

Augmented Reality and Other Visualization Technologies for Manufacturing in Boeing

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ABSTRACT

The Efficient Assembly, Integration & Test (EAIT) team at Boeing Research & Technology, Boeing's central technology organization, is working on multiple implementations of Augmented Reality to aid assembly at the satellite production facility in El Segundo, CA. This presentation will discuss our work to bring an Augmented Reality tool to the shop floor, integrating product design and manufacturing techniques into a synergistic backbone and how this approach can support the delivery of engineering design intent on the shop floor.

The team is developing a system to bring designer's 3D CAD models to the technicians on the shop floor, and spatially register them to live camera views of production hardware. We will discuss our work in evaluating multiple motion captures systems, how we integrated a Vicon system with Augmented Reality software, and our development of a user interface allowing technicians to manipulate the graphical display. We will also cover challenges we encountered relating to camera distortions and registration accuracy, and how we overcame them. Further discussions will cover how this work integrates with a key initiative called the Concept Center and the advantages of integrating visualization techniques, radio frequency-identification, (RFID) and quality and lean tools in a common venue for major stakeholders to work together on engineering design and manufacturing deployment.

INTRODUCTION

The Augmented Reality projects described in this paper are a part of two larger initiatives; the first is the EAIT project based in El Segundo, CA, and the second is the Concept Center in Tukwila, WA. The two initiatives are technology projects that are a partnership among Boeing Research &

Technology, selected Boeing business units, industry, university and government partners. The focus of the first project is the transformation of "laboratory type or one off" production areas to efficient multi-product facilities by the introduction and modification of high rate production methodologies and technologies with system level metrics (cost, cycle time, rate, quality) that are required by the business unit. The Concept Center is a venue for engineers and technicians to have an opportunity to work "hands-on" to create new solutions and solve technical challenges. It is also a domain where future technology is showcased for engineering and management demonstrating the integration and value proposition of future manufacturing opportunities.

THE TWO KEY INITIATIVE DOMAINS

The current EAIT team has leads for each involved business unit, with the primary partners being BR&T and the Space & Intelligence Systems organization of Boeing Defense, Space & Security. These leaders work closely with a core team who are responsible for the functional and sub-functional areas and ultimately for the technology tasks. Most of the core leaders are natural system thinkers or have learned systems thinking from classes or membership in systems thinking organizations.

EAIT is a true partnership with the business unit and serves as a link between the business unit and enterprise and global research efforts. The diagram below shows how EAIT interacts with other initiatives.

A Focused Collaborative Effort Is Necessary to Achieve The Factory Transformation in El Segundo

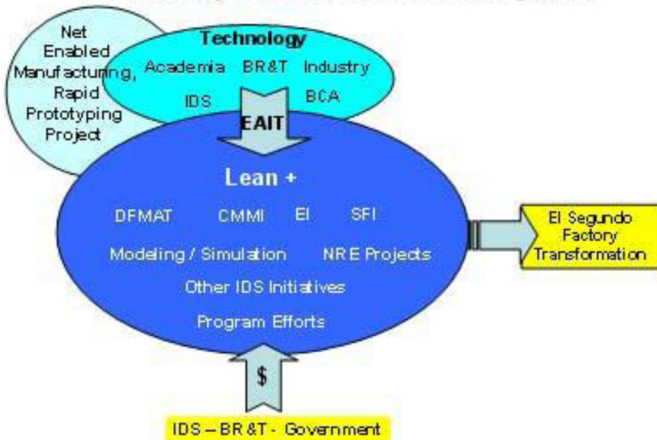


Figure 1. Model for the El Segundo Factory Transformation

As shown in figure 1, EAIT resides in BR&T and in the Lean + organization at the business unit, and touches various initiatives both inside and outside the business unit. In addition, the Concept Center is hosted in the factory of the future and sustainability domain with tents in Lean and Lean +, Boeing's companywide, overarching continuous improvement approach.

CONCEPT CENTER

The Concept Center is a physical footprint where engineers in design and manufacturing can understand and respond to the needs of manufacturing mechanics, other program engineers, quality, material, supply chain and production communities. The intent of the Concept Center is to create a technology center where engineers, technicians and all stakeholders are engaged in the design, build and manufacturing process and deployment can collaborate together on the product lifecycle. This forum allows the community to work with the production system technologies for the next generation

commercial aircraft and other business unit products. Initially the center will be hosted in a footprint adjacent to the advanced composite technology team allowing for a seamless workspace to team with product development and production engineering to focus on the people and technology synergies of the rich cultures each community bring to the forum. This forum also allows the community to take the success of the teams and replicate them across the Boeing enterprise.

The motivation behind this approach was to create a venue where an integrated product development life cycle would be the theme with multiple technologies in the infrastructure allowing for a robust backbone upon which to design, build and deploy successful products. It is critical that the engineers, technicians and other stakeholders in this footprint are doing the discovery, analysis and exploration as a team and not as "stove piped" domains working single solution sets. Single mission labs are focused on specific areas of expertise and solutions (examples: hole drilling, portable tools, electronics etc) where as the Concept Center is a showcase of the integration of multiple resources, skills, systems, tools and technologies to deliver optimal solutions in aerospace and commercial products. In addition, traditional labs do not allow for full integration and testing of article before production release.

