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ERBA 2013

23-26 August 2013

Moscow, Russian Federation

RUSSIAN FOUNDATION FOR BASIC RESEARCH

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I heartily welcome all participants of the International Workshop on Unmanned aerial vehicles (UAVs) and especially welcome those participants who have brought their vehicles and will demonstrate real achievements in UAV's design during the competition.

I would also like to thank co-organizer Moscow Institute of Physics and Technology (MIPT), sponsors and supporters, especially JAXA and TsAGI.

Small and unmanned aerial vehicles (UAVs) are being recognized for their advantages and wide range of promising applications, including monitoring of natural and man-caused disasters, security, traffic and some other important civil problems, and have got the priority in research not only in traditional aeronautical countries.

This Workshop focuses on scientific and technical aspects of UAV development. The objective is to present achievements and discuss ideas and proposals how to improve technical characteristics of UAVs such as flight duration, distance, altitude of flights, carrying capacity, effectiveness, etc.

The Workshop also aimed at discussion at the «round tables» important problems such as innovations in aerona utics, particularly in UAV area, and involving young people into the aerospace science.
ISTC has been funding projects in a wide range of scientific areas. In the field of aerospace, ISTC has funded more than 100 projects covering a wide range of fields including aeronautics. Many forms of international cooperation were developed through these projects and new partnerships were made bringing together leading experts from all over the world.
We hold this workshop in order to foster the development of international cooperation through scientific knowledge exchange and to promote innovation of this field and to encourage the involvement of young people into aerospace research, but it is important to make continuous follow-up to this Workshop.

I wish this workshop will make the opportunity for development and broader usage of UAVs.

Takuya Okamoto

ISTC Deputy Executive Director

I would like to cordially welcome you to the International Workshop "Extremal and Record-Breaking flights of the UAVs and the Aircraft with electrical power plant". I especially welcome our foreign colleagues who have travelled a long way by plane or train and all the participants who will take part in competitions and demonstration flights.

I would also like to thank our co-organizers, International Science & Technology Center (ISTC) and the main sponsors, ISTC, Russian Foundation for Basic Research (RFBR), board of trustees of DAFE of MIPT. Workshop will be held under support of Japan Aerospace Exploration Agency (JAXA) and Central

Aerohydrodynamics Institute named after professor N.Ye. Zhukovsky (TsAGI).
I am proud that so many experts from different countries will make presentations on the workshop. The idea of this thematic conference was born in Japan last year during IFAR and Aerospace Exhibition in Nagoya. From the very beginning it was supported by ISTC and our Japanese colleagues. I would like to express my especial thanks to them.

Moscow Institute of Physics and Technology (MIPT) State University now has a status of Research University. It was established in 1946 initially as a department of Moscow State University named after M.V. Lomonosov. MIPT became the Technical University in 1951. Nobel Prize Winners P. Kapitsa, N. Semenov, L. Landau and many other famous members of Russian Academy of Science, such as S. Christianovich, S. Vavilov, I. Kurchatov are the founders of MIPT.

Department of Aeromechanics and Flying Engineering (DAFE) is one of ten departments in MIPT. It was founded in 1965 as the response to the historical challenge on creating the Space Shuttle. DAFE professors and graduates took part in creating Russian "Buran". Now DAFE has a research team on UAVs and they create their own unmanned aircraft vehicles.

The flying robots are the unique theme for international cooperation and collaboration, the best field for innovations and involving young people into the aerospace sciences and technology. It helps us to understand each other and make our small Earth more comfortable and safe for living.

I wish you every success in participating in our workshop and good luck during the competitions!

Victor V. Vyshinsky,

Dean of DAFE of MIPT

Workshop Program

Time	Name	Organization	Title
Thursday, 22 August			
Arrival of guests & accommodation in hotels			
Friday, 23 August			
9.00-09.30	ISTC Headquarters Registration of Workshop participants		
09.30-10.30	Opening session Moderators: Prof. Victor Vyshinsky, Takuya Okamoto **Room 211**		
09.30	Leo Owsiacki	International Science and Technology Center (ISTC)	ISTC Executive Director Welcome
09.40	Takuya Okamoto	International Science and Technology Center (ISTC)	ISTC Deputy Executive Director Welcome
09.50	Victor Vyshinsky	Moscow Institute of Physics and Technology (MIPT)	Dean of DAFE, MIPT Welcome
10.00-10.30	Keynote speech Prof. Kenzo Nonami, Chiba University "Overview of UAVs in Japan"		
10.30-10.50	**Coffee break**		
10.50-12.55	**Session 1: General overview** Co-Chairmen: Dr. Andrey Shustov Prof. Kenzo Nonami **Room 211**		
10.50	Yuri Dobrovolsky	Institute of Problems of Chemical Physics RAS (IPCP RAS), Russia	Fuel Cell Power for Unmanned Aerial Vehicles (UAV)
11.15	Jonathan Roberts	CSIRO ICT Centre, Autonomous Systems Laboratory, Australia	UAV Challenge Competition
11.40	Hannes Ross	SolarImpulse Team, Germany	Around the World with a Solar Powered Aircraft
12.05	Andrey Scherbakov	S. P. Korolev Rocket and Space Corporation "Energia"(RSC "Energia"), Russia	Fueling Infrastructure for Unmanned Aerial Vehicles with Hydrogen Power Plants
12.30	Jozsef Rohacs	Budapest University of Technology and Economics, Hungary	New Technology Development and Deployment

12.55-14.00	**Lunch**		
14.00-15.20	**Session 2: "Small Aircraft Vehicle: CFD or Wind Tunnel Tests"** Co-Chairmen: Dr. Anton Gorbushin Prof. Evgeniy Sokolov **Room 211**		
14.00	Shigeru Obayashi	Tohoku University, Japan	Research Activities Related to Small Aircraft Vehicles at Tohoku University
14.20	Oleg Kudryavtsev	Central Aerohydrodynamic Institute (TsAGI), Russia	Theoretical and Experimental Investigation of the Tailless UAV with S-shaped Airfoil
14.40	Nikita Ageev	Moscow Institute of Physics and Technology (MIPT), Russia	Numerical Investigation of Disc-wing MAV with Wing Slot Propeller
15.00	Alexander Mitin	Central Aerohydrodynamic Institute (TsAGI), Russia	Challenges of Computational and Experimental Studies of Aerodynamic Characteristics of Solar-powered UAV at Low Reynolds Numbers
15.20-15.40	**Coffee break**		
15.40-16.40	**Session 3: "Low Reynolds problems, Micro Air Vehicles"** Co-Chairmen: Prof. Victor Vyshinsky Prof. Evgeniy Sokolov **Room 211**		
15.40	Oleg Buzykin	Central Aerohydrodynamic Institute (TsAGI), Russia	CFD Application for Micro Aerial Vehicles. Low Reynolds Number Capability.
16.00	Chinnapat Thipyopas	Kasetsart University, Thailand	High Performance Multi-Mission Electric MAV: Propeller, Aerodynamic, and Stability
16.20	Nikolay Nikolaev	Central Aerohydrodynamic Institute (TsAGI), Russia	Optimization of High-lift airfoil with High Flap-type Controls Efficiency for Solar-powered UAV
16.40-17.40	**Session 4: "Avionics"** Co-Chairmen: Prof. Jozcef Rohacs Dr. Sergey Serokhvostov **Room 211**		
16.40	Kirill Shilov	Moscow Institute of Physics and Technology (MIPT), Russia	Autonomous Multirotor UAV Flight Control System Based on GPS and INS Data Fusion
17.00	Gleb Liseykin	Moscow Institute of Physics and Technology (MIPT), Russia	Autonomous Take-Off and Landing of Helicopter Unmanned Aerial Vehicle
17.20	Tatyana Kobtseva	Moscow Institute of Physics and Technology (MIPT), Russia	Safety of Flights of Remotely Piloted Aircraft in Non-Segregated Airspace
17.40	Kirill Andreev	Telum JSC, Russia	Multiple Target Tracking with Bearing-only Measurements

Saturday, 24 August

Competitions. Hippodrome "Ramenskoe"

13:00-14:00	**Lunch**
14:30-17:00	**Round Table 1: "Involving young people into the aerospace science"** Co-Chairmen: Prof. VictorVyshinsky Prof. Jozcef Rohacs **Presentations:** > Victor Vyshinsky "Experience in Young People Involving into Aerospace Science" > Sofia Kondratyeva "Design and Manufacturing of a Hot Air Balloon for 70 kg Payload with Solid Fuel Heating Plant" > Chinnapat Thipyopas "Mini and Micro UAV Activities at Kasetsart University: the Way Young Peoples Involving Aerospace Science" > Róbert Baburin "Using UAVs in Education to Support Development of Engineering Skills" Nikita Ageev "MiniUAV Design for Specific Technical Requirements" **Discussion**

