Crew Resource Management (CRM) in Flight Testing of Unmanned Aerial Systems (UAS)

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ABSTRACT

Depending on the developments in aviation, many new and useful training programs have been prepared for flight crews in order to minimize accidents and aircraft incidents. CRM training is one of these training programs. In this document, the importance of this training and the capabilities it includes for test crew performing tests of UAS is presented.

1.0 INTRODUCTION

Throughout history, mankind has always kept the idea of flying alive in his dreams and has made many attempts to solve its mystery. For centuries, many people, from scientists to magicians, from soldiers to adventurers, have sought ways to reach the sky. The Wright brothers' first airplane flight, lasting only 12 seconds, on December 17, 1903, in the Devil Hills of North Carolina, reshaped the history of aviation.

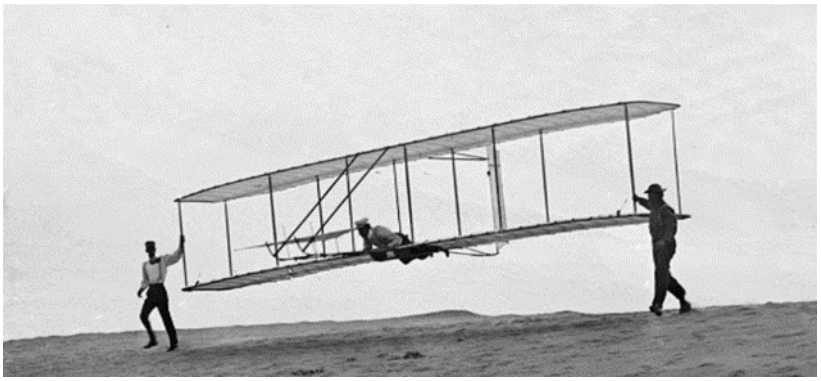


Figure 1-1: First airplane flight, Wright Brothers

With the realization of an unattainable dream, airplanes and aviation technology have continued to develop at a dizzying pace in the last 100 years. After reaching the sky, human beings continued to dream of making faster, higher and more comfortable flights and continued their search from the simple planes of the Wright brothers to the modern planes equipped with today's high-tech devices.

Parallel to these developments in aviation technology, there has been an increase in aircraft accidents that have a wide range of causes such as technical failures, bird strikes, meteorological conditions, human and management factors.

2.0 HUMAN FACTORS IN AIRCRAFT ACCIDENTS

The analysis on the aircraft accidents and incidents that have occurred in the air and on the ground within the last 40 years shows that the vast majority of them (70-80%) is caused by the human factor.

There is a considerable amount of information in the news and on the World Wide Web concerning UAV accidents. Many of these reports have mentioned human error as a contributing factor in the accident.

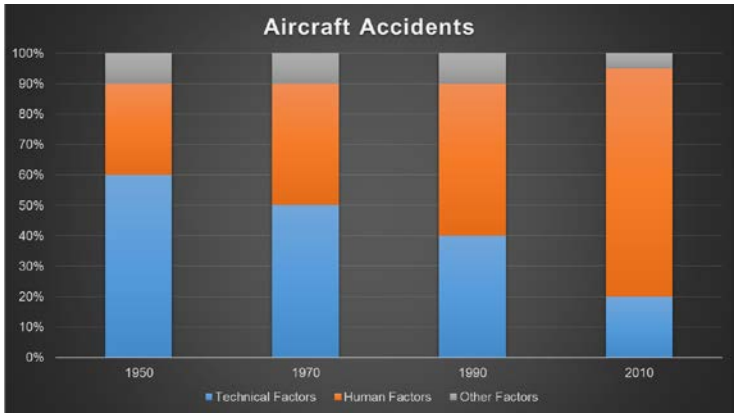


Figure 2-1: Aircraft Accidents Factors

The human factor causes can include high (or low) workload, fatigue, poor situational awareness, inadequate training, lack of crew coordination and poor ergonomic design. One or all of these causes can degrade performance, leading the accidents.

