Create to correct

Boeing engineers automate perfect Dutch roll flight-test maneuver to advance flight safety

BY MICK BOROUGHS, BOEING WRITER

Ice skaters use the outer edge of their skates to propel themselves across the ice, rocking from side to side while also moving to the left, then to the right and back again. Airplanes can make similar lateral and directional motions in flight, rolling and yawing much like a traditional Dutch ice skater rhythmically swaying down one of Amsterdam's frozen canals.

This movement is called a Dutch roll. The lateral movement of the airplane is the roll, or bank angle. The directional movement — the airplane's nose moving left or right — is the yaw angle. Just as skaters avoid swaying too far and losing their balance, airplanes are designed to keep roll and yaw within regulatory requirements to ensure safety — and potentially reduce the risk of airsickness.

DUTCH ROLL DETAILED

An airplane moves in two axes if it experiences a Dutch roll, which is caused by wind or pilot input. The nose may go left to right as the airplane simultaneously banks side to side.

GRAPHIC: BOEING

FRONT VIEW

TOP VIEW

PHOTO: TIM REINHART/BOEING

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Video: Footage from 1925 in Holland shows where the Dutch roll got its name.

SIMULATION INTEGRATION

(From left) Boeing flight test engineers Brock Larson, Tom Esser, Darren McDonald and Dunes Wijayratne hook up the Dutch Roll Initiator to the 737 flight simulator in Seattle so pilots and test engineers can validate the system and develop test procedures before putting the system on the 737-10 test aircraft.

PHOTO: LIZ WOLTER/BOEING

Dutch rolls are caused by any asymmetric input, such as wind or pilot commands, causing a series of oscillations that will continue until the movement fixes itself or the pilot corrects it. This phenomenon is important for engineers to study in simulations and flight tests.

Perfecting Imperfection: Intentionally Designing Dutch Rolls

"We intentionally stir up large Dutch rolls to gather data to update the aerodynamic model and safety margins," said Darren McDonald, a Boeing Technical Fellow and flight test engineer. "But the oscillations have to be perfectly formed for us to get the information we need."

To create these perfect Dutch rolls that can be initiated both in simulations and during real flight tests, Boeing Test & Evaluation's Flight Test Engineering team based at Seattle's North Boeing Field created the Dutch Roll Initiator (DRI) in 2019. Engineers first deconstructed the maneuver and then moved to desktop and piloted simulations before flying for two days in November 2021 onboard a Boeing 737-10.

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"We learned which parameters define a quality maneuver then studied how to effect the most predictable, highest-quality maneuver," said flight test engineer Jordan Stringfield. "We conducted trade studies with the desktop simulator and talked with the design engineers who require the data."

Simulation and Validation: Going Beyond Compliance

The team used engineering simulators throughout project development, testing and training. They introduced the rudder actuation signals to start a Dutch roll through most of the same hardware that is used on the 737-10. They also performed end-to-end validation and crew training on the system before boarding the airplane.

The DRI commands a carefully timed rudder input in one direction and then an identical rudder input in the opposite direction at a rate that matches the airplane's natural response frequency. The precise symmetry required for the maneuver is difficult to perform manually, especially when paired with aircraft structural limitations.

HAND-HELD SUPPORT

In a 737 simulator in Seattle, flight test engineer Darren McDonald monitors the Fault and Function Generator control, which controls the DRI input. The red emergency stop button is one of several ways the DRI signal can be removed.

PHOTO: LIZ WOLTER/BOEING

“We improved the quality of the maneuver by developing a system to directly send a signal to the rudder actuator without the pilot making the input,” McDonald said. “This improved maneuver quality enables the team to increase safety margins while reducing the flight-hours that would normally be required to run multiple tests.”

Digitization projects such as DRI are supported by Flight Test Engineering’s Model-Based Test and Automation strategy to further the use of flight-test maneuvers to validate models rather than simply show compliance.

Just the Start: Dutch Roll Efforts Leading to a Library

The team chose the Dutch roll to start because the maneuver requires inputs to only one control surface, without requiring any feedback, and is predictable enough to allow for pilot abort and recovery if necessary.

