Boeing 777: Use of Modeling and Simulation in Systems Design

The design, development and fielding of the Boeing 777 used modeling and simulation to a much greater extent, and with better results than previous Boeing aircraft. Compared with tradition design techniques used for the Boeing 757 and 767 designs, which involved physical mockups, the virtual process resulted in the following design efficiencies:

- **Elimination of >3000 assembly interfaces**
- **90% reduction in engineering change requests (6000 to 600)**
- **50% reduction cycle time for engineering change request**
- **90% reduction in material rework**
- **50x improvement in assembly tolerances for fuselage**

The following information came from *Boeing Frontiers* Magazine, July 2009 and contains a brief history of the use of M&S in Boeing products including leading up to, and including the use of M&S for the Boeing 777 design.

1 Product proposal

Analysts use computer-based modeling techniques extensively to model a proposed product or system to determine if an idea could result in a viable program. This is where the P-8A proposal originated. Boeing experts used a variety of performance modeling tools to demonstrate the capabilities of the 737 compared to the Navy's legacy platform—and to show how this product could suit the Navy's mission requirements. The tools demonstrated to the customer the proposed product was superior to the competitor's product, and modeling and simulation tools provided robust data for the 250-page concept of operations that ultimately won Boeing the contract.

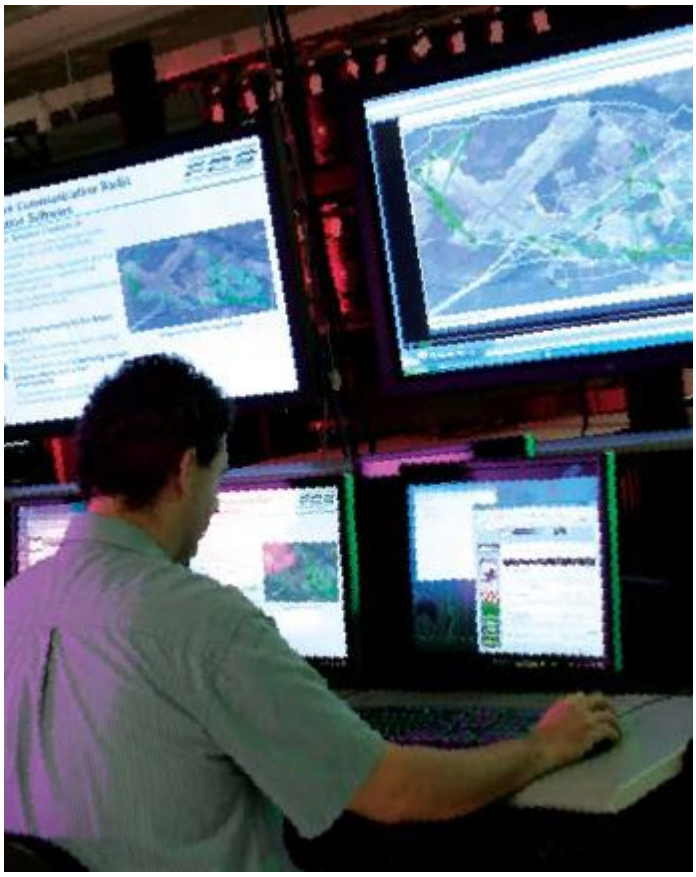
2 Detailed product design

Developing the details of—and manufacturing requirements for—a complex product or system is determined more readily using modeling and simulation activities. People on the U.S. Army's Future Combat System program are working with suppliers on product producibility and assembly simulation, and variation analysis. Product producibility and assembly simulation evaluate designs and define build sequences for a product. Simulations identify tooling, facility and ergonomic issues before

the product design is released, minimizing problems in the factory. Variation analysis assesses the impact of different assembly sequences and tooling concepts on final product form, fit and function.

3 Modeling factory environments

When analysis validates a product's viability and it's time to build, Boeing analysts apply factory-modeling methodologies to determine the optimal process to create various products. Using the physical elements of a manufacturing environment, process plans and other data, they can visualize and validate an optimal production environment before facility construction starts, identify potential bottlenecks, and establish lead times for tool and capital procurement. They also model the flow of a product through a factory. Alternate flows and resource plans are easily evaluated before introducing hardware into the factory.