Monday, 26 August

9.00-10.40	**Session 5: "Design"** Co-Chairmen: Hannes Ross Prof. Kenzo Nonami **Room 211**		
9.00	Alexey Krivoschapov	Central Aerohydrodynamic Institute (TsAGI), Russia	On the Problem of Choosing Parameters of Solar-powered UAV
9.20	Nguyễn Hồng Phong	Moscow Institute of Physics and Technology (MIPT), Vietnam	Research on Optimization of Structural Layout of the Straight-Wing Aircraft Made from Composite Materials
9.40	Sergey Kolchev	Moscow Institute of Physics and Technology (MIPT), Russia	System of Aerodynamic Design of Small-Sized Unmanned Aircraft Layout
10.00	Maria Markovskaya	Moscow Institute of Physics and Technology (MIPT), Russia	The Assessment Model of the Efficiency of Solar Radiation Receiving and Conversion by the Aircraft Surface
10.20-10.40	**Coffee break**		
10.40-12.00	**Session 6: "Aerodynamics"** Co-Chairmen: Prof. Igor Lipatov Prof. Victor Vyshinsky **Room 211**		
10.40	Wagdi G. Habashi	McGill University, CFD Lab; Newmerical Technologies International, Canada	FENSAP-ICE Applications to UAVs
11.00	Nikolay Nikolaev	Central Aerohydrodynamic Institute (TsAGI), Russia	Computational Simulation of Flow Over Solar-Powered UAV Using CFD Code Flowvision
11.20	Vladimir Golubev	Embry–Riddle Aeronautical University (ERAU), USA	High-Fidelity Numerical Experiments in Transitional Airfoil Unsteady Aerodynamics, Acoustics and Flow Control
11.40	Diana Kravchenko	Central Aerohydrodynamic Institute (TsAGI), Russia	Computational Determination of a Modern Airliner Dynamic Derivatives

12.00-13.30	**Lunch**		
13.30-15.10	**Session 7: "Flight dynamics, path optimization"** Co-Chairmen: Dr. Andrey Shustov Prof. Evgeniy Sokolov **Room 211**		
13.30	Sergey Serokhvostov	Moscow Institute of Physics and Technology (MIPT), Russia	Some Results of Electrical Aircraft Flight Path Optimization With the Help of Pontryagin Maximum Principle and Their Implementation to Design
13.50	Nikolay Trukhlyaev	Central Aerohydrodynamic Institute (TsAGI), Russia	On the Flight Path Choosing For the Electrical UAV Endurance Maximization
14.10	Leonid Nefedov	Moscow Aviation Institute (National Research University MAI), Russia	Optimization of Aircraft Motion by Method of Traveling Wave
14.30	Ivan Krylov	Moscow Aviation Institute (National Research University MAI), Russia	Intelligent Search and Tracking of Ground Mobile Objects by Using Autonomous Group of UAVs
14.50	Midori Maki	Japan Aerospace Exploration Agency (JAXA), Japan	Practical Design and Implementation Issues in Flight Control System of JAXA's Disaster-monitoring UAV
15.10-15.30	**Coffee break**		
15.30-16.50	**Session 8: "Theory and practice of "unconventional" flying vehicles (flapping wing, balloons, hovercraft etc.)"** Chairman: Prof. Boris Kritsky Prof. Vladimir Golubev **Room 211**		
15.30	Alexey Lazarev	Moscow Institute of Physics and Technology (MIPT), Russia,	Developing a Scale Model of a Tiltrotor Craft
15.50	Maxim Ovdienko	Central Aerohydrodynamic Institute (TsAGI), Russia	The Method of Choosing the Optimal Hydrodynamic Scheme and Construction Parameters of Underwater Gliders
16.10	Evgeniy Sokolov	Saint-Petersburg State Polytechnical University (SPSPU), Russia	Wind - resistant Tethered Micro - aerostat
16.30	Jozsef Rohacs	Budapest University of Technology and Economics, Hungary	Use of MagLevTechnology to Assisting The Aircraft Takeoff And Landing
16.50-17.10	**Break**		
17.10-18.00	Chairman: Mr. Takuya Okamoto **Presentations:** > Kenzo Nonami "Technical Issues and Near Future Dream of UAVs for Industrial Applications" > Kazuhiro Ishikawa "JAXA's Approaches for the Technical Problem that a Light UAV flies over Visual Line of Sight in a Resident District" **Discussion**		
18.00-18.20	**Discussion of the future steps - workshop decision-making** Panelists: Mr. Takuya Okamoto Prof. Victor Vyshinsky **Room 211**		
18.20-18.40	**Closing remarks, common photo** **Room 211**		
19.00-21.00	**Fourchettes**		

Abstracts

Keynote speech

Overview of UAVs in Japan

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Chiba University, Japan

In recent years, there has been rapid development autonomous unmanned aircraft equipped with autonomous control devices called unmanned aerial vehicles (UAVs). These have become known as "robotic aircraft," and their use has become wide spread. For example, UAVs have been attracting a great deal of attention for their use in search and rescue operations at dangerous sites such as earthquake- and fire-affected zones or accident scenes at chemical plants that are too dangerous for people to enter. People still remember that a Honeywell duct-fan UAV and air photo service fixed-wing UAV flew over the Fukushima nuclear plant buildings to take detailed aerial photographs of the nuclear disaster after the Great East Japan Earthquake in March 2011. An industry quickly grew around this function; many companies have been established that offer aerial photography services using UAVs for surveying and filming movies, and using UAVs to apply pesticide over farm fields is being considered as well. In particular, there was a large number of registered UAVs in Japan these days. This was because of the many unmanned helicopters used for agricultural-chemical spraying. The societal demand for industrial application of UAVs is also on the rise; many electric helicopters have been developed and operated in recent years. Our laboratory developed an original six-rotor helicopter (Mini Surveyor-06: MS-06) and has been examining its implementation for industrial applications. Electric-powered helicopters have many advantages including low cost, risk, and noise, but they are limited in that they cannot be mounted with a large-capacity battery owing to the payload limit, and their high energy consumption only allows for a short operating time. Anyway, our autonomous flight performance is right now as well as the top level in the world. However, there is a limit to the research and development at universities, research and development of the final phase to the aircraft for practical use in terms of reliability, durability and safety is required. Hence, companies, government agencies, research institutions such as universities interested in multi-rotor helicopter joined to build "Mini-surveyor consortium" under the industry-university-government collaboration to commercialize early for industrial applications in 2012. In this keynote, overview of Japanese activities of UAVs, our current technical issues of Mini-surveyor consortium will be introduced and also the argent advanced technologies of fully autonomous multi-rotor helicopter in the world will be presented.

Session 1: General overview

Fuel Cell Power for Unmanned Aerial Vehicles (UAV)

*Dobrovolsky Y.A., **Levchenko A.V., ***Selivanov O.D., **Valiev A.V.
** Institute of Problems of Chemical Physics of Russian Academy of Sciences (IPCP RAS), Chernogolovka, Russia*
*** OOO «AFM-Servers», Moscow, Russia*
****Central Institute for Aviation Motor Development, named after P. I. Baranov, Moscow, Russia*

The revolution in the energy sources is inavoidable in the observable time horizon once the fuel cells technologies appear into the market. Such a mobile energy sources are most demanded for the defense and security applications thanks its unique quality composition especially for UAVs of wide scope of sizes and purposes. This based on the unique advantages of electrically powered vehicles such as:

- Silence
- Infrared stealthiness
- Quick refueling
- Volt-ampere stability and significant duration

The waste majority of UAVs with an endurance time more than two hours are based on reciprocal engine technologies while the restricted work duration of the only battery powered vehicles limits significantly performances where the operational range is most crucial. In spite the early stage of development in the numerous labs the forthcoming fuel cell based energy sources are capable to solve the problems.

Fuel cells with any approaches of energy storage overlap completely the Li-Po batteries by the criteria of source's energy to weight ratio starting from two hours of duration time. Even today's fuel cells with its limited efficiency and low production rates overcome all known types of batteries by energy efficiency in the long haul applications. What will happen when the fuel cells technologies leave the labs and appear as a marketable result?

Current laboratories fuel cell demonstrators have the triple potential of improvement by the energy to weight ratio when it will be produced serially. The qualitative improvements in operational effectiveness, control and all range of environments and flight conditions implementations are also on the way. For instance the number of problems has to be solved to operate in typical Russian winter low temperatures. All aforementioned underlines the strong necessity in the fuel cells further development leading to its further commercialization.

Another underling problem of the active fuel cells implementation is the hydrogen onboard storage linked tightly with supporting infrastructure by the safe delivery of hydrogen and/or its capacitors to the place of operation or producing hydrogen onsite.

The current technologies readiness of UAVs, fuel cells and hydrogen storage solutions are on the milestone when capable to be integrated in the common project allowing to solve number of conceptual, methodical and the real implementation tasks by the fuel cells promotion into the highly prospective UAV world and rise maturity closely to the serial production.

UAV Challenge Outback Rescue - a short history

Roberts J.
Commonwealth Scientific and Industrial Research Organization,
Computational Informatics, Australia

This talk will outline the history of the UAV Challenge Outback Rescue competition in Australia. The UAV Challenge started in 2007 and has run every year since. The aim of the competition is to find a lost walker, who is lost approximately 6km from the airport. Teams from around the world compete for a $50,000 first prize. They must find the walker and deliver him a water bottle. This talk will show how the challenge has developed over the past 5 years.