One of the main goals of the center is to simulate the article process flow. Simulation models of technology insertion, product flow, quality, cost models etc. are all a critical part of the footprint. The opportunity to simulate tests on physical articles in a non-disruptive environment before release to the production line allows for sound benchmarking and robust data collection to ensure first pass quality into the production line. It also allows for alpha and beta testing in an integrated environment unlike the traditional labs focused on specific technologies

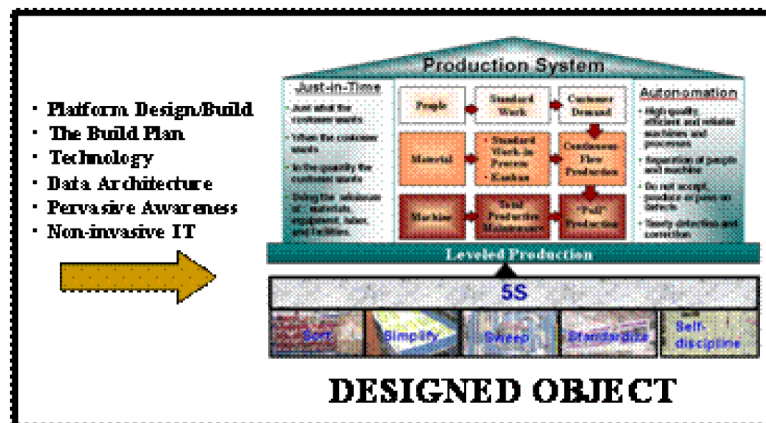


Figure 2. Production system

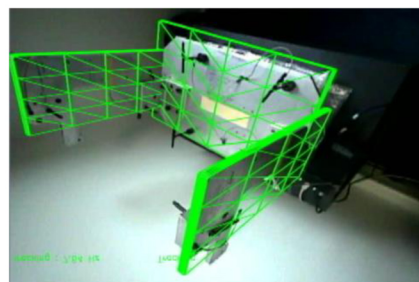


Figure 3. Examples of Augmented Reality work within Boeing

In the following sections you will see some examples of visualization technologies that are being implemented and how they work together to provide greater benefit to the system than the simple sum of the individual labs.

AUGMENTED REALITY

Augmented reality (AR) is a computer graphics and machine vision technology that spatially registers and overlays computer generated graphics onto scenes of the real world. In this paper, we discuss the use of AR as a tool to help get design intent to the builder so the product can build right the first time and every time. By spatially registering and overlaying 3D models, text instructions, callouts, etc., products can be built faster and with fewer errors^[1].

Virtual Reality (VR) is a technology which allows a user to interact with a completely computer-simulated environment. This virtual environment is an effective method to simulate many possible scenarios and multiple configurations without the need to build physical artifacts. It is also an effective method to transfer information to personnel without the need to procure and fabricate physical artifacts.

AR and VR together represent disruptive technologies that offer a compelling display medium to enhance manufacturing technician's tasks. Integration of user interfaces such as 3D head mounted, or 2D flat screen displays allow an effective man-machine interface that merges virtual content with the real world. The images below show examples of AR work within Boeing.

There is a need for a reliable process with the capacity to analyze and quantify the relationships and cost/benefit tradeoffs for various infrastructure components within its manufacturing and service delivery. Part of the assessment of an augmented/virtual reality approach is to ensure a high degree of continuity of operations, especially on unique jobs where a lapse of time between mission critical tasks creates a high learning curve for technicians. It also provides a rich digital thread from requirements analysis to disposal. The collaboration of virtual and augmented reality allows digitization and application of the processes in a virtual world with augmented reality enhancing the "real" environment

based upon the integration of approved virtual prototypes for use in manufacturing. It also supports a surge production requirement opportunity by rapidly organizing, developing and delivering quality products to meet customer needs and allowing the builder to build either identical or unique parts right each time.

PROBLEM STATEMENT BEING WORKED AT EL SEGUNDO

On the shop floor, areas of persistent rework are being identified and various methods of focusing human cognition on desired task instructions are being investigated as a technology to reduce the risk of rework. Augmented reality provides synthetic vision to shop floor technicians improving their situational awareness and allowing them a "hands" free, point of use information domain to view virtual visibility of hazards that would otherwise be unobserved. Point of use data may be overlaid on the work piece to provide better synthesis of information.

The use of virtual reality technologies such as stereoscopic visualization and intuitive 3D geometric data interaction has been limited to formal product reviews due to the cost and limited availability to these advanced capabilities and resources between customers and suppliers and biological / ergonomic issues. There is a need for all participants in the product definition and review process to have ready access to these capabilities in their daily desktop product and manufacturing process definition activities while working with and maintaining configuration controlled authority data. This is required to give all decision makers the ability to maintain product configuration control while performing interactive collaborative product development.

AUGMENTED REALITY IN SATELLITE DEVELOPMENTAL PROGRAMS

An Augmented Reality (AR) system assists manufacturing teams that are responsible for intervening and correcting challenges as they occur on the production line. This can be applied in peripheral infrastructure such as cabling, jigs/tools and other utilities. It also can extend to an information technology backbone that can deliver 3D models and metrics