From this point of view, Crew Resource Management (CRM) training programs have been developed by accepting the approach that there will be mistakes where people are and that it will be more accurate to reach the result by educating people instead of creating new pressures on them in order to attract this error within the minimum acceptable extent.

Why do we care? What is the Role of Flight Test in Human Factors?

- Often the first time human factors issues are evaluated in the flight environment using production represantative systems.
    - Liveware
    - Hardware
    - Software
- Validate human factors design goals
- Human factors are integral to other flight testing

3.0 CRM IN AVIATION

Figure 3-1: Crew Resource Management

Human errors are inevitable. For this reason, CRM is considered as a set of countermeasures. CRM has been developed as a precautionary measure to avoid errors, to detect errors early and to minimize the effects of the consequences of errors.

The first precaution is to avoid mistakes that occur with the habits and precautions defended in the trainings. CRM program development is based on the following 7 core skills. Their effectiveness has been demonstrated by the reduction of accidents and incidents. These are task analysis, adaptability and flexibility, leadership, decision-making, self-confidence, situational awareness, and communication. The basic elements of CRM skills are task analysis and leadership, the main elements are self-confidence, communication, adaptability / flexibility and situation awareness, and the critical elements are decision-making skills.

CRM includes everyone who contributed to its successful flight into the concept of crew. Therefore, every individual who supports the flight with the crew tasked with flying an airplane is a member of the team formed in order to perform a flight duty in aviation.

In summary, a crew is a group of two or more people who work in constant interaction and cooperation to achieve a common goal.

3.0 CREW CONCEPT IN UAS TEST FLIGHTS

A basic UAS consists of three fundamental elements: an aerial platform, a ground control station and a flight crew. As a product of today's modern technology, the fact that a crew of at least 2 people takes an active role from the beginning to the end of the flight in order for the unmanned aircraft, which has taken its place in the military aviation sector, reveals the importance of CRM in unmanned aerial systems.

In order for unmanned aircraft to perform the test flight task, it is necessary to divide the work and share the responsibilities. Crew harmony should be like a kind of seed-Earth relationship. In order to obtain a good

product, it is necessary to plant the seed in good and suitable soil and to maintain it regularly as well as its quality. Therefore, working in harmony with high crew performance depends on individual quality, crew quality and management quality.

- UAS flight tests are carried out by integrated test crew consisting;
    - Flight Test Engineers,
    - Test Pilots,
    - Flight test instrumentation engineers,
    - Technicians,
    - Related design, system, analysis engineers.

UASs have personnel from different branches with different fields of expertise. The test pilot who flies the aircraft and ensures that the aircraft can land safely on the ground again, flight test engineers who leads the tests according to the requests of design engineers, engineers from different units and the ground technicians who ensure the smooth operation of all ground units are the main parts of the UAS Crew.

There should be a close commitment among these members, and these irreplaceable members who are experts in at least one subject should have the ability to do the planned work even in changing environments. There must be unity around common interests, values and history. Therefore, in order for the crew concept to be fully established in UASs, the above-mentioned basic facts must be fulfilled.

By nature, test flights are flights with a very high-risk level. Therefore roles and responsibilities in a crew should be clearly defined, openness, honesty and trust should prevail, clear and exciting goals should be in question, there should be a willingness to try new paths, constructive competition and constructive work should be demonstrated, crew members should be happy to take part in that group.

In addition, it is very important that all members of the crew are highly specialized and knowledgeable in their field in order to perform these critical flights.

5.0 EVALUATION OF 7 BASIC CRM SKILLS IN TERMS OF UAS TEST FLIGHTS

Figure 5-1: 7 Basic Skills of CRM

5.1 Task Analysis

The effectiveness and safety of a task depends on the sum of the skills and abilities of the crew performing the task. One of the main functions of CRM is to create the motivation that will contribute to the synergy use of these abilities and skills and supporting the task.

There are three stage of task analyses: pre-flight planning, inflight monitoring/updating current situation and post-task review. Before each test flight and campaign, flight test requirements should be shared with the flight test engineers by the relevant design engineers and flight tests should be performed according to the prepared test cards.

