Tracking Unmanned Aerial Vehicle CTU FTS

Application of equipment

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***Abstract* — Article which is about the Tracking Unmanned Aerial Vehicle continues in the description of the project development dealing with the utilization of the UAV (unmanned aerial vehicle). Documentation of the project progresses builds on the previous article. In that article the selection of observation and transmission equipment was summarized. In the article, the reader learns about an installation of the equipment on the UAV (helicopter), about an interconnection of the equipment to create complete and functional system, about testing of the UAV, about the solutions of the problems which came into being during testing and about protection of the equipment against unfavourable effects. The location of equipment on the unmanned vehicle was chosen after a considering of several parameters. These parameters are preservation of the functionality or an influence to the balance. To find out how the added equipment affect the centre of gravity of the UAV the tabular method of the centre of gravity calculation was used. The results of the existing work on the project are location and attaching of the equipment to the unmanned vehicle, balance of the unmanned vehicle, solutions of the problems coming into being during the testing and design of the equipment protection against unfavourable effects.**

Keywords — Tracking Unmanned Aerial Vehicle CTU FTS, observation and transmission equipment, application of equipment, UAV, RPAS

I. Introduction

This article describes the development of the project which taking place at the Department of Air Transport at the Czech Technical University in Prague, Faculty of Transportation Sciences. The project deals with construction and utilization research of the unmanned vehicle in normal and extreme conditions. One article was already published. That article dealt with analysis and selection of the appropriate observation and transmission equipment. It also summarized which equipment was chosen at the end.

The reader learns about the further development of the project. Concretely, he learns about attaching of the selected equipment on the UAV, how they are connected into a functioning system, the testing process, the process of the eliminating any complications and he learns a little about the equipment protection against unfavourable effects also. Several methods were used on the project. The method for selecting a suitable location for equipment placed on unmanned vehicle is simple but effective. The method is based on determination of some criteria that are necessary to abide and follow-up reasoning whether the criteria will be fulfilled or not. If the criteria are fulfilled, the location is good. The tabular method of calculating the centre of gravity was used for calculation of a new centre of gravity after attaching all new equipment. The results should be observation and transmission systems which are ready for use and research.

II. Installation

Chosen equipment has to be attached to the unmanned vehicle and to the ground station also. The cameras, transmitter and parts of AAT system, namely GPS module and OSD (on screen display), had to be mounted on the unmanned vehicle. The methods of attachment to the construction of the UAV are mostly the same like methods commonly use in RC modelling. The methods are attachment with double-sided tape, plastic strapping tape and strapping tape with Velcro. There is the rotatable holder for the main camera described in the previous article in the figure 1.

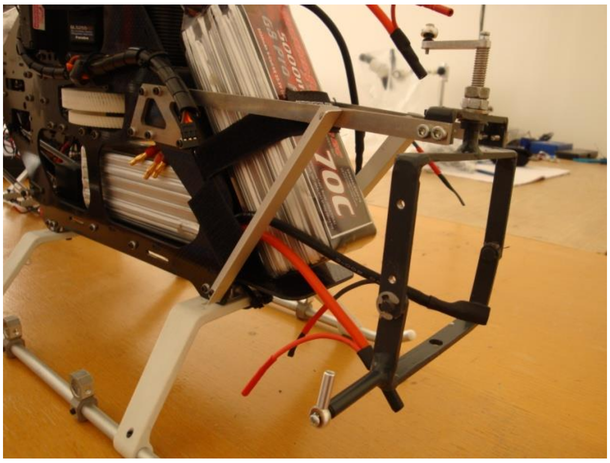

Figure 1. The picture of the rotatable holder without servomotors and camera. Holder is reinforced with an L profiled girder.

When we were choosing the suitable location for equipment, we were taking into account predetermined criteria.

The criteria are maintaining functionality, sufficient space for the equipment and impact to the balance of the helicopter. We selected the suitable locations for the equipment after consideration of these criteria and after consultation with the pilot.

Added equipment changes the centre of gravity. So it is necessary to check if the centre of gravity is in the allowed centre of gravity or not. The allowed centre of gravity was defined experimentally based on experience and opinion of the UAV project pilot. The longitudinal centre of gravity is -10 mm, 5 mm; the transverse is 2 mm on both sides. The ideal location of the centre of gravity in the longitudinal is -3 mm; in the transverse is the best position of the centre of gravity in the rotor axis. The figure 2 shows schematically the placement of the equipment on the UAV (helicopter).