Around the World with a Solar Powered Aircraft

*'** Ross H., **Ross B.
**Solarimpulse Core Team, Germany*
***Ingenieur-Büro Ross, Germany*

The presentation will cover the design, development, and flight test of the Solarimpulse HB-SIA aircraft. The Solarimpulse program was initiated by Bertrand Piccard and Andre Borschberg in Switzerland in 2003.

It is the one and only manned solar powered aircraft which has demonstrated a more than 24-hour flight with more energy on board at the end than at the beginning. It is a true "all electric" aircraft.

An overview about the transcontinental mission flight in 2012 from Switzerland to Marokko and in 2013 across the United Sates will be provided as well.

Finally an outlook on the status of the development of the record aircraft HB-SIB, which is to start the flight around the world in 2015, will be given.

Fueling Infrastructure for Unmanned Aerial Vehicles with Hydrogen Power Plants

Scherbakov A.N., Smolentsev A.A., Sokolov B.A.,
Rocket and Space Corporation «ENERGIA», Russia

Key technology for widespread use of hydrogen-air fuel cell for UAVs is creating a mobile, compact high-pressure water electrolyser. The RSC Energia has developed a conceptual design for a number of functional modules of the water electrolysers of capacity from 5 up to 50 kW and pressure up to 350 kg/cm^2. The model unit was tested at a pressure of hydrogen and oxygen 120 kgf/cm^2. This opens up possibilities for the application of electrolytic hydrogen refueling infrastructure in future UAVs.

New Technology Development and Deployment

Rohacs J.
Department of Aeronautics, Naval Architecture and Railway Vehicles
Budapest University of Technology and Economics, Budapest, Hungary

The developments of the new technologies appear in three different forms. The innovative technologies improve the existing technologies, existing solutions. The radically new solutions are called as development of the disruptive

technologies that destroy the existing systems to develop a new solution and market for them and finally overcome on the existing technologies. The disruptive technologies initiate radical changes in the given area of economy and initiate a step changes in technological level. Finally, the third type of new technologies is the subversive technologies that cause radical changes on the society levels as happened when aircraft replaced cars in long-haul transportation.

Nowadays the technology development processes are accelerating and every day many new technologies are born. The new technologies must be identified and evaluated before their selection for its deployment (especially their deployment in aeronautical systems).

The technology identification includes the technology compatibility and technology impact analysis. The technology evaluation contains four different types of investigations. At first the technology life must be determined. After that the technology must be valued with use of weighting factors came out from the operational concept of system planning to use of the given technology. Generally, the simulations and (model) tests may showhow the given technology might be useful in further application. Finally, the preliminary certification analysis must show of the possible deployment of the new technology.

The lecture analyses the methods and philosophies of technology and product developments. It describes the basic elements of the innovation theory, technology policy, system engineering method and tries to analysis how to evaluate the technology and product life, required levels of functional goodness.

The second part of the lecture deals with technology identification, evaluation and selection and application of the described method to investigation the possible use of the magnetic levitation technology to ground-based assisting the aircraft takeoff and landing.

The lecture uses the materials of the EU supported GABRIEL (Integrated Ground and on-Board system for Support of the Aircraft Safe Take-off and Landing) project, that is an EU supported project with goal the using the magnetic levitation technology to aircraft takeoff and landing.

Keywords: technology development, disruptive technologies, technology identification, evaluation and selection, GABRIEL concept, magnetic levitation, aircraft takeoff and landing

Session 2: "Small Aircraft Vehicle: CFD or Wind Tunnel Tests"

Research Activities Related to Small Aircraft Vehicles at Tohoku University

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Institute of Fluid Science,
Tohoku University, Japan

This paper summarizes four research activities related to small aircraft vehicles conducted at Tohoku University. The first topic reports the results from field experiments conducted with a team of ground and aerial robots engaged in the collaborative mapping of an earthquake-damaged building. The resulting three-dimensional maps are presented. The second topic is the development of quad rotor tail-sitter VTOL UAV. The demonstration flight will be shown. The third topic is the conceptual design of a miniature, propeller-driven airplane for Mars exploration. A three-dimensional CAD model is presented. The last topic is development of low-speed radio-controlled airplane using Busemann's biplane. To alleviate sonic boom, supersonic aircraft based on Busemann's biplane has been proposed. The small airplane was built to demonstrate its stability at low speed.

Theoretical and experimental investigation of the tailless UAV with s-shaped airfoil

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Kornushenko A.V., Kudryavtsev O.V., Utitskaya N.A.
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Theoretical and experimental investigation of the aerodynamics of tailless UAV with s-shaped airfoil is presented in the paper. Some peculiarities in flow pattern were found.

Aerodynamic characteristics calculations were made by means of XFLR soft. Special s-shaped airfoil has been designed for the aerodynamic model to be balanced at cruise lift coefficient and cruise speed. Airfoil is designed to provide relatively high lift-to-drag ratio and maximum lift coefficient of 1.3.

Experimental research of the UAV model has been made in TsAGI T-103 wind tunnel. High lift-to-drag ratio (about 20) has been obtained in the wind tunnel tests of the tailless UAV model with aspect ratio about 6.2 balanced at cruise lift. Good agreement between theoretical and experimental data is observed. Comparison of the theoretical and experimental results as well as experimental flow pattern highlighted by oil and silk streamers are presented in the paper.

Numerical Investigation of Disc-wing MAV with Wing Slot Propeller

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Moscow Institute of Physics and Technology, Zhukovsky, Russia

Concept of disc-wing MAV with propeller in a wing slot has a number of advantages and disadvantages. The concept is used by MIPTEAM for solving the problem of fixed wing MAV indoor flight by means of lift maximization for wing with low aspect ratio. There are only few investigations of disc-wing MAV aerodynamics with propeller in a wing slot. Present work describes numerical investigation technique and aerodynamic characteristics obtained. The main results are: good stall characteristics of this concept, low lift/drag ratio (further improvement is possible) and sophisticated flow pattern. It was obtained that the main part of the lift is created by wing surface in front of the actuator disk. Also, leading edge separation area produces small impact at the lift even at high angles of attack. It was found that increasing of the propeller thrust decreases maximum lift/drag ratio. Flow features in numerical results correspond to the known experimental results and flight tests.

Challenges of Computational and Experimental Studies of Aerodynamic Characteristics of Solar-Powered UAV at Low Reynolds Numbers

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Because of specific technical requirements for solar powered UAVs, experimental and computational investigation of their aerodynamic performance requires additional effort.

One of distinctive features of aerodynamics of such aircraft is that they, like most electric aircraft, operate at low Reynolds numbers. Hence, it is quite important to provide accurate prediction of transition, which often occurs with laminar separation bubble at flow regimes concerned. This imposes high requirements on computational and wind tunnel investigation techniques.

This report presents some results of computational and wind tunnel studies of aerodynamic performance of the solar powered UAV at low Reynolds numbers. Some questions concerning techniques of computational and experimental research are also discussed.

Session 3: "Low Reynolds problems, Micro Air Vehicles"

CFD Application for Micro Aerial Vehicles. Low Reynolds Number Capability.

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Interest in the design and development of micro aerial vehicles (MAV), or small unmanned aerial vehicles (UAVs), has increased dramatically in the past two and half decades. These vehicles can perform a large variety of missions including surveillance, communication relay links, ship decoys, and detection of biological, chemical, or nuclear materials. These missions are ideally suited to small UAV that are either remotely piloted or autonomous. The design and use of MAVs are currently areas of significant interest, including miniaturizing and controlling such vehicles at various flight conditions. The aerodynamic design must take into account some features of the MAV flight. There are small Reynolds numbers, three dimensional and unsteady effects, capability of flight control at various rapidly varying flight conditions. In order to realize the controllable flight it is required to use the efficient propulsive system and flight control devices on the MAV. To study the MAV aerodynamic and its efficiency it is necessary to use not only CFD modeling or Wind Tunnel tests but utilize surely *both* CFD and (not "*or*") Wind Tunnel Experiments in mutually complementary way. But many MAV flight conditions can be accomplished either in a CFD simulation or in flight tests.

The main objective of the report is to demonstrate in what way complex investigations by CFD and experimental methods may be used in order to understand the complicated phenomena accompanying the MAV atmospheric flight. The atmospheric boundary layer and turbulence such as wind gusts and unsteadiness add the many difficulties to description of the aerodynamic MAV. These difficulties include the unsteady separation, the laminar-turbulent transition, three dimensional effects, rapid changes in the ambient environment. To understand all of these it will be required the specific studies using the CFD and experimental approaches.

