
Other USA organizations	<b>Medium:</b> Proceed with detailed mission planning process based on SPICE analysis.
EXTERNAL STAKEHOLDERS	
Stakeholder	Degree/Type of Impact
NASA customer	<b>High:</b> Will reap benefits (time and labor savings) from improved SPICE accuracy and reduced rework.
USA subcontractors	<b>Medium:</b> Proceed with detailed mission planning process based on SPICE analysis.

**Table 1**

how the process is currently performing. The customer expectation is that the SPICE APM prediction is within 300 pounds of the actual APM that is later calculated by the simulation process. The team analyzed data from previous SPICE analysis deliveries and determined that the SPICE predictions of APM were ranging from under-predictions of 729 pounds to over-predictions of 794 pounds. This verified the need to improve the SPICE process/product.

During the “analyze” phase of the project, the team’s challenge was to determine the root causes for the inaccuracy in the SPICE APM prediction. The root-cause identification effort involved extensive data collection and analysis, as well as brainstorming with the SPICE process owner, SPICE engineers, SPICE software programmer, and additional subject-matter experts.

Because of the complexity of this effort, the root-cause analysis section was especially challenging to present in the Team Excellence Award Competition. The team decided to focus on some of the more common tools used during this phase, as described in this article.

The team developed a supplier-input-process-output-customer (SIPOC) chart to identify the process inputs

(and their suppliers) and outputs (and their customers). The team then examined the SPICE software and process in greater detail and developed an affinity chart depicting the approximately 200 inputs. For each input, the team collected data and conducted a gap analysis comparing the individual inputs from previous SPICE analyses to the comparable calculations from the subsequent simulations that calculated the actual mission-specific APM. The team determined that two specific inputs were the key contributors to the inaccuracy in the SPICE APM prediction.

These root causes were the SPICE estimation inputs for “propellants” (fuel and oxidizer burned by the shuttle engines and control jets) and “ballast” (added weight for the purpose of balancing the shuttle).

The next step was to verify that propellants and ballast were the two key root causes for the SPICE inaccuracy. The team used regression analysis on historical SPICE data to verify the apparent relationship between these SPICE inputs and the SPICE APM prediction. The team also used design of experiment (DOE) to validate these root causes. The DOE results verified that manipulating these two inputs produced the expected effect on the APM prediction. Having validated the root causes, the team proceeded with the task of improving the SPICE processes for calculating the propellants and ballast inputs.

## Evaluation Criteria Three: Action Plan Development

The “action plan development” step of the Team Excellence Award criteria aligns with the “improve” phase of the Lean Six Sigma project management methodology.

The team completed a wide variety of activities to identify and test potential solutions to the identified root causes.

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The team worked with additional subject-matter experts to brainstorm potential solutions, benchmark related processes within other organizations, and conduct additional data research/analysis. Subteams were chartered to focus on the specific components of the propellants and ballast inputs.

Detailed gap analysis was conducted to compare the SPICE and the simulation processes for calculating the propellants and ballast inputs. This analysis revealed that the SPICE processes were based on historical data (from previous SPICE analyses). Rather than using historical data, the simulation process simulates the upcoming mission to calculate mission-specific propellant and ballast requirements. The options for improving the SPICE estimation of propellant and ballast requirements included:

- Enhance the SPICE historical database and continue to use historical data to estimate propellant and ballast requirements.
- Develop and implement a SPICE mission-specific calculation approach (similar to the simulation calculations) to estimate propellant and ballast requirements.

The team worked closely with the project sponsor and stakeholders and with other subject-matter experts to identify solution criteria, as listed below:

- Must be data driven.
- Must have a positive impact on the problem.
- Must be practical and cost effective.
- Must be acceptable to process owners.
- Must minimize impacts to outside organizations.