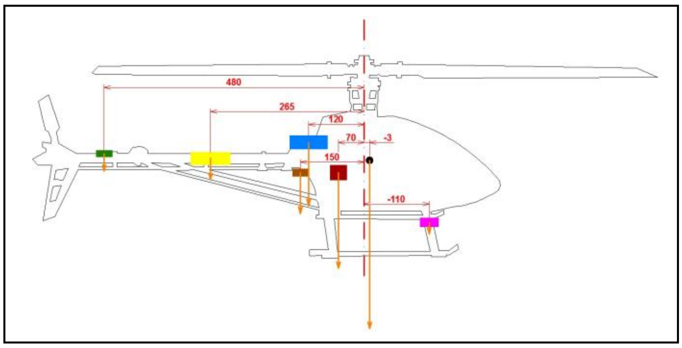

Figure 2. The location of the equipment on the helicopter T-REX 500 with marked rotor axis, distance from the axis (unit is in mm) and the gravitational forces of the equipment (only for orientation); purple – mini camera, red – voltage regulator, blue – transmitter, brown – centre of gravity of cabling, yellow – OSD, green – GPS module.

The principle of the method of calculating new position of the centre of gravity is as follows. The weight and the distance from the selected reference axis are written down to the table. Then the moment of equipment is calculated. All moments and weight of the UAV with all equipment are numbered and from these sums the new position of centre of gravity to the selected reference axis is calculated [1]. If the new centre of gravity is outside the allowed centre of gravity, it is necessary to balance the helicopter by adding weights or by moving heavy parts of the helicopter (e.g. battery).

A tripod is used as the basis of the ground station. The AAT system (tracker and driver) with receiver and directional antenna are attached to the tripod. Furthermore, observation equipment like FPV (first person view) goggles or monitor are connected to the whole system. Function and connection of the ground station are going to be explained below.

III. Connection

The following paragraphs are going to be dealt with connection of the selected equipment. The figure 3 is a diagram of the equipment which is attached to the unmanned vehicle. Batteries that power the UAV engines are used to supply the entire system. Because variously large voltage is used, it is necessary to modify the voltage first so that the video system always has 12 V. The voltage is modified by the voltage regulator. The video processing is as follows. First, the image is taken by the mini camera. The image is sent into the OSD. The OSD is the equipment which adds to the image the flight data. These data can be flight altitude, airspeed, direction and distance from the ground station, course and other. The OSD processes the GPS coordinates from the GPS module too. The flight data are calculated from the coordinates and the data are encoded into the audio channel of the broadcast signal too. The OSD is equipped by the button. When it is pressed the OSD saves the current GPS position as the position of the ground station. Therefore, it is good to use the button near the ground station. The signal with video and audio channel is sent to a transmitter that modulates it onto a carrier frequency of 5.8 GHz and sends it to the ground station. Here is a description of the figure 3. The voltage regulator contains a switching voltage regulator, Schottky diode, inductor and two capacitors. Cable colours correspond to the real colours except white; it is displayed by grey "(white)". If a cable is multicoloured, it means that it was soldered from cables with different colour of insulation. A cable drawn by a thick line indicates a bundle of cables. There is written a voltage level next to the power cables. Colours of connectors and equipment correspond with reality. Numbers at OSD and GPS indicate pin number.

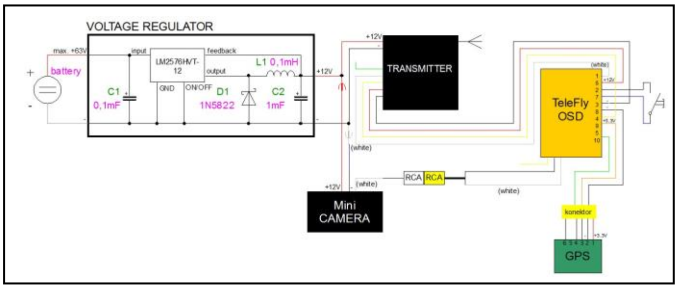

Figure 3. The scheme of the equipment connection on the helicopter.

