There are conventional aircraft and unmanned aerial vehicles, and a third category in between, called optionally piloted vehicles (OPVs). These are planes that can fly with or without a pilot as the situation requires. The Korea Aerospace Research Institute (KARI) is developing an OPV and testing its flight control system by running simulated flights in the laboratory with a test bench based on a dSPACE hardware-in-the-loop simulator.

Onboard view during a test flight. A complete preflight simulation of the mission in the laboratory is performed by a dSPACE simulator.

Developing an optionally piloted vehicle

With or Without a Pilot

Why Use OPVs?

The advantage is that OPVs can manage without a human crew on easy-to-navigate missions that do not require any on-the-spot decisions to be made by a pilot. Tedious, long observation missions are typical examples. Obviously, without a pilot on board, an OPV needs particularly mature (multi-redundant) flight control systems in order to fly autonomously and safely. KARI is developing algorithms for such flight control systems.

Realistic Flight Simulation

The flight control systems are being developed with the aid of test bench tests (i.e., virtual flights in the laboratory). Suitable MATLAB®/Simulink® models had to be developed for this. To reduce the differences between virtual and real flight, the flight dynamics model was validated with flight test data (figure 1).

Also, to aid pilot training, not just the flight itself, but also taking off, landing, and taxiing on the airfield was simulated. The virtual flights also have to cover different weather conditions (such as squalls). Using the validated flight dynamics model, all the automatic flight control laws were validated and tuned during the HIL phase. As a result, there was not any tuning necessary during unmanned flight tests. The performance matched that of virtual flights very well.

> "With the test station based on the dSPACE Simulator, we can test all the functions of the flight control system without the aircraft having to leave the ground."
>
> *Dr. Hyoung-Sik Choi, KARI*

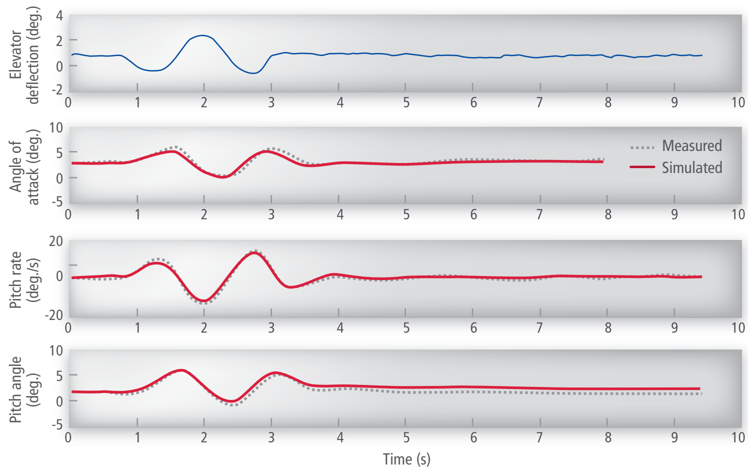


Figure 1: Flight dynamics model validation using flight test data (blue: elevator input; red: longitudinal response)

