https://doi.org/10.26552/ pas.Z.2022.2.14

UNIVERSITY OF ŽILINA

DIGITALIZATION OF THE MAINTENANCE PROCESS FOR THE NEEDS OF THE CAO ORGANIZATION

Róbert Mariňák
Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26 Žilina

Tomáš Braciník
Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26 Žilina

Abstract

Digitalization and automation are unstoppable processes that are linked to the present and have a significant impact on the efficiency of the work carried out in aviation or any other industry. The aim of this article is to create a digital maintenance environment for the needs of the Combined Airworthiness organisation (CAO), which is part of the Air Training and Education Centre of the University of Žilina. Such software would unify and facilitate the overall maintenance process performed by the CAO. In this article we have evaluate the requirements of the CAO organisation and the legislation in force. During the development process, we communicated extensively with both the experts and the maintenance staff for whom we were developing the program. Then, based on what we learned, we created a basic structure of the required software and hardware needed to create a digital maintenance environment and started building it. We have then described all the processes involved in the program and its components to the extent that this article can partially serve as a guide for the creation of such a program. Methods of drawing on software and hardware resources have been purposely limited in the article to free products or to those, that are commonly available in price. The work has resulted in functional software that contains all the necessary documents, job cards and forms to carry out maintenance and substantially replaces the more paper-intensive form of data entry and storage.

Keywords

Digitalization. Maintenance. CAO. LVVC ŽU. Server. Software. Linux.

1. INTRODUCTION

In today's modern age, technology and the digital environment impacts our daily activities without us realising it. We live in an era of unlimited digital possibilities and innovations that are advancing rapidly. These innovations have been adopted by many industries in recent years, including aviation. Aviation is widely known to be a conservative industry. Rapid change and the rapid emergence of new standards are not typical of aviation. This is because of caution and safety, as the latter is paramount in aviation. This also applies, for example, to the introduction of electronic software for maintenance-related records. Due to the level of security and their complexity, these software are often unaffordable. Although these software are currently on the rise, the cost of operating and licensing them is often beyond the budget of smaller maintenance organisations. The CAO associated with the University of Žilina's Aviation Training and Education Centre is no exception, and this motivated us to come up with the idea of creating our own software, using our own resources and capabilities, that would be inexpensive to operate.

After consulting with the maintenance staff and CAO leaders, we started building and putting ideas on paper. In this thesis, we analyse the necessary legislation that is integral knowledge for further development and integration of applications and programs into the CAO environment. We then present our design for the digital interface of the proposed software and continue with a detailed description of building the foundation for the entire software. The goal of this thesis was to produce a foundation for building CAO digitization software that would be easy to use and contain all known elements such as currently used job cards and other documents.

2. BACKGROUND

In today's technological era, it is no surprise that digital transformation is one of the most fundamental drivers of change and presents a unique opportunity to shape the future. For this reason, much of the aerospace industry is looking to digitise its technical documentation and maintenance operations to facilitate document management. However, the digital revolution, particularly in maintenance, repair and overhaul (MRO), has been slow to take off for a number of reasons like the complexity and size of manuals, older data standards such as ATA iSpec 2200 or different rules in member states regarding digital practices.

2.1. Current PC programmes in use

The maintenance process in the CAO organisation at the Air Training and Education Centre of the University of Žilina, hereinafter referred to as LVVC ŽU, is currently partially digitised by means of commonly available software from the Microsoft package such as MS Office, MS Excel, MS Access. These software packages are simple and can be used by any member of the maintenance staff. The administrators of these software are the manager of the Combined Airworthiness Organisation (CAO) and the Director of LVVC.

During the last years, the maintenance staff has been working within its own resources and capabilities to create electronic databases that would facilitate the work with the technical records of the aircraft operated at LVVC ŽU. This work has resulted in the creation of Microsoft Excel and Microsoft Access spreadsheets containing the following service information.

- Life Limited Parts and Special inspection list;
- Recurring Service Bulletins (SB) and Airworthiness Directives (AD);
- Communication and Navigation (COM/NAV) equuipment list;
- SB, Information Service Bulletines (ISB), Service Letters (SL), AD;
- SB, SL, Service Instruction (SI), AD for propeller;
- SB, SL, SI, AD for engine;
- Status of changes, repairs and damage;
- Accident record;
- Weight and Balance (W&B) change record;
- Instructions for continuing airworthiness (ICA);
- Maintenance order;
- Maintenance work order;
- Job cards;
- Finding report;
- Certificate of Release to Service (CRS).