The figure 4 shows the connection of the entire ground station. Now, it is going to be described how the video signal travels from the receiver to the monitor. The video signal modulated onto the carrier frequency of 5.8 GHz is received via one of the antennas, directional or Omni directional. The receiver demodulates the signal. Based on strength of the received signal the receiver selects from which antenna the signal is going to be received. Omni directional antenna is used at close range when the GPS error may cause that the directional antenna is not directed exactly to the UAV. The signal that includes video and audio channel passes through the tracker to the driver. The driver decodes the signal and from the data obtained from the audio channel, from which the GPS data were sent. From its and obtained GPS coordinates the driver calculates the position of the UAV. Then it sends a command to the tracker. The command says which way the tracker should direct the directional antenna. The video signal is sent from the driver to the signal splitter that splits the video signal into 4 outputs. The signal goes to the grabber from the first output. The grabber is equipment that converts input signal with RCA (cinch) connector to the USB output. The USB can be connected to the computer. In the computer we can view and record the video. The second output sends the video signal to the video converter. The converter is designed to convert the signal from the RCA input to the VGA output. From this

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output the signal is sent into the FPV goggles or into the monitor. The signal from the driver does not have to be sent into the splitter but directly into the video converter or into the grabber. It is obvious that in such a case the user must choose if he want to watch the video in the goggles (or the monitor) or to record it in the PC. The system can be used without tracker and driver. The received signal will be only by Omni directional antenna and it will be sent from the receiver straight into the splitter or the converter (according to connection). Here is a description of the figure 4. Colours of cables, connectors and equipment correspond to reality. If a cable is multicoloured, it means that it was soldered from cables with different colour of insulation. There are types of connector written next to the interconnecting cables. There is written a voltage level next to the power cables. A cable drawn by a thick line indicates a bundle of cables. There is written its type next to the antenna symbol.

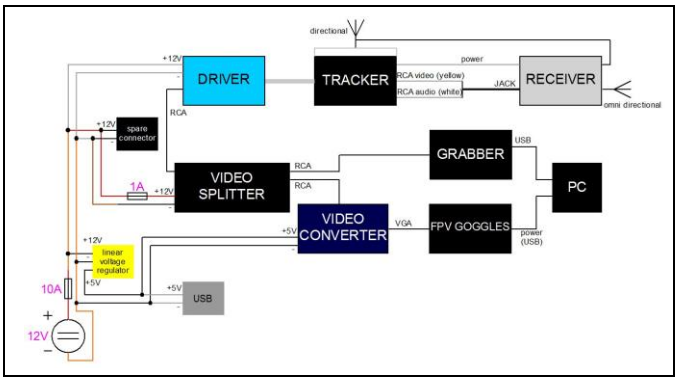

Figure 4. The scheme of the ground station with the video splitter.

Power of the ground station is evident from the figure 4 also. The 12 V car batteries are used as a source. A power cable is divided into two branches, 12 V and 5 V. The 12 V branch supplies driver with tracker and receiver, video splitter and spare connector. 5 V branch supplies video converter and spare USB connector. Grabber and FPV goggles are powered from the PC.

IV. TESTS

There were several problems during test flights which had to be solved. One of the problems was the rolling shutter of the main camera’s video. The rolling shutter is caused by high-frequency vibration in combination with the type of camera’s sensor. CMOS sensor, which the camera is equipped with, captures an image by the rows of matrix chips from top to bottom. If the camera is in motion (vibration) the image is captured shifted and the output image looks like to be waving [2]. The problem was solved by reinforcement the holder (Figure 1) and by the insertion of the rubber pads. However, this solution was ineffective. The next step was to use the anti-vibration board (Figure 5). This solution showed as a partially effective. The image is still waving at low engine speeds but at medium and higher speeds (above 1400 rev./min) the solution was effective. There were no serious complications at other equipment.