The work presented consists on the several studies of the applications of the modern CFD technologies to investigate the various unsteady separated flow peculiarities with regard to MAV aerodynamics. To simulate the aerodynamic characteristics the mathematical modeling were carried out mainly on the base of solving Reynolds Averaged Navier-Stokes (RANS/URANS) Equations. The steady and unsteady flows were studied. It was considered the aerodynamics of two dimensional profiles that are subjected to combined translation/pitch

oscillation. The airfoil dynamic stall aerodynamic characteristics were compared with available experimental data. The aerodynamic of small aspect ratio wing (Zimmerman profile) and commonly used MAV configuration at wide range of attack angle were simulated and obtained results and its comparison with available experimental data are presented. The simulation of the aerodynamic characteristics of the propeller (as propulsion device of MAV) and the propeller in ring wing are presented. The features of the flight of MAV in different conditions in presence of the orography-induced turbulence generated by different obstacles and surface bumps are discussed

High Performance Multi-Mission Electric MAV: Propeller, Aerodynamic, and Stability

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According to some limitation in term of flight speed and flight time of existing multi-mission micro air vehicles (MMMAVs), new concept of MMMAV is proposed in 2012. The Super Brown project was started by the Center of Innovative & Integrated of Mini/Micro Air Vehicle (CiiMAV), Faculty of Engineering, Kasetsart University, Bangkok, Thailand as the final goal of multi-mission hybrid MAV- the MAV which has high performance, able to perform several capabilities, including outdoor, indoor, in the air and on the ground, with high efficient. This report presents about the 1st step of the Super Brown called the Brown project. The objective of current project is design and study of a high performance multi-mission electric MAV which able to hover and fly at maximum speed of 15m/s based on tail-sitter tilt-body configuration.

The Brown MMMAV was design by CAD program. In-line propeller system was selected to attach on the rectangular MH-45 wing. Two control surfaces on the wing's trailing edge were designed for pitch and roll motion while another rudder on the vertical fin was used for direction control. Three subjects were conducted. The first topic is the main idea of the Brown MMMAV, therefore high performance propeller was analytical and experimental study. The experiment carried out in wind tunnel showed that electric power can be reduced by 20-30% compared with the old propeller system of MMMAV. Then, the project was following by the study of aerodynamic characteristics including the effect of propulsive induced flow on the wing-body for the second topic. The wind tunnel model was designed and constructed by adding load-cells inside the model for measure of propulsive parameters. The forces and the moments of model, then, were measured by an external force balance in order to find trim condition at speed of 0, 7.5, and 15 m/s. The trim conditions for all three flight speed were obtained. Twin propeller were required for hover and transition flight at 7.5m/s while only aft-propeller run at high speed flight of 15m/s. All parameters were recorded. Aerodynamic characteristics of the Brown were analyzed. Some static aerodynamic derivatives were calculated. The last topic aimed to study horizontal and vertical flight stability of the Brown. As the tilt-body concept, the Brown must perform between horizontal and vertical flight result in a difficulty for locating the center of gravity (CG). For the horizontal forward flight, CG should be placed ahead of aerodynamic center for a stable condition. This was opposite to vertical hovering where lower CG's position was desired. Therefore, artificial sensor and control system were introduced especially for hover flight. Pure pitching motion test was done for forward and hover flight. The result of PID gain agrees with the Ziegler/Nichols method.

According to these studied in wind tunnel, it confirms that the Brown MMMAV has good performance and efficiency. Maximum flight speed can be reach at 15m/s with low electric consumption rate. Low propulsive induce drag was found. Simple automatic control theory and low cost sensor were sufficient for stability of aircraft.

Optimization of High-Lift Airfoil with High Flap-Type Controls Efficiency for Solar-Powered UAV

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The modification of existing high-lift airfoil for low-Reynolds flight (Reynolds number is about 10^5 10^5) was required to design a small-sized solar-powered UAV. It should have high flap-type controls efficiency. A 12-percent Wortmann FX 63-137 airfoil was taken as an original airfoil. The main changes influenced the efficiency increase of trailing edge deflection are the decrease of camber down to 4.66% as well as the decrease of the midline curvature at 70-80% of the chord. In addition the thickness of the trailing edge was enhanced up to 0.81%. XFLR5 code was used for the airfoil design.

New airfoil neo-12-4 was compared with the original airfoil at Reynolds number Re = 100 000 using XFLR5 code. The comparison of the efficiencies of the trailing edge deflections for original airfoil and neo-12-4 was performed. Aerodynamic characteristics of the airfoil in question were computed. The advantages of the new airfoil are:

it has better glide ratio at $C_L < 1{,}3$ $C_L < 1{,}3$; the gain is about 20-40% at $C_L = 0{,}8 \div 1{,}0$ $C_L = 0{,}8 \div 1{,}0$;

efficiency of tail edge deflection downward at 70-80% of the chord is about 2 times better;

the pitch moment of the airfoil in question is about 20% less than one of the original airfoil.

The airfoil in question is inferior to the original airfoil in the maximum lift coefficient: $C_L = 1{,}55$ $C_L = 1{,}55$ versus $C_L = 1{,}6$ $C_L = 1{,}6$ for original airfoil which is about 3% less.

Session 4: "Avionics"

Autonomous Multirotor UAV Flight Control System Based on GPS and INS Data Fusion

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Multirotor Unmanned Aerial Vehicles (UAV) are known as good flying platforms for high-quality aerial photography, videography, monitoring and other terrain explorations due to their ability of low-speed flight, hovering and vertical take-off and landing, which makes them easy to use in space limited conditions.

Obviously, the behavior of such vehicles is unstable. Therefore, Flight Control System (FCS) is required which must be responsible for both stabilization and navigation functions. Key feature of such device is capability of fully autonomous flight. Rapid development of contemporary electronics makes possible to create low-cost and compact FCS, which can be integrated in small UAVs. However, accuracy of implemented measurement units is not high. Multi-sensor data fusion is one of the methods for its increasing.

Present paper describes the requirements and general concepts to be guided in the development of FCS as well as results obtained in flight tests and their comparison. Special attention is paid to multi-sensor data fusion methods, which allow increasing flight precision and reliability. Moreover, the description of hardware and software architectures is provided.

FCS's hardware consists of main board and peripheral devices. Main board includes Micro Electro-Mechanical System (MEMS) sensors for attitude and position determination. The board has accelerometers, gyroscopes, magnetometer as well as a pressure sensor for altitude measurement. In addition, there is microSD card slot for configuration storage and in-flight data logging. The board is very compact and light (60x40mm, 14g) which makes application in small UAVs possible.

The software architecture consists of several levels: from the lowest - STM microcontroller libraries to the highest – flight control logic. CMSIS Library from STM makes possible to create higher software hardware-independent. The second level is STM Library, which provides high-level functions for microcontroller peripheral communications. Next level includes drivers for sensors readings and actuators control. The highest level consists of functions responsible for stabilization, navigation, flight control and digital signal filtering where it's necessary. Additionally, the highest level includes GCS interface functions based on MAVLink communication protocol library.

By the moment, FCS described above allows multicopter UAV to fly autonomously (including auto take-off and landing) based on GPS navigation with real-time flight observation and control via GCS. The results obtained during flight tests being analyzed showed that only GPS navigation is not enough for high-precision UAV positioning. Several methods of increasing positioning accuracy are available, among which is GPS and INS (Inertial Navigation System) data fusion. One knows that the acceleration being integrated twice returns displacement. The advantage of GPS is position determination on a global scale, but precision in a certain point is poor. In contrast, INS is unable to provide global location, however relative displacement can be calculated quite accurately. One knows that MEMS sensors measurement accuracy is not high, therefore special filtration, integration and error compensation methods should be applied. Different methods and various combinations will be considered and compared in the full paper. Furthermore, pressure sensor and Z-accelerometer data fusion methods for precise altitude hold are covered. To sum up, the key idea of the method is calculation of true flight parameters having inaccurate measurements from sensors achieved by multi-sensor data fusion.

It is worth mentioning that the research is conducted with presented FCS, which provides opportunities for flight tests as well as parameters logging and their subsequent analysis.

Autonomous Take-Off and Landing of Helicopter Unmanned Aerial Vehicle

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This paper is dedicated to the actual problem of autonomous navigation of unmanned aerial vehicles (UAV). In particular, the problem of automatic vertical take-off and landing of helicopter UAV is considered. In order to solve this problem the computer vision techniques is used. In case of take-off and landing, one have to provide complete and accurate information of the aircraft's state vector and landing pad position and orientation relative to the aircraft to the automatic flight control system (AFCS). The goal of this research is the developing of computer vision system, which could provide AFCS with sufficient data to perform autonomous take-off and landing.

Briefly, algorithm of operation of computer vision system can be described as follows. System obtains images from cameras installed outside UAV. Then stabilization and normalization of images are applied. After using of automatic threshold algorithms, the system starts searching the pattern, which corresponds to the

landing pad (which has a predetermined pattern). In this case, the central moments analysis of images is applied. After finding the most likely object the systems tracks it in the sequence of images using Kalman filter.

The algorithm described above was successfully tested on the hardware-in-the-loop testing bed. The computer generated images were used as an input to the computer vision system as well as photos and videos of take-offs and landings. Helicopter's flight dynamics and AFCS were also modeled on the stand, which made it possible to test autonomous take-off and landing with computer vision system in the control loop.