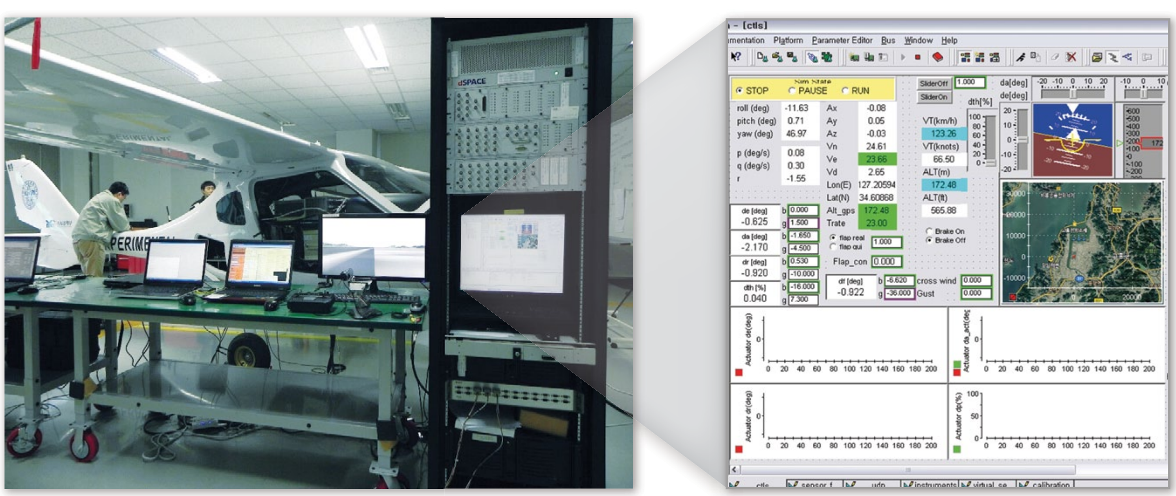
Virtual Test Flights in the Lab

The dSPACE system that simulates flights for flight control tests consists of a hardware-in-the-loop simulator with a DS1006 Processor Board that computes the flight maneuvers and associated sensor values. The simulator is connected to the flight control system onboard the aircraft via various I/O boards. It calculates the sensor values – the aircraft's position (GPS data), attitude relative to the direction of flight, acceleration, speed, etc. – and sends them to the flight control system via RS232. The flight control system uses this data to adjust the plane's control surfaces and guide it along the preplanned route. The positions of the control surfaces are then returned to the dSPACE Simulator to control the aircraft flight motion. All experiments are controlled and monitored from the test and experiment software dSPACE ControlDesk which supports tasks such as manipulating the experimental conditions (wind, etc.) and inserting any desired failures to test how the flight control system reacts – failed sensors or actuators and broken wires are some typical examples.
With this setup, comprehensive and complete tests can be performed without the aircraft having to leave the laboratory. This approach considerably reduces the number of real test flights while increasing the reliability of the overall system at the same time.

Unmanned Test Flights

The plane has already successfully performed its first test flight, which contained all the auto flight modes (table 1): stick auto, knob auto, loitering and point navigation. The flight control system automatically computes the resulting pilot stick positions to guide the plane. As a result of the accurate flight dynamics model and the preflight tests via the dSPACE HIL system, no tuning interventions were necessary.
With the model-based development process, the OPV's flight control algorithms can be developed much faster and at much less cost. The

Figure 2: The dSPACE Simulator executes virtual test flights in the laboratory. The test and experiment software dSPACE ControlDesk (shown on the right) is used to monitor all the experiments and insert failures.



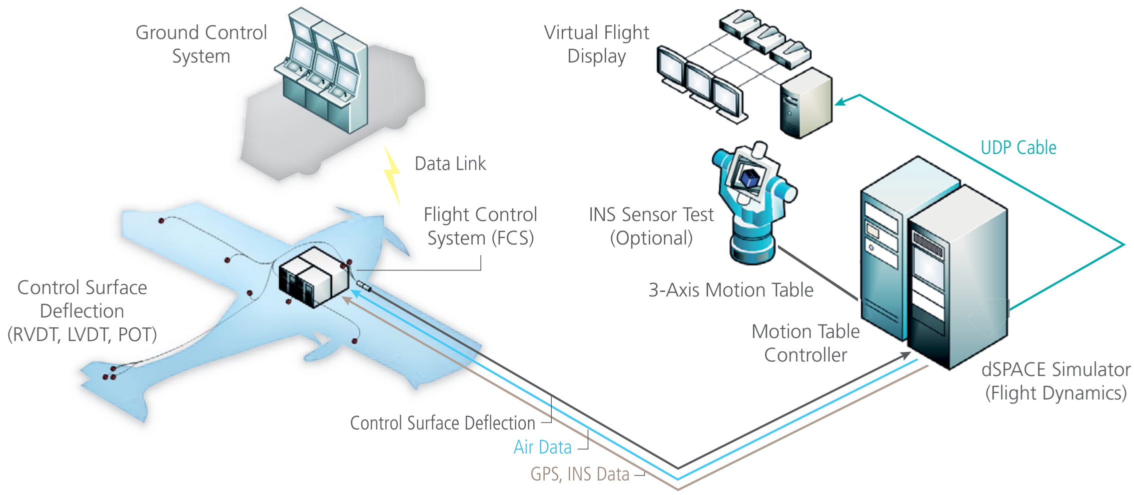


Figure 3: Schematic of the laboratory setup. A wide range of test scenarios can be performed on it without the plane having to leave the laboratory.

fact that the dSPACE tools are so well attuned to the MATLAB/Simulink world also considerably facilitates model-based development work. Being able to use function libraries is particularly helpful, as time is saved by reusing existing knowledge. ■

Dr. Hyoung-Sik Choi,
Sugchon Lee,
KARI

Stick auto mode	In this mode, the stick command is the attitude command so this is more stable than manual mode. As a result, the aircraft's attitude (pitch, roll, and yaw) follows the pilot stick command. In comparison, in manual mode the stick command is the control surface control command (for the elevator, aileron, rudder, etc.)
Knob auto mode	In this mode, the internal pilot gives a knob command (such as the altitude, airspeed, heading or roll) and the aircraft then follows the knob command.
Loitering mode	When the pilot engages loitering mode, the aircraft turns and makes a circle as long as loitering mode is engaged.
Point navigation (NAV) mode	When the pilot engages point NAV mode, the aircraft goes to the given target point. After passing the target point, the aircraft loiters as long as point NAV mode is engaged.

Table 1: Overview of the different auto flight modes that the OPV is able to perform.

Figure 4: The ground control station transmits commands to the aircraft and displays all the aircraft's instruments. Virtual 3-D graphics give a virtual cockpit view, which is useful for monitoring the aircraft's situation in case the pilot-view camera malfunctions.

Dr. Hyoung-Sik Choi
Dr. Hyoung-Sik Choi is senior researcher in the Flight Control Team at KARI (Korea Aerospace Research Institute), Daejeon, Republic of Korea.

Sugchon Lee
Sugchon Lee is senior researcher in the Flight Control Team at KARI (Korea Aerospace Research Institute), Daejeon, Republic of Korea.