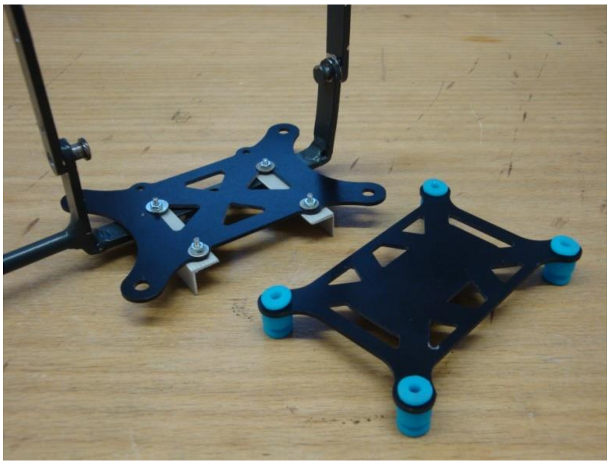

Figure 5 – Decomposed anti-vibration board attached by two L-girder and bolt connection to the rotatable holder of the main camera.

V. PROTECTION

The equipment are protected against common unfavourable effects, such as higher humidity, dust and others, by using conventional protective equipment. Protective equipment is plastic foils, camera’s housings and waterproof plastic cover supplied with the main camera. Ground equipment is protected by its plastic housings. The theoretical solutions were designed to protect equipment against more extreme conditions such as temperatures below zero. The frost protection can be implemented by using an isolation material in combination with heating, e.g. resistance wire. The disadvantage is an increasing of the weight when you are adding isolation and heating.

VI. RESULTS

The goals of the previous work on the project are functioning observation and transmission systems. From the perspective of the both systems, the unmanned vehicle is ready for use and for research at usage in extreme conditions.

Table 1 shows the calculation of the new centre of gravity after attaching all necessary equipment. It is obvious from the table that in the longitudinal axis of the centre of gravity moves under the allowable centre of gravity. In order to shift it back to the allowed centre of gravity, and preferably in an ideal position, it is necessary to balance the helicopter. This is possible by moving the heavier parts of the UAV, such as batteries, or by adding weights.

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TABLE 1 TABLE OF THE CENTRE OF GRAVITY CALCULATION AFTER THE EQUIPMENT WERE ADDED. THE UNITS WERE CHOSEN BECAUSE OF THE TABLE CLARITY. NEGATIVE SIGN INDICATES THE DIRECTION TO THE NOSE IN THE LONGITUDINAL AXIS AND DIRECTION TO THE LEFT SIDE IN THE TRANSVERSE AXIS IN DIRECTION OF THE FLIGHT.

		longitudinal axis		transverse axis	
	weight [*g*]	distance [*mm*]	moment [*gmm*]	distance [*mm*]	moment [*gmm*]
helicopter	2 344	-3	-7 032	0	0
mini camera	2	-110	-220	0	0
transmitter	58	120	6 960	0	0
TeleFlyOSD	9	265	2 385	10	90
GPS module	8	480	3 840	0	0
voltage regulator	100	70	7 000	30	3 000
wiring	30	150	4 500	20	600
total	*2 551*		*17 433*		*3 690*
centre of gravity shifting		**6,83**		**1,45**	

VII. CONCLUSION

Now, it would be good to assess the overall progress of the project so far. If we take into account only the part of the project focusing on observation and transmission systems, it managed to prepare the UAV for departments of the Faculty of Transportation Sciences usage and for other scientific activities.

There are several sections in which it is possible to improve the mentioned systems. The first section is the removal of the rolling shutter at low engine speeds. Another section, in which the observation system can be improved, is the Head Tracking putting into operation. Although the absence of the Head Tracking does not preclude the usage of the UAV, the Head Tracking is still pleasant and useful advantage. The last section, which is closely related to research in area of the UAV usage in extreme conditions, is the design and construction of the protection against extreme frost.

UAVs hide great potential in many areas and following up in the UAV research can contribute to faster and more effective development.

REFERENCES

[1] SCHOŘ, Jan, Petr ŠUSTEK. Hmotnost a vyvážení vrtulníky (031 00): Učební texty pro teoretickou přípravu dopravních pilotů dle předpisu JAR-FCL 2. první. Ludvík Kulčák. Brno: Akademické nakladatelství CERM, 2008, 68 s. ISBN 978-80-7204-597-6.

[2] TIROSH. Everything You Wanted To Know About Rolling Shutter: DIY Photography. DIY PHOROGRAPHY.NET. DIY Phorography: Hacking photography - one Picture at a time [online]. 2012 [cit. 2015-02-18]. Available from: http://www.diyphotography.net/everything-you-wanted-to-know-about-rolling-shutter/