Safety of Flightsof Remotely Piloted Aircraft in Single Airspace

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One of the most significant achievements in aviation for the last decade is the appearance and rushing development of Unmanned Aerial Systems. Originally, Unmanned Aerial Vehicles were used only for military purposes, but in the process of their development they began to be used actively in the civil sphere. It is obvious that Unmanned Aerial Systems (UAS) will play a more and more important role in military and civil spheres in future: they are already used by the Ministry of Emergency Situations, the Ministry of Internal Affairs, Frontier Service and in forest conservancy. They also carry out the monitoring of Olympic objects construction in Sochi.

The Remotely Piloted Aircraft (RPA) represents the subcategory of Unmanned Aerial Vehicles. In ICAO №328 Circular it is defined that RPA is an aircraft which is controlled by the pilot who is not onboard.

The application of Remotely Piloted Aircraft (RPA) in single airspace substantially depends on the maintenance of the safety level of their flights. It should not be less than the existing level of safety reached by civil aviation.

As the probability of the device collision with other aircraft in the air is rather small in comparison with the probability of RPA flight into terrain, in this work only the RPA destruction during flight into terrain is considered.

As a result of this work, the borders of limiting probability of RPA wreck are obtained depending on the class of the aircraft and population density of the district where the flights are carried out.

Multiple Target Tracking with Bearing-only Measurements

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Bearing-only target tracking is one of the most difficult tracking scenario. Measurement function is highly non-linear and the target range is not available.

In 1947 Stansfield has solved with this problem for the first time in terms of statistics. Since his pioneering work several bearing-only tracking algorithms were proposed. Extended Kalman filter [1], pseudo-measurements approach [2], or Unscented-transform [3]. But, all these algorithms are addressed to the single-target localization problem.

The first solution of multiple target tracking was systematically described by Ried [4] and was based on the track maintenance and measurement-to-track association. Unfortunately, the optimal solution is not feasible (due to exponentially expanding hypotheses tree) and some suboptimal methods should be applied. One of the most interesting (real-time implementation) is based on the K-best hypothesis choice [5]. The best hypotheses are chosen with a Murty's [6] K-best linear assignments. But, as noted in [7], in case of bearing-only multiple-target tracking scenario the targets' position estimates may diverge due to "ghost" tracks problem (fig. 8 of [7]).

Mahler has proposed another approach to multi-target tracking problem. Rather than maintain track tables and perform measurement-to-track association, the whole multi-target state is represented as a random finite set [8] and estimated jointly with every new set of measurements. Multi-target state is represented by a probability hypothesis density (PHD) function, which is propagated through the general Bayes' rule. The closed-form solution of the Bayesian filter may be obtained in the limited number of scenarios. Linear Kalman filter is one of such scenarios [9]. To solve the Bayesian filter equations, some PHD approximations are needed. There are two well-known approaches: the first one represents the PHD function as a system of weighted particles (SMC-PHD) [10], the other one utilizes Gaussian mixtures (GM-PHD) [11].

We have implemented both SMC and GM PHD algorithms for the single-target tracking scenario. Due to its resampling phase (see [10] for details), the SMC-PHD filtering approach has failed to obtain the target state information due to unobservable component of the target's state. The Gaussian mixture filter, implemented in the same manner as the range-parameterized Extended Kalman Filter [12], has shown good results.

Utilization of GM-PHD filtering is described in several papers (such as [13]), but the most of scenarios do not consider bearing-only measurements. For example, in [13] bearing and elevation angles are measured and the elevation angle carries information about the target range.

In this work we present a solution of multiple stationary targets bearing-only tracking problem with the following limitations and assumptions:

- Single UAV with on-board direction finder;
- Closely spaced targets;
- Random target behavior (appearing ad disappearing);
- Less-than-one detection probability and high clutter.
- Using the simulation in different scenarios we have investigated, that this algorithm does not suffer from the "ghost target" problem, and, by limiting the number of Gaussian mixture components, this algorithm may be invoked in real-time on-board the UAV. This algorithm may also be easily expanded to scenarios with multiple UAVs.

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Round Table 1: "Involving young people into the aerospace science"

Experience in Young People Involving into Aerospace Science

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"Old age and youth are merged into continuous operation
for the knowledge of the Truth" (N.Ye. Zhukovsky, 1911)

Our round table is related to a very important up-to-date problem of involving young people into the aerospace sciences. This brunch of human activity is very young. Only 110 years separate us from the first flight of aircraft, and less than 40 years from the launch of the first artificial satellite of the Earth. Problems of the flight safety, all-weather and green aircraft, space debris and many others haven't been solved up to now. Aerospace industry and science require young talented people.

Mentioned problems are not the national one, they are global. We have common sky, common atmosphere and common safety. Our Earth is very small and population is very tight to neglect these facts.

Unfortunately, we have recently seen the diminishing attraction of the aerospace professions for young people. Some examples of Department Aeromechanics and Flight Engineering of Moscow Institute of Physics and Technology practice in young people involving into aerospace sciences will be considered in the presentation. They are:

- open doors day when schoolboys and girls visit University and see auditoriums, lecture rooms and laboratories, attend the experiments with explanations and presentations, have meetings with students and professors;
- excursions of the students to the aerospace research and industrial centers;
- conferences and contests related with their future specialties;
- University's international cooperation, students exchange;
- air sport as a practical application of the knowledge gained;
- flight practice and experiments, which support the theoretical education;
- small-scale enterprise, where young men gain experience of participation in the research and technology projects; the main goal solved here is to teach young people to think in the form of the project, i.e. to do the concrete work in the restricted time based on restricted funding.

The topic of the conference is closely related to such problems as developing the flying robots and creating the artificial intellect, which represent the wide and unique possibilities for innovations. In particular such problems should be solved as the optimal power plant and source of energy, developing artificial intellect and control system especially for soft landing and flight in turbulent atmosphere, creating flapping wing or rotor type systems for the lift generation at low speed where the payment for the fixed wing lift creation increases dramatically.

The topic of the conference itself is attractive for the students, young scientists. And the idea of its organizing is motivated essentially by the task of involving the youth into the science

Design and Making of a Hot Air Balloon With Load Capacity of up to 70 kg, With Solid Fuel Heating Unit.

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The design of the modern hot air balloon was investigated. Calculations and drawings were made for chosen capacity of 70 kg. Different types of fabric were analyzed. The fabric Ray Dewspo was chosen for manufacture of the envelope. The heating unit operating on solid fuel and the suspension for a pilot on a hot air balloon were created. A variety of solid fuels which currently have not been effective was tested. At the moment launch of the thermal balloon is carried by a gas heat gun.

Mini and Micro UAV Activities at Kasetsart University: the Way Young Peoples Involving Aerospace Science

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It is absolutely hard to manufacture any type of manned aircraft in Thailand although almost 100 aerospace engineers graduated each year. Very rare aerospace engineering position can be found, except maintenance. Regarding to the concept of "learning by doing" and "creative learning", the Department of Aerospace Engineering, Kasetsart University, Bangkok, Thailand (AeroKU), few research topics were offered by AeroKU (for ex. wind turbine, composite material, and turbulence modeling). Nevertheless, these topics cannot attack young student who are interested in touchable and fun topic. Therefore, unmanned air vehicle (UAV), in particularly a micro UAV (MAV), is the solution. Moreover, the materials become less expensive, the size is small, AeroKU can support the project and even some student can buy by themselves for their fun. Now, three sectors of this area are organized in AeroKU.

First, "senior project" is an activity for students who interested in particular area. Research level activities of MAV and small UAV were organized by the support of supervisor. Young people can share their idea and apply the knowledge to solve the problem. Several projects were done since 2011 including aerodynamic of KuMAV001, aerodynamic analysis of adaptive wing, high performance propeller system, design and build of tower banner UAV, drag reduction by modify wing tip's thickness, quad-rotor and etc. Some of these projects were international presented as well.

Second, "micro air vehicle's class" is technical-selected subject. Beside of course work or lecture, students have to done term project. A small competition was organized in the class. Team of 3-4 students must design and build their own small flying vehicle. This option, young people can involve in the field of their interest such design, structure, manufacturing, aerodynamic, propulsion, electronic and control. Team work and good communication were the task to reach the great result as well. Project management must be taken in to account as well since they have very limit of time and budget. For this activity, the student can practice and apply their knowledge and idea to the real and touchable airplane.

Two options above can be involved only by the 3rd and 4th year students. The last activity which younger people or anyone can participate is a research group or the project initiated by AeroKU. As mentioned, AeroKU has several research area interested by our staffs, but these have low attractive to young people and very few students have joined the group. After the year of 2011, AeroKU started to create MAV activity. This seems to be more attractive and challenge for young students. They now spend their free time involve with the scientific topic instead of spend their time on computer games and social networks. At the moment, two groups or laboratories focus on MAV. iSAAC lab works on the control system especially multi-rotor configuration. CiiMAV group involves in aerodynamic, design, propulsion, and manufacturing. Their aim is to participate and fly their MAV in an international competition in 2014. The AeroKU's project is another section where young students can involve as well.

