Future of aviation - digital twin and prediction technologies

Александр Дремов, Павел Атакишиев, Ivan Buzdalin



Обзор

Обзор

Nowadays, the impossibility of tracking the state of plane details and parts leads to ineffective use of money and time. Consumer predicts the date of aircraft maintenance from plane mileage but this approach results in problems. Some plane parts can be still suitable for use and some can break directly in flight. We want to present our solution for it.

When we have analyzed different sources, we realized that a lot of companies work on this issue. Our team was interested in solving the worldwide problem, so we introduce our solution - digital twin (DT) applying.

DT collects data from the plane's sensors, analyzes it and builds a prediction model. It solves the problem of connection between consumer and manufacturer. Digital twin provides consumer with up-to-date information about the plane state which helps to plan maintenance more precisely. Moreover, the manufacturer can find out which parts need to be replaced soon and then plan the production of them. It decreases plane maintenance time and cost and at the same time increases flight safety.

The result of our work is an Unmanned Vehicle Plane with a digital twin which helps to check the actual state of some parts of the UAV (Unmanned Aerial Vehicle) and predict their future state and service time date (we checked technology of digital twin in the diminished scale). We plan to improve our DT with addition of new parts for analysis and then take part in the development of real plane DT.

Video: https://youtu.be/jRftP2nFUUQ

Постановка вопроса

Today plane maintenance is based on its mileage but such predictions are often inaccurate. When the plane is under service and manufacturer cannot provide spare parts in time, aircraft stands idle resulting in sustain losses for the owner. Predictions based on mileage also leads to the problems of vehicle safety.

Is it possible to increase flight safety and decrease aircraft maintenance cost? Can we predict aircraft maintenance duration, basing on condition of particular details and not on plane's mileage? Can aircraft manufacturers produce spare details before consumer requests it? If all of this are possible, how to implement it?

It sounds like a miracle, but we can achieve the goals it by the use of a digital twin. The result of our work is an Unmanned Vehicle Plane with a digital twin, which helps to check the actual state of some part of the UAV and predict it future state and maintenance date (we check technology of digital twin in the diminished scale).

The objective of the project:

Develop digital twin for accumulator state predictions and test it at designed UAV.

Our way to solve a problem:

1) Market analysis.
2) Problem formulation.
3) Our way of problem solution as digital twin (DT) elaboration.
4) Accumulation of experiences in the field of engineering of the modeling device.
5) Digital twin development.
6) Digital twin testing and adjusting in the laboratory environment.
7) Final checks in order to test digital twin precision.

Исследования

Fifteen years ago aviation companies focused mostly on selling planes. Today it is impossible just to sell a plane and forget about it. Companies continue to support planes after selling and it is really a problem to provide good and fast maintenance.

Aviation organizations are working on this problem in order to solve it. We have analyzed approaches of these companies and realized that they have only started the search of the solution and there is not a lot of information about their success. Some Aircraft companies published the top challenges they are facing now. And the necessity of predictive analytics is the major one.

The main purpose of prediction analytic services is to create an adjustable digital twin to provide a consumer with up-to-date data about the plane and to give manufacturer information about required spare parts in advance. These companies helped us to understand the concept of the digital twin and to develop an idea of our project.

There are still no solutions from top aircraft companies, so we introduce ours inasmuch as the problem is of interest present.

Методика и эксперимент

The accumulator is a fast-degrading and a very important element of UAV. It is important to know its state to prevent unexpected electricity cut off through a flight. Moreover, it is very difficult to utilize accumulator properly, so we should replace it with a new one only when it is really necessary.
Our team wrote a code for the accumulator digital twin with use of special software to predict the replacement date and real-time accumulator state.

Accumulator prediction model development.

Our digital twin is focused on accumulator state prediction based on its usage and environment characteristics. We programmed our accumulator predictions (AP) model basing on already known data for our accumulator type and then decided to test it and adjust preciseness by the experiment.

Variables: environment temperature, accumulator temperature, humidity, circuit current, accumulator voltage, number of recharge cycles.

Tools:

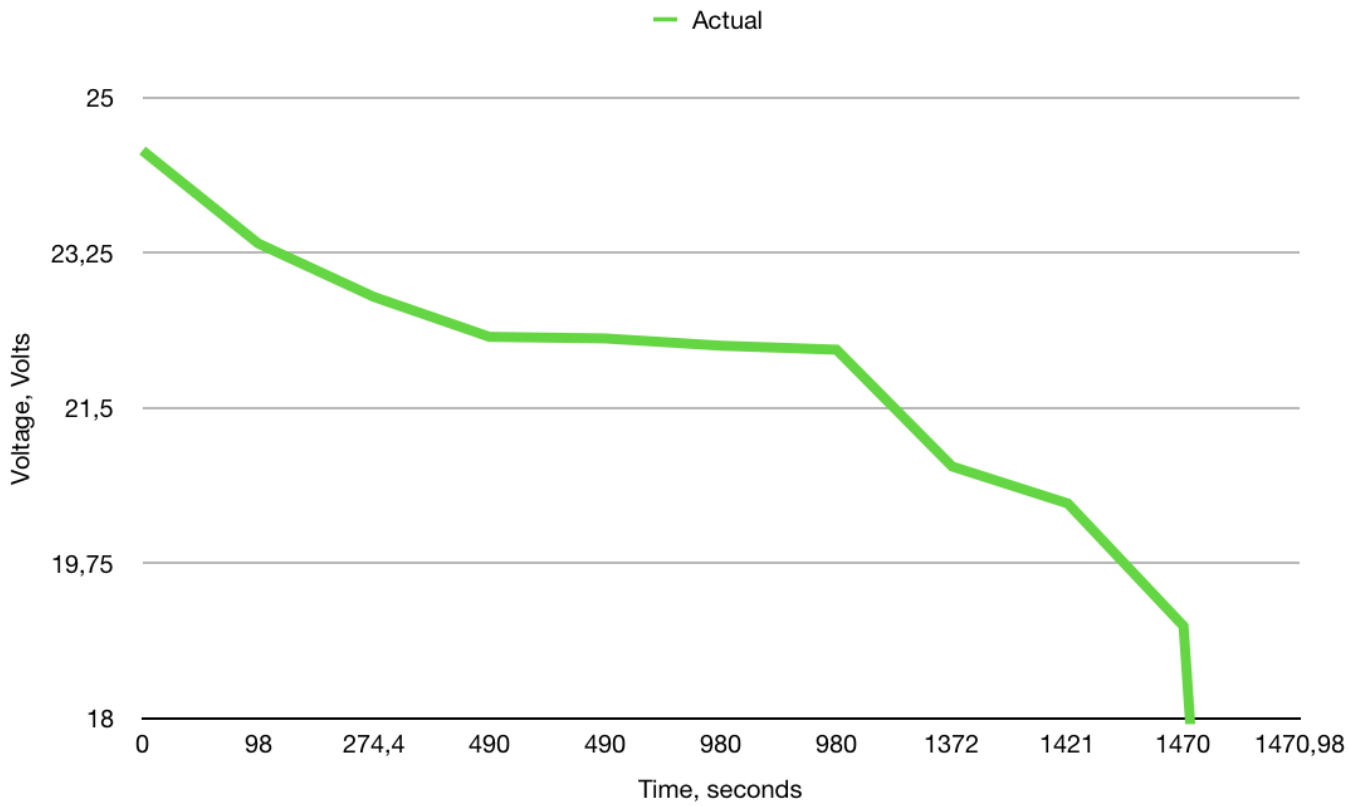
digital multimeter, programmable discharger, temperature sensor, humidity sensor.

Experiment design:

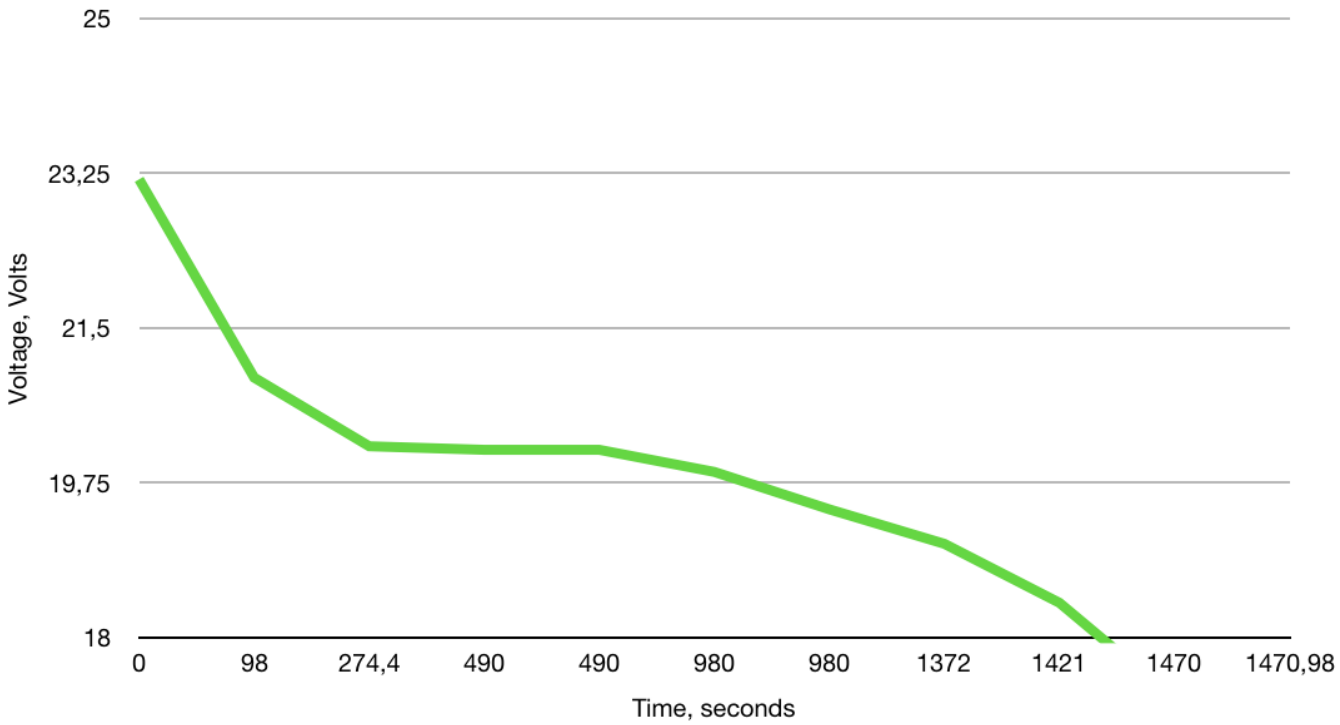
1. Charge accumulator to the top.
2. Accumulator discharge in different conditions to provide our AP with discharging data and all variables.
3. Comparison of the difference between real data and our AP every charge cycle, then change coefficients if data do not coincide accurately.
4. Record accumulator voltage and time.
5. Repeat experiment and check AP results with new coefficients.

