HIDDEN RISK

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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

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In 2012 Boeing was sub-contracted to provide an Optionally Piloted Vehicle (OPV) to support the development and demonstration of Unmanned Arial Vehicle (UAV) systems 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.

Figure 1: H-6U[1]

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.

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 unprepared 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 (Figure 2).

Figure 2: Fixed-Flat Surface Landing and Sloped Landing[2]

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 (Figure 3). 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.

Figure 3: 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 (Figure 4).

Figure 4: Deck Lock System[1]

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.

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 (Figures 5 & 6). 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. 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. This allowed precise control of speed down to 5 knots during the test. The truck/trailer was also configured with an anemometer to measure relative wind speed and direction. Multiple cameras were situated on the trailer and, in addition to recording the video, the video feed was displayed in the cab of the truck allowing the FTE to monitor the aircraft during the final phase of the landing since there was no view to the rear of the truck cab.

Figure 5: H-6U landing to trailer[1]

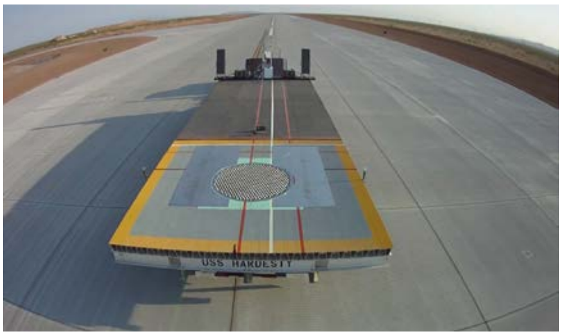

Figure 6: Trailer view from pilots station[1]

Both the aircraft and trailer were equipped with a NovAtel OEM-4 SPAN differential GPS. This system provided TSPI data accurate to 2cm and was used for “truth data” in evaluating the overall performance. This truth data helped the design team to allocate the total landing error accurately between the landing system and the aircraft control.

2.4 Ship Testing

In September and October 2012, the completion of development testing and a program demonstration were performed aboard the French Frigate Gueprattte following limited testing of the systems following shipment from the U.S. to France. Due in part to the aircraft and the experience of the joint, multi-national team working the program, the testing was very successful and incident free during the testing. Within 2 weeks, the team demonstrated a flight envelope for the aircraft decking and performed over 30 autonomous sorties to the ship using the developed technology and test program. Four snapshots in time are presented below in Figures 7-10.

Figure 7: View through EO/IR[2]

Figure 8: Approach to Deck[2]

Figure 9: Descent to Deck[2]

Figure 10: Safely on Deck[2]

3. Hidden risk

We are fortunate when we have opportunities to collaborate in our vibrant, diverse international aerospace industry. We come from different countries, technical backgrounds, cultures, and speak different first, native languages.

However, these differences can cause additional risks that are not always apparent at the start of a test program. This is especially true when performing tasks which require immediate coordinated reaction by test team members. In aviation, this can occur on a delivery flight, a commercial flight, or a test flight, when the flight crews are communicating with ground crews without a common language and culture. The following sections will discuss some of the challenges that face a test team comprised of individuals from different countries and technical specialties.

3.1 Language

It is estimated that there are over 6,700 different languages spoken around the world. Fortunately a single language, English, is customarily used in aviation. For the test project discussed in this paper, all of the engineers and people supporting the test were fluent in English. However, fluency in a language does not necessarily mean instantaneous comprehension and full understanding by test team members. Herein lies a hidden hazard.

As with other languages, English words often have more than one meaning. Those who speak English as a second language cannot be expected to know all of the meanings of the English words they do know. Those who have English as their native language often use the second or third meaning of a word to communicate, and rely on the context in which the word is used to convey the intended meaning.

Several years ago a demonstration flight was given to a prospective customer. The flight took place in England but the pilot was an American. When the pilot entered the traffic pattern for multiple practice landings, he requested “closed traffic”. The English tower operator did not understand or recognize the request and a short discussion ensued. In the United States, “closed traffic” is common terminology to approve multiple successive traffic patterns and landings with a single control tower clearance. In England, the terminology for this request is “circuits”.

For the project discussed in this paper, the initial hazard assessment identified a hazard associated with the different primary languages of the team members. However, the severity of the hazard was not realized until testing began in New Mexico. After suffering through several miscommunications during tests, the Flight Test Engineer generated scripted standard challenges and responses that the test team used consistently during the remaining testing. The ground test team even practiced the scripted responses for the anticipated different situations that could occur during the test. This method worked well in minimizing the probability of the hazard of miscommunications during the test and was used during the shipboard testing the following year.