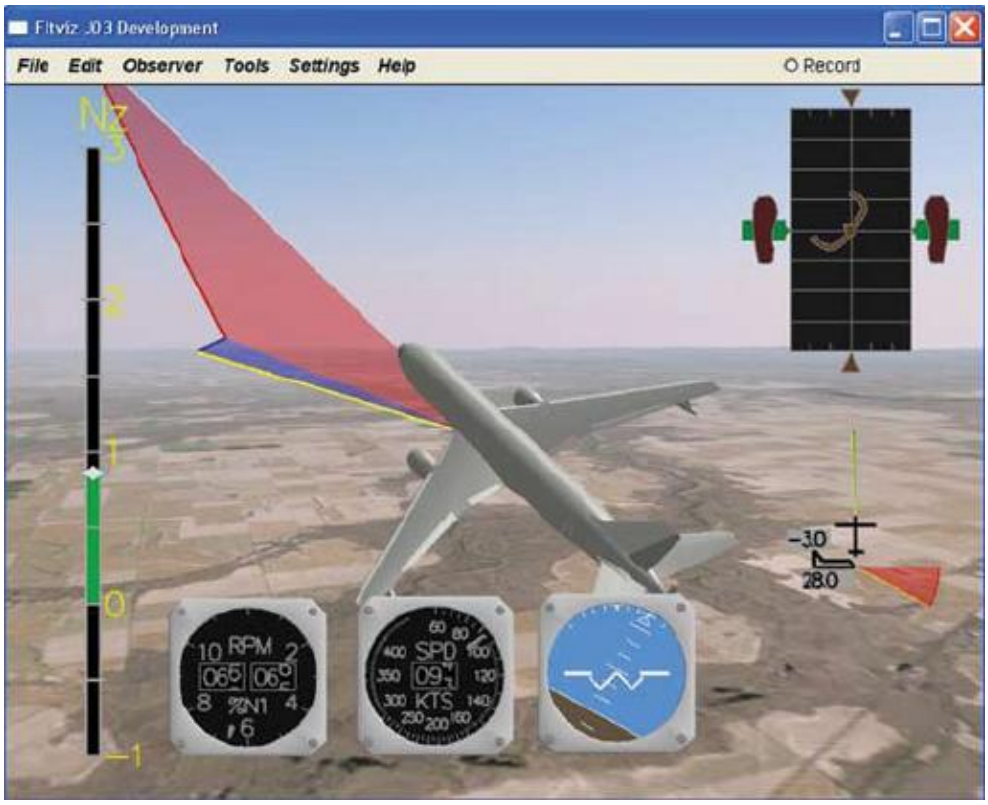
Boeing workers at the FCS System of Systems Integration Lab in Huntington Beach, Calif., simulate activity along nodes in a communication network, forming and breaking and reconnecting systems in support of Boeing's Future Combat System program. This element of FCS is considered to be a mobile, ad hoc, self-forming, self-healing network.

4 Product or system testing

Models and simulations are used to test products or prototypes in a variety of simulated environments. This is particularly true of warfare (see reason 9 on page 39). Modeling and simulation has been an extremely important element of Future Combat System testing. The hundreds of vehicles, sensor platforms and networked computer systems in the FCS system of systems will be tested in a large-scale distributed simulation facility called the FCS System of Systems Integration Lab. The SoSIL provides a synthetic combat environment for simulating the entire FCS Brigade Combat Team. FCS vehicles and platforms will initially be simulated systems in the lab. As FCS development progresses, simulated systems will be replaced by operational hardware and software.

5 Modeling variants or enhancements to existing products or systems

Models and simulations are useful when proposing new courses of action, identifying new uses for a product or determining the viability of product enhancements. Many Boeing programs use such tools as a normal course of business. The 777 Engineering Team applied simulation and modeling tools to actual data from flight-test 777 airplanes. This helped demonstrate the quality of airplane handling, such as lateral and longitudinal control, and performance in a variety of circumstances—and validated system enhancements on both the 777-200LR and 777-300ER programs.



The Boeing Commercial Airplanes 777 Engineering Team used data from flight-test 777 airplanes with

simulation and modeling tools to validate proposed system enhancements to the 777-200LR and 777-300ER programs. Depicted here is a simulation, based on actual flight-test data, visualizing airplane performance during a flight-test maneuver.

6 Training systems and maintenance

Flight simulators such as those found at Boeing subsidiary Alteon are prime examples of the benefits of simulation training systems. Using flight simulators, customer pilots are immersed in the operational environment, enhancing their learning experiences. For example, pilots can practice recovery maneuvers related to a controlled descent into terrain without actually being in a true high-risk scenario. Flight simulator time costs approximately one-tenth as much as an actual flight.