During experiment we have recorded data of accumulator discharge:

- Graph of the new accumulator under load.



- Graph of the accumulator under load after the 93rd charge cycle.



Our experiment has been held in the laboratory of the educational centre. We organized our workspace as sufficiently safe to prevent any injuries during discharging.

To provide safety during the experiment, we placed accumulator into the fireproof box to prevent the fire injury in case of the explosion.

Result:

We have recorded data about the accumulator discharge process in different conditions. According to the data, we concluded that accumulator effectiveness depends on it charge cycles number. Using this fact we adjusted and improved AP model.

Motor parts group predictions development.

Our AP model works well only if we have obtained a lot of information about discharging conditions, but it is difficult to provide it in the flight. We have developed a motor predictions unit, which analyzes motor working mode and produces data for AP model.

Variables: Motor RPM, Velocity, Flight Height, Motor temperature, Throttle level.

Tools:

load cell, multimeter, power supply block, RPM sensor.

Experiment design:

1. Test of motor work on every throttle level.
2. Repeat step no. 1 with the other voltage.
3. Check motor data and record the difference between them and the predictions model.
4. Adjust coefficients.
5. Repeat experiment with new coefficients.

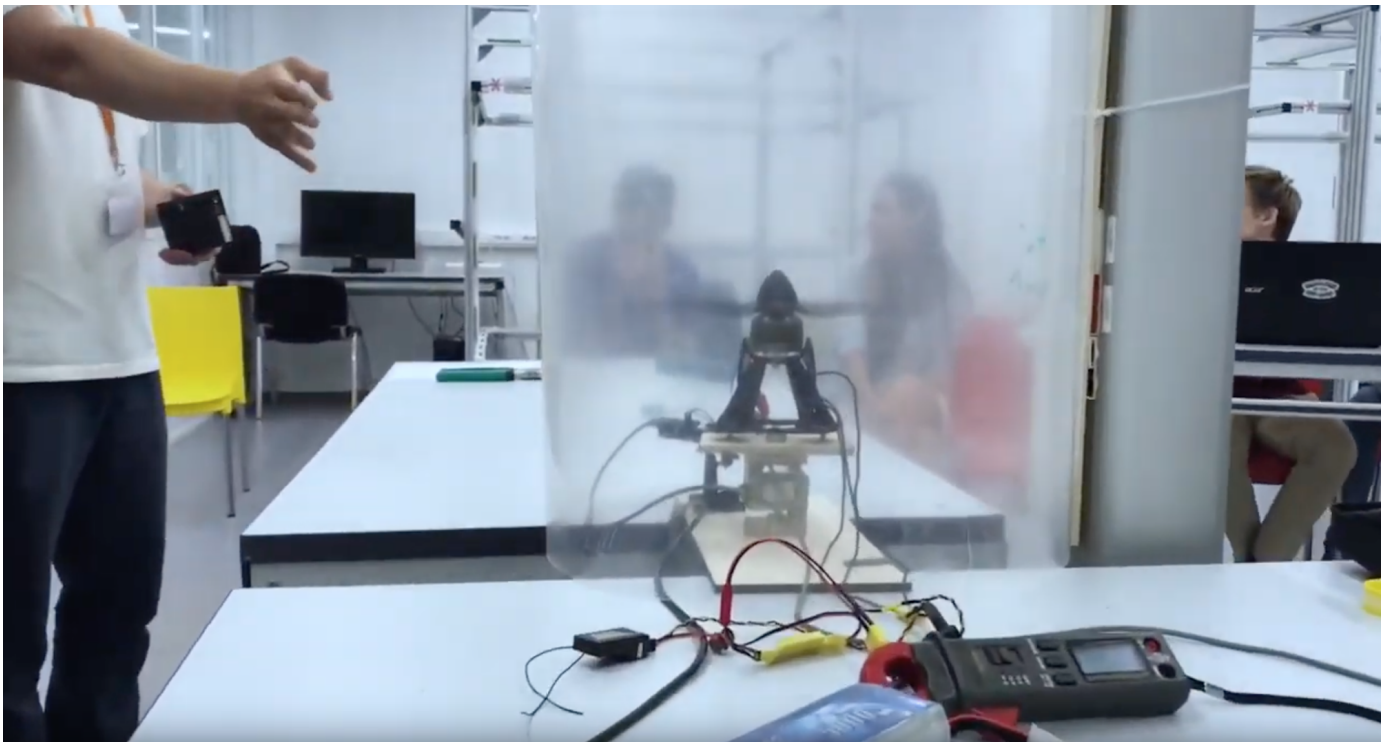
Our experiment was held in the laboratory of the education center. We organized our workspace sufficiently safe to prevent all possible injuries caused by a motor's blade.

