

## Digital Fly-by-Wire Technology

Digital fly-by-wire (DFBW) is one of many success stories where technology developed under the U.S. space program has proven beneficial in other areas. Based in part on a recommendation from Neil Armstrong, who was directly familiar with the Apollo Guidance Computer through his historic lunar landing, NASA's Dryden Flight Research Center chose to work with Draper Laboratory to adapt the concept for aircraft, beginning with experimentation on a U.S. Navy F-8 Crusader in 1972.



From top to bottom: Space Shuttle, Airbus A320, B-2 Stealth Bomber, Boeing 777, Dassault Falcon 7X, and Joint Strike Fighter X35  
(Sources: NASA, Airbus, Boeing, and Dassault)

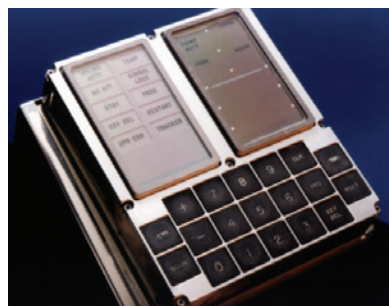
Draper developed DFBW as an extension of its work on the Apollo Guidance Computer. The concept uses a highly reliable computer and electronic flight control system, rather than mechanical or hydraulic-based systems, to stabilize and maneuver a vehicle. The computer is able to execute far more frequent adjustments than a human pilot, thus helping maintain stability while offering increased maneuverability.

The 15-year DFBW technology research program also demonstrated adaptive control laws, sensor analytical redundancy techniques, and new methods for flight testing digital systems remotely.

### Real-World Applications

The F-8 digital fly-by-wire program served as the springboard for DFBW technology to be used in both military and civilian aircraft. Today, commercial launch service providers and satellite manufacturers also routinely use the technology in their vehicles and spacecraft. Below is a partial list of aircraft and spacecraft with DFBW technology:

- Space Shuttle
- Launchers: Ariane, Vega, Titan, Delta, Proton
- Airbus A320 (first airliner with DFBW controls)
- Boeing 777 and 787
- Jet fighters: F-18/22, Dassault Rafale, Eurofighter, Joint Strike Fighter X35
- Stealth Fighter/Bomber: F-117, B-2
- Dassault Falcon 7X (first business jet with DFBW controls)
- Rotorcraft: V-22 Osprey, RAH-66 Comanche, AH-64 Apache, NH-90, Sikorsky S-92
- Several unmanned aerial vehicles (UAVs)



Apollo computer interface box used in the F-8C digital fly-by-wire program  
(Source: NASA)



NASA used an F-8C for its digital fly-by-wire program, the first DFBW aircraft to operate without a mechanical backup system. This photo shows the Apollo hardware jammed into the F-8C. The computer is partially visible in the avionics bay. (Source: NASA)

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## Space Technology Hall of Fame 2010

NASA's Dryden Flight Research Center, Draper Laboratory, The Boeing Company, and Airbus were inducted into the Space Technology Hall of Fame in 2010 for the development of digital fly-by-wire technology that makes modern aircraft easier and safer to operate.



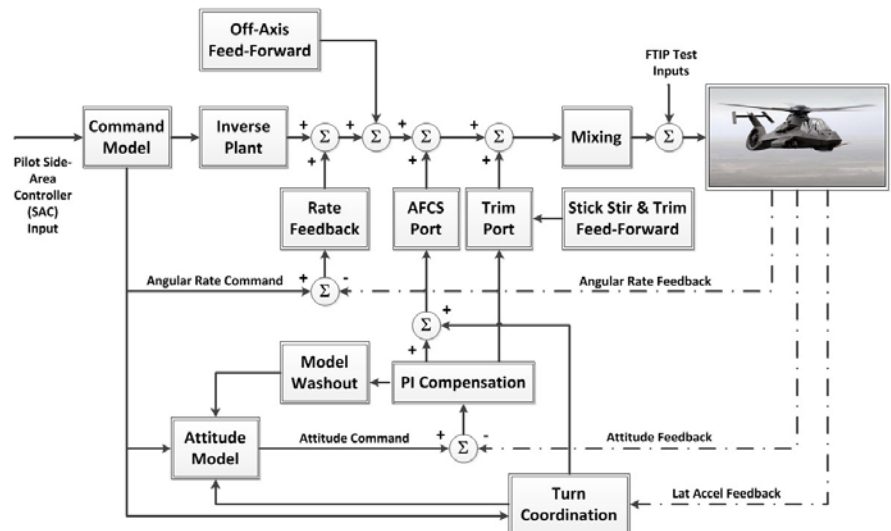
Left: The RAH-66 was the first helicopter that was capable of backflips. Right: X-31 demonstrating high angle of attack maneuver.  
(Sources: Boeing/Sikorsky and NASA)

### Major benefits of DFBW flight controls include:

- Overall cost reduction
- Overall airframe weight reduction
- Increased safety and reliability
- Fuel efficiency
- Reduced CO<sub>2</sub>/NO<sub>x</sub> emissions
- Improved flying (or handling) qualities
- Improved passenger comfort
- Reduced pilot workload
- Ease of assembly and maintenance
- Improved survivability
- Improved mission performance

### The following features, enabled by DFBW, are currently implemented onboard fighter aircraft:

- Reconfigurable flight control system allowing mission continuation or safe recovery following system failures or battle damage
- Flight envelope protection such as bank angle protection, turn compensation, stall and overspeed protection, pitch control and stability augmentation, and thrust asymmetry compensation
- Online system identification for verification of the aerodynamic effects on aircraft flexible modes



RAH-66 Comanche multimode control law architecture  
(Source: Boeing/Sikorsky)

For more information: J.E. Tomayko, *Computers Take Flight: A History of NASA's Pioneering Digital Fly-By-Wire Project*, The NASA History Series, NASA SP-4224, National Aeronautics and Space Administration, 2000; NASA Dryden Technology Facts - Digital Fly By Wire, <http://www.nasa.gov/centers/dryden/about/Organizations/Technology/Facts/TF-2001-02-DFRC.html>.