In order to motivate the UAS test mission crew at the briefings to be held before each flight and during the shift handover, it is necessary to create a suitable environment for directing the crew to the target. It means planning and organizing what can happen at all stages of the flight, observing the current state, providing feedback and repetition of events. Not being able to plan a test flight mission well or revise the planning when the situation changes can lead to a failed mission.

Easy adaptation of the UAS crew to changing situations and conditions can be achieved with full mental preparation.

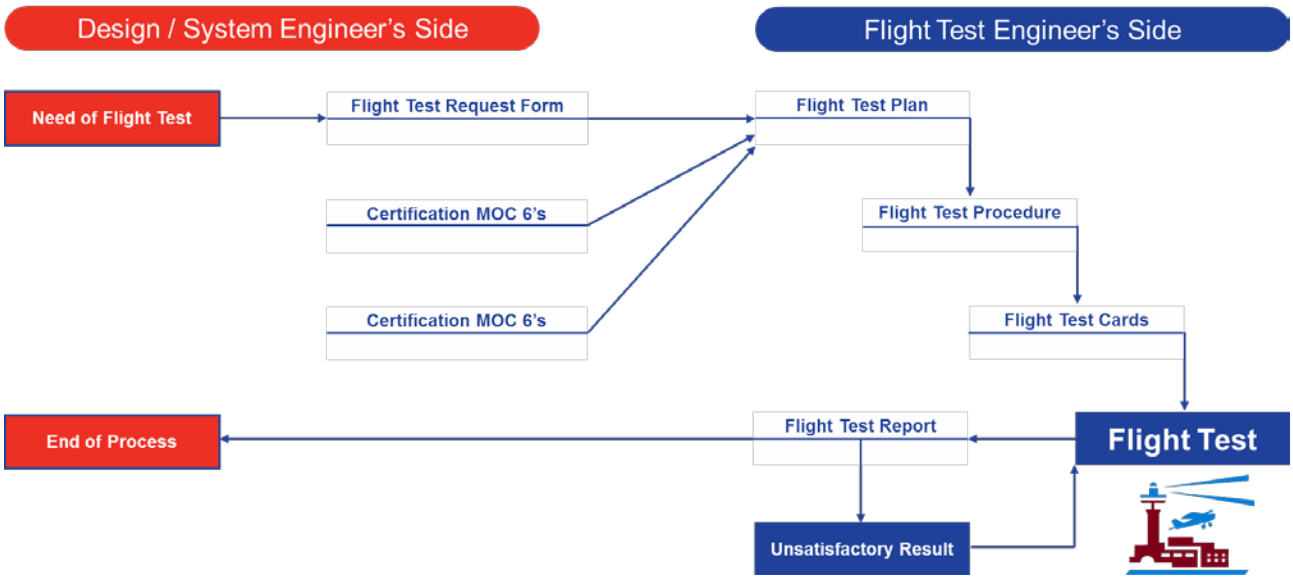


Figure 5-2: Test and Evaluation Flow Diagram

The diagram of the process that must be run before the test flights is as seen above. Test Procedures are based on;

Flight Test Requests made by design groups
Contractual requirements
Certification and qualificaion requirements and
System Safety Assessments

Each planned test topic is detailed with specific subheadings in the flight test procedure . Flight test safety assessments are expressed inside the flight test procedure. Flight test procedure explains each test separately

and includes;

Purpose of tests,
Required data,
Flight test instrumentation,
All test methods to be performed,
Test points,
Flight test safety issues and limits.

Flight test procedures forms the basis of flight test cards. Flight Test Card is a kind of checklist that briefly describes what Flight Test Crew should apply during flight tests. Flight test cards are prepared from the flight test procedure, taking into account aircraft limitations. For flight test time and budget optimization, flights under the same conditions are collected on the same test card.