We have built a transparent plexiglass tube for the motor to prevent accidents caused by the motor propeller.

Result:

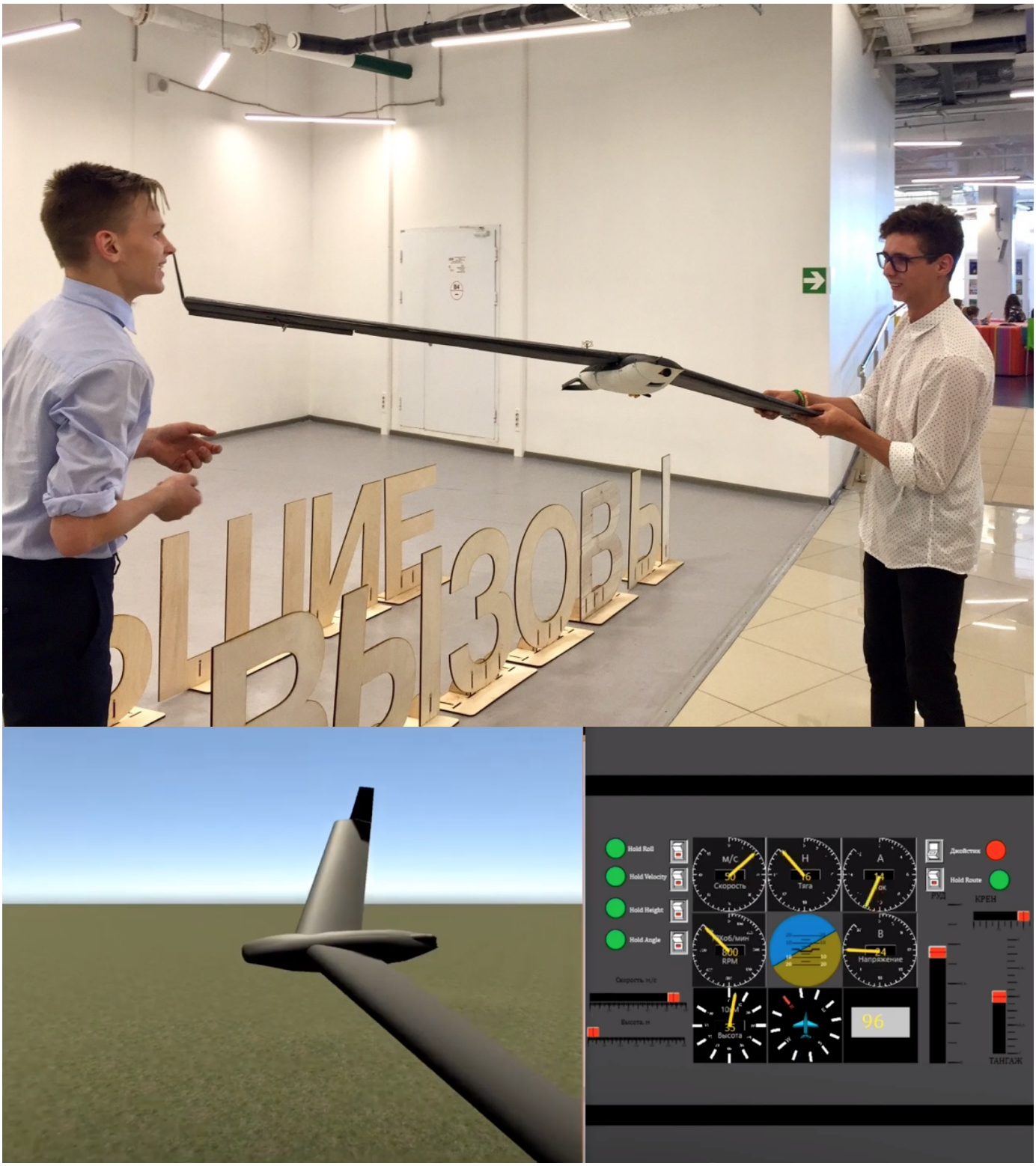
We have successfully developed and adjusted motor predictions module to provide AP module with necessary data.

