Sweeping changes

Why Rockwell International was involved in working on the Forward Swept Wing—and how this technology lives on today

By Erik Simonsen

During World War II one of the primary goals of fighter pilots engaged in aerial "dog fights" was to maintain a tight turn inside the attacker. After the war, aeronautical engineers were anxious to achieve air combat maneuverability superiority for future aircraft. It was believed that development of a Forward Swept Wing (FSW), which positions the wings' leading edges further forward in the airflow, could provide that capability.

Boeing predecessor company Rockwell International aimed to deliver this ability. Although the customer elected not to extend FSW technology beyond two demonstrator aircraft built by a competitor, work done by Rockwell has led to aerospace innovations that live today.

The FSW concept was not new. During World War II, U.S. engineers were aware of FSW problems that severely limited the speed of the German Junkers Ju 287 four-engine bomber. Although not intended for increased maneuverability, the bomber's FSW configuration enabled its bomb bay to be located at the aircraft's center of gravity.

In the quest for increased maneuverability, the top post-World War II U.S. fighter, the P-51 Mustang, was selected for the new wing. Boeing predecessor company North American Aviation designed an FSW P-51 concept. However, during wind tunnel tests the rigid aluminum wings twisted asymmetrically, indicating potential loss of control. Further testing determined the wings had to be limited to 15-degrees forward sweep. Increased speed and high g-force turns would lead to structural divergence, or wing separation. The FSW P-51 was never built.

But this initial study uncovered additional FSW advantages, including super agility; reduced drag, resulting in the need for a smaller engine; increased lift characteristics; reduced aircraft size; and smooth transonic/supersonic transition. Yet it would take decades of technological evolution before a fully capable FSW concept could actually take to the air.

Norris Krone, a retired U.S. Air Force colonel who joined the Defense Advanced Research Projects Agency (DARPA) in 1976, had long envisioned the advantages of forward swept wings. At DARPA, Krone continued to advocate the concept for modern fighters, and it seemed necessary technologies had matured. Advanced lightweight composite structures (30 percent lighter than metal) and aeroelastic tailoring (controlled flexing of the wings) helped pave the way. In addition, computerized flight controls were available to dampen out instability. Krone's dream was gaining traction.

A sophisticated flight test program became a reality in 1977, as the FSW program was initiated under the auspices of DARPA, NASA and the U.S. Air Force Flight Dynamics Laboratory. Technical gains would be applied to the forthcoming Advanced Tactical Fighter competition.

Three contractors submitted proposals. General Dynamics submitted a FSW variant of the F-16, but was eliminated from the competition. Grumman Corporation proposed a new design that used several off-the-shelf aircraft sections not directly involved in

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FSW technology. These included the forward fuselage and cockpit of a Northrop F-5A, and the F-16 nose and main landing gear.

Rockwell International entered a "clean sheet" design named the Sabrebat—in keeping with the North American Sabre Jet legacy. The forward wing sweep was 40 degrees compared to 30 degrees on the Grumman design. To aid in high-angle-of-attack flight, Sabrebat featured a lower fuselage intake, similar to the F-16. In addition, the cockpit seat inclined 30 degrees, providing excellent all-aspect visibility.

Both designs included forward canards. Rockwell featured aft-swept canards placed above the main wing to alleviate wake interference. Grumman designed canards that interacted with the forward swept wings.

On Dec. 22, 1981, DARPA chose Grumman to build two X-29A demonstrators, relegating the Sabrebat to only a full-scale mockup. In December 1984, the No. 1 X-29A made its first flight at NASA/Dryden Flight Research Center at Edwards Air Force Base, Calif. As the aircraft cruised to an altitude of 15,000 feet (4,572 meters) and speed of 235 knots, the triplex fly-by-wire flight control system was pulsing 40 commands-per-second to counter the wings' inherent instability.

Mike Robinson, the Sabrebat program manager for Rockwell and now with Phantom Works business development, recalled that the Sabrebat FSW concept was based on the HiMAT (Highly Maneuverable Aircraft Technology) test flight experience (see Page 8 of the May 2007 *Boeing Frontiers*). "That program amassed a wealth of transonic/supersonic data on HiMAT's graphite composite variable-camber wing." Robinson continued, "The FSW demonstrator program proved to be very successful in that we developed a high-tech design team, tools and insights at a time when there were few new designs in work. Those technologies served us well in many subsequent programs. And the enabling technology was ultimately used on other programs during the ensuing two decades."

Although DARPA, NASA and the Air Force concluded that FSW technology would not extend beyond the X-29A, the program helped revitalize X-Plane research. It also led to innovative work such as the Boeing Phantom Works F/A-18 Active Aeroelastic Wing program, where an aircraft's wing surfaces change shape subtly in flight to provide improved control and better performance (see Page 68 of the December 2002/January 2003 *Boeing Frontiers*). ■

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Forward thinking

What capabilities were engineers looking for in a Forward Swept Wing design? Here's a list.

- Reduced transonic and supersonic drag
- First thin supercritical wing
- Advanced flight controls
- Higher maximum lift
- 25 percent reduction in landing speed
- Extreme high-angle-of-attack flight
- 20 percent reduction in size, compared to a similar fighter with conventional wing

PHOTOS:

FAR LEFT: Graceful interaction of the aft-swept canards and forward swept wings are depicted on the Rockwell Sabrebat full-scale mockup. BOEING ARCHIVES **LEFT:** A planform view of the Grumman X-29A FSW demonstrator over the Edwards Air Force Base, Calif., test range. NASA