2.2. The contribution of digitalisation in the CAO organisation

For the CAO organisation, digitisation can help create faster and more efficient ways of checking maintenance records. The main reasons for digitization are:

- Reducing risk of human error;
- Reducing security risks;
- Improving maintenance delays;
- Improving the flow of information between maintenance technicians and organisation managers.

Paper documents are often complex files, especially when considering the long maintenance history of older aircraft. It is highly likely that the maintenance history may not be complete, as over time paper documentation may be lost or degraded when files are transferred or moved from one organization to another, or when the organization changes office space. As more operators become involved over time, the risk of missing documents can increase - but digitising records could significantly mitigate this risk.

There is no doubt that updating the current culture of technical documentation is a multi-layered and complex challenge. Many things currently stand in its way, such as various organisational and regulatory processes. However, it is up to the aerospace industry, from aerospace engineers and company executives to manufacturers, suppliers and regulators, to come together to address this challenge in the interest of a more standardised global industry. Such shared responsibility would ensure that important technical and maintenance documentation poses less of a safety risk [1].

2.3. Information on available applications

Currently, there are many forms of applications that would meet the requirements of the CAO organization under the LVVC ŽU. Some of the available applications on the market that could meet the needs of a CAO organization were developed in the framework of the master thesis by Ing. Dominik Mikulec, who compared Flight Office, SAM and Envision. He compared the programs in terms of content and benefits, but from the analysis he concluded that only Flight Office is suitable, as this program is the most affordable and contains all the necessary attributes for the operation of CAO records. The cost of running such an application would be approximately EUR 1400 in the first year and approximately EUR 480 annually thereafter [2].

2.4. Electronic aircraft maintenance records

The current ICAO provisions on aircraft maintenance records and continuing airworthiness records describe the use of both paper and electronic formats. Currently, aircraft maintenance records are mostly kept in paper form. However, aircraft operators, aircraft manufacturers and maintenance organisations are steadily moving towards the use of electronic aircraft maintenance records (EAMRs) and continuing airworthiness records and digitally supported aircraft maintenance information. This includes electronic maintenance records and continuing airworthiness records for aircraft, engines, propellers and related parts. Some States have already published advisory material on the use of EAMR and continuing airworthiness information, already allowing aircraft operators, aircraft manufacturers and maintenance organisations to use EAMR and digitally supported aircraft maintenance information [3].

Guidance material on EAMR and continuing airworthiness records has been included in the unmodified edition of the Airworthiness Manual - Doc. 9760 approved in July 2020. At present, the Slovak Republic does not have any guidance material of its own in relation to EAMR.

2.5. Assesnebt of the regulatory base

The CAO is required to have all the records mentioned above and is also required to archive them accordingly. This means that this information is currently recorded in partially digitised databases created in MS Excel, which has made it much easier to find the necessary documents and increase their clarity. However, there is still a lot of documentation that is archived in purely paper form, which represents a large number of records after years of aircraft operation. These quantities of records could be rapidly reduced by a process of digitisation of the maintenance environment, including the digitisation of all aircraft records. However, the Slovak legislation is currently not set up and fully prepared for such a form of digital records as well as their control, therefore it is still necessary to print and store these documents in case of an external audit. These are mainly output documents related to the airworthiness of aircraft.

However, for the internal needs of the CAO, such fully digital records may be maintained in parallel with paper documentation. The introduction of a digital maintenance environment together with digital record keeping would

prepare the CAO for the future transition to a fully digitalised EAMR environment as presented by ICAO in document 9760.

3. DESIGN AND STRUCTURE OF THE DIGITALIZATION PROGRAMME

The aim, is to design and create the basis of a digital maintenance environment for the technical staff of a CAO organization. It also includes the design of a simple maintenance order entry system along with the design of digital job cards. These designs are based on the basis of currently used documents and forms.

3.1. Design of the logical process structure

In the following sections, we present the design of the individual logical process structures. These processes build on each other and all the interconnections are explained in the individual subsections.

3.1.1. Login

The interface of the application, whether on a fixed or portable device, should have uniform basic attributes, which may differ in graphical representation depending on the device on which the application is used, but their essence and meaning must remain the same.