- Experiment over the motor in the plastic safety cover.



Результаты

- Complete UAV and its digital twin simulation panel.

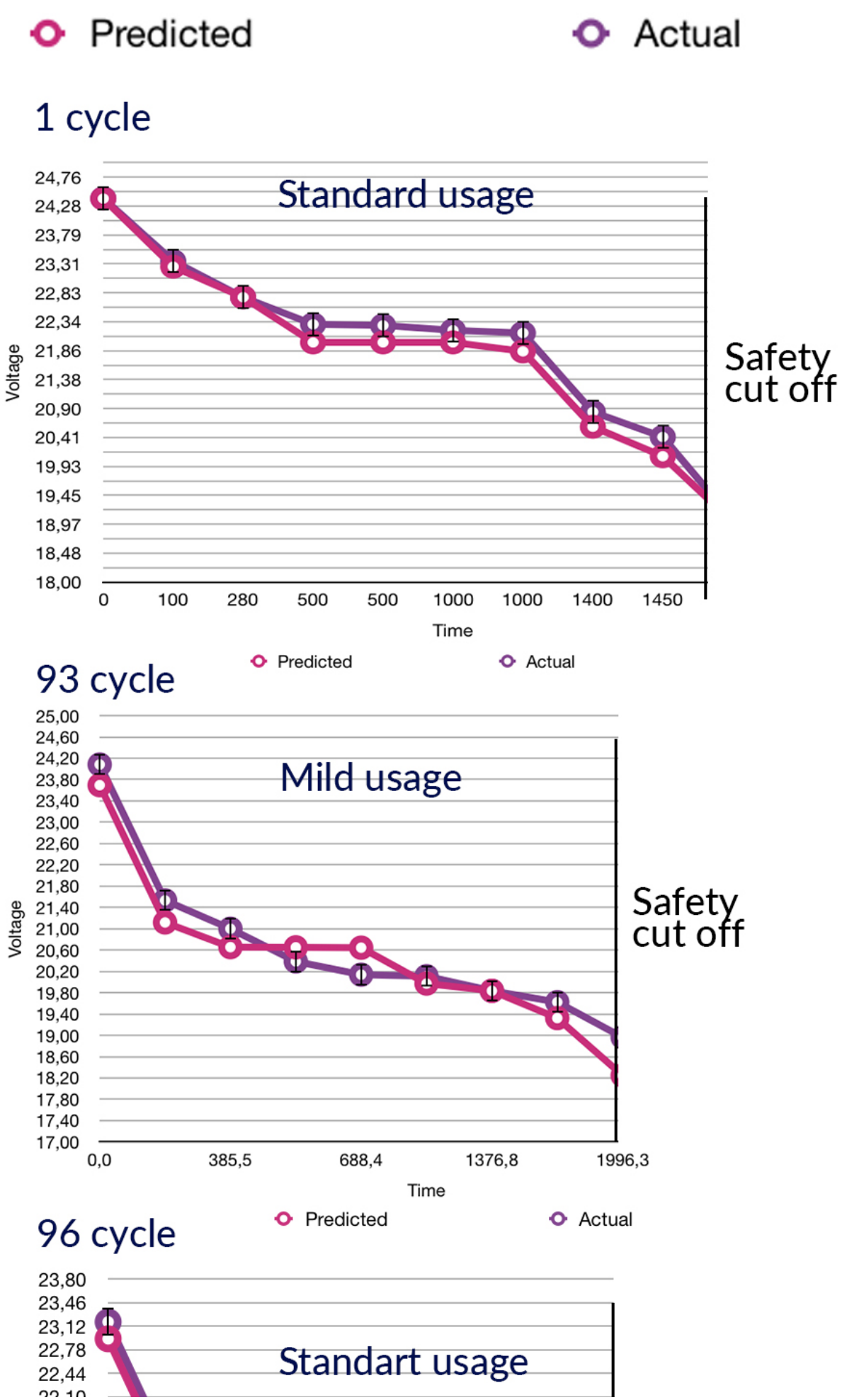


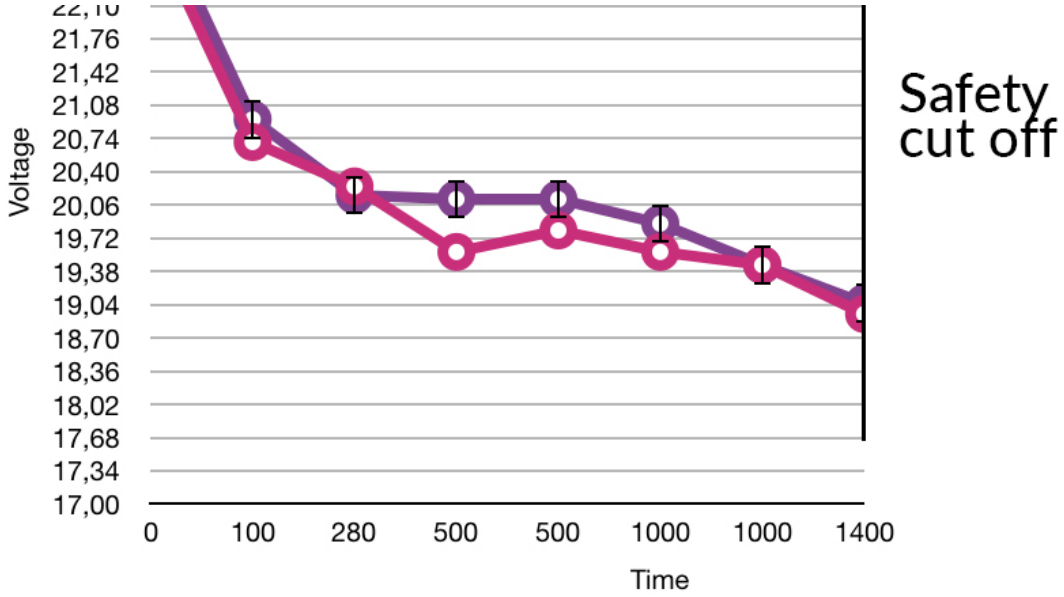
Designed plane assembly video: https://youtu.be/EjmgTdQd43Y (not necessary)

During our work, we created UAV and its digital twin, which can predict accumulator state and the remaining number of possible charge cycles. We used the microcomputer for all calculations on UAV, and microcontroller for collecting and sending sensors data to the calculating core. We used algorithms of dynamic modeling environment software to reach our goal. We programmed the large part of processes running on the UAV to make predictions more accurate.

And we succeed.

- Graphs of discharge for our accumulator, generated by our prediction unit and real data.





These three graphs represent the work of our digital twin in conditions of the different number of charging cycles and usage types. Real data was received from our UAV's sensors during the flight. It can be easily inferred that accumulators degrade after many recharges, but our predictive model regards it and provides accurate information. We are pleased with the achieved results.

The difference between real data and data, generated by our digital twin is less than 5%! Therefore we can understand when it's time to utilize our accumulator and buy new exactly when it is necessary. It helps us to diminish maintenance cost and predict its date. And what is more important, our work is a small, but an impressive step in the development of big digital twin model for a real-life plane.

Заключение

We concluded that it is possible to predict plane parts state according to real data, not mileage. Our team proved this concept by its use in on real self-designed UAV with the digital twin. In this case, the idea of a digital twin of the real-life plane is possible, the only problem in the development of a full-scale digital twin is lack of the experimental data from real plane sensors and complexity of some prediction model calculations for 17-year-olds.

Our solution is plausible to increase flight safety and decrease maintenance cost. **We can predict maintenance date based on actual parts state, not all plane mileage, and planes manufacturer can produce spare parts before consumer request them. Moreover, we can know the real state of a detail, so it will increase flight safety.** It is like a dream come true.