Using UAVs in Education to Support Development of Engineering Skills

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The students specialized on vehicle engineering especially on aeronautical engineering must study several special subjects. These subjects and generally the curricula include three major parts: aircraft development philosophies, aircraft design and aircraft systems and parts design. Of course, students have passed the subjects like mechanics, stress analysis, aerodynamics, flight mechanics, etc., because without this knowledge the basic fundamentals wouldn't be understood.

Today an Aerospace student cannot even get a Bachelor degree without useful software and practical knowledge. Buying software is just the beginning; students have to learn how to use it and how to integrate this knowledge into practice.

At the Department of Aeronautics, Naval Architecture and Railway Vehicles in Budapest University of Technology and Economics lot of high level software are used (e.g. ANSYS Workbench, LabView, MATLAB) to support students to learn modern software environments used by companies in many field of innovation.

Using the rapidly developing UAV technology provides the best way to transfer theoretical knowledge and developed high-level software skills into practice. In the Department there is an opportunity for every student to develop CFD software, design and build UAVs for different purposes, design control laws, which can be tested in flight simulator laboratory or on UAVs and this is a new way to involve people to this industry who do not have degree in Aerospace Engineering, because the structure of software built in a UAV is not perforce a job only for an Aerospace Engineering.

The paper describes how different software, UAVs and the flight simulator laboratory are used to wake up students' interest on aeronautical sciences, support their choice to be and support their education while becoming an aeronautical engineer. Finally it shows some results of applying high level software and UAVs to solve aircraft development, design and research projects.

Keywords: high level engineering software, UAV, Unmanned Aerial Vehicles, teaching method, practical applications

MiniUAV Design for Specific Technical Requirements

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There is a number of specialized and multipurpose small unmanned aircraft for various purposes. MiniUAV creation doesn't require a large productive capacity, so there is task of design specialized unmanned aircraft for specific technical requirements and payload. The small UAV design process for the specific requirements is considered in this work.

The main technical requirements for the vehicle here: range of 120 km, the possibility of the payload disposition in front of the propeller, take-off speed of 15 m/s, maximum speed of 30 m/s, mass of avionics 200 grams, payload 100 grams.

The closest UAVs for the requirements are the T23 Aileron, AeroVironment Raven and Zala Aero 421-08. Based on the open technical data for these UAVs, the total mass of designed UAV is estimated to be 2.5 kg.

The "flying wing" configuration was initially chosen for washed surface area minimization. Wing area was varied for the constant span and overall "range parameter" (multiplication of the lift-to-drag ratio and propeller efficiency) was estimated under two cases: constant airfoil and constant absolute thickness of the wing (that corresponds to the wing disposition of the accumulators). The most efficient propeller for the wide range of configurations is APC Thin Electric 11x7. All calculations and estimates are carried out with Belotzerkovsky vortex method (realized in XFLR free software), engineering methods and experimental results for airfoils and propellers [Selig].

The maximum propeller efficiency mode and maximum lift-to-drag ratio are investigated to be reached at different flight speeds. For each wing area optimal flight mode (speed) was calculated. The mode of the maximum range is at the inductive branch of the aerodynamic polar that requires special measures to reduce the inductive losses (trapezoidal wing planform with a moderate taper ratio, special winglets).

An airfoil was selected for the specified lift coefficient and Reynolds number obtained in the research. It is found that wing with the smallest possible surface area (0.25 m2, active restriction - takeoff speed) provides the best range in case of constant airfoil, and all configurations are essentially the same in the case of constant absolute thickness of the wing.

Fuselage configuration was investigated. It's found that this configuration has essentially the same range as flying wing due to use of the airfoil with smaller relative thickness (9% vs. 13%, required for the area of 0.25 m2) and drag coefficient at zero lift. Assembly of the fuselage configuration is more convenient than flying wing one.

Range parameter significantly increases with the wingspan from 1m to 1.2m (17%), then the growth slows down (with increasing magnitude from 1.2 m to 1.5 m parameter is increased by 15%).
Fuselage assembly with wing span 1.2 m, area 0.28 m2, profile RG-15, taper ratio 2 was selected. Wingtips are protected from stall by geometric twist of -3 °. Given twist was chosen due to maximum lift-to-drag ratio conservation relatively to untwisted one.

V-tail configuration was chosen with reverse V. This configuration is good for the coordinated turn, and doesn't get into the propeller stream, that reduces the roll torque due to thrust regulation.
Tail parameters are selected from a Byushgens cross (stability/controllability diagram) and lateral stability/controllability recommendations. The established parameters determine V angle in 35 °. Tail beam length is chosen for minimization the total area of the beams and tail and is about 0.6 m. This criterion takes into account both the mass and the friction drag of the tail and beam.

Thus, miniUAV configuration was formed for the technical requirements.

Session 5: "Design"

On the Problem of Choosing Parameters of Solar-powered UAV

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- Solar-powered UAVs have a large potential of increasing the flight duration among heavier-than-air aircrafts since the available energy can be permanently replenished.
- The goals of this work are:
- evaluation of the flight duration of solar-powered UAV at Moscow latitude;
- obtaining the equations for the mass of the chemical power sources and photocells used in the solar-powered aircrafts;
- finding the allowed range of specific wing loads and flight speeds typical for the aircraft under consideration.

- The time periods at which solar-powered aircrafts such as Solar Impulse can maintain the flight 24 hours a day are considered. The dependencies of these time periods on the main parameters of the design and the flight regimes are analyzed. The computation of the power source mass for the high-endurance aircraft is accomplished. The range of speeds and specific wing loads typical for such aircrafts with possible restrictions arisen due to the design features of such aircrafts is considered.

Research on Optimization of Structural Layout of the Straight-wing Aircraft Made FromComposite Materials

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This work considers the wing of an unmanned flight vehicle made from composite materials. The possibility of reducing design loads on the wing using the anisotropy of composite material is investigated in the article. The various variants of the anisotropy are also investigated in order to receive optimal ratio of orientation angles of composite layers. The different strength criteria of the composite wing skin are applied and comparison of optimal variants is performed.

System of Aerodynamic Design of Small-sized Unmanned Aircraft Layout

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The paper presents a technology of quick calculation of aerodynamic characteristics of small-sized unmanned aircraft-type aerial vehicles on cruising. The technology is based on the effective methods of direct aerodynamic computation, mathematical apparatus of artificial neural networks and information technologies. Examples of applications of this technique are given in the preliminary design of the prototype.

A layout generator with a fixed base of profiles, mathematical model of the layout, space of input parameters and the range of their changes are described in detail. Examples of a number of obtained layouts are given.

Descriptions of the method of direct aerodynamic computation and examples of computation for the layouts mentioned are given. An approach to the development of the system of quick calculation and design, based on the above components, is described.

The Assessment Model of the Efficiency of Solar Radiation Receiving and Conversion by the Aircraft Surface

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The assessment model of the efficiency of solar radiation receiving and conversion by the aircraft surface has been developed. It includes the model of sunlight transmission in the atmosphere and the model simulating a 24-hour autonomous flight of a solar aircraft. Computer programs ("Sun" and "Flight") based on these models have been created.

"Sun" program enables to calculate current sun energy flux and integral energy for a given time period coming onto a square meter of a sun-following panel. The Solar radiation reflected by the underlying surface and scattered by the clouds is estimated to be negligible in comparison with the direct irradiance. So in the model of transmission only direct radiation was considered. The input data for the program are: a day number of a year, latitude and an altitude of a solar panel location, a time interval and a time integration step. The results obtained with the aid of "Sun" program was compared with ones from Modtran and showed good adequacy. So the developed model gives credible results and can be used at the initial stage of a solar aircraft projecting.

The energy collected during the day by the solar panel, calculated by "Flight" program, is stored in the accumulator battery with a given efficiency. The power needed for the flight was calculated and compared with the incoming solar energy. The input data for the "Flight" program are: a day number of a year, a flight altitude, aircraft characteristics, a latitudinal interval and a time integration step. The altitude-latitude feasibility area was obtained for the range of solar battery efficiency (10-20-30 %).

Atmospheric regions (altitude – latitude frame) where a 24-hours flight of the concrete solar aircraft at constant altitudes is possible at different days of the year were obtained.

Session 6: "Aerodynamics"

Fensap Ice Applications to UAVs

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Although UAVs are still not mandated to be certified against atmospheric icing, it is becoming more of a concern as sophisticated and expensive UAV designs are entering service. UAV all-weather operation for surveillance and reconnaissance missions demands adequate performance in adverse atmospheric environments. Therefore, more UAV designs are incorporating active ice protection systems, which require more in-depth performance analysis of the aerial vehicle for flight into known icing. We will present FENSAP-ICE, a state-of-the-art in-flight icing simulation system, and demonstrate 3-D highly detailed ice accretion predictions for a rotorcraft and a fixed-wing UAV, as well as the necessary electro-thermal anti-icing. The complete vehicle simulations include rotors and propellers modeled as actuator disks, as well as all incoming or outgoing flow through main or auxiliary inlets or outlets. The calculations show that modeling of these features are crucial in obtaining realistic ice shapes as they are strongly influenced by the streamtube contraction, which causes local enrichment, as well as directional changes. On a fixed-wing UAV, this can be observed on the horizontal stabilizer, which is located close to the propeller because of the pusher configuration, while on a rotorcraft UAV, flow through the tail rotor drives the ice accretion process on the tail assembly.

