

# Flight Test *Safety* Fact



Published for the Flight Test Safety Committee

## Gulfstream G500 Takeoff Testing *Clay Harden*

Gulfstream presented a paper on [G500 Takeoff Field Performance](#) at the 2019 SETP Symposium in Anaheim, CA. The presenters included a flight sciences/flight control law design engineer (your humble correspondent) along with seasoned flight test engineer Ben Luther and experimental test pilot/company director Todd Abler. It seemed at first that a technical engineering presentation, and more so a control law design engineer, would be out of place among a group of pilots at SETP. The paper turned out to be a good fit, well within the core of technical and safety-related discussions around flight test planning and execution. Many hallway and dinner hour discussions resulted, and a common theme seemed to emerge at this year's gathering: The aerospace industry is grappling to balance cockpit automation and complexity with our expectations for flight crew recognition and reaction to abnormal scenarios. SETP seems to be at the forefront on this question, and it should continue to stimulate the discussion across the industry and the globe.

## Flight Test Safety Committee



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## Chairman's Comments *Tom Huff*

By all accounts, the 63rd SETP Symposium and Banquet was a major success. Attendance was at a record high of 692! Although some attend for networking and socializing, I consider this the largest, global flight test safety information sharing event. The presentations were informative and accommodated a broad cross-section of flight test activities. As we wind-down symposia across all our flight test professional organizations for 2019, I detect great energy in new aircraft, systems and capabilities that teams are testing and fielding. Hats-off to the testers that take the time to prepare presentations and to their homeroom organizations that approve the sharing of this critical information!

We all know and appreciate the value that flight test brings to "programs," and these new/novel and ever-more complex systems will inevitably challenge our traditional thinking and legacy methods. This was a prominent theme in the recently released [Joint Authorities Technical Review \(JATR\) regarding the Boeing 737 MAX Flight Control System](#). The FAA Associate Administrator for Aviation Safety commissioned the JATR to focus on the certification process. The JATR highlighted several areas where dated certification standards don't sufficiently accommodate increasing system complexity, and recommends a fresh look at several certification requirements related to pilot recognition and response to abnormal conditions. In short, the JATR pushes for fail-safe design for which pilot reaction is not the primary means of risk mitigation.

## Flight Test Safety Committee

Update to the SETP S&B 2019  
Tom Huff, Chairman



*Chairman's Report Slides*

Of course, this begs the question: how do we determine the spectrum of pilot/operator behavior in both normal and abnormal aircraft/system operations. Recall, media reporting was quite critical on mishap crew training and experience following the two Boeing 737 MAX aircraft that crashed in Indonesia and Ethiopia. I can't help but see parallels in the [A-29 Super Tucano](#) crash that was recently briefed at both the 2019 Flight Test Safety Workshop as well as this year's S&B. The pilot performed a maneuver that was apparently not expected or similar to previously flown profiles. Should the safety risk assessment consider a non-test fleet aviator flying a different, more aggressive flight profile than what might have been validated in envelope expansion/profile development?

The JATR challenges assumptions on alerting and response-time too. (continued next page)

## Chairman’s Comments (continued)

With multiple “alarms” that may be present, is the corrective action intuitive even after being startled? The effectiveness and adequacy of training necessarily becomes debatable, particularly for those failure conditions not practiced. Returning to language in the executive summary, “...compliance with every applicable regulation and standard does not necessarily ensure safety.” Although the JATR offers several recommendations to the FAA to improve the certification process, one key takeaway—at least for me—is the need for absolute transparency about the “system under test.” This is critical for testers AND certifying agencies. JATR Recommendation R6 articulates the need for safety over cost considerations. It states that new aviation products should be both safe and certifiable. Safety culture should drive both with an independent system safety function, separate from the design organization, “...with authority to impartially assess aircraft safety and influence the aircraft/system design details. Adoption of safety management system is one way this can be achieved.”

We have introduced STPA or Systems-Theoretic Process Analysis previously. Its principal creator, Dr. Nancy G. Leveson, professor of aeronautics, astronautics, and engineering at MIT, recognized the shortcomings of reliability-centered hazard analysis and further, that dated methods simply did not accommodate the increasing complexity of our systems. In her book, *Engineering a Safer World* (MIT Press 2011), she describes how to use systems theory to evaluate organizational, human, and technical elements. This enhances hazard identification and promotes robust mitigation development to address potential component interaction risks (and thus accidents).