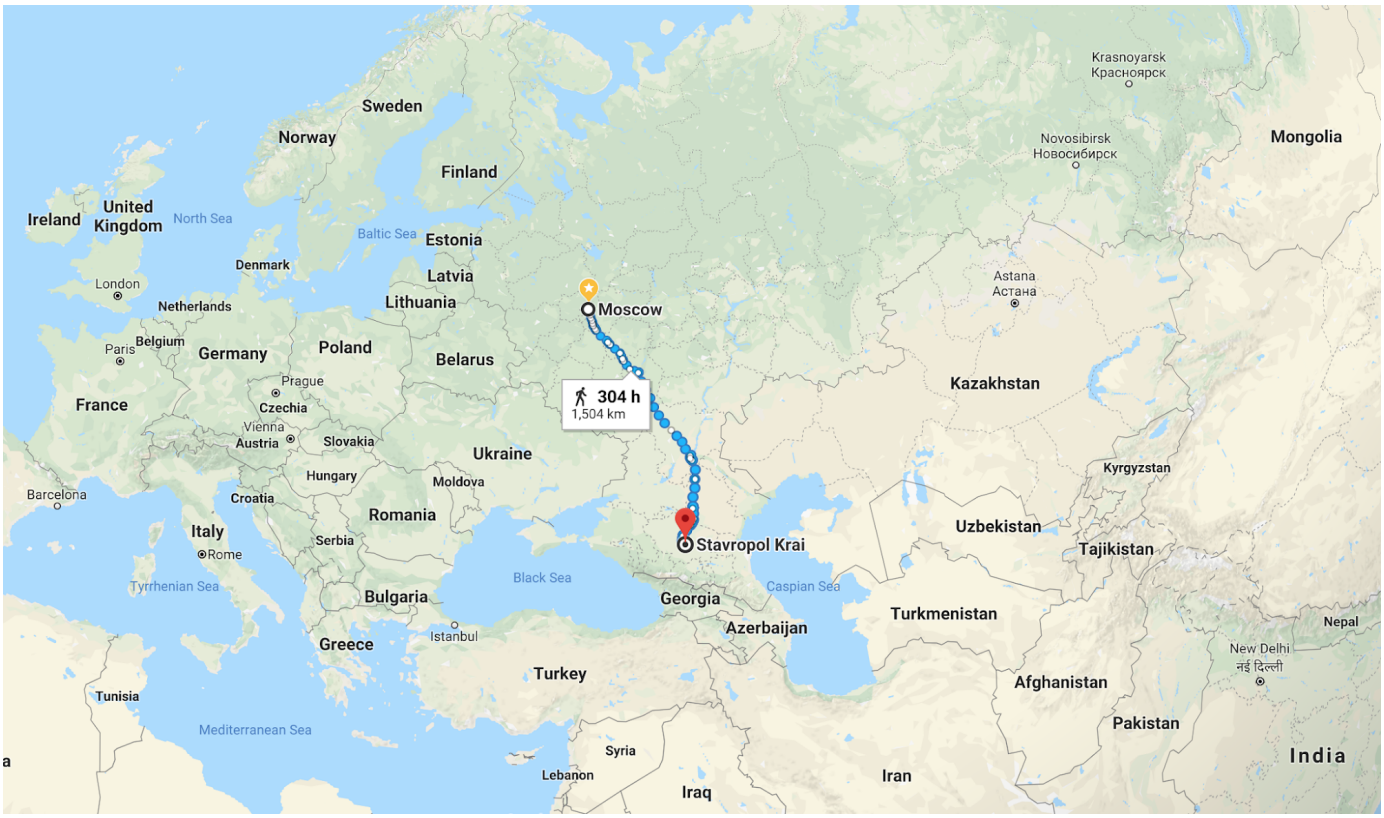
In our future work, we plan to extend and improve our UAV digital twin functionality by introducing a module of composite wing damage predictions, fuselage corrosion predictions and developing of stimulating environment, in which we could change parameters of UAV and momentously see results (this module is already started and we see first benefits).

We think that our project is flourishing and **we have reached the goal**. We will continue to improve our digital twin and will work on data generation to make it more accurate. Our team is ready to introduce our solution to aircraft companies and to work on new features with them.

О себе

The story of our team started in the education center. We are all different people that live far from each other, but our love and interest in science have united us, so we started our project concerning predictive analytics. Members of our team have always been inspired by the examples of William Boeing, Sergey Korolev, Pavel Sukhoi, and Konstantin Tsiolkovsky. In addition to similar fields of activity, these people had something in common - a dream! On their way to the dream, they pulled down all the obstacles. Just like these outstanding people, we have a dream. And this dream is to make the world better and to help people, which is also the main purpose of our project, too.

During the education program, we have completed 60% of the project, but we decided to continue working on it after we return to our home cities. Approximately 1500 kilometers disunited our team but we continue working online using video calls, git repositories, and Google tools. We have reached our goal - our predictions system worked. "Worked" how much sense this phrase means for an engineer.



During our work, we faced such problem as the lack of special knowledge, thus we understood that the good education plays an important role and why it is needed. It was necessary for us to win this contest, to learn something new and to meet interesting people. We wish to continue to make the world better and to help society with our ideas.

Здоровье и безопасность

We used masks and goggles to protect the face. While working with toxic substances (glue, epoxy resin) respirators and gloves were used. Everyone wore protective clothes that prevented accidental hits into the machines or popping. The removal of chips from the drilled hole was made only after the tool was stopped and retracted. All items intended for processing were installed on the table or plate of the drilling

machine motionless with the help of a vice, jigs and other reliable devices. A protective cover was used to protect the environment from the propeller.

