Phase I Submission
Name of Program: Synthetic Vision System for Head-Up Display

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Bio for program leader:

Jean Pollari is the Manager, Program Management for the Rockwell Collins Flight Management System (FMS). Jean manages the product line funding, scope, cost, schedule, risk, earned value, and long term strategic direction. Prior to this position, Jean was the Product Line Manager for the Situational Awareness product line, which includes the Synthetic Vision System (SVS), Terrain Awareness Warning System (TAWS), and Integrated Flight Information System (IFIS) software applications. The FMS and Situational Awareness applications are used in the Rockwell Collins business and regional avionics systems.

Jean holds a bachelors degree in Chemistry and Mathematics from Quincy College (Illinois) and a masters degrees in Astronomy from the University of Iowa. Jean completed her MBA with the University of Iowa in 2010.

Jean joined Rockwell Collins in 1986 as a systems/software/project engineer on the Joint Program Office (JPO) Global Positioning System (GPS) User Equipment program. She moved into Program Management in 2003, leading the deployment of a major new business system to worldwide Rockwell Collins locations. In 2008, Jean became a Program Manager for the U.S. Army’s Future Combat Systems (FCS) program. She moved to the commercial side of the business as a Product Line Manager in 2011.
Overview
Maintaining a natural head-up, eyes-forward position is critical to pilot safety and responsiveness, particularly in low-visibility conditions and unfamiliar territory. Rockwell Collins’ Synthetic Vision on a Head-Up Display (SVS on a HUD) brought this revolutionary capability to military and commercial platforms. Using advanced software algorithms and graphics technology, the team created visually stunning, high-resolution 3-D depiction of terrain, runways and obstacles. The geographically-dispersed team utilized strong management and systems engineering practices, and applied Lean Electronics methods to realize significant recurring and non-recurring savings.

The technology debuted in 2012 on the Bombardier Global platform, and is slated for future fixed wing and rotary wing platforms including the AgustaWestland AW609 tilt rotor aircraft. The program resulted in 42 patent applications, is the only SVS to have FAA Technical Standard Order (TSO) design approval, and has been widely recognized for its innovation, including the 2011 Wall Street Journal Technology Innovation Awards, being a finalist for the 56th Annual Aviation Week Laureate Awards as well as a finalist for the 2013 Edison Awards.

Organizational Processes
The Rockwell Collins Technical Consistent Process (TCP) is an enterprise-wide process that governs product design and development. The TCP provides a framework of activities that define how a program is planned and executed. Programs tailor the TCP by completing a questionnaire on the program scope, complexity, and risk. These answers are used to define the mandatory and optional process activities appropriate for the specific program. The SVS program followed a tailored TCP, but augmented the process in several critical areas.

Requirements
SVS was a new concept and no customer or industry requirements existed. Pilot acceptance was critical for both the Federal Aviation Administration (FAA) and Original Equipment Manufacturer (OEM). To address these risks, the team implemented an efficient “rapid prototyping” model to facilitate requirements capture. Engineers developed numerous software prototypes using different technologies and visual designs. The team then had Rockwell Collins, OEM, and FAA pilots evaluate the prototypes and provide feedback. Early prototypes were evaluated on systems rigs; later prototypes were actually flown in OEM test aircraft. This process directly led to the choice of a “full featured” SVS rather than wire-frame or ridge-line representation. The end result was a visually stunning, high-resolution, three-dimensional synthetic vision image that is regarded as the best in the industry.

Design
The team knew that high-resolution, real-time graphics would require large amounts of processing power yet had to operate in a size, weight, and power constrained environment. Early prototyping revealed that the selected graphics processor would not be powerful enough to render the desired image quality. The team re-architected the solution to use a more powerful
graphics processor without impacting the program schedule. If this problem had been discovered later in the program, the team would have had to either reduce the image quality or delay schedule.

The team knew that the SVS had to be at a price point that the customer would accept and that the product had to be profitable. The team used the Rockwell Collins Design to Cost (DTC) method to optimize the recurring cost of the system. DTC is a cross-functional effort to define and achieve a cost requirement which supports a competitive strategy and results in profitability for the company. It is an engineering discipline which elevates recurring cost to a critical product design requirement.

The team identified DTC targets for each hardware component and for the overall system and then used these targets to drive design choices. For example, the team integrated several hardware components into a single module, eliminating the cost, size, weight, and power penalty of a second module. They also worked with the Rockwell Collins Enterprise Sourcing group to identify parts that the company procures in volume to reduce cost. The team tailored the design of another processor card to meet the needs of SVS, enabling reuse and lowering recurring cost. They replaced traditional board connectors with fiber cable, reducing size and cost. All of these intelligent design decisions resulted in a cost-competitive and profitable SVS solution.

Software Verification
SVS would be used in commercial aviation and therefore had to be developed in accordance with DO-178B, Software Considerations in Airborne Systems and Equipment Certification. DO-178B requires formal verification tasks to assure that the software fully satisfies all the expected requirements. DO-178B also requires structural coverage analysis to ensure that all paths in the code are tested during verification.