When the flight test card is prepared, its printed copy is approved by the flight test engineer and test pilot. All observations of the pilot and flight test engineer should be written in this report immediately after the test flight. Observations and evaluations about the flight should be recorded accurately. It allows the pilot and flight test engineers to use their flight reviews and observations in the future. Daily flight test reports are including flight test activities related to the project during the day, important events during the test, recommendations regarding the tests, weather etc. It provides a basis for the flight test report.

Flight Test Report is written at the end of the relevant flight campaign. However, interim reports or reports at the end of phases can also be written and published. The report contains results from all flight tests. With the necessary engineering transformations, the desired graphics and tables are transferred. Test pilot observations and evaluations are included in the flight test report (including those observations taken from the daily flight test report).

5.2 Adaptability and Flexibility

It is the ability to make behavioural changes in accordance with the changing conditions in the performance of the flight test and to solve the problems. When it is necessary to go out of the plan, each crew member has to understand the task assigned to him well and adapt to the new situation.

Especially during test flights, the probability of encountering unexpected scenarios is quite high. For this reason, all adverse situations that may be encountered should be discussed at pre-flight briefings and meetings, and measures should be taken reduce the risk. In this way, the adaptation time of the flight test crew to changing situations can be shortened and correct responses can be ensured.

Figure 5-3: Flight Test Risk Classification

The use of some programs like above that will help determine the risk level of the flight test provides the opportunity to detect some risks that will be encountered in the flight. Moreover, some measures can be taken to reduce the risk level.

Human – most reliable under moderate workload, so constant and steady workload is important.

Excessive workload is equal unable to cope. Cockpit complexity and regulations will make things even more difficult.

Low workload is dangerous as it will cause boredom and low attention. Especially high automation can cause this situation to occur.

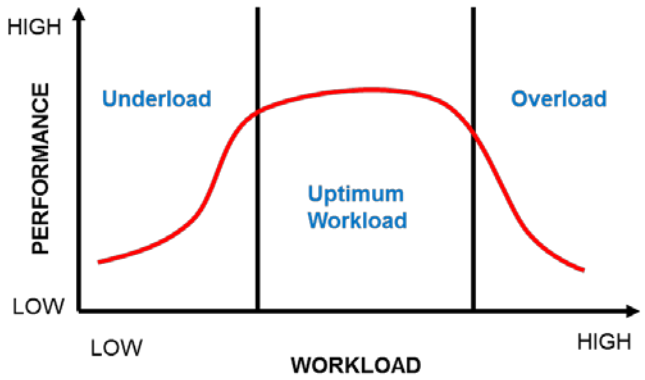


Figure 5-4: Workload-Performance chart

In the graph above, the relationship between human performance and workload can be seen.

5.3 Leadership

A leader is a person who develops plans that determine everyone's task and goals, tries to solve problems, accepts changes and corrects mistakes by sharing tasks and delegating authority. Leadership in aviation is the ability to define, direct activities and encourage personnel to work as a crew. A leader directs and

coordinates the crew's activities, makes assignments, ensures that staff understand what is expected of them and is responsible for the performance of his crew.

In UAS test flight crew, the person who will undertake this task will be the lead flight test engineer. The lead flight test engineer should have a grasp of the critical points of the flights, equip the crew with test flight information, request the necessary information from the crew about the test flight, provide feedback on the performance of the personnel and should be able to establish and maintain a professional environment.

5.4 Decision Making

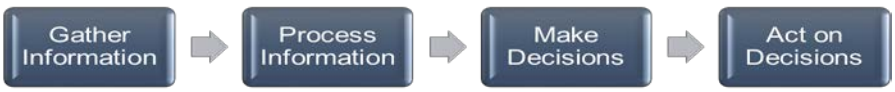
Decision making is the ability of understanding the situation, considering all the information at hand, reviewing the results they will bring with alternative forms of action, and choosing and implementing the appropriate action.

To improve decision making skills;

Detect: changes in events that require attention
Estimate: possible changes
Choose: the one related to flight safety from the alternatives
Identify: the correct controllers to control the flight
Do: the chosen decision
Evaluate: the changes applied later in the flight.

