Success Story

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*–Norm Riegsecker,*
*Pilot Training System Manager,*
*Boeing*

# Boeing: Advanced Technology Drives the Success of the F-22 Raptor Air Dominance Fighter Program

At Boeing, a long-standing commitment to use the latest technology in all phases of aircraft development has contributed to the company's success as the world's largest manufacturer of commercial and military aircraft. The latest visualization hardware and software are used throughout the design and manufacture of leading-edge aircraft. These technologies are just as critical in the development of training systems and curricula to ensure the success of pilots and maintenance personnel.

In 1991 Boeing was awarded a joint contract with Lockheed Martin and Pratt & Whitney to develop the F-22 Raptor Air Dominance Fighter for the U.S. Air Force (USAF). Over the past decade the three partners have been working as a team to design, manufacture, and test the aircraft and prepare for deployment. The advanced stealth features, weaponry, and avionics systems of the single-seat fighter aircraft, and the need for close collaboration, have made the use of visualization technology more critical than ever in the development of this next-generation fighter.

"Advanced computer systems from SGI have been instrumental in every phase of F-22 development," said Norm Riegsecker, pilot training system manager. "The use of SGI systems for advanced visualization has made an invaluable contribution to the F-22 program, helping us meet important deadlines while reducing the overall expense of design, manufacturing, courseware production, and training."

The F-22 is scheduled to begin deployment in 2003. With this deadline rapidly approaching, preparations for the training of pilots and maintenance crews form an increasingly large part of the F-22 program. SGI® systems are playing a critical role in the F-22 training program.

## Raising the Bar on Aircraft Design

In the late 1980s Boeing began moving from the traditional physical mock-ups used in the aircraft design process to an integrated digital engineering process known as electronic mock-up. This transition has helped to reduce expenses significantly and has allowed Boeing to meet aggressive project timelines consistently. Everyone involved in the design and manufacturing process can visually inspect and understand a design in great detail using FlyThru®, Boeing's real-time visualization and interaction software developed and executed on Silicon Graphics® Onyx2® visualization systems and SGI visual workstations.

Boeing is responsible for the design and manufacture of the wings and aft fuselage of the F-22. These structures have to mate seamlessly with structures from other contractors. Using FlyThru and CATIA® CAD/CAM/CAE software from Dassault Systemes, design engineers were able to perform all large-scale design reviews using Silicon Graphics Onyx2 systems for advanced visualization to achieve a high degree of design accuracy without physical mock-ups. The F-22 manufacturing team was included in all design reviews to ensure that the final design was not only accurate but also easy to build.

The mating of the mid and aft fuselage—structures designed and manufactured by separate teams at separate companies—was accomplished in three days, as opposed to the three weeks that traditionally would have been needed. Because of the outstanding design accuracy achieved by the F-22 program, military and government contractors are now strongly encouraged to use digital mock-up for all new programs.

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### Bringing the Pilot into the Loop

Boeing is also responsible for integrating the various advanced avionics systems for the F-22, including systems for radar; electronic warfare; and communication, navigation, and identification. Test pilots and military decision makers are being brought into the design process to ensure that the F-22 cockpit is laid out for maximum utility and efficiency. The F-22 Cockpit Development Station (CDS) was created using SGI systems and Designer's Workbench from Centric Software, allowing tactical cockpit displays to be prototyped rapidly. According to Deborah Brey, lead software engineer on the CDS, "Because of the computational power of Onyx2 systems in combination with advanced software, head-down displays can be changed on the fly. Anyone can request a change and see it instantly." Now that cockpit design work has been largely completed, the CDS has become an important tool for training test pilots and for developing training materials.

### Training Pilots for 21st-Century Air Combat

Training a pilot to fly a modern fighter aircraft and to operate all its advanced systems is a daunting task. Boeing is responsible for both interim training of test pilots and for the development of training systems that will be used after the aircraft is deployed.

### Cockpit Display Station for Interim Training

F-22 prototypes are now being flight-tested to validate the cockpit design choices made thus far, resulting in ongoing changes to the cockpit layout. This process creates some unique challenges, because instructors and equipment must keep pace with the aircraft design as it evolves. Because of its built-in flexibility, the CDS has proved ideal for this purpose. The CDS is being used to train new test pilots and to give other pilots a first look at the F-22. It will also be used to train USAF pilots chosen for dedicated initial operational test and evaluation (DIOT&E).

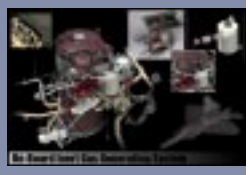
A 4-CPU Onyx2 system and two Silicon Graphics® Octane2™ visual workstations power the CDS. A single channel from the Onyx2 system drives a video projector to create out-the-window displays. Heads-up displays—which allow the pilot to view critical flight information without looking down into the cockpit—are overlaid on the projected out-the-window scene. Cockpit displays are viewed on four small CRT screens positioned appropriately within the CDS. A replica of the integrated control panel found on the F-22 is used for pilot input.

Two Wingman stations, each driven by a dual-CPU Octane2 workstation, complement the CDS. Both stations share an SGI® Origin® 3400 server. Although the Wingman stations do not provide the same level of cockpit realism as the CDS, they do have a realistic stick and throttle, with other controls viewed on a 20-inch, flat, touch-panel display. Out-the-window views are provided by 24-inch displays. The Wingman stations allow pilots to fly both in formation with a pilot in the CDS or against other pilots in the various stations. Instructors can use the Wingman stations to provide realistic threats.