In the case of the application login process, it is necessary to select which person with which authority wants to log in to the program. There are two options to choose from: Administrator and Worker. The login can be made up of the person's last name and first name or an identification number or license number. The user password should be strong enough. It should be formed by a personal identification number or PIN, a cryptographic key or by attaching a card to a reader. In the future, two-factor authentication of the user's identity could be added to the password.

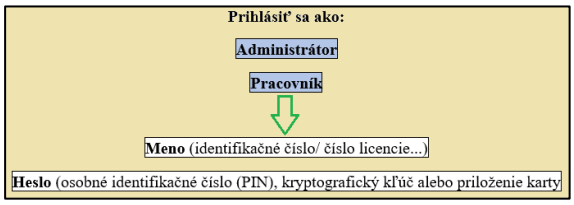

Fig. 1. Application login window design

3.1.2. Basic interface

After logging into the application, the basic interface is displayed to the user. This is made up of a list of actions that can be performed. The available actions vary based on the user account through which the user has logged in.

3.1.3. Admin interface

This interface has more items available than the maintenance worker interface. There are action items "Fleet, Enter Maintenance Order, End Maintenance Order, Maintenance Database, Update, Ongoing Maintenance" and the interface can be extended with other actions. The "Fleet" item will list the aircraft with the number of hours flown and hours remaining until inspections. Through the "Enter Maintenance Order" command, the administrator will be able to assign tasks to be performed by individual maintenance personnel. For a quick overview of how maintenance is progressing on the aircraft, there may be an option to view the maintenance in progress, where it will be written which worker is working on which jobs and how they are progressing. The "Maintenance Database" item will contain a long term database of all inspections performed on the aircraft, which will also be backed up on another disk. The administrator should have the possibility to additionally add or delete information via the action item "Update".

3.1.4. Maintenance worker interface

The interface that is displayed to maintenance personnel has fewer responsibilities than the admin interface. This type of interface includes the actions "Fleet, New Maintenance Order, Maintenance in Progress, Maintenance Database, Current Information, Search" and a place to add additional actions. When an Administrator enters a new maintenance order, after logging into the worker's account, the worker to whom the order was entered will see a notification on the "New Maintenance Order" item. The worker will then complete and execute each procedure according to the maintenance type. "Current Information" contains any changes/updates that the administrator has made.

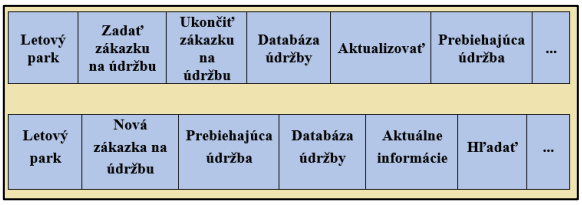

Fig. 2. Application interface design for administrator (top) and maintenance worker (bottom)

3.1.5. Flight fleet

The action item "Flight Park" is common to both the administrator and maintenance worker accounts. When clicked, a list of aircraft maintained in the CAO managed environment, including the LVVC ŽU fleet, will be displayed. It should be possible to add additional aircraft to the application as the CAO is authorized to maintain aircraft outside of their fleet.

The list of aircraft is created via a scrolling window with an alphabetical list of aircraft matriculation marks (Figure 3. shows a generic list). After selecting an aircraft by matriculation mark, a background with the selected aircraft is displayed. The aircraft type is displayed with basic data (Serial Number (S/N), Flight Hours, Hobbs (motor hours), Number of Landings, Hours to Next Inspection, etc.).

Also, an algorithm can be set up to colour-code the need to prepare the aircraft for the next inspection according to the number of hours remaining and the current use of the aircraft (green- inspection is still "far away", yellow- inspection will come in "n" hours or in "n" days (for the current use of the aircraft), red- aircraft needs to be withdrawn from service), similarly to the document of parts with a limited service life and the list of special inspections.