Perhaps STPA could be considered as a means to address the observations, findings and recommendations that JATR provided. Other recently released documents relating to 737 MAX as well as STPA references can be found at our website under the [LINKS/RESOURCES](#) tab, as pictured below. Also under [WORKSHOPS/2019 Charleston\\_SC](#) is an

excellent video presentation on STPA by Col Doug Wickert. He worked extensively under Dr. Leveson, has been applying STPA to our more traditional flight test planning processes and won the Ray E. Tenhoff Award for Best Paper on this topic at the 2018 Symposium. Let us know what you think. Launch an air mail to [chairman@flighttestsafety.org](mailto:chairman@flighttestsafety.org). In your service,  
*Tom Huff, Chairman*

## Updates: Training for Tomorrow’s Flight Test

**Update:** *New webinar time: The SFTE plans a fourth webinar at 12:00 EDT on November 20th.*

**Update:** I received a letter from SFTE member Dr. Mike Bromfield of Coventry University after last month’s newsletter. He reports: “Last week we completed this semester’s exercises with 63 students; we have had well over 500 students do this course.” He sent these pictures of the Classroom of the Future flight test familiarization exercise offered each semester to their students. A detailed description of his course including links to his paper appeared in the digital article here: <https://flighttestfact.com/training-for-tomorrows-flight-test/>.

The screenshot shows a web browser window with the URL flighttestsafety.org/web-links. The navigation menu includes: FLIGHT TEST SAFETY, ABOUT, NEWS, WORKSHOPS, AWARDS, RECOMMENDED PRACTICES, CALENDAR, and LINKS/RESOURCES. The main content area is titled "STPA Resources From 2019 Workshop:" and lists two items: "Engineering a Safer and More Secure World Systems Theoretic Process Analysis (STPA) Tutorial" and "Engineering a Safer World - Systems Thinking Applied to Safety STPA Handbook". Below this is a section titled "Reference Guides From 2019 Workshop:" with four items: "Safety Management Manual (SMM)", "Operator's Flight Safety Handbook, Issue 2", "SETP Partners Handbook", and "The ERP DRILLIT Template Compliments of Fireside Partners". At the bottom, there is a section for "Government Agencies:".



## Hidden Risk

**Roger Hehr**

**Editor's note:** The 2019 Symposium included a presentation based on this paper by SETP's Roger Hehr. It highlights two very relevant topics. First, it discusses unmanned flight test, which is becoming increasingly more important almost daily. This month, there were almost a hundred emails going back and forth about the coming challenges of test and certification of urban air mobility aircraft. Roger's paper also addresses one of my favorite subjects and a catalyst for the creation of this newsletter: **communication**, how we talk during and about flight test. This is a particular challenge on multi-national test teams. He has shared his complete paper and [the slides](#) for your reading pleasure, and it is attached to this newsletter. You can read an excerpt below.



*Test article – H-6U, Unmanned Little Bird*

**Abstract:** Prior to the start of any flight test program, one of the principal tasks the test pilot and test team must complete is identifying the hazards and associated risks expected to be encountered during the testing and to either eliminate the hazards or mitigate the risk that hazards will occur. For an experienced test pilot and test team, this task does not present a noteworthy problem when preparing for classical testing such as performance or handling qualities tests since most of the hazards are well known. However,

when testing will involve a multi-national test team, some members of which are not familiar with the special processes and constraints of testing system components on aircraft, unforeseen hazards can be encountered

In 2012 Boeing was sub-contracted to provide an Optionally Piloted Vehicle (OPV) to support the development and demonstration of Unmanned Aerial Vehicle (UAV) systems, which the two prime contractors, DCNS and Thales, were developing independently for the French Navy. Thales had developed an accurate short range aircraft navigation system which did not depend on GPS. DCNS had developed a new pneumatic helicopter deck locking device. Boeing's task was to integrate these two systems on the H-6U Unmanned Little Bird (ULB) helicopter and conduct flight testing of the systems to demonstrate their potential for use on a UAV helicopter.

This paper describes the H-6U Optionally Piloted Vehicle used for this test with an appropriate emphasis on its control system. Due to ITAR considerations, only a brief description of the Thales and DCNS devices will be included. In addition, a novel means of performing an intermediate test, as build up to shipboard landings, will be described. Finally, some of the hazards and associated risks that were not discovered until testing was underway, along with their mitigation, will be described.

### 1. INTRODUCTION

In 2004 Boeing designed an Optionally Piloted Vehicle (OPV) in the Vertical Takeoff and Landing category (VTOL) using an MD500FF helicopter. The aircraft was designed as optionally piloted to support lower risk, rapid prototyping of sensors and systems for Unmanned Aerial Vehicles (UAV's). The initial effort from first flight to fully autonomous functionality from take-off to landing was achieved in six weeks. This OPV was used for several system

development tests during its first two years as well as an unmanned flight in June 2006.