After further analysis of the SPICE and simulation processes, the team members and other subject-matter experts determined that developing a SPICE process similar to the simulation process would render the greatest improvement to the key process output, the SPICE APM prediction. Subject-matter expert subteams were formed to develop the individual calculations of the new propellants and ballast calculation processes. The SPICE engineers were actively involved in developing and testing the new SPICE estimation processes and tools. These new processes and tools were developed to automate and integrate the complex new propellants and ballast calculations.

Extensive verification of project benefits was conducted during this phase. The new calculations and tools were tested and piloted. The SPICE engineers and NASA customer were involved directly in this effort. The quality improvement was also validated by regenerating previous SPICE analyses using the new SPICE calculations and tools. The result was a 76% increase in the accuracy of the SPICE APM prediction, rendering results that would meet the customer expectation of being within 300 pounds of the simulation calculation.

### Evaluation Criteria Four: Project Buy-In, Implementation, Progress, and Results

The “project buy-in, implementation, progress, and results” step of the Team Excellence Award criteria aligns with the “control” phase of the Lean Six Sigma project management methodology. In this phase of a Lean Six Sigma project, the team implements the changes, establishes and implements process controls, and transitions the improved process back to the process owner.

The key factor in mitigating resistance and obtaining buy-in/agreement was the thorough communication and active involvement of all stakeholders throughout the project. At each gate review, the team obtained buy-in and approval to proceed to the next phase of the project. The new calculations and tools were developed in close conjunction with subject-matter experts and affected stakeholders. SPICE engineers and other stakeholders were involved in testing and piloting the new calculations/tools and process changes. The details of the new calculations/tools and process changes were presented and approved at the “improve” gate review. All impacts to internal and outside organizations were coordinated prior to presentation for formal approval at the gate reviews. Stakeholder concurrence sheets were signed at each gate review. Management also signed detailed memorandums of agreement between organizations to document the approval of process changes to outside organizations.

A key aspect of Lean Six Sigma projects is ongoing monitoring of process performance and establishing process controls. The team developed metrics for monitoring the accuracy of future SPICE analyses. The metrics measure the accuracy of the propellants and ballast calculations, as well as the overall

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accuracy of the APM prediction. The new process, calculations, and tools were documented in users' guides, desk instructions, operating procedures, memorandums of agreement, and a comprehensive process control plan.

The SPICE engineers were formally trained on the process changes, tools, and new procedures. The metrics, controls, procedures, and process control plan were presented in detail at the "control" gate review. Two additional reviews "validate one" and "validate two," were scheduled to verify that the process control plan was being followed and to validate the improved performance. These follow-up reviews will be conducted after new shuttle mission SPICE analyses are conducted using the new process/tools and the accuracy of the SPICE APM predictions are compared to the simulation calculations.

The quality improvement was significant. Prior to the project, SPICE APM predictions had a variance range of 1,523 pounds. Using the new calculations/tools, this range was reduced by 76% with SPICE APM predictions ranging from 284 pounds under to 86 pounds over the simulation calculation. A significant reduction in labor hours previously spent on rework activities also was achieved.

Intangible benefits included improved communication across USA organizations and increased consistency among like processes.

Additionally, customer satisfaction increased. This new technology also provides long-term return on investment that may benefit future USA efforts in support of NASA.

## Summary

The team's approach to preparing its Team Excellence Award Competition presentation was to focus on the detailed criteria descriptions. Each criterion was addressed individually, making every effort to thoroughly meet its requirements. As with the project itself, teamwork was essential in preparing for the competition.

One of the main challenges the team faced was to sufficiently address all of the criteria within the allotted 25 minutes. The team struggled with effectively addressing each criterion while minimizing the amount of detail on each; the team realized that the time constraint did not allow for elaboration.

The greatest challenge of all was to effectively present a synopsis of the technical and highly specialized process to an audience outside the aerospace environment. The team recognized that this was an unfamiliar process to many people, and members made every effort to present the material in a descriptive and interesting manner. Team members revised the presentation many times before feeling confident that they had overcome these challenges.



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