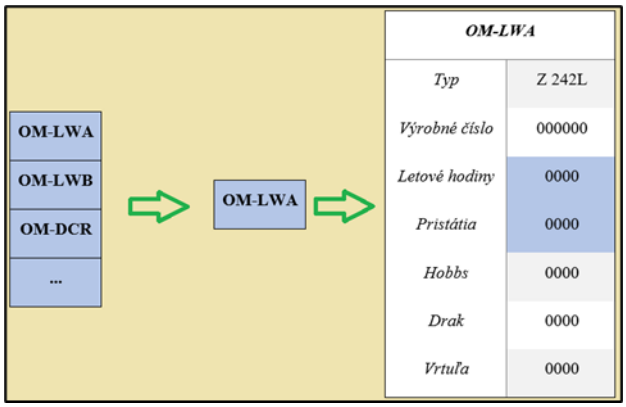

Fig. 3. Proposed structure for displaying the list of aircraft and consequently their basic information

3.1.6. Maintenance order

At the heart of the entire program is the ability for the administrator to enter a maintenance contract to the maintenance technicians using the "Enter Maintenance Contract" action item. If an aircraft needs to be inspected, the administrator selects from the list of aircraft (the same as in the "Fleet" item) the specific aircraft on which maintenance needs to be performed and what type of maintenance needs to be performed.

- The administrator selects the aircraft to be maintained from the list.
- The administrator shall select from the list the type of maintenance to be performed.
- The administrator shall select the maintenance personnel to carry out the maintenance.
- The administrator confirms the selection of the aircraft, type of maintenance and maintenance personnel and submits the order.

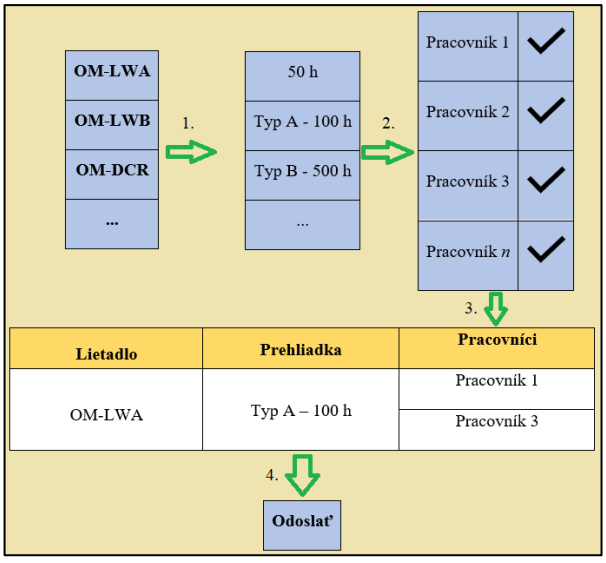

Fig. 4. Proposal of the principle of a logical contracting structure

4. ESTABLISHING THE BASIS FOR A DIGITAL MAINTENANCE ENVIROMENT IN CAO

The aim, is to create a digital maintenance environment for the needs of a CAO organization. Digitizing the maintenance process in a CAO organization is a time consuming and complicated challenge, therefore it should be created and implemented in a phased manner. As mentioned earlier, there are currently many functional and available applications and software for maintenance organizations. However, these software are costly to operate and a small organization such as the CAO at LVVC ŽU cannot afford to fund such a program at this time. Therefore, the idea of developing such software using own resources was conceived.

The problem of designing an electronic aircraft maintenance planning system for ATO needs was dealt with by Ing. Dominik Mikulec. In his work he created a proposal for the structure of the aircraft planning system and the interconnection of the information flow between the ATO and the maintenance organisation. In this thesis, we deal with the design of the digital maintenance environment and its creation.

4.1. Hardware selection

Firstly, it is necessary to select the appropriate hardware that will serve as a server and ensure the smooth operation of the application and information flow. The following factors need to be taken into consideration when selecting the hardware:

- Dimensions
- Processor
- Operating memory (RAM)
- Storage

For example, a server where documents and folders will be stored needs a less demanding processor, so we can save on energy, but on the other hand it needs a much larger storage for data processing. A web server needs a larger amount of RAM than a document server, this depends on how many users we intend to connect to the server. The dimensions of the server are important when choosing where we want to store it. The server should generally be stored in a well-cooled, dark room with air conditioning to ensure that the heat produced by the internal parts of the server is dissipated and new, cool air is brought in.

As a basis, we have chosen a desktop computer (PC) with classical dimensions with an Intel Core 2 Quad Q 6600 processor, a Samsung 80 GB SATA HDD and 3.24 GB RAM. For the initial start-up and setup of the server, a monitor is also required along with a keyboard.

4.2. Software selection

The original operating system on the PC was Windows XP Professional, Version 2002. However, for our server's operating system, we selected Linux Ubuntu 20.04, which is an open-source operating system that provides a five-year warranty of software support and security in regular updates. This operating system is very stable and therefore suitable for building structured applications or setting up a server.