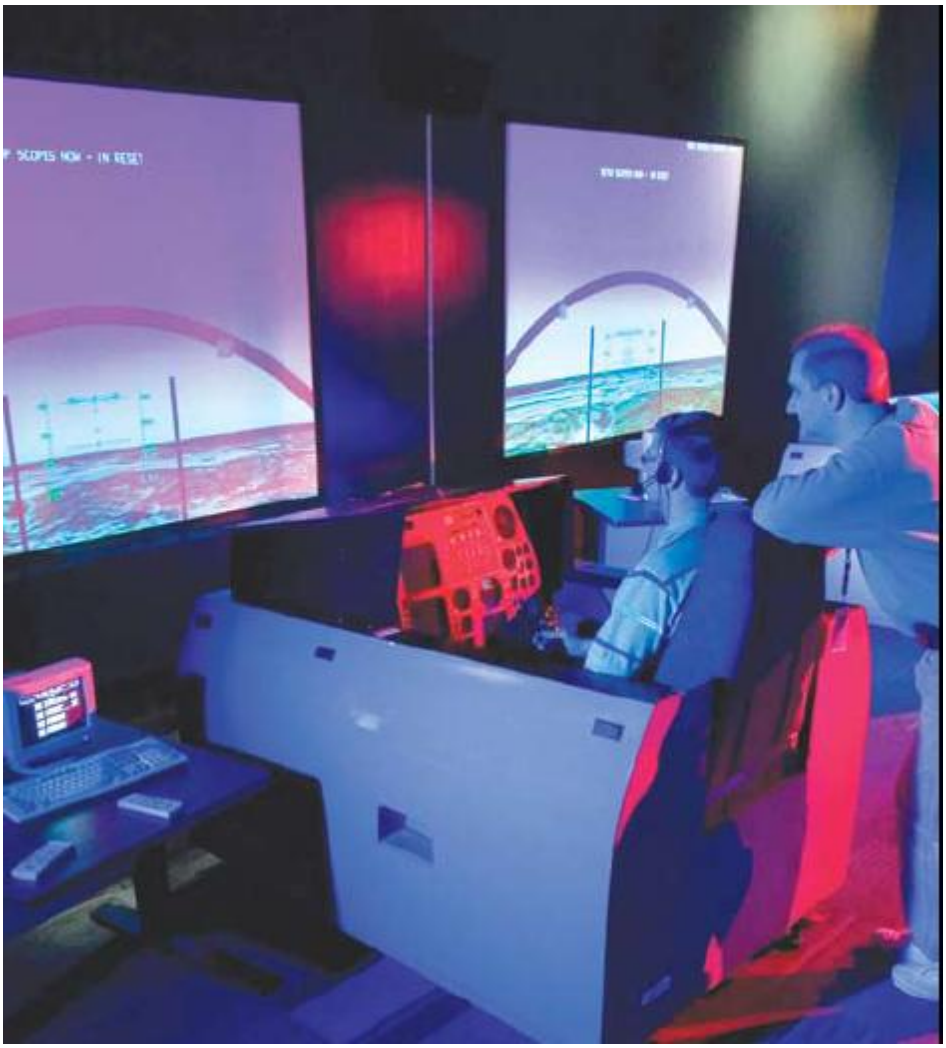
Using flight simulators, Boeing Commercial Airplanes customers are immersed in a realistic flight environment, enhancing their learning experience. Using computer-generated visuals to simulate surroundings, pilots can practice a variety of maneuvers related to high-risk situations without ever being in jeopardy

7 Financial or cost modeling

Modeling financial risk is extremely useful to businesses such as Boeing Capital Corporation. In 2004 BCC rolled out a new software modeling tool that looks at financial data and all of BCC's customers in aggregate, along with historical market data. The software provides a clearer picture of how each financing decision affects BCC's total exposure to risk. Examining all risk factors simultaneously helps decision makers understand how to mitigate volatility in the financing business and make better predictions

9 Simulated warfare

Evaluating the effectiveness of warfighting systems requires diverse, highly complex computer simulations that model warfare from different perspectives. At the Virtual Warfare Center, for example, Boeing engineers and customers use special types of virtual simulations with human participants to create, modify and assess concepts of operation as well as tactics, techniques and procedures. Boeing also employs tools such as Joint Warfare System, an advanced, theater-level campaign-analysis simulation tool developed and managed by the Joint Forces Command—to assess how Boeing advanced concepts will perform in warfare campaigns of the future.



At the Virtual Warfare Center in St. Louis, Boeing engineers and customers use virtual simulations with human participants to create, modify, and assess concepts of operation as well as tactics, techniques and procedures.