Computational Simulation of Flow over Solar-powered UAV Using CFD Code FlowVision

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In this work an UAV with electric motor having solar cells set on the wing surface is considered. A numerical computation of flow over the vehicle using CFD code Flow Vision is performed. Aerodynamic characteristics at different Reynolds numbers corresponding different altitudes and speeds of flight are obtained.

High-Fidelity Numerical Experiments in Transitional Airfoil Unsteady Aerodynamics, Acousticsand Flow Control

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We report on a series of benchmark high-fidelity numerical studies investigating various forms of low-speed airfoil unsteady responses in non-uniform flow and means of their control.

The first part of the talk discusses numerical predictions elucidating micro air vehicle (MAV) behavior in gusty environments. The flight path of an aircraft in an urban canyon is often characterized by sudden crosswinds and turbulent drafts that may have a particularly strong effect on small vehicle aerodynamics and overall flight stability. Development of efficient flight control strategies should benefit from high-fidelity studies revealing airfoil responses to various types of flow disturbances characteristic of such unsteady environments. To this end, we propose several deterministic and non-deterministic canonical forms of impinging flow disturbances and examine their effect of unsteady aerodynamic, aeroelastic and aeroacoustic responses. For a transitional airfoil, we particularly focus on complex nonlinear resonant phenomena such as flow-acoustic feedback-loop interactions and their effect on the airfoil response.

The second part of the presentation is devoted to studies of the airfoil flow control using distributed arrays of synthetic-jet micro-actuators. We show that micro-jets may produce significant impact on boundary-layer vorticity dynamics and thus on aerodynamic and even acoustic responses.

Computational Investigation of an Airliner Damping Derivatives

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Investigation of unsteady aerodynamic derivatives is carried out using BLWF program [1]. Aerodynamic configuration of a typical airliner that oscillates harmonically with small amplitude at a specified frequency in compressible flow is considered. The configuration includes fuselage, moderate sweep wing, two nacelles without struts and horizontal and vertical tail. For configuration under investigation the aerodynamic interaction effects are considered. At the first stage the basic steady flow field about aircraft is computed with taking into account viscosity effect within the framework of the boundary layer theory including moderate flow separation on the wing. This flow field is used as an input for unsteady computations. The procedure of nonstationary computation is based on unsteady Euler equation linearization in the vicinity of stationary solution. Derived set of equation is then integrated numerically by implicit method using method of cross computational nets.

The derivatives of aerodynamic forces and moments with respect to kinematic parameters in longitudinal and lateral channels for a modern airliner are computed. A comparison with experimental data obtained on the dynamic rig with free oscillation on elastic hinge in the wind tunnel T-128 [2] at TsAGI is carried out. Good agreement of experimental and calculation data is demonstrated. The dependence of rotational and unsteady derivatives on oscillation amplitude and frequency is investigated.

This work was supported by the Ministry of Education and Science of the Russian Federation within the federal target program "Scientific and scientific-pedagogical personnel of innovative Russia" in 2009-2013 (project No 14.U01.21.8377, 14.U01.21.8759) and the Russian Foundation for Basic Research (project No 12-08-00679).

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Session 7: "Flight dynamics, path optimization"

Some Results of Electrical Aircraft Flight Path Optimization with the Help of Pontryagin Maximum Principle and Their Implementation to Design

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Present day technologies and materials (especially in energy storage and solar cells) do not allow to make the electrical aircraft with good flight characteristics without the thorough design process and appropriate control during the flight. The best results can be obtained with the help of Pontryagin maximum principle.

In the report a set of results of flight path optimization will be presented.

Rather simple and rather important is the task of flight for maximal time (minimal mean power) at the constant altitude for airplane without solar cells. The results obtained also allow to define the optimal weight of energy storage as part of total weight for the flight time optimization. Calculations show that, depending on the viscous drag model, the mass of energy storage is 66-70% of total aircraft mass. It should be mentioned that the same result is valid for hovering helicopters and multi-copters. Also, if the energy storage mass is reduced to 50% of total mass the flight time decreases only on about 5%. The other result is that for constant non-dimensional characteristics of airplane the maximal flight time increases linearly with wing span increase.

Other task is the consumed energy minimization for the flight from point to point with the wind presence in the case of fixed trajectory and non-fixed trajectory.

The next important task is the mean power minimization for the airplane with solar cells. First of all, for the fixed value of solar radiation intensity the optimal flight altitude exist that corresponds to the minimal energy consumption from onboard energy storage. For the case of changing solar intensity (for example, during the day time) some optimal trajectory exist. At the first approximation, at any moment of time the flight altitude must correspond to the optimal altitude for the solar intensity at that time moment. Of cause, if the intensity is low enough or during the night flight the aircraft must fly along the lower altitude restrictions. Results show that optimal trajectory in vertical plane allows to save up to 35% of energy comparing with the flight at constant "optimal" altitude.

At least, the results obtained allow to optimize the design of airplane with solar cells. Analysis shows that for the defined flight conditions and fixed value of constant masses (payload, electronics etc.) some maximal value of airplane gross weight exist, and for this case the constant masses are some fixed part of total weight.

On the Flight Path Choosing for the Electrical UAV Endurance Maximization

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Application of solar batteries on the electrical UAVs currently seems to be very attractive. Obtained by the solar batteries during the daytime, the electrical energy can be spent during the hours of darkness. That can considerably extend the UAV endurance. However, to store more energy on the UAV board, more accumulators are needed, what results in the aircraft mass increase and hence, flight duration reduction.

The current work deals with the UAV trajectory optimization problem. The flight endurance is taken as an optimization criterion, while the flight path is treated as a consequence of climb and descent parts. The accumulator mass reduction at the expense of appropriate trajectory choosing is also considered

Optimization of Aircraft Motion by Method of Traveling Wave

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This paper considers the possibility of using a method of traveling wave to optimize the movement of an aircraft in flight, presented the essence of the method and application features for the problems of flight dynamics as well as some features of the choice of criteria and control parameters.

The proposed method allows obtain optimal depending on the time control actions to ensure minimum energy consumption when climbing, descending, and other phases of flight. Also, considered the problem of flight for a certain period of time to a maximum height or maximum range.

In the calculation of the optimal controls also is getting the optimal flight trajectories, and these results can be used during the installation of the payload, defining the terms of the equipment, etc. In solving the optimization problem of the trajectory of motion by this method are taken into account constraints on the various parameters of flight, such as airspeed, altitude, angle of attack or lift coefficient, the maximum available thrust.

The presented results were obtained for UAV's of two different classes. Showing results of solving next problems: a problem of flight to maximum height and maximum range for a specified period of time, and a problem of minimization of power consumption in climbing at preassigned height for a given time.

Intelligent Search and Tracking of Ground Mobile Objects by Using Autonomous Group of UAVs

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In present time UAVs are widely used in tasks of searching terrestrial mobile objects. The method with using only one UAV has some shortcomings, such as restricted field of view of camera, algorithms of tracking and etc. By using of coordinated group of UAVs [1] and adaptive algorithm of tracking can significantly improve performance of the processes of observation such as intelligence, search of objects, aerial photography, monitoring of emergency situation, monitoring of pipelines and power lines, etc. The complexity of managing group (groups) of UAVs is related to solving several problems. For example, operative flights planning of individual UAVs, because of changing the field of interest, supporting of safety flight etc. In many cases, these procedures can't be implemented by the operator in real time and need to reduce their volume and / or automation.

In the present paper is considering the problem of solution the task of intelligent autonomous search of ground mobile objects by using autonomous group of UAVs.

A method of selecting an area where the object could be with most probability was developed to solution assigned task. This method is based on analyzing of the current situation [2] and uses for its work database, knowledge bases, descriptions, which should be formed before.

One of the approaches that allow improving efficiency of observation tasks solution in uncertain conditions is the implementation of an adaptive complex algorithm of image processing and analysis. The algorithm provides the ability to implement the observation processes in a complex and changing conditions of observed scene or during the study of less informative scenes using the technologies of situation analysis.

An adaptive complex algorithm involves set of private observation algorithms and algorithms of the situation analysis. A set of particular algorithms provides a solution of problems of detection, tracking and motion parameters based on the identification and evaluation of particular features of the objects of interest. Particular features can be the distribution of brightness, color features, motion features, contours and shapes, constellations of characteristic points and etc. By increasing the number of private informative features, may be increased the reliability of the whole adaptive algorithm.

Keywords: analyzing of the current situation, autonomous group of UAVs, selecting an area of interest, intelligent search of ground objects

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Practical design and implementation issues in flight control system of JAXA's disaster-monitoring UAV

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Our main focus here will be on design and development process relating flight technologies to achieve fully automatic operations of a fixed-wing mini UAV developed for disaster-monitoring mission. The JAXA's UAV has been developed for 5 years mainly for assisting an early stage of rescue activities by providing a bird's-eye view immediately after an earthquake occur. The technological efforts have been put into an improvement of practical availability and safety. The key concept of the developed system is "full-automatization" of whole operational procedures. The proposed system needs no human intervention in total operation between launch and recovery.