4.3. Software setup

After successfully installing the server on our PC, we need to set up the root account. The root account is unavailable after installation for security reasons, as we can use root commands to change basic settings and access all commands as an administrator. For our server's needs, we will access root using the command: sudo passw root and type the password for root in the next line. The password for the root administrator is never the same as the password to access the server, so you must enter a different one.

Continue by installing net tools. Net tools is an important toolkit in Ubuntu for controlling the network subsystem of the Linux kernel. These include arp, ifconfig, route, rarp, nameif, and netstat. In addition, this package contains tools related to specific types of network hardware and advanced Internet Protocol (IP) configuration options [4].

For remote server administration, port 22 , which is required for Secure Shell (SSH) communication, must be enabled. This port itself is not secure and poses a potential risk of unauthorized access to the server. Therefore, when enabling port 22, it is necessary to have a password set on the server.

To enable port 22, use the ufw allow 22/tcp command. The abbreviation UFW stands for uncomplicated firewall. This is used to manage the Linux firewall and aims to provide a simple interface to the user [5].

A port is generally used to let the computer know what type of data is being received from or sent to the computer over a similar network connection. Each port is assigned a different function and number. A port is a virtual numeric address that is used as an endpoint to communicate with various protocols [6].

From this point on, we could control our server via remote access, using the PuTTY software. PuTTY is a client of SSH and other protocols (Telnet, rlogin, TCP and terminal) for serial port connections.

Next, we downloaded the Snappy software. Snap is a package of applications and dependencies that works without modification on various Linux distributions. It works as a superstructure to simplify the control of web services and evaluates what the server needs to download (e.g. PHP, SQL, Apache) Snappy can be found and installed from the Snap Store or by using the terminal command sudo apt install snap. After entering this command, a password was required. Along with snap, we also installed Wget, which is software for reading the contents of files from various web servers, using the sudo apt-get install wget command. Wget stands for world wide web get and supports downloading via FTP, SFTP, HTTP and HTTPS.

4.4. Establishing the basis for a digital enviroment

The output of this is to create the basis of a digital maintenance environment for the CAO organisation. In the previous chapters we described how we proceeded to create the foundation-a server that will be used to store all maintenance information. In order to work with the server and use its full potential, we needed to install the Nextcloud software.

Nextcloud is a client-server software package for creating and using file hosting services. It is ready to be used in enterprises with comprehensive support options. As it is free and open source software, anyone can install and run it on private devices. Nextcloud is functionally similar to Dropbox, Office 365 or Google Drive when used with the integrated office suite solutions of Collabora Online or OnlyOffice. It can be hosted in the cloud or in an on-premises environment. It is scalable from home office solutions to full-fledged data centre solutions used by millions of users [7].

To install the Nextcloud software, we used the following sudo snap install nextcloud command to install it on our server. For the software to work properly, we needed to enable ports 80 HTTP and 443 HTTPS using the ufw allow 80/tcp and ufw allow 443/tcp commands. This allowed our server to communicate with the network using these protocols. Port 80, is only opened when the security certificate is verified.

By default, port 80 is used for HTTP connections. It is a popular and widely used port on all over the world. A user can use this port to connect to websites available on the Internet. This means that unencrypted data is exchanged between the user's browser and the server using this port. On the other hand, the secure version of HTTP is HTTPS, which uses port number 443. This port establishes a secure connection between the website and the browser. The main difference between port 80 and 443 is strong security. Port 443 allows data to be transferred over a secure network, while port 80 allows data to be transferred in plain text. Therefore, when accessing an insecure site that does not have HTTPS, the user receives a security warning [23].

After enabling the ports, and installing the Nextcloud software on our server, we proceeded by logging into Nextcloud on the other machine. We again typed the IP address of the server into the browser in the following format: http://10.10.10.116 and connected to the web interface of the Nextcloud site. First, we then created an administrator account, from which we created the entire digital environment on the site.

First, we used the admin account to create the admin interface. Through the add files item, we created a group of files representing our proposed look and feel for the admin interface. We then uploaded the relevant documents to the individual folders.

Subsequently, for the purposes of this thesis, and to validate the functionality of client-server communication, we created fictitious users to represent the maintenance staff. In the application, we created 4 accounts for the maintenance technicians, and one for the maintenance manager. For their accounts, we had to create email addresses with which the server would be able to contact them. We created these addresses using Gmail accounts, and we set up the server's e-mail on the Centrum.sk web.