The Distributed Interactive Simulation protocol allows multiple cockpits to participate in the same simulation. An upcoming version will upgrade this capability to use the High Level Architecture (HLA) protocol, as mandated by the government for all simulators used by the military. This capability allows a wide variety of simulators for military aircraft to participate in the same simulation, thus more closely approximating combat conditions.

Both the CDS and Wingman stations can simulate a battle environment with computer-generated airborne and ground-based threats. All stations can also simulate various terrains and weather environments and provide accurate and realistic outputs for aircraft sensors and avionics displays.

"The CDS and Wingman stations are of enormous value to our training program," said Riegsecker. "The stations are used to familiarize pilots with aircraft capabilities that have been introduced during academic instruction. The computer-generated models for the physical environment, aircraft performance, sensors, displays, and threats provide a very realistic, representative F-22 cockpit training environment. This enables the test pilot to effectively and efficiently train before flying the actual aircraft. We expect equally effective training on the CDS with the DIOT&E pilots. The CDS also gives operational pilots who visit the facility a good sense of the advanced capabilities of the F-22, building enthusiasm for the eventual deployment of the aircraft."



## Full Mission Trainer

A Full Mission Trainer (FMT) will be used for pilot training after the F-22 is deployed. The development of this training system has been subcontracted to Link Simulation and Training, a division of L-3 Communications. The first FMT is scheduled for delivery in April 2003.

In addition to air- and ground-based threats, the FMT will simulate a variety of atmospheric and environmental conditions, including wind shear, turbulence, storm cells, and lightning. The visual environment consists of a fixed-base, nine-facet, 360-degree visual system with a high-fidelity representation of the F-22 cockpit. Six of the nine facets provide high-resolution visuals. An SGI® Onyx® 3800 InfiniteReality3™ visualization system™ and other SGI components provide all out-the-window views, cockpit displays, and simulation of correct aircraft behavior. A head-tracking system monitors pilot head movement to display high-resolution images in whatever direction the pilot looks.

During the initial deployment, up to four FMTs will be networked together to support combat mission rehearsal and to simulate the flight of F-22s in a single-threat environment. HLA compliance will be added to the FMT later, to allow it to collaborate in more extensive multi-simulator virtual environments.

Most of the software for the FMT is being derived from existing sources, including F-22 operational flight software, existing simulations of the F-22 and other aircraft, and commercial off-the-shelf products. Only 9% of the software is new, representing a huge savings in development time and cost.

## Taking Computer-Based Training to the Next Level

Spending time in a flight simulator is the last phase of pilot training. Boeing is also responsible for the many hours of coursework that pilots must complete before entering flight simulators or flying real aircraft, not to mention the many hours of courseware needed to prepare maintenance personnel and to produce qualified instructors. Computer-based training (CBT) curricula will consist of 75 lessons for pilots and about 500 lessons for maintenance personnel.

The F-22 training system provides 2D, 32-bit captures of 3D imagery in interactive multimedia courseware. Boeing has been able to substantially streamline the process of courseware creation by integrating information from the CDS and design data from FlyThru.

## Improved Courseware Accuracy with the CDS

The CDS provides significant benefits to the training effort. First, it allows courseware developers to become intimately familiar with the cockpit and the aircraft. In addition, static and dynamic images of cockpit displays can be captured directly from the CDS for incorporation in training materials. Instructors can simulate engagement with specific air- or ground-based threats and capture a full digital record of how those threats were employed against the F-22 and how they were countered.

Rich Maki, pilot training courseware manager, stated, "Since the CDS replicates actual aircraft software performance, it provides us with the highest levels of confidence that our courseware includes accurate, dynamic display presentations. Without this capability, the artist workload would be extreme and the graphics would only represent data that was as good as a subject matter expert's research could determine. We and the customer are very happy with the performance of this equipment."

## FlyThru Data Streamlines Graphics Development

The F-22 team is able to bring 3D engineering data from CATIA into FlyThru and add realism and animation using TAV and Maya® software from Alias|Wavefront. By capturing the latest engineering models from the actual air-vehicle geometry and adding detail and photo-realistic qualities, the training team has access to a near-virtual 3D aircraft to create images for use in courseware. Images that used to take technical illustrators hundreds of hours of intensive labor can now be completed in just a few hours and with greater accuracy. With 90% of the graphics for CBT coming from engineering design data, Boeing has been able to realize a significant cost reduction for the training program, due in large part to its use of SGI technology.

According to Pam Valdez, Boeing's F-22 training systems manager, "With a computer-based aircraft design in three dimensions, we can use the aircraft geometry to develop our graphics for the F-22 training system. What the student sees in the CBT is the exact aircraft geometry, not an artist's conception. It really comes into play in the maintenance world, when you start stripping away the surfaces of the aircraft and get into the deeper sections of the aircraft. You can show the students the actual 'components tree' of the aircraft with extremely high fidelity."

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## On the Horizon

The CDS, now complemented with the additional Wingman stations, has proved immensely valuable in all phases of F-22 development. The utility of the CDS is expected to continue up to the field deployment of the F-22 and beyond. Future upgrades will include a new, more detailed cockpit for the CDS. Brey would also like to upgrade the existing Origin 3400 server to an SGI® Origin® 3800 server. With this upgrade, the system will be able to drive both Wingman stations without the need for the individual Octane2 systems.

The development and deployment of an advanced fighter takes years of preparation. Success depends not only on the quality of the engineering and manufacturing but also on the quality of pilot training and support. The combination of Boeing's dedicated personnel and the latest technology from SGI are making an enormous contribution to the success of the F-22 program.


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