Generally speaking, design and implementation of a flight control system for a fixed-wing aircraft has been recognized as a trivial task already tried-and-tested many times in the past, so control engineer's main concern has been shifted to a constrained path optimization rather than control problems, which minimizes a cost for mission achievement and energy efficiency considering the maneuverability of the aircraft, obstacle avoidance against natural terrains, artificial structures and so on. On the contrary to this trend of research, we consciously high lightened flight control system again considering what we really need actually in disaster situations.

In building fully automatic system, the number of flight modes tends to increase. As the flight modes increase, the design points in the conventional linear controller design also increase synergistically. The design and development of control software would be complicated accordingly, and the resulting cost would be higher and higher. To deal with this problem we have used a nonlinear dynamic inversion based control structure from the following advantages; 1) Straightforward extensibility according to the increase of flight mode, 2) Systematic design procedure considering robustness issues and 3) Tuning and debugging process with clearly physical meanings. What should be done is always clear in the proposed control structure.

Session 8: "Theory and practice of "unconventional" flying vehicles (flapping wing, balloons, hovercraft etc.)"

Developing a Scale Model of a TiltrotorCraft.

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The aviation park of Russia has not an important type of aircraft - convertiplane that takes mix characteristics for plane and helicopter and combines their advantages.

Convertiplane indispensable in situations where the helicopter not able to reach, or the airplane not able to land. World of convertiplanes at the beginning of rapid growth. Russia have a unique opportunity to take a leading position in a new segment of world production of this type of unconventional aircrafts.

MIPT students in cooperation with the staff of "TsAGI" and DB "Stalker" (Krasnodar) a draft of the transport tiltrotor craft, in general shapes looks like a "V-22 Osprey" and its main parameters are optimized for tasks of operational maintenance of gas condensate fields, removed from the main base to the 50-600 km.

In the research were involved undergraduate and graduate students MIPT. Basic research of the project "Stalker-501" have been made under the state contract number P-612/2010 FTP, won the competition Ukhta State Technical University (Ural State Technical University).

On mathematical models studied the problem of creating the device with the specified basic characteristics using two TV3-117VMA-03 rated at 2,500 hp (Used on Mi-8 helicopters).

The Method of Choosing the Optimal Hydrodynamic Scheme and Construction Parameters of Underwater Gliders.

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A modern development of microelectronics and electric accumulators allows to create underwater vehicles which have a high cruising range and endurance. Nowadays in the world for realizing this opportunities the so called underwater glider is popular. These devices are made by an aircraft scheme and their movement is carried out by changing buoyancy, with the wings providing horizontal movement. The available literature does not mention the energy efficiency of underwater gliders, its comparison with the classical vehicles, which move by using a propeller. In this paper a number of numerical calculations are made to determine the hydrodynamic characteristics of the existing underwater gliders. Basing on these results, we have defined the required energy to move underwater vehicles. Also, the estimates of energy consumption were made for similar vehicles without wings, which use the classic thrusters to move. It is shown that in terms of energy consumption underwater gliders do not have explicit advantage and existing layouts do not have optimal hydrodynamic characteristics. Basing on an analysis of previous investigations the airframe assembly with higher characteristics is suggested, which allows to increase the velocity of the vehicle with the same cruising range. In the work an analysis of potential energy of on-board equipment, sensors, telecommunications, mechanism of changes of buoyancy and possible sources of energy was carried out. Based on this, a method of selection of basic geometric size, shape, design concept, the parameters of change buoyancy depending on the destination system, the requirements for range, speed, depth, speed was developed.

Wind - resistant Tethered Micro - aerostat

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It is well known that the decreasing of mass and dimension of basic on-board equipment required for the any aircraft mission gave a start to intensive development of micro airplanes. Realization of such trend in airship design meets some difficulties. Main of them seems as follows.

Let L be the characteristic dimension of airship. Buoyancy force which products lift B of airship is proportional to L^3 (airship volume) and aerodynamic drag D due to horizontal wind is proportional to it's middle area L^2. It means that sensitivity of any airship to wind gust described as drag – to – lift ratio E= D/B increases with L decreasing. The idea of this work is to use combination of aerodynamic lift Y proportional to L^2 and buoyancy force for increasing of airship performance.

Effectiveness of such approach is studied in application to an analysis of hybrid tethered micro aerostat (HTMA) with payload 0.2 kg. It consists of inflated body of revolution originated by rotation of NACA 0025 airfoil, rectangular wing (aspect ratio 8, NACA 2510 airfoil), elevator,which is used for control of angle of attackα, fin as vane, and tether connected aerostat with ground. Evidently, without any wind tether is orthogonal to ground, total weight of airship and tether is equal to buoyancy force. With known payload, this condition gives an equation for determination of L. An analysis of equilibrium of airship against its confluence point gives the following equation for angle χ of tether inclination to vertical axis:

$$ctg\chi = \frac{c_Y}{c_D} = K(\alpha)$$

Here $C_Y$and C_D – coefficients of aerodynamic lift and drug of whole HTMA including tether. Function $K(\alpha)$ of airship under the study was determined in its aerodynamic analysis with the use of XFLR5 Program. It is visible from the equation that in absence of aerodynamic lift χ® 0 and airship will "lay down" on ground. In turn, it is shown in this work that the control of aerodynamic lift produced by wing and, finally, $K(\alpha)$ with the help of elevator make it possible to hold micro airship under the study in the angle χ about 5 ¸ 7 degrees at any velocity of wind. Transient response of HTMA to horizontal wing gust is studied, too. The mathematical model of pendulum harmonic motion at its oscillations about equilibrium is used for it.

Use of MagLevTechnology to Assisting The Aircraft Takeoff And Landing

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The EU supported L1 level GABRIEL (project is a typical "out-of-the-box" project that envisions innovative solutions to overcome some of the present limitations of the European air transportation system. The project investigates the possible use of magnetic levitation technology to ground- based assisting the aircraft takeoff and landing.

The project consortia after analysis of the possible new solutions for radical improvement in aircraft existing takeoff and landing procedures, has developed an operational concept of using the magnetic levitation technology to this purposes. The project team has identified, evaluated and selected the method of magnetic levitation technology, as well as it has developed the methodology for future theoretical and practical investigation.

The lecture introduces the GABRIEL project, shows the first and second years theoretical investigation and simulation study results and shortly describes the future practical investigations.

Keywords: GABRIEL concept, magnetic levitation, aircraft takeoff and landing

Round Table 2: "Innovations in UAVs"

Technical Issues and Near Future Dream of UAVs for Industrial Applications

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UAVs have many applications in emergency situations; humans often cannot come close to a dangerous natural disaster such as an earthquake, a flood, an active volcano, or a nuclear disaster. Since the development of the first UAVs, research efforts have been focused on military applications. Recently, however, demand has arisen for UAVs such as aero-robots and flying robots that can be used in emergency situations and in industrial applications. Among the wide variety of UAVs that have been developed, small-scale HUAVs (helicopter-based UAVs) have the ability to take off and land vertically as well as the ability to cruise in flight, but their most important capability is hovering. Hovering at a point enables us to make more effective observations of a target. Furthermore, small-scale HUAVs offer the advantages of low cost and easy operation. On the other hand, there are several disadvantages, namely, not only technical issues as short flying time, small payload limit, a great deal of time and effort for autonomous flight including reliability, durability and safety but also inadequate social infrastructure as UAV insurance, test flying area, school of flight training course, sharing of safety standards guidelines etc. a lot of UAVs will be able to fly freely over the metropolitan space if such disadvantages subjects could be completely solved and UAVs have a extreme high reliability during flight, for example, safety factor 99.99% like aircraft with passengers. UAVs have an unlimited potential, so UAVs may cause a big innovation. In this round table discussions, several new technologies and new social infrastructure and near future dream will be presented.

JAXA's Approaches for the Technical Problem that a Light UAV flies over Visual Line of Sight in a Resident District

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The safety and rules, as well as technological R&D, are important that any UAVs flies above populated area. ICAO's working group has been discussing about these problem to develop long awaited regulatory framework for integration of UAVs. The target of the regulations to enable a UAV, witch operated by a remote pilot located in one country, flies in airspace controlled by another country. ICAO's scope is out of the non-international flights under the airspace controlled by ATC, where a light electric UAV is more required to use.

The Japan Aerospace Exploration Agency (JAXA) has been conducted R&D on disaster monitoring system with small electric motor powered fixed wing UAV (4-5 kg, 2.2m wing span) to operate above sparsely populated area. The operational flight tests were conducted in mountainous area autumn 2012 to evaluate its mission capability.

To operate the system safely by a user in the future, JAXA has been conducting following two studies. Since the safety of humans on the ground is crucial to flights above populated areas, JAXA has been conducting research on mitigating damage by the collision of light UAV with human heads. As an interim solution to "Detect and Avoid," JAXA is also conducting research on the inclusion of the disaster monitoring UAS to D-NET, Disaster relief aircraft information sharing Network.

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