DO-178B requires that software development and requirements verification be independent – the same person cannot write and verify the same piece of code. Many organizations hand over the completed software to a separate verification team late in the program. This results in late detection of untestable requirements and rework of the design. In contrast, the SVS verification team was established at the start of the program and was actively involved during all stages of development. They were empowered to provide feedback to improve all of the program processes, not just those related to verification. These steps facilitated early discovery and resolution of errors and dramatically reduced the problems discovered late in the program.

The team performed early feature-based structural coverage runs to identify testing gaps and code issues. Programs often delay structural coverage analysis until late in the program, resulting in rework. By implementing an incremental approach, they avoided this risk.

The team also established the verification environment early in the program. They created a common test architecture, test templates, and both host-based (representative hardware) and
In order to reduce risk and improve testing efficiency, the host and target environments shared common interface tools and used the same graphics processor.

**Continuous Process Improvement**

The SVS team used Kaizen principles to continuously improve processes throughout development. For example, the team optimized the timing of formal reviews and baseline establishment. Baselining too soon results in unnecessary overhead; baselining too late increases the risk of late discovery of errors. The SVS team would develop a draft parent artifact, hold informal reviews, develop draft child artifacts, hold informal reviews, and then update the parent and child artifacts concurrently. This rapid detect and fix cycle – without the overhead of formal tracking – allowed the documents to be matured quickly. The team then held final reviews to baseline the parent and child artifacts concurrently.

The team used earned value to manage the program. Part way through development, they realized that the milestone method of claiming performance was not always accurately reflecting the true state of the program. The team switched to a qualified percent complete method for the development tasks, using metrics generated from the peer review and change request tracking systems. The metrics were a natural output of these systems and required minimal effort to capture, and they ensured that the claimed progress was consistent with the actual status of the program.

**Adapting to Complexity**

The SVS/HUD solution was technically complex and required expertise from across the organization – avionics experts from Cedar Rapids, HUD experts from Portland, and graphics experts from Salt Lake City. Co-location of the team was not practical, so the team carefully managed this logistical complexity. They defined clear roles and responsibilities at the start of the program so everyone knew what was expected and could be held accountable. They decomposed the SVS/HUD function early in the program, ensuring that each location understood the requirements for their component. The teams held regular online meetings with all locations using agendas and action items to keep the group focused. Meetings were scheduled at times convenient for all affected time zones.

SVS was developed entirely on Rockwell Collins discretionary funding; no customer funding was used. As with all companies, discretionary is limited. The SVS team used several techniques to reduce near-term and long term recurring cost. First, the SVS team established a partnership with a key OEM. The OEM agreed to share flight test costs – a major expense – and, in return, would be the first OEM to offer the new system on their high-end business jets. This partnership was so successful that it was later expanded to an “advanced vision system” partnership. Second, the team designed SVS to be a product line solution that could be applied to a broad range of aircraft. The team actively solicited input from multiple sources and culled program-specific requests that didn’t benefit the product line. The result is a solution that can easily be ported to different aircraft by updating a single software configuration table.
SVS was new in the industry and the team knew that they would have to break new ground with the regulatory agencies. Rockwell Collins actively participated in the Radio Technical Commission for Aeronautics (RTCA) SC-213 committee to define the Minimum Aviation System Performance Standards (MASPS) for a synthetic vision system. Due to this early involvement, the MASPS were developed and a subsequent Advisory Circular (AC) was issued prior to certification of SVS on the target aircraft. Lack of MASPS/AC could have led to delays in certification with the regulatory agencies. The FAA and Transport Canada Certification Agency (TCCA) were invited to several demonstrations using the OEM aircraft and prototype HUD SVS. This allowed them to become fully familiar with the proposed technical approach and operational implications. Early exposure to HUD SVS resulted in no change in requirements with regard to the synthetic vision scene.

**Metrics**
The team defined and managed key technical performance measures (TPMs) – such as processor utilization, memory utilization, and system latency – throughout the program. Regular monitoring of these TPMs, especially during the early prototyping phase, resulted in the early decision to move to a different graphics processor.

The team also used key program metrics to manage scope and track development progress. Examples include planned vs. actual number of change requests, planned vs. actual cost per change request, and percent complete of development and test tasks. The team also collected actual cost for product reapplication and used these to refine estimates for new programs.

**Value Creation**
The SVS/HUD program created value for Rockwell Collins, the OEMs, and our customers. This six-year, high risk program was completed only 7% over its original budget estimate and was the first Pro Line Fusion® application to submit for TSO approval. SVS can be reused with almost no changes across all Pro Line Fusion® platforms and is now being reapplied in the military and civil markets with only minimal changes (e.g. higher resolution databases).

Rockwell Collins is the only company that offers SVS on a HUD to enable “head up, eyes forward” operation. SVS provides market-leading image quality and unique capabilities not offered by competitors, such as airport domes, occluded runway depiction, and smooth terrain morphing.