Using the maintenance supervisor account, we created an event in the calendar, with a description of the inspection, the aircraft type, and assigned several maintenance workers to it. Once the data was saved, the server automatically contacted the required maintenance personnel via their email. Emails from the server appeared on the maintenance workers' accounts, with an invitation to the event. The event description contained the exact information entered by the administrator. After the maintenance workers accepted or declined the invitation, the maintenance manager's account showed a confirmation for the event.

5. CONCLUSION

In this thesis we have dealt with the development and building of software for the CAO organization, which is part of the Aeronautical Training and Education Centre of the University of Žilina. First of all, we analysed the current state of the problem in detail. The current state of slow digitalization in smaller maintenance organizations is often due to the high price of software, which these organizations cannot afford. Another problem is that outdated standards are currently being used and are only slowly being replaced by new, compatible standards. The lack of national legislation on this issue is only contributing to the slower uptake of the digitisation of maintenance processes.

Therefore, we decided to create a set of information and available legislation on the subject. In this way we can help the CAO to better prepare for future changes in national legislation that will result from the new European standards and regulations. In this paper we describe in detail the current technologies and procedures used in carrying out maintenance, most of which are in paper form. Furthermore, we present the design of a digital maintenance environment that is simple, clear and structurally contains all current procedures.

The output of this thesis is a working software that serves as a basis for the future building of the digitalization of the maintenance process. We have described its construction and development in detail in the core of the thesis, explaining the individual steps. The built server forms the basis on which the CAO organization can further build its digital interface. The server can use simple software to send emails and alert maintenance staff of incoming inspections or other important information. This server can store data related to maintenance in the CAO.

Creating comprehensive software that can match current licensed software is a complex and time-consuming task. Therefore, the created server can also serve as a good basis for further bachelor and diploma theses, which would further build individual parts of the maintenance digitalization software on its basis.

REFERENCES

[1] HERBERT, I. 2020. Why MROs should go digital with technical documentation. [online]. [cit. 2022.03.06]. Dostupné na internete: <https://resources.vistair.com/articles/why-mros-should-go-digital-with-technical-documentation>.

[2] MIKULEC, D. 2021. Návrh elektronického systému plánovania údržby lietadiel pre potreby ATO. Diplomová práca. Žilina : Žilinská univerzita v Žiline, 2021. 72 s.

[3] ICAO. 2021. Electronic Aircraft Maintenance Records (EAMR) and Continuing Airworthiness Records. [online]. [cit. 2022.03.09]. Dostupné na internete: <https://www.icao.int/safety/airnavigation/OPS/airworthiness/Pages/EAMR.aspx>.

[4] UBUNTU. 2022. Binary package „net-tools“ in ubuntu bionic [online]. [cit. 2022.04.09]. Dostupné na internete: <https://launchpad.net/ubuntu/bionic/+package/net-tools>.

[5] nixCraft. 2021. How to open ssh 22/TCP port using ufw on Ubuntu Linux [online]. [cit. 2022.04.09]. Dostupné na internete: <https://www.cyberciti.biz/faq/ufw-allow-incoming-ssh-connections-from-a-specific-ip-address-subnet-on-ubuntu-debian>.

[6] LINUX JOURNAL. 2008. Graphic Administration with Webmin [online]. [cit. 2022.04.09]. Dostupné na internete: <https://www.linuxjournal.com/magazine/graphic-administration-webmin>.

[7] 9TO5LINUX. 2021. Canonical, Collabora, and Nextcloud Deliver Work From Home Solution to Raspberry Pi Users [online]. [cit. 2022.04.09]. Dostupné na internete: <https://9to5linux.com/canonical-collabora-and-nextcloud-deliver-work-from-home-solution-to-raspberry-pi-users>.

[8] NOVÁK, A., NOVÁK SEDLÁČKOVÁ, A. 2010. Medzinárodnoprávna úprava civilného letectva. Žilinská univerzita, 2010. - 125 s. ISBN 978-80-554-0300-7.

[9] BUGAJ, M. 2011. Systémy údržby lietadiel. vyd. - V Žiline : Žilinská univerzita, 2011. - 142 s., ilustr. - ISBN 978-80-554-0301-4.