While working with electricity, the condition of the flexible electric cord, plugs, supply cables was checked. Devices were cleaned from dust with a dry clean cloth. Devices were loaded in accordance with the requirements. Hands were wiped dry before turning on electrical appliances into the network. The included appliances were not left unattended. Included supply and exhaust ventilation. Electrical appliances were installed on a stable flame-resistant, dielectric stand. Devices were disconnected from the mains, not pulling the power cord. After a complete stop of the electric motor, the instrument was

cleaned. The electrical appliances were not dropped. After the work was finished, the workplace was established to the order.

To provide safety during soldering we used this instruction.

Safety instructions were provided by the laboratory chief of the education centre.

All works were performed according to the safety regulations under the supervision of our mentor.

Подобин Евгений: eapodobin@gmail.com

Библиография, ссылки и источники

Sources:

Б. А. Карташов, Е. А. Шабаев, О. С. Козлов, А. М. Щекатуров. Среда динамического моделирования технических систем SimInTech. Практикум по моделированию систем автоматического регулирования. М.:ДМК Пресс, 2017, 424с.

UAC (United Aircraft Corporation). Обзор рынка 2017-2036.

А. М. Знаменская, П. С. Лимар, В.П. Шведов. Информационно измерительные системы для летных испытаний самолетов и вертолетов. М.: Машиностроение, 1984, с 10-87.

В. Г. Микеладзе. Авиация общего назначения. Рекомендации для конструкторов. 1996, с 83-128

А. Ф. Бочкарев, В. В. Андреевский. Аэромеханика самолета. М.: Машиностроение, 1985, с 11-43, с 72-80, с138-173

Calculation of Constant Power Lithium Battery Discharge Curves.

How can we calculate the state of Charge (SOC) of the battery in on load condition?

How do we can calculate the charge/discharge efficiency of a battery?

Li-Po accumulator overview (http://rcsearch.ru/wiki/LiPo-аккумулятор).

Effect of Temperature on the Aging rate of Li-Ion Battery Operating above Room Temperature.

"The Path to Predictive Analytics and Machine Learning" by Gary Orenstein, Kevin White, Steven Camina, Conor Doherty Publisher: O'Reilly Media, Inc. Release Date: October 2016 ISBN: 9781492042884.

Li-Po accumulator calculations.

Aviation companies, which we have analyzed: Boeing, Airbus, UAC (United Aircraft Corporation).

Predictive analytics services, which we have analyzed: Aviatar, Skywise, Predix.

Used microcomputer: Raspberry Pi 3b.

Used microcontroller: Arduino Nano.

Dynamic modeling environment software "SimInTech" (Russian analog of "MatLab Simulink")

Цифровые двойники помогут заработать миллиарды долларов

Digital conversion program of KAMAZ PJSC

Digital Transformation Scenarios

We used Google search to find useful information.

Mentors:

Подобин Евгений Александрович (Моско́вский авиацио́нный институ́т (национальный исследовательский университет) (МАИ))

Ершов Сергей Александрович (Моско́вский авиацио́нный институ́т (национальный исследовательский университет) (МАИ))

Mentors taught us how to work with toxic substances and machines. After that, we ourselves performed the actions under mentor's control. If something went wrong, the mentors helped us to get it right. We studied most of the theory ourselves. Mentors explained to us the complex conceptions and provided information that we could not get by ourselves. They also helped us in programming and algorithms logic.

Thanks:

Our team would like to express words of gratitude to Podobin Evgeny Aleksandrovich and Ershov Sergey Aleksandrovich for support in difficult times and for teaching things that seemed inconceivable at the first stages of the project.

Our team thanks to the administration of Foundation "Talent and Success", Education Center «Sirius» for providing workplaces, good community, materials, and tools. For providing security during all education session.

Our team thanks to UAC for providing unique opportunity to bring in to life such a complex project.

We thanks to parents for patience during our creative moments of a mess in the living room, and for cheers in times when everything goes wrong.

Our team thanks to our school teachers for good education and help in complex calculations.

Our team thanks to Kalestrova Kate for helping with the translation of this work.

Our team thanks to Elena Olkhovskaya for constructive criticism toward our ideas and help in project's main idea depiction.

Our team thanks to Lizaveta Kurapina for the perfect organization of Education Center «Sirius» session.

Our team thanks to Sorokina Nastia for providing good mood even in moments of stress.

Laboratory:

Foundation "Talent and Success", Education Center «Sirius». We had access to a lathe, miller, drilling machines, 3D printer, various measuring devices, laboratory power units, load cell, multimeter, power supply block, RPM sensor, programmable discharger, temperature sensor, humidity sensor, computers.