Following the success of the MD500FF OPV, an upgraded OPV (H-6U) was developed based on the U.S. Army's Mission Enhanced Little Bird (MELB) helicopter's dynamic components and engine (Fig. 1). The H-6U is a modified MD500FF airframe with the drive train, rotors/engine/transmission, from the MD600 helicopter. This raised the maximum gross weight from 3100 pounds (1406 Kg) to 4100 pounds (1860 kg) manned and 4700 pounds (2131 Kg) unmanned. The H-6U provides the ability to test significantly larger payloads and, with the installation of auxiliary fuel tanks, fly for longer periods than its manned counterpart.

The H-6U is equipped with the MD500 mechanical flight control system which is basically unchanged from the OH-6A. To control the aircraft autonomously, electro-mechanical actuators were connected to each of the controls. These actuators are in turn controlled by a Flight Control Computer (FCC) that generates the actuator motions required to provide the aircraft stability and navigational control for autonomous flight.

UAV's can be classified into one of two categories of trajectory control, stick and rudder or waypoint control. The H-6U falls into the waypoint control category. A flight plan consisting of 3D waypoint "breadcrumbs" is created for the mission to be performed using a Ground Control Station (GCS). The waypoints have associated attributes such as airspeed, altitude, and in some special cases, instructions on what to do at the defined waypoint such as performing a loiter pattern of some specific shape. This flight plan is then uploaded to the aircraft's FCC from the GCS and a command is sent to execute the flight plan.

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## 2. Aircraft/test

Boeing, Thales and DCNS were placed under contract by the French Navy to develop and demonstrate several VTOL UAV technologies under the program title of D2AD. Thales had developed an accurate short range RF navigation system that could be used in a GPS denied environment or in instances when reduced RF emissions might be required. DCNS had developed a helicopter deck lock system for VTOL UAV's as well as a ship "green deck" predictor to provide the GCS operator an indication of when it was safe to land on the deck. Testing of these systems was divided into several stages as described below.

### 2.1 Test Description

The testing was broken into three phases: testing to the land at either a prepared or un-prepared surface, testing to either translational and/or rotational moving platform, shipboard testing. This approach, coupled with the use of the OPV test aircraft, reduced the risk during the development of the systems.

### 2.2 Ground Based Test

Following integration of the systems onto the aircraft, testing started with both manned flight and autonomous approaches to the sensors which were mounted to the ground. These approaches were to flat and sloped surfaces and prepared and unprepared landing sites. The manned flights helped to baseline the autonomous flight performance and allowed a low risk rapid optimization test approach of the Thales system.

A six degree of freedom motion platform was used to evaluate both the navigation systems ability to command aircraft position in the presence of motion as well as testing of the ship state estimator. The RF receivers and ship state estimation hardware were mounted to the Motion Table and it was commanded with actual ship motion data in various sea states. The aircraft was commanded to a hover aft of the motion table, in a position similar to what it would be during

ship board testing. The desired result of a fixed point autonomous hover as achieved where the navigation reference frame mounted to the ship was oscillating as a ship at sea. This approach worked well in evaluating the system performance with one exception. When the sea state was increased to sea state 5, at the extreme condition of maximum ship stern down (pitch) and down heave, the projected landing spot, which was a projected spot well aft of the motion table, resulted in a spot that was below the local ground level. During a landing, this below ground projected landing point caused unacceptable vertical velocities as the ground was approached and disengagement of the system prior to landing was required.



*Aircraft following Motion Table*

Manual landings were also made to a stationary landing pad, described in the next paragraph, allowing testing of the deck lock device.

### 2.3 Intermediate Testing

Due to the cost and difficulties of scheduling either a military or civilian ship for development testing of the sensors and aircraft, a unique approach was developed by Boeing to evaluate the system performance in a controlled dynamic environment. By design, this intermediate test step validated all of the land based requirements, but also reduced the ship based program risk as the testing progressed.



*Deck Lock System*

A 16 ft x16 ft (4.9x4.9m) helicopter landing platform was mounted to the rear of a commercial trailer with the Thales sensors mounted at the forward end of the trailer. The center of the platform was modified with the DCNS grid for testing of the deck lock system. A modified truck was used to tow the trailer.



*H-6U landing to trailer*

The truck was equipped with a steel barrier plate to protect the passengers, which included the flight test engineer (FTE) and ground control operator, in the event of a mishap. The speed of the truck/trailer was controlled using a cruise controller similar to ones used on passenger vehicles. The speed control was different from the typical speed control used on passenger vehicles in that it regulated engine speed instead of vehicle speed.

*Roger Hehr*

**Read the entire paper attached to this newsletter.**