Since UAS test flights can be performed in areas where the airspace is heavily used by other aircrafts, it is necessary to evaluate the snapshots correctly and start the decision process immediately. When evaluated in this context, it is inevitable for all crew personnel to develop their decision-making skills.

The steps to be taken in the test flight should be discussed and decided before the flight. All crew members showing the same sensitivity about not trying the steps that are not discussed in the pre-flight briefing and not written on the test cards positively to the decision-making processes of the lead flight test engineer.



Gaining the ability to make decisions will be easier thanks to the collection of the right information at the right time and the processing of this collected information. After decision has been made, acting on decision should be started without delay.

5.5 Self-Confidence

Self-Confidence is the courage to speak up or act in the face of adversity. This is a person’s willingness to make a decision and act on that decision. Defending the truth is difficult but necessary. If it is believed that a job done, an instruction from the air traffic controller, a procedure applied by the maintenance team, or information received is false and unsafe, it is imperative to talk, ask, and defend the truth. This does not mean an infringement on the authority of the leader. The aim is to clarify the situation.

Every crew member should be assertive or persistent if the directive, methods or procedures are violated due to the fact that safety is at stake. Participation and self-confidence are essential at every stage of flight.
Situations where self-confidence is needed include:

At the pre-flight briefing: The leader should speak in a manner that supports the personnel to express their motivational ideas openly without hesitation, in terms of both their expressions, questions and behaviours.
During the flight: Situations where inputs cannot be made when necessary due to overly aggressive attitudes or close friendships should be avoided.
At the debriefing: It is very important to express the problems encountered and unresolved in flight and ideas on how to do the flight-test better.

The leader should allow the personnel in this regard, take their ideas into account and adapt them to the next flights and convey them to the relevant places as lessons learned when necessary.

5.6 Situational Awareness

The ability to perceive what is happening at the moment can be defined as the ability to use existing information. Situational awareness in aviation refers to the ability to accurately grasp what is happening inside and outside the aircraft. It is the correct perception of the events that may occur both now and in the near future regarding the aircraft and the environment.

Three levels of failure associated with reduced situational awareness:

Level 1 – Failure to correctly perceive information.
Level 2 – Failure to correctly integrate or comprehend information.
Level 3 – Failure to project future actions or state of the system.

In unmanned aircraft, the pilot who steers the remotely controlled aircraft without being inside the aircraft should be more careful about the situational awareness. Developing situational awareness ensures that the crew is prepared for contingencies.

Technology should be used effectively to increase situational awareness of pilots and all units involved in the test activity. The layout of the screens used in the Ground Control Station (GCS) should be user-friendly and provide the pilot with all the necessary information about what is happening on board and in the environment. Likewise, in the telemetry room where the test flight is followed, the relevant engineers should be provided with all the information they need about their systems.

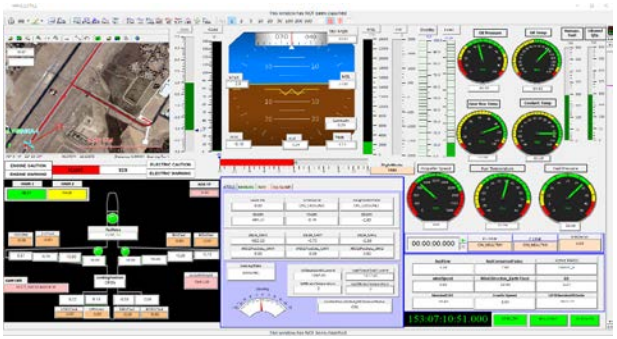


Figure 5-5: Telemetry Room-GCS

Controls should be easily identifiable to be operated quickly and instinctively by crewmember under stress;

- Shape - According to purpose
- Texture - Smooth, fluted, knurled
- Size - Practical limit
- Location - Group functional switches together
- Color - Red guarded = emergency only

The Arrangement philosopy shown in the table can be used for optimal placement.