Developing an automated system requires a robust and thorough safety analysis, so the Seattle team selected the Systems Theoretic Process Analysis (STPA) methodology as a new approach.

MEETING OF THE MINDS

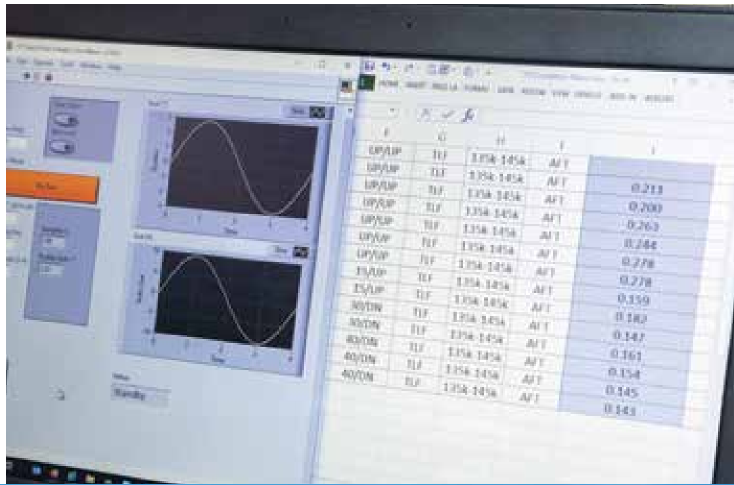
(From left, front) DRI flight test engineers Dunes Wijayratne, Sean Richardson, Shannon Clark, (back) Tom Esser, Brock Larson and Darren McDonald gather at Seattle’s Boeing Field. The DRI is part of flight tests aboard this 737-10.

PHOTO: LIZ WOLTER/BOEING

ON BOARD

Flight test engineer Dunes Wijayratne operates the DRI system on a 737-10.

PHOTO: LIZ WOLTER/BOEING



DRI CLOSE-UP

The DRI rudder signal can be manipulated using a custom DRI software client, which controls the Fault and Function Generator system commonly used for other flight testing.

PHOTO: LIZ WOLTER/BOEING

STPA is a relatively new hazard-analysis technique based on an extended model of accident causation. It assumes that accidents can occur from not just component failures but also the unsafe interactions of system components, none of which may have failed. STPA, developed by professors at the Massachusetts Institute of Technology, is being adopted by a growing number of industries as well as numerous Boeing organizations.

“The final result is a more detailed understanding of all aspects of a Dutch roll — something we’re documenting so we can add this knowledge to a library of flight-test maneuvers that will grow over time,” McDonald said. “Having this library will simplify the process for implementing a maneuver on a new aircraft model.”

Saving the Test for Last: Repetition Is the Key to Learning

The Flight Test Engineering team saved the most difficult Dutch roll flight-test condition for last, as it required an aircraft dive of more than 5,000 feet (1,524 meters) to achieve the target speed of 5 knots (5.8 mph or 9.3 kph) below the maximum operating speed with landing gear extended.

“Thanks to the DRI system, the pilot is able to safely and efficiently initiate a Dutch roll,” said Jennifer Henderson, 737 chief pilot for the tests. “The system allows us to gather test data in a repeatable manner for each test condition.”

Boeing design engineers also appreciate the DRI project because the improved data quality streamlines their efforts to update and validate the models.

“The DRI produced nice, crisp rudder inputs that resulted in clean conditions. Automating flight-test maneuvers is a big step forward for repeatability and data quality,” said stability and control engineer Craig Plendl.

Where Does DRI Go From Here?

“The DRI system is the first maneuver of many that will follow,” McDonald said. “Each maneuver will get progressively more complicated, with a transition to closed loop and multiple surfaces, multiple axes and multiple parameters included in the control loop.

“Our goal is to build the capability to fly any quantitative flight-test maneuver that our customers require, enabling improved designs, increased safety and a better customer experience for our future aircraft.” **IQ**