3.1.1 Jargon

Webster, one of the English language dictionaries, defines jargon as the “specialized language of a trade, profession, or similar group”. The use of jargon is prevalent in the pilot community as it is within many communities of professionals. Imagine an accountant walking into a bar full of test pilots and trying to follow the conversations. The use of jargon can introduce unrecognized hazards when working within a multi-lingual group. When pilots and ground crews are working with electrical engineers and computer programmers, and other specialists from outside the aviation field, the use of aviation terms can cause confusion or a total lack of understanding due to the specialized meaning of words used within the aviation community. Again, beyond the team members who had English as a primary language trying to eliminate the use of jargon in the conversations, the scripted challenge and response method worked well during the test.

3.1.2 Acronyms

As with jargon, acronyms are a way of life within most professions and especially in aviation. Acronyms were originally intended to efficiently shorten written communications but have migrated into spoken communications. They effectively reduce the time to discuss a particular device or subject by using a few letters to communicate what would otherwise be a mouth full of words. As with jargon, if one is not familiar with the acronyms, the meaning of the conversation can be lost or misunderstood. The problems this can cause when working within a team with mixed backgrounds (electrical engineers, radar engineers, flight test personnel, etc) is obvious. While we can identify some of the risks associated with using acronyms, mitigating that risk is another matter. The use of acronyms has become ingrained in the way we communicate and while the pace of a test is slow we can consciously avoid using them. However, when the pace of the test gets high, such as when something goes wrong, we naturally tend to fall back on the way we usually communicate. This is exactly the wrong situation to have communications issues.

3.1.3 Idioms

Idioms and slang are used in most languages. In addition to being specific to a particular language, they can also be regional within the language and country. As with jargon and acronyms, the use of idioms and slang can be detrimental to clear communications within diverse groups. It is intuitively obvious that the trend to fall back on jargon, acronyms, and slang increases proportionally with stress. This in turn increases the probability of the hazard occurring. Obviously these are the situations when the crew can least tolerate a delay in communications or a misunderstanding.

3.2 Customs

As with languages, the world is made up of people with diverse cultures and customs. Within each culture there are acceptable and unacceptable behaviors. Americans are renowned for challenging authority with little regard to deference. Quite often this is not the case for people of other cultures that value and engender personal respect. Of primary concern to the test team should be overcoming the reluctance of a team member to speak up when he/she thinks something may be amiss. For instance, in some Far East cultures it is seen as impolite to disagree with somebody who is considered higher in social or professional rank or to disagree and cause someone else public embarrassment. There are others who do not want to be wrong. Whatever the reason, this behavior is not acceptable during testing and these authors found no sure way to eliminate this risk. What we did do was emphasize open communication and the fact that there would be no shame or repercussions if a team member “raised the safety flag” unnecessarily during the morning flight briefing, which was done a few times during testing by members needing clarification of the proposed test or their responsibilities in the execution of the test.

4. Summary

As more and more aviation programs embrace this multi-national approach to development, consideration must be given to the level of comprehension each team member has relative to the language used for the project and the customs in the represented cultures. Time should be allotted to practice test execution of both normal and especially emergency procedures prior to the actual test. The team should agree to and use a reduced vocabulary set that will reduce the possibility of misinterpretation during the execution of the test. A protective atmosphere should be created which allows test participants to raise issues during testing without suffering embarrassment or some other recourse. Aviation development is a high risk endeavour and its success should not rely on luck when communications issues are a concern.

5. Acronyms

D2AD	Démonstration technologique d’un systéme d’Appontage et d’Atterrissage pour Drones
DCNS	Company, formally DCN (Direction de Constructions Navales)
FAA	Federal Aviation Administration
FCC	Flight Control Computer
GCS	Ground Control Station
GPS	Global Positioning System
ITAR	International Traffic in Arms Regulations
MELB	Mission Equipped Little Bird
OPV	Optionally Piloted Vehicle
RF	Radio Frequency
TSPI	Time Space Position Information
ULB	Unmanned Little Bird
VTOL	Vertical Takeoff and Landing

6. Acknowledgements

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Finally we would be remiss in not recognizing Dino Cerchi, the ULB Program Manager, for all of his hard work keeping the ULB program alive when others did not have the vision he did.

7. REFERENCES

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