Table 5-1: Arrangement Philosopy

Arrangement Philosopy	
Functional	Group elements together according to function
Importance	Most important elements grouped together in best location
Optimum	Each element located in its own optimum location
Sequence	Elements arranged to take advantage of sequence of use
Frequency	Most frequently used elements located in best position

5.7 Communication

Communication is the ability to clearly and accurately send and receive information, instructions or commands. Communication is vital to the success of the mission. It enables situational awareness to continue and lays the foundation for other abilities.

It can be defined as methods of reducing and eliminating communication barriers, active listening, choosing the appropriate tone and level of voice, using known terms, professional attitude or behaviour, dividing into understandable sections, solving problems on the spot, avoiding inappropriate crew matches. 7500 crews took part in a study conducted by NASA. The two most important findings in terms of correct communication were determined as the captain giving detailed briefings, the second pilot asking questions and expressing his own recommendations. Recognizing the validity of this research and adapting it to UAS

test crews, the lead flight test engineer detailed mission briefing and the UAS pilot, operator, design engineers and technicians asking questions and exchanging information about their expertise will enable more effective test flights to be fulfilled.

Achieving good crew coordination requires eight elements: Communicating positively, directing assistance, offering assistance, announcing actions, acknowledging actions, being explicit, providing aircraft control and obstacle advisories, and coordinating action sequences and timing.

It is so important that GCS has uninterrupted communication with the telemetry room, Air Traffic Control unit and all other units it may need. For this reason, the communication infrastructure must be very strong with all the redundancy.

Figure 5-6: Communication

6.0. CONCLUSION

Since the human factor has been shown as the cause with the highest rate in aircraft accidents, it is natural and necessary to consider this phenomenon as the first target in terms of flight safety. The foundations of human factor studies in the aviation industry were laid during the second World War with studies on equipment design and human performance. Before the study of war, many people had a rather simplistic view of the effects of humans on the environment. The idea that humans can adapt to anything guided the creation of many designs. But over time, it has become apparent that people's interactions with their jobs and the tools they use are much more complex than previously thought. It was determined that in addition to the size, shape and placement of controls and indicators, other psychological factors also affect human performance.

With the developments in the field of aviation, the factors that contribute to the realization of a flight mission have also increased. Parallel to this increase, management problems caused by the human factor and causing accidents have also started to increase. In order to solve these problems, many scientific studies have been carried out and various programs and models have been created.

With the developed programs, it is aimed to perform flight tasks with safety, aiming to reduce human error in flight management. Among these programs, CRM has been an effective tool in the training of teams in terms of effective team coordination, communication and leadership skills, and has contributed to flight safety in

the execution of effective and efficient flight missions, which are becoming more important day by day. It has become one of the priority conditions for all personnel who work or will work in UAS to gain this awareness.

Flight-testing is the process where both the initial evaluation is done and the final compliance is determined. Flight-testing is very expensive process and hence one crucial thing is that if something can be verified without flight then it should be verified without flight.

Another inevitable process during flight testing phase is precise planning, test discipline and risk assessment. All test requirements that need flight should be properly consolidated into most efficient sortie planning and some opportunity tests should be reserved. Essential steps of the test that defines the core objective of a particular flight must be predetermined end if test conditions are not met mission should be aborted. Flight safety is another vital part of flight testing. Depending on the kinetic energy and the cost of the aircraft proper risk management level should be maintained. All risk areas, their probability, effect and criticality should be evaluated and mitigations should be taken.

UASs, while having been under development and having seen limited use for several decades, are finally and rapidly coming into their own as major tactical and strategic systems on the modern battlefield. This rapid increase in use has been accompanied by increased frequency of accidents.

When the accident crimes related to UASs are examined around the world, we see that the human factor plays a leading role. The loss of attention can be eliminated by the formation of a very strong coordination between the crews. This reveals the importance of the role of the test pilot and lead flight test engineer in UASs test flights.

As a result, the most important factor in aviation accidents, including UAS accidents, is human. And CRM has come to the fore among many programs developed to minimize the human factor in accidents. Bringing CRM skills to flight and test crews is so important, as their aim to develop human-machine interfaces to prevent human-related accidents with flight tests.

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